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Water quality study of Lake Mead

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Bureau of Reclamation

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

WATER QUALITY STUDY OF LAKE MEAD

Report No. ChE-70

CHEMICAL ENGINEERING BRANCH
DIVISION OF RESEARCH

OFFICE OF CHIEF ENGINEER
DENVER, COLORADO

NOVEMBER 1967
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Where approximate or nominal English units are used to express a value or range of values, the converted metric units in parentheses are also approximate or nominal. Where precise English units are used, the converted metric units are expressed as equally significant values.

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by
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ACKNOWLEDGMENT

This study was conducted by Dr. Dale A. Hoffman and Mr. Frank C. Heller under the supervision of Mr. Paul R. Tramutt, Head, Chemistry and Water Quality Research Section. Mr. Lloyd O. Timblin, Jr., is Chief of the Chemical Engineering Branch. The contributions of others in the preparation of this report is acknowledged separately herein.

This reprint includes minor corrections

Cvd 209F

ERRATA SHEET

Water Quality Study of Lake Mead
Laboratory Report ChE-70

Abstract

Page iv - Lines 5 and 6, should read: cycle characterized by summer stratification, fall overturn leading into a continuous circulation throughout the winter temperatures - - -.

Report

Page 4 - Paragraph 2, line 8: change homothermous to isothermous.

Page 6 - Paragraph 5, line 3, should read: spring surveys were made during the spring mixing and before stratification had formed.

Appendix A

Page 101 - Station 6
pH:

Change 5', November 1965 value from 0.8 to 8.8.
Change 50', April 1966 value from 0.3 to 8.3.

Page 103 - Station 8
pH:

Change 5', November 1965 value from 0.5 to 8.5.

Page 105 - Station 9
pH:

Change 5', November 1965 value from 0.2 to 8.2.

Page 107 - Station 10
pH:

Change 150', November 1966 value from 0.05 to 7.7.

Page 123 -
Carbon dioxide:

Delete under column headed "November 1965," 0.0 for depths of 5', 50', 100' and 2.2 for 140'.

Enter under column headed "23A November 1965," 0.0 for depths of 5', 50', 100' and 2.2 for 140'.

Page 129 -

No CO_3 was detected.

Pages 131, 136, 140 -

CO_2 should read CO_3.

Appendix B

Units of measurement are mg/L for TDS, Ca, Mg, Na, K, CO_3, HCO_3, SO_4, Cl, NO_3.

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CONTENTS - Continued

CONTENTS - Continued

TABLES

ABSTRACT

This report presents Lake Mead Water quality data obtained from 1964 to 1966. The effect of filling Lake Powell on the water quality of Lake Mead is evaluated. General limnological principles and the present limnology of Lake Mead are discussed. Lake Mead has a warm monomictic annual temperature cycle characterized by summer stratification, fall overturn leading into a continuous circulation throughout the winter; temperatures never fall below 39 deg F (4 deg C). During stratification, lower dissolved oxygen values were recorded in the thermocline than in the epilimnion and hypolimnion. Mineral content increases from the upper to the lower end of Lake Mead. The greatest increase is in calcium and sodium sulfates and chlorides, although there is an overall decrease in bicarbonate. The filling of Lake Powell intensified the deterioration of water quality in Lake Mead during 1965, as evidenced by increased temperature, conductivity, and total dissolved solids and decreased dissolved oxygen. Las Vegas Bay reach was found to be a major source for degradation of water quality in Lake Mead because of its large input of dissolved salts and algae nutrients. The monitoring station at Hoover Dam has been a useful indicator of water quality in the lower reach of Boulder Basin.

DESCRIPTORS-- *dissolved oxygen/ electrical conductance/ reservoirs/ water supplies/ *limnology/ pH/ temperature/ salinity/ *water quality/ multiple purpose projects/ test procedures/ chemical engineering/ chemical analysis/ chemistry/ basins/ field laboratories/ field tests/ laboratory tests/ water sampling/ field data/ water management/ *water analysis/ reservoir surveys
IDENTIFIERS-- Lake Mead/ Boulder Canyon Project/ *water chemistry/ Winkler method/ dissolved carbon dioxide/ Lake Powell/ impoundments

UNITED STATES
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INTRODUCTION

During FY 64, the Bureau of Reclamation initiated a research program at Lake Mead to obtain: (1) dissolved oxygen data, (2) water quality data before the impoundment of water in Lake Powell became a significant factor in the quality of water in Lake Mead, and (3) additional measurements for evaluating the data previously collected at the Hoover Dam intake tower station. A previous study was conducted during 1948-50, cooperatively by the Bureau of Reclamation, Geological Survey, and the Navy Electronics Laboratory. Since that time, continuing monthly measurements have been made of a limited number of water quality parameters at the intake towers. Although these measurements are a valuable guide to the water quality released from the reservoir, they do not describe the water quality throughout the remainder of the lake. For this reason, it was decided that a study of Boulder Basin would establish a basis for future surveys regarding the effect of future storage. Chemical Engineering Report ChE-46, dated June 1965, presented the results of the initial program, and includes data on such parameters as pH, electrical conductivity, temperature, dissolved carbon dioxide, and dissolved oxygen. 1/

The purpose of this report is to: (1) present the data collected at selected seasons during the 3-year study describing the physical and chemical limnology of Lake Mead, (2) evaluate the effect of filling Lake Powell upon the limnology of Lake Mead, (3) provide information on problem areas where future research and/or remedial measures are needed, (4) describe the present limnology of Lake Mead and its significance to current and future water quality in the reservoir, and (5) describe general limnological principles to engineers and scientists in the Bureau of Reclamation, who are not familiar with this aspect of water resources.

SUMMARY AND CONCLUSIONS

During the spring of 1964, a water quality survey was initiated at Lake Mead to determine: (1) the chemical and physical limnology of Lake Mead, (2) the effect of impounding water in Lake Powell upon the water quality in Lake Mead, and (3) to evaluate the data previously collected at the intake tower station. This survey was continued with field trips during the spring and fall of 1964, 1965, and 1966.

1/ All citations are listed in Bibliography at end of text.

The annual temperature cycle of Lake Mead can be classified as warm monomictic, in that the temperature is never below 39.2° F (except perhaps at the inlet), undergoes circulation during the winter, and is directly stratified in the summer.

During the period of stratification a negative heterograde dissolved oxygen profile develops, in which the minimum is located in the thermocline. Also, at this time the total alkalinity and carbon dioxide increased in the thermocline and hypolimnion.

There is an increase in mineral content from the upper to the lower end of Lake Mead with the greatest increases being in the sulfates and chlorides of calcium and sodium. The only decrease noted was in the bicarbonate value.

The impoundment of water in Lake Powell, which lowered the level of water in Lake Mead, intensified the deterioration of water quality in Lake Mead. This was typified by increased mineral content, increased conductivity, increased temperature, and decreased dissolved oxygen values. However, since the elevation of Lake Mead has raised, the water quality has improved.

Water quality data collected from the Las Vegas Wash drain, Virgin River, and Muddy River indicated that these sources are contributors of poor quality water to Lake Mead. These rivers may cause the deterioration of water quality in the basins into which they drain.

The inflow from Las Vegas Wash is of particular importance since it is a major source of wastes which contribute to the deterioration of water quality in Lake Mead, and will become more important as the Southern Nevada Project reaches full operation.

The determination of the existence of a negative heterograde dissolved oxygen profile during summer stratification presents the opportunity for selecting water of optimum dissolved oxygen value for enhancement of downstream water quality if necessary.

The survey data indicate that the monitoring station at the intake towers of Hoover Dam has provided a general indication of water quality parameters in Boulder Basin, but not in the other reaches of the lake. For more specific and detailed water quality information concerning future uses of Lake Mead, other stations will be necessary.

Limnological Background - Part I

In order to more clearly describe the limnological characteristics of Lake Mead, a short review of some general limnological principles will be presented, using a temperate zone lake as an example. When considering the following limnological principles, one must remember that although a reservoir has lentic* (lake-like) characteristics, being located on a stream or river, it will also possess lotic (flowing) characteristics. Consequently, at certain times of the year, some reservoirs may be more like a river than a lake.

The most important phenomenon in the annual cycle of a lake or reservoir is that concerning temperature. All biological, chemical, and other physical cycles are directly or indirectly influenced by temperature. An important characteristic of water is that as its temperature decreases, its density increases. This inverse relationship between temperature and density continues until a temperature of 3.9° C (39.2° F) is reached. With further cooling, the density decreases and water becomes lighter. Thus water with a temperature between zero and 3.9° C (32 and 39.2° F) is lighter than water with a temperature of 4° C (39.4° F).

A convenient time of the year to begin a description of the temperature cycle of a lake is in the spring, when the ice cover starts to melt. At this time a temperature profile, from surface to bottom, would show water with a temperature of 0° C immediately under the ice. Below this layer of water, the temperature increases from 0° to 4° C as one follows the profile into the deeper water. This arrangement is known as winter stratification or inverse stratification, since colder water is on top of warmer water.

With the advent of spring, the ice cover melts exposing the surface layer of water to solar radiation, thereby raising its temperature above 0° C. As the water becomes warmer it also becomes denser and sinks down through the colder but lighter water, setting up convection currents. However, the action of the spring winds is the most important factor in mixing the surface waters with the deeper waters. The combined action of convection currents and wind brings the water temperatures to an equilibrium from top to bottom, thereby reducing the stability and resistance to mixing of the lake to zero. At this point, the lake is in complete circulation. During circulation the lake is resupplied with organic material and nutrients brought up off the bottom and dissolved oxygen is distributed throughout the area of mixing. This period of circulation is known as the spring overturn.

During the summer, the increased amount of solar radiation heats the upper waters of the lake. As the surface waters become warmer, the temperature and density gradients between them and the deeper waters increase.

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*Glossary on page 92.

With a greater density gradient, the lake becomes more resistant to mixing and more stable. Consequently, the area of mixing is reduced and limited to the upper warmer layer, known as the epilimnion. Beneath the epilmnion is a zone of transition, in which the rate of decrease in temperature per unit of depth is greater than in the upper and deeper layers. This zone or layer is known as the thermocline, and acts as a barrier between the epilimnion and the lower layer, the hypolimnion. The hypolimnion is colder than the other two layers and essentially isolated from further contact with the atmosphere. The period during which the three layers are present is known as summer stratification. In this case the stratification is direct, i.e., warmer water on top of colder water. This contrasts with the condition during the period of winter stratification.

As fall approaches, the days are shorter and cooler, decreasing the amount of heat input from solar radiation. The upper layer of the lake decreases in temperature due to heat loss to the colder air. As the surface water cools, it becomes denser and sinks into the underlying warmer water setting up convection currents. Essentially the same factors that caused the spring overturn, wind action and convection currents, are responsible for the fall overturn. At this time, the lake again becomes isothermous and undergoes complete circulation.

With the advent of colder fall and winter air temperatures, the surface waters continue to cool until reaching a temperature of 3.9° C. Further cooling results in a decrease in density and the surface waters remain on top of the underlying warmer but denser waters. With continued cooling and windless conditions, the ice cover forms and isolates the lake from the atmosphere, beginning the period of winter stratification.

In conjunction with the temperature cycle are those of various chemical constituents. For example, as the lake passes through the period of spring overturn, it is reoxygenated. But after summer stratification begins, no further oxygen is brought into the hypolimnion and organic material settling out from the upper waters will utilize the oxygen resulting in a profile of decreasing oxygen values from surface to bottom. At the same time, carbon dioxide is produced in the hypolimnion from decomposition of organic material. Thus, at the end of the summer, it is possible for the deeper waters to be devoid of oxygen and rich in carbon dioxide.

The lack of dissolved oxygen will cause iron, manganese and phosphorus to come into solution from the benthic mud. If this water is used for domestic purposes, the iron and manganese may cause taste and stain problems. When the fall overturn occurs, these materials are mixed with the upper waters, thus affecting a larger volume of water with potential problems. This is why some domestic water supplies have reduced water quality each fall. Also, the carbon dioxide brought up into the upper waters can cause fish kills. The phosphorus brought up during the spring overturn acts as a nutrient supply for algae blooms.

Essentially, the same temperature cycle occurs in both a lake and a reservoir located in the temperate zone. However, since a reservoir is usually located on a river or stream, its limnological cycles will be altered by the incoming flow. Also, the location and operation of the outlets will affect the limnological regime of a reservoir, especially after summer stratification is established.

As the inflowing stream enters, it will sink into the reservoir until reaching water of its same density. If the inflow is colder, it will sink through the warmer upper waters of the reservoir. Thus it is possible for a river to flow through a reservoir and out the discharge gates, although usually it becomes mixed with the reservoir water. An inflow containing silt, organic debris, and/or waste could flow through a reservoir and have a detrimental effect on the quality of the water being discharged. When the lower tunnel of Hoover Dam was being used, silt-laden density currents flowed through Lake Mead. 1/ Now that the upper outlets are being used, the density currents are no longer detected downstream. Similarly, if the temperature of the inflowing water is warmer than that of the reservoir, the inflow will remain on top or within the upper layer. The quality of the water released from a stratified reservoir will be the same as that at the depth of the outlet. If the outlet is located near the bottom of the dam, the released water will come only from the hypolimnion and not from the upper layers. Water from the upper layers will not appear in the discharge until the hypolimnetic water has been discharged. A knowledge of the quality and quantity of the water in a reservoir and the rate of discharge will enable the dam operator to predict the time at which the type of water will change. This also holds true for outlets in the upper part of the dam. It is readily apparent that multiple outlets enable the operator to select the desired quality of water to serve downstream users.

The above description is that of a typical temperate zone lake and reservoir. The temperature cycles of lakes or reservoirs located in the arctic or tropical zones will be different. For example, in some polar lakes the water temperature is always below 4° C and in some tropic lakes always well above 4° C. Lake Mead has a temperature cycle that is classified as warm monomictic, that is, never below 4° C, freely circulating in the winter above 4° C, and directly stratified during the summer. 2/

Lake Mead Study - Part II

Introduction

The water quality study of Lake Mead was initiated during 1964. A report of the 1964 survey has been published. 1/ In order to maintain continuity with the 1965 and 1966 surveys, some 1964 data have been included in the present report.

Lake Mead is a canyon-type reservoir formed by impounding the Colorado River behind Hoover Dam. Photographs of the lake are presented in Appendix C. At full elevation, the reservoir extends a distance of 115 miles upstream and has a capacity of 31,047,000 acre-feet. The maximum depth is 589 feet, and when full the shoreline of 550 miles encompasses 158,000 surface acres. The water is used for power, domestic and industrial supply, recreation, flood control, and irrigation. The lake is made up of four major sections, Boulder Basin, Virgin Basin, Overton Arm, and the reach extending from Virgin Basin upstream to Pierce's Ferry (Figures 1 and 2).

Methods and Materials

Sample dates. - Field studies were made during the spring of 1964 and the spring and fall of 1965 and 1966. The survey dates and season of the year are given in Table 1.

Table 1

SURVEY DATES AND SEASON
LAKE MEAD LIMNOLOGY STUDY

Season	Date
Spring	April 23 - May 8, 1964
Spring	May 11-24, 1965
Fall	November 1-11, 1965
Spring	April 14-20, 1966
Fall	November 1-9, 1966

The 1964 spring survey was scheduled so that data could be collected before Lake Mead reached a low level due to filling Lake Powell. The 1965 spring survey was made at the time Lake Mead was at a low level and the 1965 fall surveys and both 1966 surveys were conducted after Lake Mead had returned to the early 1964 elevation.

By scheduling the surveys as described above, data were collected during key periods of the lake's annual temperature cycle. Thus the spring surveys were made during the spring mixing and before stratification had formed, while the fall surveys were made after the lake

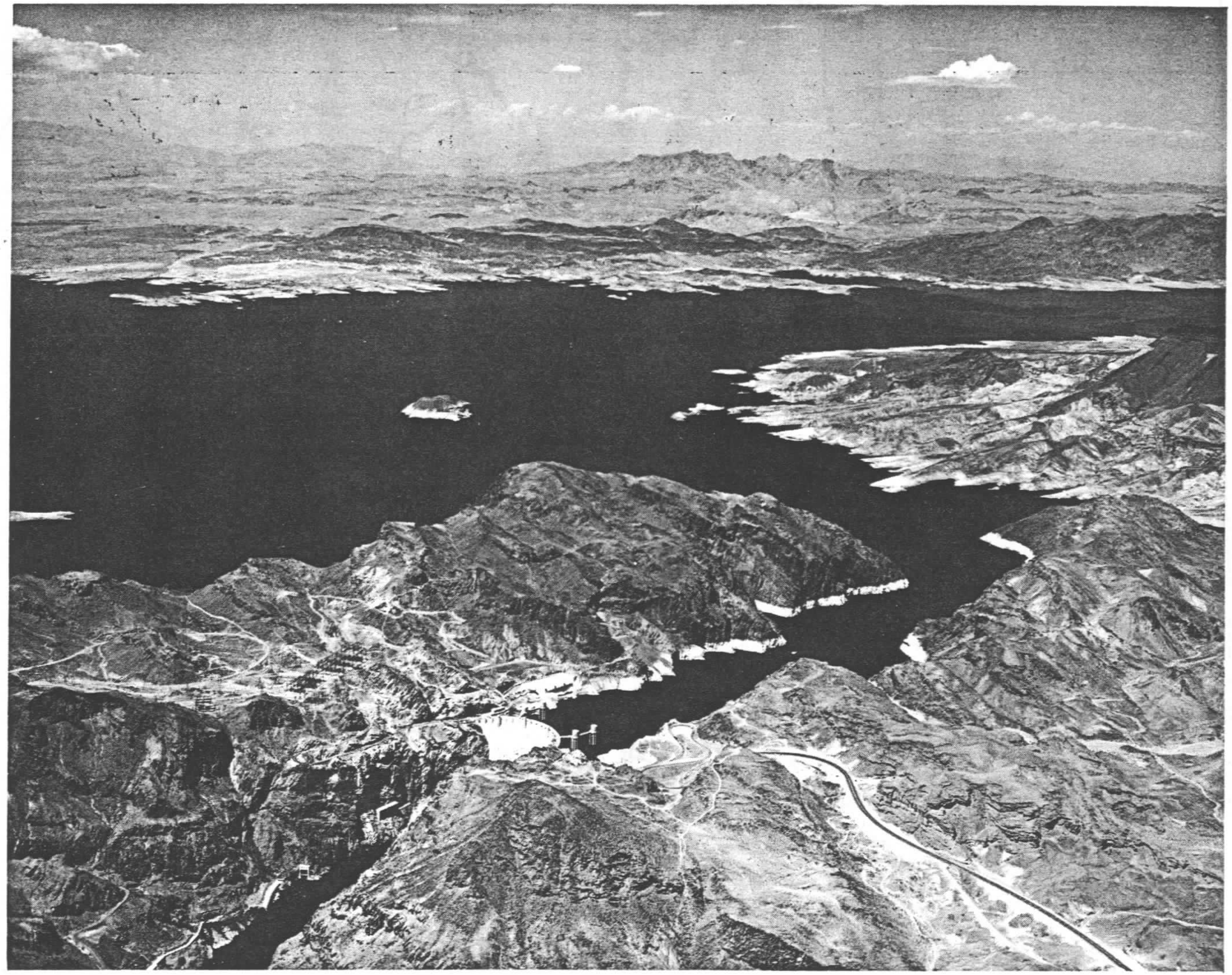

Figure 1. Boulder Basin, Lake Mead.
Photo P45-300-7327

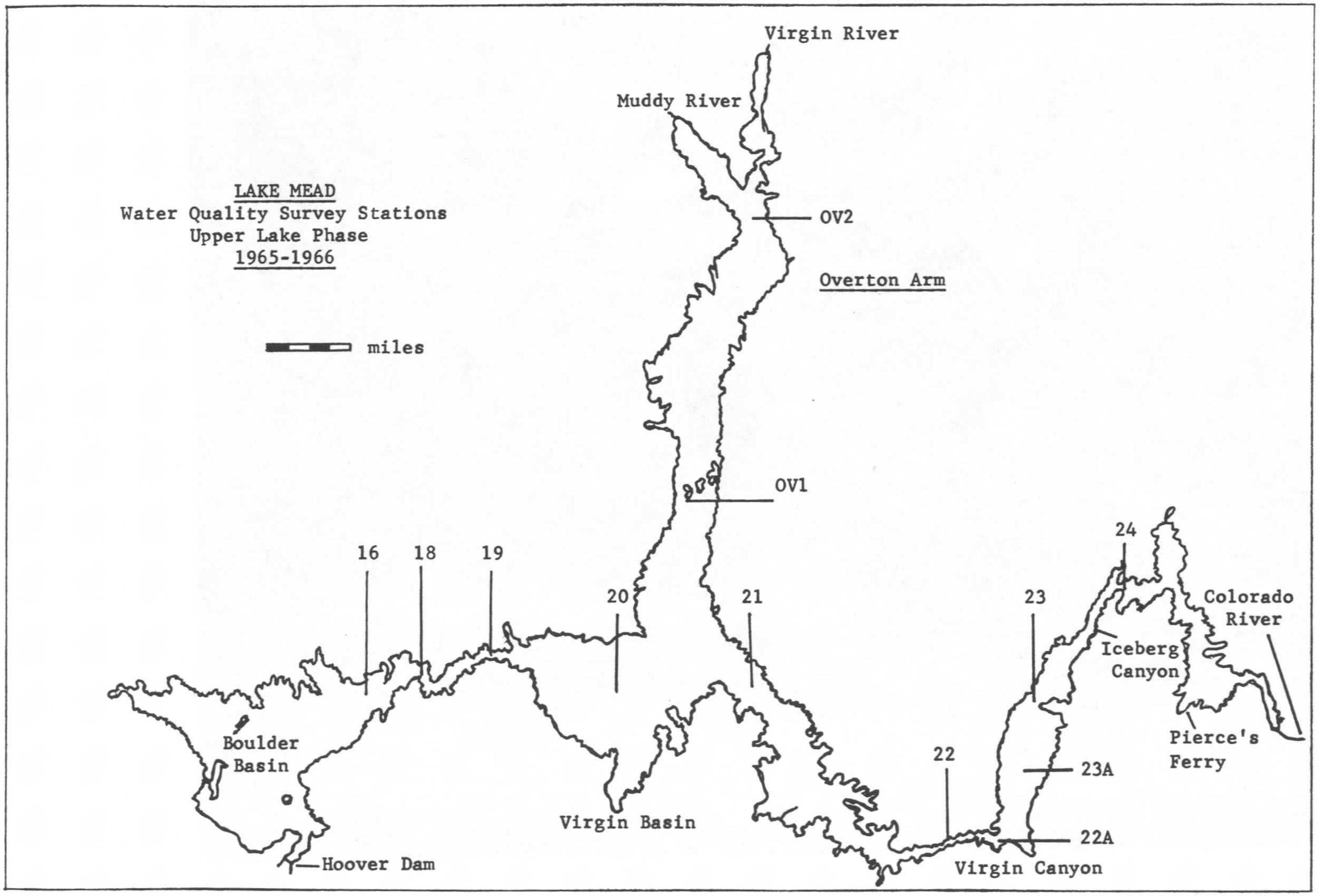
LAKE MEAD
Water Quality Survey Stations
Upper Lake Phase
1965-1966
miles
Virgin River
Muddy River
OV2
Overton Arm
OV1
16
18
19
20
21
22
22A
23
23A
24
Colorado River
Iceberg Canyon
Pierce's Ferry
Boulder Basin
Hoover Dam
Virgin Basin
Virgin Canyon

Figure 2

was well stratified. Also, the effect of filling Lake Powell upon the limnology of Lake Mead could be ascertained by using the 1964 data as a base line. The spring surveys were limited to Boulder and Virgin Basins. During the fall, the water quality studies were combined with the annual sediment surveys and the upper reaches of the lake as well as Boulder and Virgin Basins were studied.

Sample Stations. - Twenty-eight sample stations were initially established throughout the length of Lake Mead. The station locations are given in Figures 2 and 3. The station locations are in the same general areas as those of the 1948-50 study. 3/ Since data collected during the first and second trips indicated that some stations were similar, only one of the similar stations was sampled during the later surveys.

Station 1, located between the intake towers of Hoover Dam, is unique in that water analyses have been conducted at this point for over 20 years. Over the past years, this station has been used as the key monitoring station for Lake Mead. However, due either to operator error and/or instrument malfunction, some of the data collected before the start of this survey are questionable. Figures 4, 5, and 6 show plots of temperature, conductivity, and dissolved oxygen at Station 1 during the period of study covered by this report, 1964-66.

Due to size of the lake and the best utilization of men and equipment, the principal part of the work has been accomplished in Boulder Basin. This basin is also the most important reach of the lake from the standpoint of present and future water use.

Analytical Techniques. - Water samples were collected by means of a plexiglass Kemmerer water sampler. Photographs of the equipment are presented in Appendix C. Tests for dissolved oxygen, carbon dioxide, pH, and alkalinity were conducted in the boat laboratory immediately after collection. Temperature and conductivity were measured with a portable instrument. Light transparency was measured with a 20-centimeter-diameter Secchi disc, divided into alternate black and white quadrants. Water samples for chemical analyses were placed in polyethylene bottles for return to the chemistry laboratory in Denver, Colorado. These samples were analyzed for calcium, magnesium, sodium, potassium, carbonate, bicarbonate, sulfate, chloride, nitrate, electrical conductivity, total dissolved solids, and pH. The analyses for the above parameters were conducted according to the methods given in Standard Methods for the Analysis of Water and Waste Water. 4/ Separate water samples for phosphorus analyses were collected and treated to prevent bacterial decay by a variety of techniques as follows: those collected in the fall 1965 were quick frozen in polyethylene bottles, those collected in the spring of 1966 were treated with chloroform in polyethylene bottles, and those collected in the fall of 1966 were treated with mercury bichloride in acid washed pyrex bottles. The


BOULDER BASIN
Sentinel Island
Boulder Islands
Fortification Hill
RIVER MOUNTAINS
LAS VEGAS BAY
NEVADA ARIZONA

Figure 3

analyses of the 1965 and spring 1966 samples were for soluble phosphate by the amino naphthol sulfonic acid method. 4/ The samples collected the fall of 1966 were filtered through a membrane filter and the residue analyzed for insoluble phosphorus, while the filtrate was analyzed for soluble phosphorus according to the method of Jenkins. 5/

Discussion of Results

The data collected during this study are given in Appendix A.

Temperature. - Temperature measurements were taken during each seasonal survey. Although the spring surveys had similar profiles, the overall temperatures in 1964 were colder than 1965 and 1966, and those in 1966 colder than 1965. For example, during the spring the temperatures at the 100-foot depth, in consecutive order for the years 1964, 1966, and 1965, in Boulder Basin were: Station 1, 52.7, 53.8, and 56.5; Station 4, 52.3, 54.5, and 55.5; Station 6, 52.5, 54.0, and 56.2; and Station 16, 54.0, 54.2, and 56.0 (Figures 7, 11, 13, and 17).

The sequence in the development of summer stratification can be seen in the spring survey temperature profiles of the representative stations, starting with the data from April 1964, then April 1966, followed by May 1965. The April data show the gradual warming of the surface waters; and the beginning of the thermocline is apparent at the 50- to 100-foot level in the May survey. The established thermocline can be seen at the 100- to 200-foot level in the fall surveys of 1965 and 1966 (Figures 7-27).

During stratification, the upper zone, the epilimnion, consists of 67-70° F water; the middle zone, the thermocline, is located between 100-250 feet, with temperatures between 54° and 66° F; and the deep zone, the hypolimnion, below 250 feet, consists of water of temperatures between 52° and 54° F. This condition exists throughout the lake (Figures 27 and 28).

The data from the monthly surveys at Station 1 indicate that stratification begins to break up and circulation begins during December and January, with the lake becoming isothermous within 30 days. At this time, the lake temperatures from bottom to surface were 53° to 55° F in 1964, 54° F in 1965, and 53° to 56° F in 1966 (Figure 4).

After an initial warming period during the early spring, there is a decrease in the water temperatures of the upper 50 feet, and an increase in temperatures below this depth. This may be due to the inflow of spring runoff consisting of water with a temperature near those at the 50-foot level. The spring winds help to mix the warmer surface water with the colder spring inflow resulting in a net decrease in the temperature of the upper waters. Anderson and Pritchard's work showed that the spring inflow current set up a countercurrent in the deeper waters, creating a cell of circulating water. 3/ Such a circulating cell could mix the colder deep water with the warmer inflow, resulting in a net temperature increase in the deeper zone. The effect of this mixing can be seen in Figure 4 with the concurrent temperature increase in the 50- to 100-foot layer and a decrease in the surface to 50-foot layer, during May 1964, June 1965, and May 1966.

Dissolved Oxygen. - Closely associated with the temperature cycle is that of dissolved oxygen. The largest part of the dissolved oxygen in a reservoir is supplied during the spring and fall overturns. A lesser amount is provided by photosynthetic action of algae and aquatic plants. Still another source of dissolved oxygen is that of the inflowing streams.

The dissolved oxygen isopleths in Figures 28 and 29 show that during the spring the reservoir is reaerated from surface to bottom. However, after stratification is formed, the lower depths are isolated from the atmosphere and no further oxygen is supplied directly from the atmosphere. The normal pattern of dissolved oxygen during stratification shows decreasing amounts from surface to bottom. However, in Lake Mead, the pattern of dissolved oxygen fits Hutchinson's classification as negative heterograde. 2/ This type of oxygen profile is typified by a marked minimum in the thermocline with higher quantities in the epilimnion and hypolimnion. This condition existed throughout the reservoir during the fall of 1965 and 1966 (Figures 31 and 32).

Two probable causes for this type of dissolved oxygen distribution are suggested by Hutchinson. 2/ In one case organic material, such as algae, is produced in the epilimnion, then sinks into the thermocline where it is oxidized. The other possible cause is that the depth of the oxygen minimum corresponds to a shelf in the bottom contour. It is not known what causes the low dissolved oxygen zone in Lake Mead, but it may be a combination of the two above-mentioned causes. Although Lake Mead is considered as a canyon-type reservoir, Boulder and Virgin Basins have a flat contour which could be described as shelf-like. Work by Sisler indicated a large number of bacteria in the sediments at the towers. 6/ Such a bacterial population could be a source of oxygen utilization. Algae blooms have been reported in Lake Mead and taste and odor problems have occurred in domestic water supplies taken from the lake. The magnitude and classification of the algae blooms have not been thoroughly studied in Lake Mead. Work by the FWPCA indicates the presence of algae blooms in the Las Vegas Wash area and the potential for greater blooms. 7/ Another source of organic material is the debris brought in with the spring runoff. Still another cause of the oxygen depletion could be the presence of large populations of zooplankton.

Examination of the dissolved oxygen profiles for the Boulder Basin indicates that the amount of dissolved oxygen below 100 feet, at the beginning of the summer, decreased with each succeeding year (Figures 7, 9, 11, 13, 15, 17, and 19). To date (1967) the layer of low dissolved oxygen (<3 mg/L) has not reached the depth of the outlets of Hoover Dam.

Carbon Dioxide. - The water quality parameters of carbon dioxide carbonate, and bicarbonate will be discussed concurrently since they are interrelated in the carbonate cycle. The principal sources of carbon dioxide in water are the atmosphere, decomposition of organic material, respiration by plants and animals, and combination with such elements as calcium and magnesium.

When present in sufficient quantities, carbon dioxide combines with water forming carbonic acid. This in turn acts upon the relatively insoluble carbonates forming the relatively soluble bicarbonates. This relationship is apparent in the figures for free carbon dioxide, phenolphthalein alkalinity and total alkalinity. The depth at which the total alkalinity increases, 50 to 150 feet, is approximately the same as that at which the carbonate alkalinity decreases and the carbon dioxide increases. The profile for carbon dioxide and total alkalinity is nearly inverse to that for oxygen. Also, during 1965, there was a loss in total alkalinity in the upper 100 feet and a gain below this depth during the summer. To a lesser degree, the same trend is noticeable during 1966.

Station 3 is unique from the others in that during the spring 1965 survey, carbonate alkalinity was detected from the surface to 300 feet. This was the only station and the time that carbonate alkalinity was detected below 150 feet (Figure 10).

pH. - Values of hydrogen ion as pH ranged from 7.0 to 9.3 during the period of study. During periods of stratification values below 8.3 were found in the thermocline and hypolimnion. These values reflect the presence of carbon dioxide in these zones. The pH of the epilimnion was usually 8.6 to 9.3. During the spring, the pH values averaged 8.3 from the surface to the bottom, with lower values in the deeper waters.

Conductivity. - Measurement of electrical conductivity is a method by which an indication of the quantity of dissolved solids can be determined. The results given in the tables and figures are corrected to a standard temperature of 25° C (77° F). The significant feature in the conductivity data during the period of study is the large increase during 1965. The data from Station 1, as given in Figure 5, depict the change in electrical conductivity during 1964, 1965, and 1966. The large increase is due to the retention of water in Lake Powell and subsequent release from the lower depths of that lake.

During the fall surveys of 1965 and 1966, a layer of lower conductivity (as compared to the rest of the lake) was detected at the bottom of the thermocline. The conductivity of this layer was approximately

50 micromhos less than that of the water above and below. This layer occurred both years even though the conductivity values were higher in 1965. The layer was only present in the Boulder Basin, whereas the conductivity in the remainder of the lake increased with increasing depth (Figures 32 and 33). This layer may be part of the fall inflow moving along a temperature gradient.

In general, the conductivity increases from the inlet to the outlet. For example, during the fall surveys the conductivities of Stations 1, 20, and 24 at various depths are given in Table 2.

Table 2

CONDUCTIVITY MICROMHOS/CENTIMETER AT 25° C

Station	5 feet		100 feet		300 feet	
	1965	1966	1965	1966	1965	1966
1	1,250	1,040	1,210	1,050	1,250	1,060
20	1,000	920	1,100	920	1,190	970
24	650	795				

The highest conductivity measured in the lake proper was 1,460 micromhos, at Station 10 during the fall of 1965 (Figure 25).

Light Transparency. - The amount of light penetration was determined by Secchi disc measurements. These data provide a comparison of the turbidity between stations and are presented in Table 3.

Stations 10 and 10A had consistently low readings as compared with the rest of Lake Mead. Low readings are also noted for Stations 23, 23A, and 24 near the mouth of the Colorado River, and Station OV2, near the mouth of the Virgin River. The low readings at the latter stations are due to silt from the rivers, whereas the low readings at Stations 10 and 10A are due to algae blooms and silt. The effect of the algae blooms is especially noticeable during the spring.

Algae Growth Nutrients. - Water samples were collected from selected stations for phosphorus and nitrogen analysis (Table 4). These data give an indication of the potential for algae growth. Although the specific amounts vary from lake to lake, the generally accepted threshold values to support algae blooms are 0.3 mg/L nitrogen and 0.015 mg/L phosphorus. On the basis of the above threshold values, it can be seen that the large algae blooms observed in Las Vegas Bay, as compared to Boulder Basin, are due to the larger amounts of phosphorus and nitrogen in the Bay.

Table 3

SECCHI DISC READINGS - LAKE MEAD
Depth in Feet

Station	5/65	11/65	4/66	11/66
1	28	22	38	18
2	35	17	30	--
3	28	--	35	17
3A	23	--	--	--
3B	--	21	--	--
3C	28	17	33	17
4	--	20	36	19
4A	32	--	--	--
4B	--	20	31	21
5	--	15	--	--
6	22	20	36	19
7	26	18	--	--
8	18	14	36	18
9	8	18	46	18
10	5.5	18	8	12
10A	--	11	4	10
11	38	--	--	--
12	36	18	28	20
13	31	--	--	--
14	30	24	26	22
15	27	--	--	--
16	22	25	34	--
17	34	--	--	--
18	30	25	30	19
19	--	16	--	--
20	--	21	28	25
21	--	18	--	--
22	--	14	--	25
22A	--	17	--	--
23	--	11	--	--
23A	--	10	--	--
24	--	1	--	4
OV1	--	19	--	21
OV2	--	9	--	10

Phosphorus and nitrogen analyses were conducted on samples from similar stations during May 1966 by the Federal Water Pollution Control Administration. 7/ Their data show lower values for ammonia and nitrate-nitrogen and total phosphorus and higher values for organic nitrogen than during our November 1966 survey (Table 4). This difference may be due to the utilization of these nutrients by algae blooms which were present during the spring but not the fall survey.

No samples for algae identification and enumeration were collected by the Bureau of Reclamation, but such analyses were made by the Federal Water Pollution Control Administration and their data confirm the presence of algae blooms in Las Vegas Bay. 7/

Table 4

PHOSPHORUS AND NITROGEN, LAKE MEAD
mg/L

Station	Depth	Phosphorus (PO_4)		Nitrogen (N)		
		Insoluble	Soluble	NO_3	NH_3	Organic
3C	Surface	0.33	0.10	-	0.22	0.32
	10 feet	0.26	0.16	0.27	0.25	0.20
4B	Surface	0.33	0.16	-	0.25	0.36
	10 feet	0.35	0.10	0.14	0.28	0.30
10	Surface	0.43	0.10	-	0.34	0.30
	10 feet	0.45	0.04	0.27	0.44	0.36
10A	Surface	0.78	0.04	-	0.63	0.37
	10 feet	0.85	0.00	0.14	0.53	0.39
North Shore Drive	Surface	-	7.90	0.00	0.89	0.16

Mineral Quality. - Water samples were collected from the shallow, 5 to 10 feet, and deep, 100 to 200 feet, zones of the lake for chemical analysis. The data are presented in Appendix B, with selected stations plotted in Figures 34, 35, and 36 in order to show seasonal, geographical, and zonal variations.

It is evident that the mineral content of the water in Lake Mead was greater during 1965 than 1964 or 1966. For example, during the spring season, the values for calcium and bicarbonate in the shallow zone at Station 1 were as follows: 1964, 87 mg/L and 144 mg/L; 1965, 110 mg/L and 154 mg/L; and 1966, 94 mg/L and 144 mg/L.

Seasonal differences can be seen by examination of the data in Figures 35, 36, and 37, which show that the values for the parameters measured are higher during the spring than in the fall at the same station. During stratification, the mineral content increases with depth; this is especially noticeable with the bicarbonate values during the fall of 1965 (Figure 36).

In general, there is an increase in mineral content from the upper to the lower end of Lake Mead and the greatest increases are found in the sulfate and chlorides of calcium and sodium; however, there is a decrease in bicarbonate. The chemical analyses from the upper and lower end of Lake Mead are given in Table 5 and represent samples taken in the fall of 1966. Other chemical data showing the improved mineral quality of the water since the period of poor condition (1965) are found in Figures 34, 35, and 36.

Since it is desirable to know the chemical quality of the incoming rivers and streams, samples were collected from the Las Vegas Wash drain, Muddy River, and Virgin River. The total volume of water coming from flows of the Virgin and Muddy Rivers is small compared to the volume of water in Lake Mead; however, they contribute a considerable amount of minerals into the local area of the Upper Overton Arm. The high mineral content contributed by these rivers could effect the future water quality of withdrawals from the Upper Overton Arm for both domestic and irrigation uses. Samples were also taken within the zone of convergence of the Colorado River with Lake Mead. The results of these analyses are given in Table 6.

Similarly, the impact of the mineral contribution from the Las Vegas Wash to Boulder Basin will effect the quality of water withdrawn for future use in the Southern Nevada Project. Since the current patterns in Boulder Basin are not well known, the possibility exists that water from Las Vegas Wash will short circuit into domestic water intakes near Saddle Island. The deterioration of water quality at Stations 9 and 10 in Las Vegas Wash as compared to Station 8 in Boulder Basin can be seen in Figures 23, 24, and 25.

<u>Effect of Lake Powell</u>. - One purpose of this study was to determine the effect of Lake Powell upon the water quality in Lake Mead. During March 1963, storage was begun in Lake Powell. While water was being stored in Lake Powell, the flow into Lake Mead was reduced, resulting in a decrease in the water level in the latter. The lowest level during this period was reached in January 1965. During the spring and summer of 1965, the flow to Lake Mead increased and the lake reached the early 1964 level (Figure 37).

<u>Table 5</u>

CHEMICAL ANALYSIS--STATIONS 1, 12, 20, 22
Lake Mead
1966

Station No.	1--Hoover Dam		12--Boulder Basin		20--Virgin Basin		22--Virgin Canyon	
Depth	10	100	10	100	10	100	10	100
Parameter								
Ec x 10^6 at 25° C	1,106	1,100	1,076	1,084	971	976	881	885
pH	8.3	7.9	8.2	8.0	8.1	8.3	8.2	8.0
TDS mg/L	748	740	812	828	676	692	628	608
Ca mg/L	80	87	82	85	78	78	72	69
Mg mg/L	31	27	28	30	26	26	21	23
Na mg/L	105	101	101	98	90	90	81	78
K mg/L	5.5	5.5	5.5	5.5	4.7	4.7	4.3	3.9
HCO_3 mg/L	129	146	125	138	140	144	145	154
SO_4 mg/L	312	303	304	299	268	269	223	213
Cl mg/L	94	94	92	93	74	77	70	73
NO_3 mg/L	1.2	2.5	0.6	2.5	1.2	1.9	1.9	1.9

Table 6

Chemical Analysis of Inflowing
Waters to Lake Mead

Station	Iceberg Canyon*		Muddy River	Virgin River	Las Vegas Wash	
Date	Nov 8 1965	Oct 31 1966	Nov 1 1966	Nov 1 1966	Nov 12 1965	Nov 6 1966
Parameter						
Ec x 10^6 at 25° C	632	851	2,232	1,276	6,384	6,144
pH	8.0	7.9	8.1	8.0	8.1	8.2
TDS mg/L	408	608	1,712	908	5,424	5,256
Ca mg/L	52	71	154	95	496	516
Mg mg/L	20	20	78	35	228	253
Na mg/L	53	77	221	121	656	656
K mg/L	3.1	3.9	22	7.4	63	68
CO_3 mg/L	0.0	0.0	0.0	0.0	0.0	0.0
HCO_3 mg/L	124	151	299	135	271	292
SO_4 mg/L	124	209	715	369	1,718	1,824
Cl mg/L	53	65	178	119	1,264	1,179
NO_3 mg/L	0.6	0.6	1.2	0.6	44	0.0

*Convergence Area of Colorado River

The effect of this fluctuation is reflected in the data from Station 1 (Figures 4, 5, and 6). Data from the other stations also show the difference in water quality during the study period.

The overall effect of filling Lake Powell was to intensify the deterioration of water quality in Lake Mead caused by low flows in the Colorado River Basin. This is indicated by lower quantities of dissolved oxygen, increased amounts of carbon dioxide, higher temperatures, higher conductivity, and higher alkalinity.

Where data are available, it appears that the spring 1966 water quality values are similar to those of 1964. This indicates that the deterioration during 1965 is being alleviated and the lake is returning to 1964 conditions.

Future Research

The present study indicates that there is a decrease in dissolved oxygen during periods of stratification. It is desirable to identify and measure the material which utilizes this oxygen. The probable sources of the material are plankton, waste products, or debris from the inflowing rivers. More frequent surveys to measure the organic constituents of Lake Mead would be necessary. This would include such measurements as Biological and Chemical Oxygen Demand, photosynthetic production of oxygen, the relationship between zooplankton and oxygen, and the effect of the benthic environment upon the dissolved oxygen.

The present study and those of others indicate that Las Vegas Wash is a source of nutrients and wastes for Boulder Basin. Since the present use of Boulder Basin as a source of water supply and recreation will increase, it is desirable to ascertain the fate of the inflow from Las Vegas Wash. In order to do this, it is necessary to determine the current patterns in Boulder Basin by tracer studies, drouges, floats, and current meters.

Another monitoring station should be established in the vicinity of the mouth of Las Vegas Bay. This station would provide more accurate data as to the water quality in Boulder Basin than the present station at Hoover Dam.

A study should be conducted to ascertain the effect of the Muddy River and the Virgin River upon the water quality of the Overton Arm. These rivers drain a developing area and may cause a rapid deterioration of water quality in the Overton Arm reach of Lake Mead.

GLOSSARY

Benthic	The bottom zone of a body of water, ranges from the shore to the deep water.
Epilimnion	The upper area of a lake or reservoir during stratification, lies on top of the thermocline.
Hypolimnion	The bottom area of a lake or reservoir during stratification, lies below the thermocline.
Isopleth	A line on a map or graph joining points of a specific constant value.
Isothermous	Having the same temperature.
Lentic	Flowing water, i.e., river or stream.
Limnology	The study of inland waters.
Lotic	Standing water, lake or reservoir.
Negative Heterograde Dissolved Oxygen Curve	Dissolved oxygen curve in which a marked minimum occurs in the area of the thermocline.
Overturn	Condition whereby a lake or reservoir becomes isothermous and circulates from surface to bottom.
Photosynthesis	Construction of organic material (carbohydrates) from CO_2 and water with the aid of energy, usually from sunlight, by chlorophyll-bearing plants.
Thermocline	The area of a stratified lake or reservoir that separates the epilimnion from the hypolimnion. The area where the change in temperature is greatest with depth.
Warm monomictic	Thermo classification of a lake or reservoir in which the water temperature is never below 4° C and freely circulates during the winter at or above 4° C.

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BIBLIOGRAPHY

1. Bureau of Reclamation, 1965. Water Chemistry Survey of Boulder Basin, Lake Mead. Chemical Engineering Report No. ChE-46, 33 pp.

2. Hutchinson, G. E., 1957, A treatise on Limnology, Vol I, Geography, Physics, and Chemistry. John Wiley and Sons, Inc., New York, 1015 pp.

3. Anderson, E. R. and D. W. Pritchard, 1951, Physical Limnology of Lake Mead, Lake Mead Sedimentation Survey, U.S. Navy Electronics Laboratory, San Diego, California, Report 258, October 3, 1951, 153 pp.

4. American Public Health Association, Inc., 1960, Standard Methods for the Examination of Water and Waste Water, APHA, New York, 626 pp.

5. Jenkins, D., 1965, A Study of Methods Suitable for the Analysis and Preservation of Phosphorus Forms in an Estuarine Environment. San. Eng. Lab Report No. 65-18, University of California, Berkeley, November 1965, 50 pp.

6. Sisler, F. D., 1954. Lake Mead Comprehensive Survey of 1948-49, Vol III, pp 266-281, U.S. Department Interior and U.S. Department Navy, February 1954.

7. Federal Water Pollution Control Administration, 1967. Report on Pollution in Las Vegas Wash and Las Vegas Bay, 18 pp.

APPENDIX A

CHEMICAL AND PHYSICAL DATA

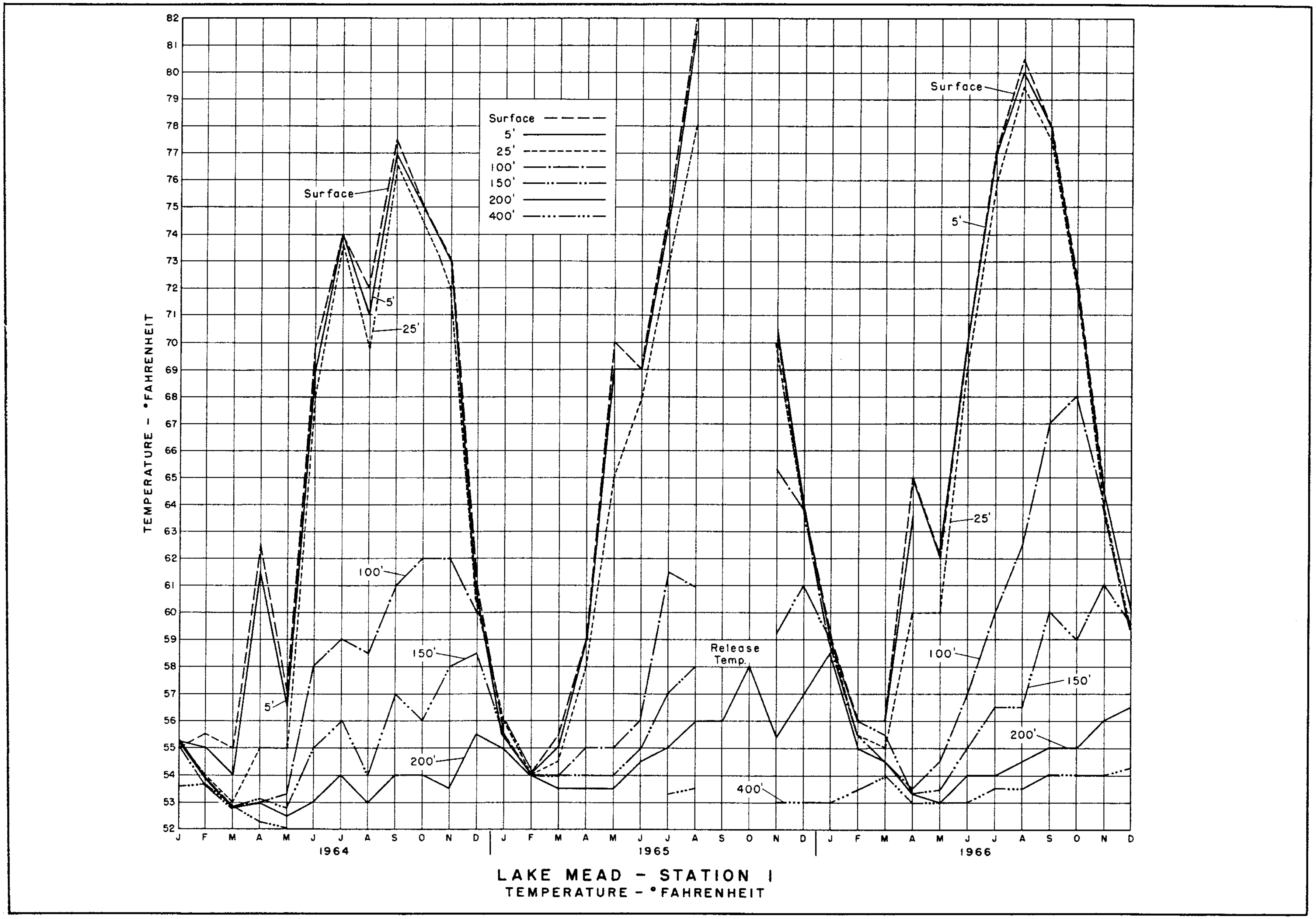

TEMPERATURE - °FAHRENHEIT
Surface
5'
25'
100'
150'
200'
400'
Release Temp.
J F M A M J J A S O N D
1964
1965
1966
LAKE MEAD - STATION I
TEMPERATURE - °FAHRENHEIT

Figure 4

CHEMICAL AND PHYSICAL DATA
Lake Mead Station 1

	Collection depth	April 1964	May 1965	November 1965	April 1966	November 1966
Temperature, °F	5	55.4	66.5	70.7	56.2	70.5
	25	55.4	65.2	70.0	55.0	70.2
	50	55.4	64.5	70.0	54.8	70.2
	100	52.7	56.5	65.3	53.8	65.9
	150	52.0	-	59.2	53.5	58.9
	200	52.0	54.0	55.4	53.5	54.2
	250	-	-	54.0	53.5	53.5
	300	52.0	53.2	53.6	53.5	53.2
	350	52.0	53.0	53.0	53.5	53.2
	400	52.0	53.0	53.0	53.5	53.2
Dissolved oxygen, mg/L	5	9.53	8.92	7.50	8.7	7.20
	25	-	8.96	7.35	8.4	-
	50	9.27	8.55	7.05	8.2	-
	100	9.08	8.12	1.18	7.9	0.75
	150	8.94	-	2.18	-	-
	200	8.68	7.93	4.50	6.7	5.70
	250	8.50	-	5.52	-	-
	300	8.42	7.72	5.75	6.2	5.50
	350	8.35	7.55	5.00	-	-
	400	8.27	7.58	2.65	6.0	1.60
Conductivity, Ec x 10^6 at 25° C micromhos/cm	5	1,090	1,300	1,100	1,050	1,040
	25	1,075	1,305	1,200	1,050	1,040
	50	1,050	1,305	1,200	1,050	1,040
	100	1,085	1,290	1,000	1,080	1,050
	150	1,095	-	1,100	1,090	1,060
	200	1,110	1,305	1,200	1,090	1,005
	250	-	-	990	1,090	1,020
	300	1,120	1,325	1,350	1,090	1,060
	350	1,125	1,325	1,300	1,090	1,060
	400	1,125	1,325	1,300	1,090	1,090
pH	5	7.4	8.5	8.4	8.2	8.2
	25	7.4	8.5	8.5	8.3	-
	50	7.2	8.5	8.5	8.3	-
	100	7.0	8.1	7.8	8.3	7.7
	150	7.9	-	7.7	-	-
	200	7.9	8.1	8.0	8.1	7.8
	250	-	-	8.1	-	-
	300	7.9	8.0	8.0	8.1	7.8
	350	7.2	8.0	8.0	-	-
	400	7.2	8.0	7.9	8.0	7.6

Lake Mead Station 1
Continued

	Collection depth	April 1964	May 1965	November 1965	April 1966	November 1966
Alkalinity, phth as $CaCO_3$ mg/L	5		7.1	3.0	-	3.0
	25		4.4	-	0.0	-
	50		4.8	1.0	-	-
	100		0.0	0.0	0.0	0.0
	150		0.0	0.0	-	-
	200		0.0	0.0	0.0	0.0
	250		0.0	0.0	-	-
	300		0.0	0.0	0.0	0.0
	350		0.0	0.0	-	-
	400		0.0	0.0	0.0	0.0
Alkalinity, MO as $CaCO_3$ mg/L	5		127.8	104.5	120.0	104.8
	25		128.8	-	117.0	-
	50		128.8	103.5	120.0	-
	100		128.3	123.2	122.0	117.5
	150		131.0	138.5	-	-
	200		131.0	138.0	124.0	125.5
	250		-	135.2	-	-
	300		132.8	131.2	126.0	127.5
	350		132.2	-	-	-
	400		133.5	135.5	127.0	130.5
Carbon dioxide, mg/L	5	0.00		0.0	0.96	-
	25	0.00		0.0	1.45	-
	50	0.00		0.0	1.92	-
	100	0.97		6.96	2.90	4.07
	150	1.94		7.06	-	-
	200	2.13		6.58	3.87	2.71
	250	-		5.51	-	-
	300	1.45		3.38	2.90	2.91
	350	2.72		4.35	-	-
	400	4.07		6.48	3.87	4.07

CHEMICAL AND PHYSICAL DATA
Lake Mead Station 3

	Collection depth	April 1964	May 1965	November 1965	April 1966	November 1966
Temperature, °F	5	58.8	59.5	69.8	63.5	71.7
	25	57.4	57.0	-	62.5	70.7
	50	-	56.0	69.8	57.5	70.2
	100	53.0	54.8	68.0	54.5	68.2
	150	-	53.5	59.9	53.8	58.7
	200	51.8	53.5	-	53.8	55.2
	250	51.8	53.0	-	53.5	53.7
	300	51.8	53.0	58.1	53.2	53.7
Dissolved oxygen, mg/L	5	10.30	9.01	8.05	9.7	8.02
	25	10.20	8.50	-	10.0	-
	50	-	8.50	7.45	9.3	-
	100	9.55	8.30	1.00	8.2	2.48
	150	-	8.12	1.75	-	-
	200	9.16	8.03	-	7.9	3.05
	250	9.10	-	-	-	-
	300	-	7.92	5.10	6.8	5.55
Conductivity, Ec x 10^6 at 25° C micromhos/cm	5	1,060	1,300	1,200	1,110	1,025
	25	1,060	1,290	-	1,110	1,040
	50	-	1,300	1,190	1,110	1,040
	100	1,080	1,300	1,100	1,120	1,070
	150	-	1,320	1,050	1,120	1,080
	200	1,110	1,320	-	1,120	1,040
	250	1,110	1,340	-	1,160	1,040
	300	1,120	1,340	800	1,160	1,060
pH	5	8.2	8.3	8.4	8.6	8.6
	25	8.1	8.3	-	8.6	-
	50	-	8.1	8.7	8.4	-
	100	8.1	8.0	8.0	8.2	8.0
	150	-	8.0	7.9	-	-
	200	8.1	7.9	-	8.1	8.0
	250	8.1	-	-	-	-
	300	8.1	7.9	8.2	8.0	8.0
Alkalinity, phth as $CaCO_3$ mg/L	5		5.3	4.2	6.0	5.0
	25		3.2	-	5.0	-
	50		4.5	5.0	0.0	-
	100		3.0	0.0	0.0	0.0
	150		3.0	0.0	-	-
	200		-	-	0.0	0.0
	250		2.0	-	-	-
	300		3.8	0.0	0.0	0.0

Lake Mead Station 3
Continued

	Collection depth	April 1964	May 1965	November 1965	April 1966	November 1966
Alkalinity,	5		126.5	106.5	122.0	106.5
MO	25		124.0	-	121.0	-
as $CaCO_3$	50		124.5	105.0	121.0	-
mg/L	100		122.0	122.0	121.0	115.0
	150		123.8	137.0	-	-
	200		124.8	-	118.0	125.0
	250		-	-	-	-
	300		130.0	131.0	122.0	129.8
Carbon	5	2.42		0.0	0.0	0.0
dioxide,	25	0.97		-	0.0	-
mg/L	50	-		0.0	0.0	-
	100	0.97		5.03	1.93	2.91
	150	-		6.50	-	-
	200	0.97		-	1.93	4.36
	250	1.45		-	-	-
	300	1.45		3.97	2.90	3.68

CHEMICAL AND PHYSICAL DATA
Lake Mead Station 4

	Collection depth	April 1964	May 1965	November 1965	April 1966	November 1966
Temperature °F	5	56.8	63.5	69.0	65.0	70.2
	25	55.8	61.5	68.5	62.5	70.2
	50	54.7	59.5	68.0	57.2	70.2
	100	52.3	55.5	63.5	54.5	67.7
	150	52.2	-	59.0	54.0	59.2
	200	51.0	54.0	56.0	53.5	54.7
	250	51.8	-	53.8	53.5	53.7
	300	51.6	53.0	53.0	53.2	53.2
	350	51.6	53.0	52.8	53.0	53.2
	400	51.6	-	-	53.0	53.2
Dissolved oxygen, mg/L	5	10.1	9.30	7.65	9.4	7.7
	25	9.84	9.07	-	9.8	-
	50	9.45	8.75	7.15	9.0	-
	100	9.05	8.40	6.85	8.2	4.1
	150	-	8.10	2.15	-	-
	200	8.75	8.20	4.30	6.2	5.7
	250	-	8.32	-	-	-
	300	8.87	8.18	5.70	6.2	5.6
	350	8.88	8.00	-	-	-
	400	8.42	-	-	4.6	-
Conductivity, Ec x 10^6 at 25° C micromhos/cm	5	1,075	1,300	1,210	1,105	1,000
	25	1,080	1,300	1,210	1,110	1,020
	50	1,080	1,300	1,210	1,110	1,020
	100	1,085	1,300	1,200	1,110	1,060
	150	-	-	1,190	1,110	1,050
	200	1,115	1,310	1,200	1,150	1,000
	250	-	-	1,220	1,150	1,020
	300	1,125	1,330	1,250	1,190	1,040
	350	1,125	1,340	1,270	1,190	1,080
	400	1,130	-	-	1,200	1,100
pH	5	8.2	8.4	8.65	8.6	8.5
	25	8.2	8.2	-	8.7	-
	50	8.1	8.1	8.65	8.4	-
	100	8.0	7.9	8.5	8.2	8.1
	150	-	7.8	7.9	-	-
	200	8.0	7.8	7.9	8.1	8.0
	250	-	7.8	-	-	-
	300	8.0	7.7	7.9	8.0	8.1
	350	7.9	7.7	-	-	-
	400	7.8	-	-	7.8	-

Lake Mead Station 4
Continued

	Collection depth	April 1964	May 1965	November 1965	April 1966	November 1966
Alkalinity, phth as $CaCO_3$ mg/L	5		4.2	3.0	7.0	4.2
	25		2.8	-	6.0	-
	50		0.0	2.5	0.0	0.0
	100		0.0	4.0	0.0	-
	150		0.0	0.0	-	-
	200		0.0	0.0	0.0	0.0
	250		0.0	-	-	-
	300		0.0	0.0	0.0	-
	350		2.0	-	-	-
	400		-	-	0.0	0.0
Alkalinity, MO as $CaCO_3$ mg/L	5		125.4	109.5	123	105.0
	25		125.0	-	122	-
	50		125.0	111.5	120	-
	100		125.8	112.0	122	112.5
	150		125.2	144.0	-	-
	200		126.2	146.0	122	126.5
	250		126.0	-	-	-
	300		127.9	155.0	126	127.8
	350		128.8	-	-	-
	400		-	-	130	-
Carbon dioxide, mg/L	5	0.0		0.0	0.0	0.0
	25	0.0		-	0.0	-
	50	0.0		0.0	0.0	-
	100	1.45		0.0	3.88	1.45
	150	-		5.80	-	-
	200	1.94		3.88	2.90	2.71
	250	-		-	-	-
	300	1.94		2.90	5.80	2.52
	350	0.97		-	-	-
	400	0.97		-	5.80	-

CHEMICAL AND PHYSICAL DATA
Lake Mead Station 6

	Collection depth	April 1964	May 1965	November 1965	April 1966	November 1966
Temperature, °F	5	61.2	68.5	77.5	65.0	71.2
	25	58.6	-	-	60.5	70.2
	50	54.7	64.5	70.7	57.2	70.2
	100	52.5	56.2	68.9	54.0	69.2
	150	52.8	-	63.5	53.8	59.2
	200	51.6	-	59.9	53.0	54.2
	250	51.6	-	-	53.0	53.7
	300	51.6	53.5	57.2	53.0	53.2
	350	51.6	-	-	53.0	53.2
	400	51.6	-	-	53.0	-
Dissolved oxygen, mg/L	5	9.9	8.98	7.7	9.5	7.8
	25	10.0	9.30	-	9.7	-
	50	9.6	8.70	7.3	8.6	7.8
	100	9.0	8.20	3.0	8.0	7.5
	150	-	-	2.15	-	-
	200	8.8	8.20	4.4	7.4	5.8
	250	-	-	-	-	-
	300	8.9	8.18	5.58	6.1	5.7
	350	8.9	7.95	-	-	5.4
	400	8.5	-	-	4.2	-
Conductivity, Ec x 10^6 at 25° C micromhos/cm	5	1,080	1,250	1,200	1,110	1,040
	25	1,075	-	-	1,110	1,040
	50	1,080	1,300	1,200	1,110	1,040
	100	1,080	1,300	1,225	1,120	1,080
	150	-	-	1,200	1,120	1,080
	200	1,110	-	1,250	1,150	1,005
	250	-	-	-	1,150	1,040
	300	1,115	1,325	1,250	1,180	1,040
	350	1,125	-	-	1,190	1,065
	400	1,130	-	-	1,195	-
pH	5	8.4	8.3	8.8	8.5	8.4
	25	8.4	8.5	-	8.5	-
	50	8.2	8.4	8.8	8.3	8.5
	100	8.2	8.2	8.2	8.1	8.5
	150	-	-	8.0	-	-
	200	8.2	8.0	8.1	8.0	8.0
	250	-	-	-	-	-
	300	8.2	7.9	8.2	7.8	8.0
	350	8.2	7.9	-	-	7.9
	400	8.2	-	-	7.7	-

Lake Mead Station 6
Continued

	Collection depth	April 1964	May 1965	November 1965	April 1966	November 1966
Alkalinity, phth as $CaCO_3$ mg/L	5		5.0	4.8	6.5	4.5
	25		-	-	2.0	-
	50		5.0	4.5	0.0	4.5
	100		0.0	0.0	0.0	4.0
	150		0.0	0.0	-	-
	200		0.0	0.0	0.0	0.0
	250		-	-	-	-
	300		0.0	0.0	0.0	0.0
	350		0.0	-	-	0.0
	400		-	-	0.0	0.0
Alkalinity, MO as $CaCO_3$ mg/L	5		128.5	105.0	119.0	107.5
	25		-	-	120.0	-
	50		130.2	106.5	120.0	105.0
	100		128.7	121.0	-	105.5
	150		-	139.5	-	-
	200		127.8	141.0	124.0	-
	250		-	-	-	-
	300		130.5	135.5	127.0	121.5
	350		133.0	-	-	126.5
	400		-	-	125.0	-
Carbon dioxide, mg/L	5	0.0		0.0	0.0	0.0
	25	0.0		-	0.0	0.0
	50	0.0		0.0	1.45	-
	100	-		3.10	1.94	-
	150	0.97		7.74	-	-
	200	0.97		6.87	1.94	2.42
	250	-		-	-	-
	300	0.97		5.32	3.39	3.20
	350	0.97		-	-	3.39
	400	0.97		-	3.87	-

CHEMICAL AND PHYSICAL DATA
Lake Mead Station 8

	Collection depth	April 1964	May 1965	November 1965	April 1966	November 1966
Temperature, °F	5	60.8	70.2	71.6	61.5	70.7
	10				61.5	70.7
	25	58.5	-	-	56.8	70.2
	50	55.2	61.8	-	54.5	70.2
	100	53.1	56.0	68.0	53.5	67.2
	150	52.2	-	61.7	53.0	59.7
	200	51.8	53.8	62.6	53.0	55.7
	250				53.0	53.7
	300	-	-	-	53.0	
Dissolved oxygen, mg/L	5	9.60	10.48	7.75	9.6	-
	10					7.8
	25	9.68	9.30	-	9.7	-
	50	9.38	8.72	-	9.0	-
	100	9.00	8.25	2.55	8.3	7.5
	150	8.55	-	2.00	-	-
	200	8.55	7.65	3.08	7.7	4.8
	250					-
	300	-	-	-	6.8	
Conductivity, Ec x 10^6 at 25° C micromhos/cm	5	1,085	1,305	1,200	1,100	1,040
	10					1,040
	25	1,070	-	1,200	1,100	1,040
	50	1,060	1,305	1,210	1,110	1,040
	100	1,070	1,300	1,210	1,110	1,040
	150	-	-	1,150	1,110	1,055
	200	1,110	1,325	1,230	1,110	1,025
	250				1,150	1,020
	300	-	-	-	1,150	
pH	5	8.2	8.6	8.5	8.6	-
	10					8.5
	25	8.2	8.5	-	8.7	-
	50	8.2	8.3	-	8.4	-
	100	8.1	8.0	7.9	8.3	8.5
	150	8.1	-	7.8	-	-
	200	8.1	8.0	7.8	8.2	8.0
	250					-
	300	-	-	-	8.1	

Lake Mead Station 8
Continued

	Collection depth	April 1964	May 1965	November 1965	April 1966	November 1966
Alkalinity, phth as $CaCO_3$ mg/L	5		7.3	5.0	7.5	-
	10					5.0
	25		6.3	-	0.0	-
	50		4.2	-	0.0	-
	100		0.0	0.0	0.0	4.0
	150		-	0.0	0.0	-
	200		0.0	0.0	0.0	0.0
	250					-
Alkalinity, MO as $CaCO_3$ mg/L	5		123.0	106.5	127.5	-
	10					105.5
	25		124.2	-	-	-
	50		126.2	-	123.0	-
	100		128.0	119.5	125.5	107.0
	150		-	130.5	-	-
	200		129.5	139.0	123.0	129.0
	250					-
	300		-	-	123.0	
Carbon dioxide, mg/L	5	0.00		0.0	0.0	-
	10					0.0
	25	0.00		-	0.0	-
	50	0.00		-	0.98	-
	100	0.97		3.19	2.42	0.0
	150	0.97		4.26	2.42	-
	200	1.94		5.30	2.42	3.8
	250					-
	300	-		-	2.90	

CHEMICAL AND PHYSICAL DATA
Lake Mead Station 9

	Collection depth	April 1964	May 1965	November 1965	April 1966	November 1966
Temperature, ° F	5	61.5	70.2	67.5	63.5	69.7
	10					69.5
	25	59.5	-	67.5	56.5	69.5
	50	55.0	63.0	67.5	55.5	69.5
	100	52.9	58.5	67.5	54.5	69.5
	150	52.9	-	59.5	53.8	58.2
	200	52.3	53.0	56.0	53.5	55.2
	270					53.7
Dissolved oxygen, mg/L	5	9.70	12.32	7.70	9.8	-
	10					7.9
	25	9.86	9.12	-	9.8	-
	50	9.10	8.50	7.60	8.7	7.8
	100	8.69	7.97	7.60	8.2	7.7
	150	8.69	-	2.30	-	-
	200	8.42	7.35	1.78	7.3	3.2
	270					3.8
Conductivity, Ec x 10^6 at 25° C micromhos/cm	5	1,090	1,320	1,210	1,130	1,020
	10					1,020
	25	1,080	-	1,210	1,110	1,030
	50	1,060	1,280	1,210	1,130	1,030
	100	1,085	1,300	1,210	1,160	1,030
	150	1,100	-	1,190	1,160	1,065
	200	1,135	1,360	1,250	1,160	1,060
	270					1,060
pH	5	8.0	8.8	8.2	8.7	-
	10					8.5
	25	8.0	-	-	8.7	-
	50	8.2	8.35	8.6	8.4	8.6
	100	8.2	8.1	8.6	8.2	8.7
	150	8.2	-	7.8	-	-
	200	8.1	8.0	7.8	8.2	7.9
	270					7.8

Lake Mead Station 9
Continued

	Collection depth	April 1964	May 1965	November 1965	April 1966	November 1966
Alkalinity, phth as $CaCO_3$ mg/L	5	-	8.5	5.2	0.0	-
	10		-			4.8
	25	-	-	-	0.0	-
	50	-	3.7	-	0.0	5.0
	100	-	0.0	5.0	0.0	5.3
	150	-	0.0	0.0	0.0	-
	200	-	0.0	0.0	0.0	0.0
	270					0.0
Alkalinity, MO as $CaCO_3$ mg/L	5	-	117.5	108.0	118.0	-
	10		-			103.5
	25	-	-	-	125.0	-
	50	-	128.0	-	130.0	106.5
	100	-	127.2	107.5	120.0	109.0
	150	-	-	137.0	-	-
	200	-	129.5	134.5	123.0	127.5
	270					130.6
Carbon dioxide, mg/L	5	0.0	-	0.0	0.0	0.0
	10					-
	25	0.0	-	-	0.0	0.0
	50	0.0	-	-	2.42	-
	100	1.45	-	0.0	2.42	0.0
	150	1.45	-	4.06	-	-
	200	1.94	-	3.39	3.39	5.1
	270	-				5.0

CHEMICAL AND PHYSICAL DATA
Lake Mead Station 10

	Collection depth	April 1964	May 1965	November 1965	April 1966	November 1966
Temperature, °F	5	59.7	71.2	67.5	63.2	70.2
	10					70.2
	25	59.0	65.0	67.5	61.0	69.7
	50	58.8	63.0	67.5	57.0	69.7
	100	52.5	57.0	67.5	55.0	69.2
	150	52.5	57.0	60.0	54.0	59.3
	200	52.0	-	-	-	
Dissolved oxygen, mg/L	5	9.57	13.85	7.90	11.7	-
	10					8.0
	25	9.62	9.22	-	9.3	-
	50	9.67	7.20	-	8.7	7.75
	100	8.94	6.68	8.05	7.8	7.72
	150	8.74	6.30	0.20	7.5	0.05
	200	8.75	-		-	
Conductivity, Ec x 10^6 at 25° C micromhos/cm	5	1,080	1,350	1,210	1,125	1,040
	10					1,040
	25	1,080	1,310	1,210	1,125	1,040
	50	1,080	1,460	1,210	1,125	1,040
	100	1,070	1,460	1,210	1,125	1,060
	150	1,085	1,480	1,210	1,090	1,095
	200	1,100	-		-	
pH	5	8.0	8.8	8.7	8.6	-
	10					8.4
	25	8.2	8.6	-	8.5	-
	50	8.2	8.2	-	8.2	8.45
	100	8.2	7.9	8.7	8.1	8.5
	150	8.1	7.9	8.7	8.0	7.70
	200	8.1	-	-	-	
Alkalinity, phth as $CaCO_3$ mg/L	5	-	8.0	5.5	9.0	-
	10					5.0
	25	-	-	-	0.0	-
	50	-	0.0	-	0.0	4.5
	100	-	0.0	5.8	0.0	5.5
	150	-	0.0	0.0	0.0	0.0

Lake Mead Station 10
Continued

	Collection depth	April 1964	May 1965	November 1965	April 1966	November 1966
Alkalinity,	5	-	111.0	109.5	120.0	-
MO	10					104.5
as $CaCO_3$	25	-	-	-	123.0	-
mg/L	50	-	125.0	-	123.0	105.2
	100	-	127.8	109.0	126.0	107.5
	150	-	129.8	145.5	123.0	129.0
Carbon	5		-	0.0	0.0	-
dioxide,	10					0.0
mg/L	25		-	-	0.0	-
	50		-	-	0.96	0.0
	100		-	0.0	3.38	-
	150	0.97	-	7.1	3.87	5.5
	200	2.42	-	-	-	

CHEMICAL AND PHYSICAL DATA
Lake Mead Station 12

	Collection depth	April 1964	May 1965	November 1965	April 1966	November 1966
Temperature, °F	5	54.8	69.5	68.0	65.5	70.7
	10					70.7
	25	57.9	-	68.0	61.5	70.7
	50	57.6	62.8	68.5	57.5	70.7
	100	54.3	55.5	67.5	54.0	66.2
	150	-		59.5	53.5	58.7
	200	52.0	53.5	56.0	53.2	54.2
	250	-		54.0	53.0	53.2
	300	52.0	53.0	53.0	53.0	53.2
	350	-	53.0	53.0	53.0	53.2
Dissolved oxygen, mg/L	5	9.51	8.75	7.50	10.00	-
	10					7.42
	25	9.50	9.20	-	10.20	-
	50	9.48	8.85	7.50	9.4	7.53
	100	8.93	8.20	0.75	8.5	1.58
	150	-	-	2.50	-	-
	200	8.83	8.05	4.10	7.7	5.72
	250	-	-	-	-	-
	300	8.80	8.05	5.40	6.5	5.65
	350	-	7.30	5.35	5.7	-
Conductivity, Ec x 10^6 at 25° C micromhos/cm	5	1,080	1,310	1,200	1,120	1,020
	10					1,020
	25	1,080	-	1,200	1,120	1,025
	50	1,085	1,300	1,210	1,120	1,025
	100	1,085	1,300	1,210	1,105	1,025
	150	-	-	1,150	1,105	1,030
	200	1,100	1,320	1,200	1,150	990
	250	-	-	1,250	1,120	1,020
	300	1,120	1,325	1,250	1,120	1,040
	350	-	1,340		1,190	1,070
pH	5	8.0	8.5	8.4	8.3	-
	10					8.5
	25	8.1	8.5	-	8.5	-
	50	8.1	8.35	8.3	8.2	8.5
	100	7.8	8.0	7.5	8.1	7.8
	150	-	-	7.6	-	-
	200	7.5	7.9	7.7	8.0	7.8
	250	-	-	-	-	-
	300	7.5	7.8	7.8	7.1	7.8
	350	-	7.9	7.8	7.8	-

Lake Mead Station 12
Continued

	Collection depth	April 1964	May 1965	November 1965	April 1966	November 1966
Alkalinity, phth as $CaCO_3$ mg/L	5	-	9.0	4.0	3.0	-
	10					4.5
	25	-	-	-	4.0	-
	50	-	4.3	4.8	0.0	4.0
	100	-	0.0	0.0	0.0	0.0
	150	-	0.0	0.0	0.0	-
	200	-	0.0	0.0	0.0	0.0
	250	-	0.0	0.0	0.0	-
	300	-	-	-	-	0.0
	350	-	-	-	-	-
Alkalinity, MO as $CaCO_3$ mg/L	5	-	126.2	107.0	123	-
	10					105.5
	25	-	-	-	126	-
	50	-	125.5	109.0	126	106.0
	100	-	126.0	129.0	126	123.5
	150	-	-	139.5	-	-
	200	-	129.7	-	126	129.0
	250	-	-	-	-	-
	300	-	132.0	141.0	126	127.5
	350	-	134.2	137.0	130	-
Carbon dioxide, mg/L	5	0.0	-	0.0	0.0	-
	10					-
	25	0.0	-	-	0.0	-
	50	0.0	-	0.0	2.42	-
	100	1.94	-	4.55	1.94	5.1
	150	-	-	5.61	-	-
	200	2.42	-	4.07	2.90	4.1
	250	-	-	-	-	-
	300	2.42	-	3.68	2.90	4.3
	350	-	-	2.71	2.90	-

CHEMICAL AND PHYSICAL DATA
Lake Mead Station 14

	Collection depth	April 1964	May 1965	November 1965	April 1966	November 1966
Temperature, °F	5	58.5	68.5	68.5	66.0	70.7
	10					70.7
	25	58.5	67.0	68.5	61.3	70.7
	50	58.5	60.0	68.5	57.0	70.2
	100	58.0	55.0	66.0	53.5	67.7
	125					62.7
	150	52.7	-	59.0	53.0	58.7
	175					55.7
	200	52.0	53.8	56.0	52.5	54.2
	250	-	-	53.5	52.5	53.2
	300	52.0	53.5	53.0	52.5	53.2
	350	-	-	-	52.5	53.2
Dissolved oxygen, mg/L	5	9.49	9.00	7.00	9.9	-
	10					7.22
	25	9.49	9.20	-	10.3	-
	50	9.55	8.85	6.97	9.3	7.28
	100	8.78	8.32	0.75	8.3	4.30
	125					-
	150	8.87	-	2.32	-	-
	175					-
	200	8.90	8.20	4.43	7.8	5.52
	250	-	-	-	-	-
	300	8.86	8.00	5.15	6.1	5.60
	350	-	-	5.00	6.2	-
Conductivity, Ec x 10^6 at 25° C micromhos/cm	5	1,080	1,300	1,225	1,110	1,020
	10					1,020
	25	1,080	1,305	1,225	1,110	1,020
	50	1,080	1,300	1,200	1,110	1,020
	100	1,080	1,310	1,210	1,095	1,065
	125					1,040
	150	1,065	-	1,125	1,100	1,025
	175					990
	200	1,085	1,320	1,200	1,100	990
	250	1,100	-	1,250	1,100	1,000
	300	1,120	1,325	1,250	1,100	1,000
	350	-	-	-		1,050

Lake Mead Station 14
Continued

	Collection depth	April 1964	May 1965	November 1965	April 1966	November 1966
pH	5	8.2	8.3	8.5	8.6	-
	10					8.6
	25	8.2	8.5	-	8.6	-
	50	8.3	8.25	8.5	8.4	8.6
	100	8.3	8.0	7.8	8.2	8.2
	125					-
	150	8.2	-	7.8	-	-
	175					-
	200	8.1	7.9	7.9	8.1	8.2
	250	-	-	-	-	-
	300	8.0	8.0	8.0	8.0	8.2
	350	-	-	8.0	7.8	-
Alkalinity, phth as $CaCO_3$ mg/L	5	-	3.5	4.3	1.0	-
	10					4.0
	25	-	4.8	-	5.0	-
	50	-	3.2	-	0.0	3.8
	100	-	0.0	0.0	0.0	0.0
	125					-
	150	-	0.0	-	0.0	-
	175					-
	200	-	0.0	0.0	0.0	0.0
	250	-	0.0	-	0.0	-
	300	-	0.0	-	0.0	0.0
	350	-	0.0	-	0.0	-
Alkalinity, MO as $CaCO_3$ mg/L	5	-	131.0	108.0	120	-
	10					107.5
	25	-	131.2	-	123	-
	50	-	134.8	-	123	106.0
	100	-	135.5	132.5	125	114.0
	125					-
	150		-	-	-	-
	175					-
	200	-	134.0	141.5	122	125.0
	250	-	-	-	-	-
	300	-	134.0	-	127	-
	350	-	-	-	125	-

Lake Mead Station 14
Continued

	Collection depth	April 1964	May 1965	November 1965	April 1966	November 1966
Carbon dioxide, mg/L	5	-	-	0.0	0.0	-
	10					0.0
	25	-	-	-	0.0	-
	50	-	-	0.0	1.93	0.0
	100	1.94	-	3.68	1.93	1.16
	125					-
	150	1.94	-	4.84	-	-
	175					-
	200	2.42	-	4.65	2.40	2.42
	250	-	-	-	-	-
	300	2.42	-	3.87	2.90	3.39
	350	-	-	3.40	3.87	-

CHEMICAL AND PHYSICAL DATA
Lake Mead Station 16

	Collection depth	April 1964	May 1965	November 1965	April 1966
Temperature, °F	5	61.0	70.5	68.0	67.0
	25	61.0	68.5	68.0	62.0
	50	59.5	61.5	68.5	58.0
	100	54.0	56.0	66.5	54.2
	150	-	55.5	59.0	53.5
	200	53.0	54.0	56.0	53.0
	250	53.0	53.5	54.0	52.5
	300	-	-	53.5	52.0
	350	-	-	-	-
Dissolved oxygen, mg/L	5	9.46	8.85	7.15	9.8
	25	9.46	8.91	-	10.0
	50	9.39	8.00	7.00	9.1
	100	8.94	7.90	0.72	8.1
	150	-	8.15	2.72	-
	200	8.91	8.00	4.35	7.4
	250	8.85	8.02	-	-
	300	-	-	4.60	7.1
	350	-	-	-	-
Conductivity, Ec x 10^6 at 25° C micromhos/cm	5	1,070	1,310	1,150	1,105
	25	1,080	1,305	1,150	1,105
	50	1,080	1,275	1,150	1,105
	100	1,080	1,290	1,175	1,110
	150	-	1,290	1,125	1,110
	200	1,120	1,300	1,200	1,110
	250	1,125	1,310	1,225	1,110
	300	-	-	1,225	1,080
	350	-	-	-	-
pH	5	8.0	8.45	8.6	8.6
	25	8.1	8.42	-	8.5
	50	8.0	8.0	8.6	8.1
	100	7.9	7.95	7.9	8.1
	150	-	7.90	7.9	-
	200	7.8	7.88	8.1	8.0
	250	7.8	7.85	-	-
	300	-	-	8.1	8.0

Lake Mead Station 16
Continued

	Collection depth	April 1964	May 1965	November 1965	April 1966
Alkalinity, phth as $CaCO_3$ mg/L	5		6.2	4.0	4.0
	25		6.0	-	4.0
	50		0.0	-	0.0
	100		0.0	0.0	0.0
	150		0.0	-	0.0
	200		0.0	-	0.0
	250		0.0	-	0.0
	300		0.0	-	0.0
	350		0.0	-	-
Alkalinity, MO as $CaCO_3$ mg/L	5		132.2	113.0	124.0
	25		133.0	-	122.0
	50		142.5	-	122.0
	100		135.5	130.5	121.0
	150		135.3	-	-
	200		134.5	141.0	123.0
	250		134.5	-	-
	300		-	-	126.0
Carbon dioxide, mg/L	5	0.00		0.00	-
	25	0.00		0.00	-
	50	0.00		-	0.00
	100	0.97		6.29	1.94
	150	-		5.13	-
	200	0.97		3.39	2.42
	250	0.97		-	-
	300	-		3.39	2.91
	350	-		-	-

CHEMICAL AND PHYSICAL DATA
Lake Mead Station 18

	Collection depth	May 1965	November 1965	April 1966	November 1966
Temperature, °F	5	71.5	68.0	62.8	69.7
	25	70.5	68.0	59.0	69.7
	50	63.0	68.0	55.5	69.7
	100	56.0	67.0	53.0	69.2
	150	-	59.0	52.5	59.7
	200	53.2	55.5	52.5	56.2
	300	53.0	53.0	52.5	53.2
	350	53.0	53.0	52.5	53.2
Dissolved oxygen, mg/L	5	8.75	6.85	9.2	6.83
	25	8.85	-	9.1	-
	50	8.42	4.30	8.8	-
	100	7.80	0.60	8.6	4.60
	150	-	2.72	-	-
	200	8.22	6.55	8.4	5.55
	300	8.03	4.95	7.6	4.35
	350	7.98	4.25	7.4	-
Conductivity, Ec x 10^6 at 25° C micromhos/cm	5	1,300	1,050	1,000	930
	25	1,300	1,075	960	930
	50	1,275	1,075	960	930
	100	1,275	1,150	950	925
	150	-	1,125	950	980
	200	1,310	1,200	950	990
	300	1,320	1,250	960	1,030
	350	1,325	1,250	975	1,040
pH	5	8.4	8.1	8.6	8.3
	25	8.4	-	8.5	-
	50	8.15	8.4	8.4	-
	100	7.89	7.6	8.3	8.0
	150	-	7.7	-	-
	200	7.9	7.8	8.3	7.9
	300	7.8	7.8	8.2	7.9
	350	7.8	7.8	8.1	-
Alkalinity, phth as $CaCO_3$ mg/L	5	6.5	4.5	5.0	3.8
	25	7.2	0.0	4.0	-
	50	3.0	0.0	0.0	-
	100	0.0	0.0	0.0	0.0
	150	0.0	0.0	0.0	-
	200	0.0	0.0	0.0	0.0
	300	0.0	0.0	0.0	0.0
	350	0.0	0.0	0.0	-

Lake Mead Station 18
Continued

	Collection depth	May 1965	November 1965	April 1966	November 1966
Alkalinity,	5	131.5	118.5	127.0	112.5
MO	25	132.5	-	126.0	-
as $CaCO_3$	50	139.8	-	130.0	-
mg/L	100	140.0	131.0	129.0	122.5
	150	-	-	-	-
	200	137.2	140.2	127.0	127.5
	300	138.2	-	128.0	131.0
	350	137.8	-	-	-
Carbon	5		0.0	0.0	0.0
dioxide,	25		-	0.0	-
mg/L	50		0.0	0.0	-
	100		6.58	3.39	1.45
	150		5.61	-	-
	200		4.36	1.93	2.42
	300		3.68	2.90	3.85
	350		3.09	3.87	-

CHEMICAL AND PHYSICAL DATA
Lake Mead Station 20

	Collection depth	November 1965	April 1966	November 1966
Temperature, °F	5	70.0	60.0	70.2
	25	67.5	59.0	70.2
	50	67.0	58.5	70.2
	100	65.0	53.8	69.7
	150	58.5	52.8	63.7
	200	56.0	52.0	58.7
	250	54.0	52.0	55.2
	300	53.5	52.0	52.7
Dissolved oxygen, mg/L	5	7.50	9.7	7.32
	25	-	-	-
	50	7.35	9.7	-
	100	1.85	9.0	5.60
	150	2.55	-	-
	200	4.05	8.7	5.10
	250	-	-	-
	300	4.30	8.3	5.55
Conductivity, Ec x 10^6 at 25° C micromhos/cm	5	1,000	925	920
	25	1,000	925	920
	50	1,000	925	920
	100	1,100	950	920
	150	1,150	950	940
	200	1,200	950	980
	250	1,250	950	980
	300	1,190	950	970
pH	5	8.4	8.5	8.5
	25	-	-	-
	50	8.4	8.5	-
	100	7.7	8.3	8.3
	150	7.6	-	-
	200	7.8	8.3	7.9
	250	-	-	-
	300	7.7	8.1	7.8
Alkalinity, phth as $CaCO_3$ mg/L	5	5.2	7.0	4.0
	25	-	-	-
	50	-	5.0	-
	100	0.0	0.0	1.2
	150	0.0	0.0	-
	200	0.0	0.0	0.0
	250	-	0.0	-
	300	0.0	0.0	0.0

Lake Mead Station 20
Continued

	Collection depth	November 1965	April 1966	November 1966
Alkalinity, MO as $CaCO_3$ mg/L	5	115.5	129	114.0
	25	-	-	-
	50	-	130	-
	100	131.0	128	117.8
	150	138.5	-	-
	200	140.5	128	126.5
	250	-	-	-
	300	139.5	128	127.2
Carbon dioxide, mg/L	5	0.0	0.0	0.0
	25	-	-	-
	50	0.0	0.0	-
	100	2.90	2.9	0.0
	150	3.38	-	-
	200	3.87	2.9	2.91
	250	-	-	-
	300	3.38	2.9	2.91

CHEMICAL AND PHYSICAL DATA
Lake Mead Station 21

	Collection depth	November 1965
Temperature, °F	5	69.0
	25	68.5
	50	68.0
	100	66.0
	150	59.5
	200	56.0
	300	53.5
Dissolved oxygen, mg/L	5	7.40
	100	3.00
	150	2.92
	200	4.15
	300	4.25
Conductivity, Ec x 10^6 at 25° C micromhos/cm	5	940
	25	950
	50	975
	100	1,075
	150	1,110
	200	1,175
	300	1,275
pH	5	8.3
	100	7.7
	200	7.6
	300	7.8
Alkalinity, phth as $CaCO_3$ mg/L	5	3.5
	100	0.0
	200	0.0
	300	0.0
Alkalinity, MO as $CaCO_3$ mg/L	5	113.5
	100	123.5
	200	137.5
	300	136.0
Carbon dioxide, mg/L	5	0.0
	100	3.4
	200	3.4
	300	4.4

CHEMICAL AND PHYSICAL DATA
Lake Mead Station 22 & 22A

	Collection depth	22 November 1965	22 November 1966	22A November 1965
Temperature, °F	5	67.0	70.7	68.0
	25	67.0	70.7	67.5
	50	67.0	70.7	67.5
	100	64.5	65.7	64.2
	125	61.0	60.7	61.0
	150	59.0	56.7	58.8
	200	55.5	53.2	55.5
	250	54.0	52.2	54.0
Dissolved oxygen, mg/L	5	7.8	7.60	7.75
	50	7.5	-	7.25
	100	6.05	7.58	4.80
	150	4.10	4.55	3.60
	200	3.55	4.55	4.00
	250	3.15	4.40	3.45
Conductivity, Ec x 10^6 at 25° C micromhos/cm	5	650	825	790
	25	650	825	800
	50	650	825	800
	100	790	825	950
	125	1,050	865	1,060
	150	1,090	865	1,105
	200	1,190	870	1,190
	250	1,210	900	1,225
pH	5	8.75	8.7	8.35
	50	8.70	-	8.40
	100	8.4	8.6	7.95
	150	7.9	8.0	7.70
	200	7.9	8.0	7.85
	250	8.0	8.0	7.75
Alkalinity, phth as $CaCO_3$ mg/L	5	2.5	3.3	5.5
	50	3.2	-	3.0
	100	0.0	3.2	0.0
	150	0.0	0.0	0.0
	200	0.0	0.0	0.0
	250	0.0	0.0	0.0

Lake Mead Station 22 & 22A
Continued

	Collection depth	22 November 1965	22 November 1966	22A November 1965
Alkalinity,	5	111.0	119.5	117.0
MO	50	114.5	-	118.5
as $CaCO_3$	100	117.0	126.5	130.5
mg/L	150	139.0	134.2	147.0
	200	140.5	139.2	144.5
	250	140.0	139.0	145.0
Carbon	5	0.0	0.0	0.0
dioxide,	50	0.0	0.0	0.0
mg/L	100	0.97	0.0	2.91
	150	2.4	2.6	4.36
	200	4.4	3.1	3.88
	250	5.0	2.9	4.07

CHEMICAL AND PHYSICAL DATA
Lake Mead Station 23 & 23A

	Collection depth	23 November 1965	23 November 1966	23A November 1965
Temperature, °F	5	68.0	69.7	66.5
	10	67.0	69.7	67.0
	25	66.7	69.7	67.0
	50	65.7	69.7	66.0
	100	64.2	65.7	63.8
	140	59.0	56.7	58.5
Dissolved oxygen, mg/L	5	8.75	-	8.05
	10	-	7.70	-
	50	7.95	-	7.65
	100	8.00	8.25	8.20
	140	3.15	-	4.40
Conductivity, Ec x 10^6 at 25° C micromhos/cm	5	650	810	640
	10	650	810	640
	25	640	810	640
	50	640	810	640
	100	660	810	670
	140	1,100	860	1,110
pH	5	8.95		8.35
	50	8.75		8.30
	100	8.70		8.35
	140	8.15		7.80
Alkalinity, phth as $CaCO_3$ mg/L	5	5.5		3.0
	50	1.0		3.0
	100	2.0		2.5
	140	0.0		0.0
Alkalinity, MO as $CaCO_3$ mg/L	5	112.0		107.0
	50	108.5		108.2
	100	112.0		109.5
	140	139.0		136.0
Carbon dioxide, mg/L	5	0.0		0.0
	50	0.0		0.0
	100	0.0		0.0
	140	4.2		2.1

CHEMICAL AND PHYSICAL DATA
Lake Mead Station 24

	Collection depth	November 1965	November 1966
Temperature, °F	5	62.5	60.2
Dissolved oxygen, mg/L	5	8.55	8.35
Conductivity, Ec x 10^6 at 25° C micromhos/cm	5	650	795
pH	5	8.9	8.5
Alkalinity, phth as $CaCO_3$ mg/L	5	3.0	4.0
Alkalinity, MO as $CaCO_3$ mg/L	5	114.5	124.5
Carbon dioxide, mg/L	5	0.0	0.0

CHEMICAL AND PHYSICAL DATA
Lake Mead Station OV1

	Collection depth	November 1965	November 1966
Temperature, °F	5	67.8	69.2
	10	67.5	68.7
	25	67.5	68.7
	50	67.0	68.7
	-	-	-
	100	67.0	68.7
	125	-	68.7
	150	59.0	58.5
	200	56.0	54.7
Dissolved oxygen, mg/L	5	7.80	-
	10	-	7.50
	50	7.58	-
	100	4.85	1.75
	150	0.65	-
	200	1.82	4.30
Conductivity, Ec x 10^6 at 25° C micromhos/cm	5	950	920
	10	950	930
	25	950	930
	50	1,000	930
	-	-	-
	100	1,205	935
	125	1,205	960
	150	1,210	980
	200	1,230	980
pH	5	8.10	-
	10	-	8.4
	50	8.45	-
	100	8.15	7.7
	150	7.70	-
	200	7.75	7.8
Alkalinity, phth as $CaCO_3$ mg/L	5	4.0	-
	10	-	4.0
	50	4.0	-
	100	0.0	0.0
	150	0.0	-
	200	0.0	-

Lake Mead Station OV1
Continued

	Collection depth	November 1965	November 1966
Alkalinity, MO as $CaCO_3$ mg/L	5	118.5	-
	10	-	113.2
	50	118.0	-
	100	119.5	125.5
	150	146.5	-
	200	141.5	127.2
Carbon dioxide, mg/L	5	0.0	-
	10	0.0	0.0
	50	0.0	-
	100	1.2	4.0
	150	7.5	-
	200	6.6	4.5

CHEMICAL AND PHYSICAL DATA
Lake Mead Station OV2

	Collection depth	November 1965	November 1966
Temperature, °F	5	67.2	65.2
	25	67.2	-
	50	67.0	-
	75	67.0	-
Dissolved oxygen, mg/L	5	7.85	8.50
	25	7.40	-
	50	7.30	-
	75	7.05	-
Conductivity, Ec x 10^6 at 25° C micromhos/cm	5	1,125	1,240
	25	1,125	-
	50	1,125	-
	75	1,200	-
pH	5	8.40	8.40
	25	8.45	-
	50	8.45	-
	75	8.45	-
Alkalinity, phth as $CaCO_3$ mg/L	5	5.0	4.0
	25	4.5	-
	50	4.2	-
	75	4.5	-
Alkalinity, MO as $CaCO_3$ mg/L	5	116.0	110.8
	25	118.0	-
	50	119.5	-
	75	121.0	-
Carbon dioxide, mg/L	5	0.0	0.0
	25	0.0	-
	50	0.0	-
	75	0.0	-

APPENDIX B

CHEMICAL ANALYSES DATA

LAKE MEAD CHEMICAL ANALYSIS
Station 1

Parameter	Depth	April 1964*	May 1965	November 1965	April 1966	November 1966
Ec x 10^6	5	1,060	1,232	-	1,115	-
at 25° C	10	-	-	1,224	-	1,106
	100	-	-	1,177	1,156	1,100
	200	1,100	1,234	1,195	-	1,059
pH	5	8.1	8.0	-	8.0	-
	10	-	-	7.8	-	8.3
	100		-	7.5	8.0	7.9
	200	7.9	7.9	7.9	-	8.0
TDS	5	796	856	-	792	-
mg/L	10	-	-	848	-	748
	100	-	-	836	812	740
	200	796	868	828	-	724
Ca	5	87	110	-	94	-
mg/L	10	-	-	96	-	80
	100	-	-	99	98	87
	200	90	120	103	-	89
Mg	5	28	19	-	29	-
mg/L	10	-	-	30	-	31
	100	-	-	28	27	27
	200	30	26	25	-	26
Na	5	91	116	-	107	-
mg/L	10	-	-	114	-	105
	100	-	-	109	107	101
	200	98	116	109	-	95
K	5	5.5	6.3	-	5.9	-
mg/L	10	-	-	6.6	-	5.5
	100	-	-	5.9	-	5.5
	200	5.5	6.3	5.9	5.5	4.7
HCO_3	5	144	154	-	144	-
mg/L	10	-	-	115	-	129
	100	-	-	146	-	146
	200	151	149	164	148	154
CO_3	5	0.0	0.0	-	0.0	-
mg/L	10	-	-	0.0	-	0.0
	100	-	-	0.0	0.0	0.0
	200	0.0	0.0	0.0	-	0.0

Station 1
Continued

Parameter	Depth	April 1964*	May 1965	November 1965	April 1966	November 1966
SO_4 mg/L	5	291	345		330	
	10			360		312
	100			335		303
	200	294	338	332	337	287
Cl mg/L	5	86	122		99	
	10			108		94
	100			98		94
	200	95	115	102	98	86
NO_3 mg/L	5	0.6	1.2		2.5	
	10			0.0		1.2
	100			1.2		2.5
	200	0.0	1.2	2.5	2.5	1.9

*Data given at 200 feet were collected at 400 feet on April 1964.

LAKE MEAD CHEMICAL ANALYSIS
Station 3C

Parameter	Depth	Fall 1965	Spring 1966	Fall 1966
Ec x 10^6	5	1,195	1,155	1,100
at 25° C	100	1,244	1,155	1,137
pH	5	7.8	8.3	8.2
	100	7.7	8.1	8.1
TDS	5	832	800	764
mg/L	100	884	808	784
Ca	5	101	89	80
mg/L	100	104	104	85
Mg	5	25	33	31
mg/L	100	28	25	32
Na	5	112	104	101
mg/L	100	118	106	104
K	5	5.9	5.5	5.1
mg/L	100	6.3	5.5	5.9
CO_3	5	0.0	0.0	0.0
mg/L	100	0.0	0.0	0.0
HCO_3	5	122	147	125
mg/L	100	131	147	134
SO_4	5	345	332	314
mg/L	100	360	330	317
Cl	5	109	98	95
mg/L	100	114	100	100
NO_3	5	0.6	1.9	1.2
mg/L	100	0.6	2.5	1.9

LAKE MEAD CHEMICAL ANALYSIS
Stations 4 and 4B

Station		4		4B
Parameter	Depth	Spring 1965*	Fall 1965	Fall 1966
Ec x 10^6 at 25° C	10	1,227	1,195	1,096
	100	1,225	1,168	1,141
	200	1,232		1,060
pH	10	8.1	7.6	8.3
	100	8.1	7.8	8.1
	200	8.0		8.0
TDS mg/L	10	880	836	748
	100	916	832	776
	200	968		744
Ca mg/L	10	133	91	82
	100	104	96	85
	200	116		86
Mg mg/L	10	11	32	30
	100	28	32	32
	200	22		28
Na mg/L	10	113	116	104
	100	112	107	105
	200	114		97
K mg/L	10	6.3	5.9	5.5
	100	6.3	5.5	5.9
	200	6.3		5.1
CO_3 mg/L	10	0.0	0.0	0.0
	100	0.0	0.0	0.0
	200	0.0		0.0
HCO_3 mg/L	10	151	123	125
	100	146	154	132
	200	154		151
SO_4 mg/L	10	341	357	314
	100	338	331	320
	200	346		285
Cl mg/L	10	119	110	93
	100	117	97	101
	200	121		86

Stations 4 and 4B
Continued

Station		4		4B
Parameter	**Depth**	**Spring 1965***	**Fall 1965**	**Fall 1966**
NO_3 mg/L	10	1.2	0.6	0.6
	100	1.2	2.5	1.9
	200	1.9		2.5

***Data given as 10 feet were collected from 25 feet on April 1965.**

LAKE MEAD CHEMICAL ANALYSIS
Stations 6 and 8

Station		6	8		
Parameter	Depth	May 1965*	November 1965	April 1966	November 1966**
Ec x 10^6 at 25° C	5	1,218	1,195	1,149	1,096
	100		1,171	1,155	1,094
	200	1,232	1,157		1,083
pH	5	8.1	7.9	8.1	8.3
	100		8.0	8.1	8.2
	200	7.8	8.1		8.0
TDS mg/L	5	896	844	800	780
	100		868	812	804
	200	872	812		804
Ca mg/L	5	112	97	92	79
	100		95	102	80
	200	110	97		92
Mg mg/L	5	14	28	31	31
	100		31	25	31
	200	26	29		26
Na mg/L	5	115	112	106	104
	100		109	107	104
	200	113	106		98
K mg/L	5	6.3	5.9	5.5	5.5
	100		5.9	5.5	5.5
	200	6.3	5.5		5.1
CO_3 mg/L	5	0.0	0.0	0.0	0.0
	100		0.0	0.0	0.0
	200	0.0	0.0		0.0
HCO_3 mg/L	5	148	115	149	125
	100		144	146	125
	200	146	159		157
SO_4 mg/L	5	344	351	330	313
	100		335	332	316
	200	340	323		301
Cl mg/L	5	119	114	94	95
	100		101	95	94
	200	121	96		87

Stations 6 and 8
Continued

Station		6	8		
Parameter	Depth	May 1965*	November 1965	April 1966	November 1966**
NO_3 mg/L	5	0.0	0.6	1.9	1.2
	100		2.5	2.5	0.6
	200	2.5	3.7		1.9

*Data given at 5 feet were collected from 25 feet on May 1965.
**Data given at 5 feet were collected from 10 feet on November 1966.

LAKE MEAD CHEMICAL ANALYSIS
Station 10

Parameter	Depth	May 1965	November 1965	April 1966	November 1966*
Ec x 10^6 at 25° C	5	1,261	1,199	1,182	1,094
	50	-	-	-	1,112
	100	1,366	1,224	1,240	1,096
pH	5	7.7	8.0	8.2	8.3
	50	-	-	-	8.4
	100	7.7	7.8	8.1	8.3
TDS mg/L	5	924	840	840	796
	50	-	-	-	780
	100	1,012	872	916	792
Ca mg/L	5	119	94	101	80
	50	-	-	-	81
	100	120	94	108	80
Mg mg/L	5	23	33	29	31
	50	-	-	-	32
	100	31	34	30	31
Na mg/L	5	117	112	107	104
	50	-	-	-	105
	100	125	114	114	105
K mg/L	5	7.0	5.9	5.9	5.5
	50	-	-	-	5.9
	100	7.8	6.6	6.3	5.5
CO_3 mg/L	5	0.0	0.0	0.0	0.0
	50	-	-	-	0.9
	100	0.0	0.0	0.0	0.0
HCO_3 mg/L	5	126	125	142	121
	50	-	-	-	121
	100	154	123	144	124
SO_4 mg/L	5	368	352	344	315
	50	-	-	-	317
	100	391	358	360	312
Cl mg/L	5	126	109	101	94
	50	-	-	-	97
	100	140	111	111	94

Station 10
Continued

Parameter	Depth	May 1965	November 1965	April 1966	November 1966*
NO_3 mg/L	5	0.6	1.2	1.9	1.2
	50	-	-	-	1.2
	100	1.9	0.0	3.1	1.2

*November 1966 data collected from 10 feet, 50 feet, and 100 feet.

LAKE MEAD CHEMICAL ANALYSIS
Stations 12 and 14

Station		12	14			12
Parameter	Depth	May 1965	May 1965	November 1965	April 1966	November 1966
Ec x 10^6 at 25° C	5	1,228	1,232	1,181	1,160	1,076
	100			1,168	1,068	1,084
	200	1,232	1,232			1,037
pH	5	8.2	8.3	8.0	8.3	8.2
	100			8.0	8.4	8.0
	200	8.0	8.0			8.1
TDS mg/L	5	844	904	812	828	812
	100			828	800	828
	200	896	876			764
Ca mg/L	5	97	99	93	93	82
	100			97	98	85
	200	126	86			85
Mg mg/L	5	34	32	30	30	28
	100			30	22	30
	200	19	41			28
Na mg/L	5	113	115	111	102	101
	100			106	96	98
	200	113	113			94
K mg/L	5	6.6	6.3	5.9	5.5	5.5
	100			5.5	5.1	5.5
	200	6.6	6.3			5.1
CO_3 mg/L	5	0.0	0.0	0.0	0.0	0.0
	100			0.0	2.1	0.0
	200	0.0	0.0			0.0
HCO_3 mg/L	5	149	151	115	148	125
	100			157	144	138
	200	144	156			154
SO_4 mg/L	5	316	340	346	327	304
	100			328	305	299
	200	341	341			276

Stations 12 and 14
Continued

Station		12	14			12
Parameter	Depth	May 1965	May 1965	November 1965	April 1966	November 1966
Cl mg/L	5	115	130	107	100	92
	100			95	90	93
	200	124	117			84
NO_3 mg/L	5	1.9	1.2	1.9	2.5	0.6
	100			3.1	3.1	2.5
	200	1.9	2.5			3.1

*Data given as 5 feet were collected from 10 feet on November 1966.

LAKE MEAD CHEMICAL ANALYSIS
Station 18

Parameter	Depth	May 1965	November 1965	April 1966	November 1966*
Ec x 10^6 at 25° C	5	1,232	1,103	1,102	985
	100		1,155	1,029	987
	200	1,232			1,037
	300				1,088
pH	5	8.2	8.0	8.3	8.2
	100		7.9	8.4	8.0
	200	8.0			8.0
	300				8.0
TDS mg/L	5	856	788	808	700
	100		792	748	732
	200	880			744
	300				784
Ca mg/L	5	94	87	98	75
	100		102	92	82
	200				86
	300	91			89
Mg mg/L	5	36	30	27	28
	100		26	26	25
	200	41			27
	300				28
Na mg/L	5	113	101	109	89
	100		106	98	89
	200	115			92
	300				97
K mg/L	5	6.3	5.5	5.1	4.7
	100		5.5	4.7	4.7
	200	6.3			5.1
	300				5.1
CO_3 mg/L	5	0.0	0.0	0.0	0.0
	100		0.0	0.9	0.0
	200	0.0			0.0
	300				0.0
HCO_3 mg/L	5	154	125	149	136
	100		156	149	148
	200	154			151
	300				154

Station 18
Continued

Parameter	Depth	May 1965	November 1965	April 1966	November 1966*
SO_4 mg/L	5	342	313	308	269
	100		323	287	267
	200	333			279
	300				294
Cl mg/L	5	122	95	91	79
	100		92	82	77
	200	124			84
	300				92
NO_3 mg/L	5	1.9	1.2	2.5	1.9
	10		3.1	3.1	1.9
	100	2.5			3.1
	200				2.5

*Data given as 5 feet were collected from 10 feet on November 1966.

LAKE MEAD CHEMICAL ANALYSIS
Station 20

Parameter	Depth	November 1965	April 1966	November 1966*
Ec x 10^6 at 25° C	5	970	985	971
	100	1,070	1,006	976
pH	5	8.2	8.3	8.3
	100	8.1	8.2	8.1
TDS mg/L	5	644	708	676
	100	740	708	692
Ca mg/L	5	78	86	78
	100	91	86	78
Mg mg/L	5	26	25	26
	100	25	26	26
Na mg/L	5	82	93	90
	100	93	94	90
K mg/L	5	4.7	4.7	4.7
	100	5.1	4.7	4.7
CO_3 mg/L	5	0.0	0.0	0.0
	100	0.0	0.0	0.0
HCO_3 mg/L	5	129	148	140
	100	160	154	144
SO_4 mg/L	5	261	271	268
	100	295	280	269
Cl mg/L	5	75	80	74
	100	80	82	77
NO_3 mg/L	5	1.2	2.5	1.2
	100	3.7	2.5	1.9

*Data given as 5 feet were collected from 10 feet on November 1966.

LAKE MEAD CHEMICAL ANALYSIS
Stations 21, OV1, and OV2

Station		21	OV2	OV1	OV2
Parameter	Depth	November 1965	November 1965	November 1966	November 1966
$Ec \times 10^6$ at 25° C	5	886	1,116		1,284
	10			985	
	50		1,114		
	100	1,028		1,005	
pH	5	8.5	8.0		8.1
	10			8.3	
	50		8.0		
	100	8.3		8.0	
TDS mg/L	5	600	760		892
	10			692	
	50		764		
	100	708		692	
Ca mg/L	5	79	89		99
	10			75	
	50		94		
	100	84		82	
Mg mg/L	5	19	28		36
	10			28	
	50		29		
	100	27		28	
Na mg/L	5	77	99		123
	10			90	
	50		102		
	100	90		92	
K mg/L	5	4.3	5.1		7.4
	10			4.7	
	50		5.5		
	100	4.7		4.7	
CO_3 mg/L	5	0.9	0.0		0.0
	10			0.0	
	50		0.0		
	100	0.0		0.0	
HCO_3 mg/L	5	134	134		134
	10			139	
	50		129		
	100	146		154	

LAKE MEAD CHEMICAL ANALYSIS
Stations 21, OV1, and OV2

Station		21	OV2	OV1	OV2
Parameter	Depth	November 1965	November 1965	November 1966	November 1966
SO_4 mg/L	5	231	316		376
	10			269	
	50		313		
	100	280		269	
Cl mg/L	5	70	95		119
	10			78	
	50		94		
	100	81		80	
NO_3 mg/L	5	1.9	0.6		0.6
	10			0.6	
	50		0.6		
	100	2.5		2.5	

LAKE MEAD CHEMICAL ANALYSIS
Stations 22, 23, and 24

Station		24	23	24	22
Parameter	Depth	November 1965	November 1965	November 1966*	November 1966*
Ec x 10^6 at 25° C	5	632	623	851	881
	100		613		885
pH	5	8.0	8.0	7.9	8.2
	100		8.0		8.0
TDS mg/L	5	408	400	608	628
	100		392		608
Ca mg/L	5	52	54	71	72
	100		53		69
Mg mg/L	5	20	15	20	21
	100		15		23
Na mg/L	5	53	50	77	81
	100		50		78
K mg/L	5	3.1	2.3	3.9	4.3
	100		2.7		3.9
CO_3 mg/L	5	0.0	0.0	0.0	0.0
	100		0.0		0.0
HCO_3 mg/L	5	124	127	151	145
	100		135		154
SO_4 mg/L	5	124	130	209	223
	100		128		213
Cl mg/L	5	53	48	65	70
	100		47		73
NO_3 mg/L	5	0.6	0.6	0.6	1.9
	100		0.6		1.9

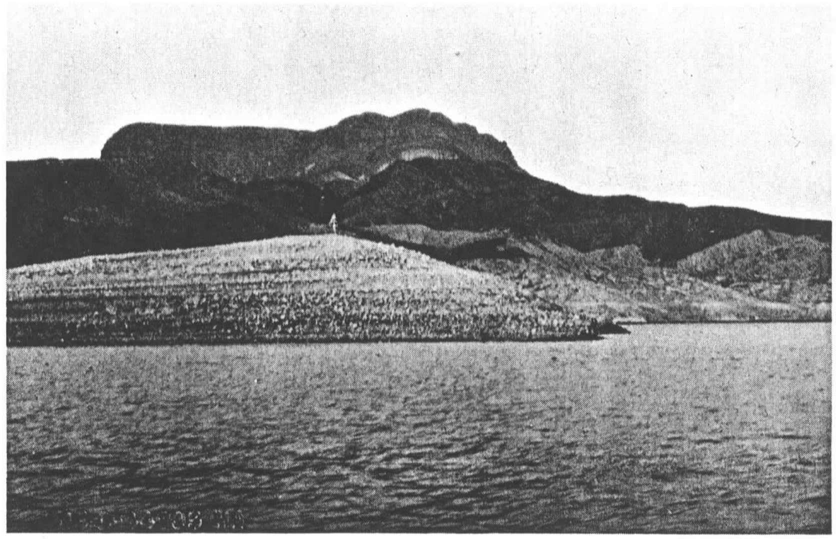
*Data given as 5 feet were collected from 10 feet on November 1966.

FIGURES 5 – 37 were not copied.

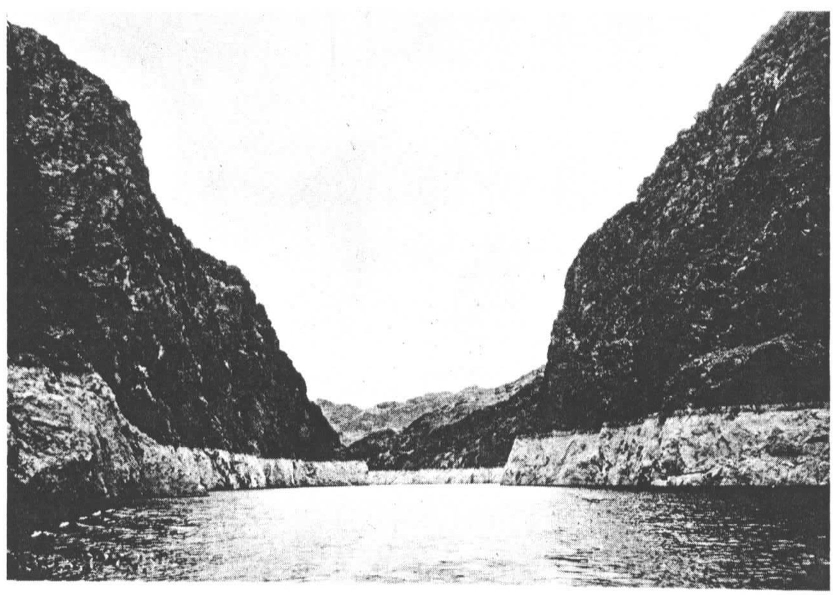
To see these figures, contact the U.S. Bureau of Reclamation in Denver, Colorado.

APPENDIX C

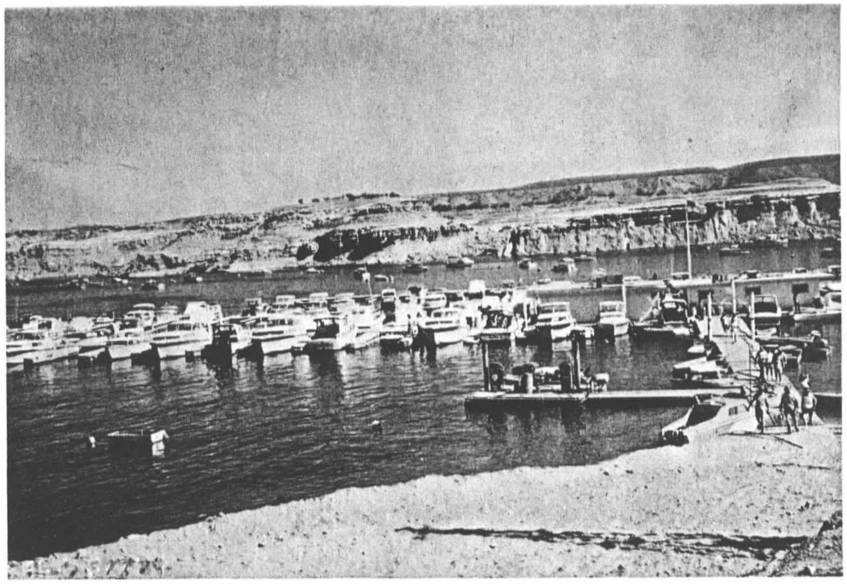
PHOTOGRAPHS



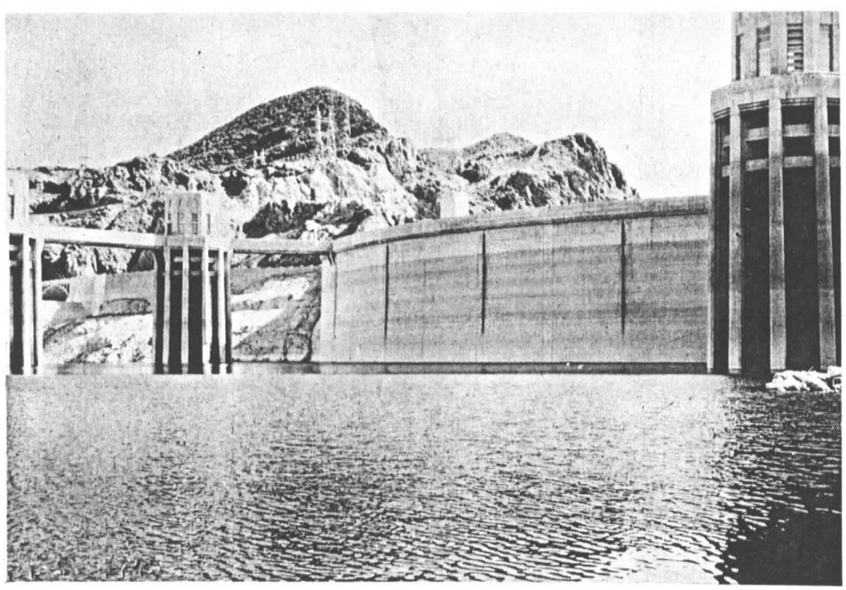
View of flat type of shore, Lake Mead.
Photo P45-D-44305 NA.



View of steep type of shore, Lake Mead.
Photo P45-D-57735.

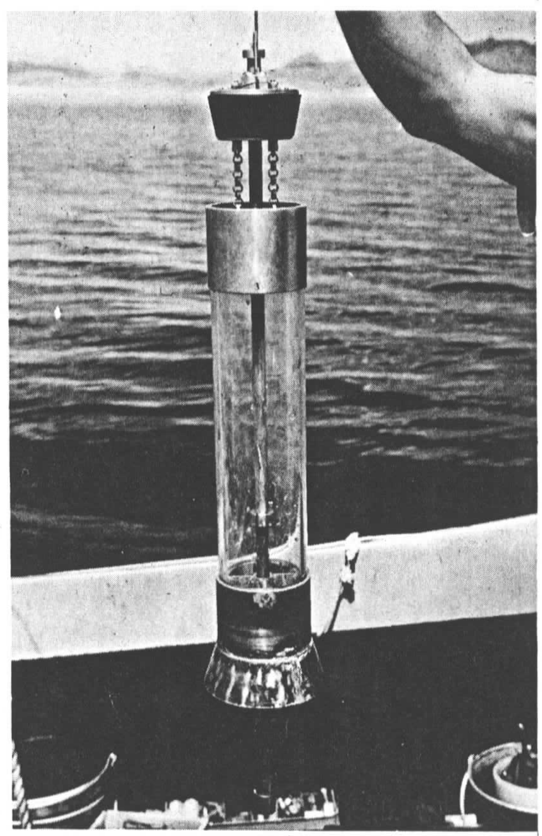


Typical Marina, Lake Mead. Photo P45-D-57734.

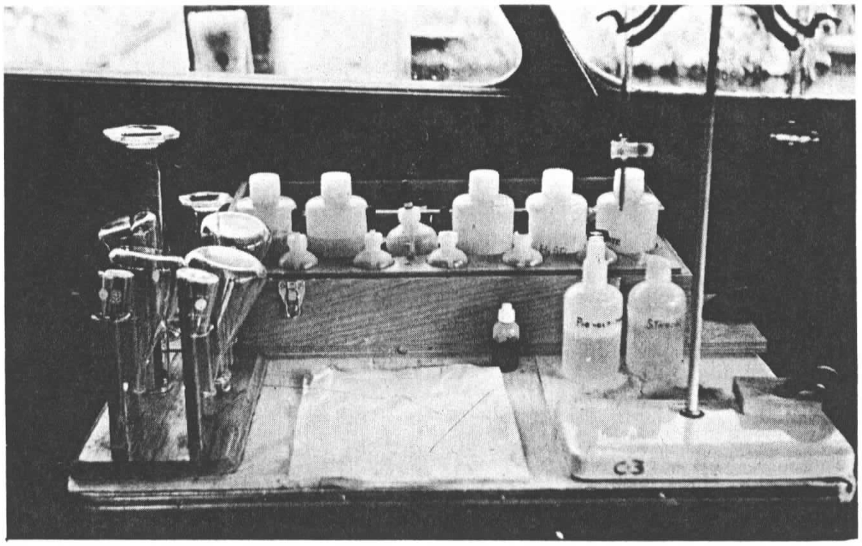


Upstream face of Hoover Dam. Photo P45-D-57740.

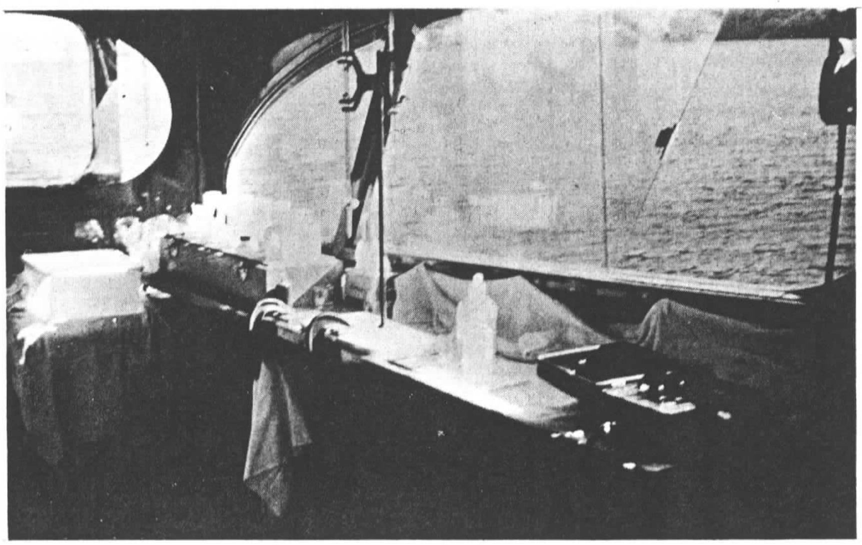
Survey boat. Photo P45-D-57738.



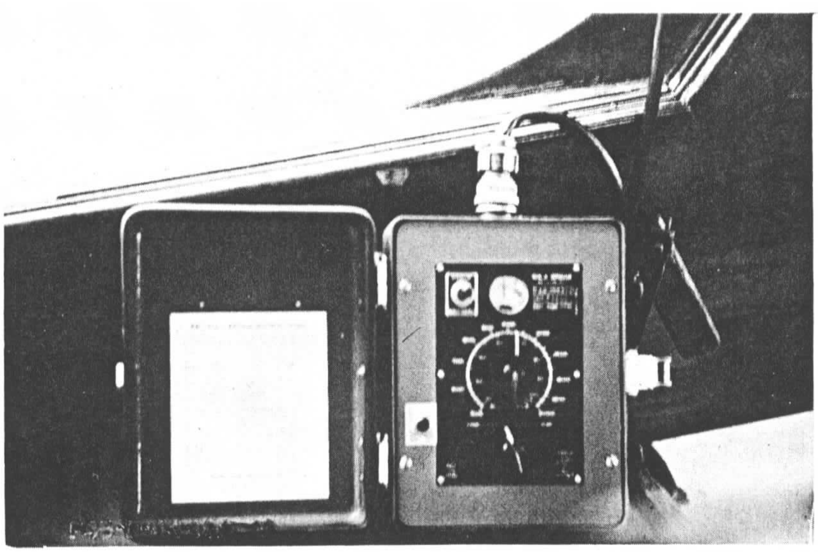
Kemmerer Water Sampler.
Photo P45-D-44303 NA.



Laboratory in survey boat.
Photo P45-D-57736.



Laboratory in survey boat.
Photo P45-D-57737.



Conductivity Meter.
Photo P45-D-44299 NA.

pH Meter. Photo PX-D-60076 NA.

7-1750 (1-70)
Bureau of Reclamation

CONVERSION FACTORS--BRITISH TO METRIC UNITS OF MEASUREMENT

The following conversion factors adopted by the Bureau of Reclamation are those published by the American Society for Testing and Materials (ASTM Metric Practice Guide, E 380-68) except that additional factors (*) commonly used in the Bureau have been added. Further discussion of definitions of quantities and units is given in the ASTM Metric Practice Guide.

The metric units and conversion factors adopted by the ASTM are based on the "International System of Units" (designated SI for Systeme International d'Unites), fixed by the International Committee for Weights and Measures; this system is also known as the Giorgi or MKSA (meter-kilogram (mass)-second-ampere) system. This system has been adopted by the International Organization for Standardization in ISO Recommendation R-31.

The metric technical unit of force is the kilogram-force; this is the force which, when applied to a body having a mass of 1 kg, gives it an acceleration of 9.80665 m/sec/sec, the standard acceleration of free fall toward the earth's center for sea level at 45 deg latitude. The metric unit of force in SI units is the newton (N), which is defined as that force which, when applied to a body having a mass of 1 kg, gives it an acceleration of 1 m/sec/sec. These units must be distinguished from the (inconstant) local weight of a body having a mass of 1 kg; that is, the weight of a body is that force with which a body is attracted to the earth and is equal to the mass of a body multiplied by the acceleration due to gravity. However, because it is general practice to use "pound" rather than the technically correct term "pound-force," the term "kilogram" (or derived mass unit) has been used in this guide instead of "kilogram-force" in expressing the conversion factors for forces. The newton unit of force will find increasing use, and is essential in SI units.

Where approximate or nominal English units are used to express a value or range of values, the converted metric units in parentheses are also approximate or nominal. Where precise English units are used, the converted metric units are expressed as equally significant values.

Table I

QUANTITIES AND UNITS OF SPACE

Multiply	By	To obtain
	LENGTH	
Mil	25.4 (exactly)	Micron
Inches	25.4 (exactly)	Millimeters
	2.54 (exactly)*	Centimeters
Feet	30.48 (exactly)	Centimeters
	0.3048 (exactly)*	Meters
	0.0003048 (exactly)*	Kilometers
Yards	0.9144 (exactly)	Meters
Miles (statute)	1,609.344 (exactly)*	Meters
	1.609344 (exactly)	Kilometers
	AREA	
Square inches	6.4516 (exactly)	Square centimeters
Square feet	929.03*	Square centimeters
	0.092903	Square meters
Square yards	0.836127	Square meters
Acres	0.40469*	Hectares
	4,046.9*	Square meters
	0.0040469*	Square kilometers
Square miles	2.58999	Square kilometers
	VOLUME	
Cubic inches	16.3871	Cubic centimeters
Cubic feet	0.0283168	Cubic meters
Cubic yards	0.764555	Cubic meters
	CAPACITY	
Fluid ounces (U.S.)	29.5737	Cubic centimeters
	29.5729	Milliliters
Liquid pints (U.S.)	0.473179	Cubic decimeters
	0.473166	Liters
Quarts (U.S.)	946.358*	Cubic centimeters
	0.946331*	Liters
Gallons (U.S.)	3,785.43*	Cubic centimeters
	3.78543	Cubic decimeters
	3.78533	Liters
	0.00378543*	Cubic meters
Gallons (U.K.)	4.54609	Cubic decimeters
	4.54596	Liters
Cubic feet	28.3160	Liters
Cubic yards	764.55*	Liters
Acre-feet	1,233.5*	Cubic meters
	1,233,500*	Liters

Table II

QUANTITIES AND UNITS OF MECHANICS

Multiply	By	To obtain
MASS		
Grains (1/7,000 lb)	64.79891 (exactly)	Milligrams
Troy ounces (480 grains)	31.1035	Grams
Ounces (avdp)	28.3495	Grams
Pounds (avdp)	0.45359237 (exactly)	Kilograms
Short tons (2,000 lb)	907.185	Kilograms
	0.907185	Metric tons
Long tons (2,240 lb)	1,016.05	Kilograms
FORCE/AREA		
Pounds per square inch	0.070307	Kilograms per square centimeter
	0.689476	Newtons per square centimeter
Pounds per square foot	4.88243	Kilograms per square meter
	47.8803	Newtons per square meter
MASS/VOLUME (DENSITY)		
Ounces per cubic inch	1.72999	Grams per cubic centimeter
Pounds per cubic foot	16.0185	Kilograms per cubic meter
	0.0160185	Grams per cubic centimeter
Tons (long) per cubic yard	1.32894	Grams per cubic centimeter
MASS/CAPACITY		
Ounces per gallon (U.S.)	7.4893	Grams per liter
Ounces per gallon (U.K.)	6.2362	Grams per liter
Pounds per gallon (U.S.)	119.829	Grams per liter
Pounds per gallon (U.K.)	99.779	Grams per liter
BENDING MOMENT OR TORQUE		
Inch-pounds	0.011521	Meter-kilograms
	1.12985×10^6	Centimeter-dynes
Foot-pounds	0.138255	Meter-kilograms
	1.35582×10^7	Centimeter-dynes
Foot-pounds per inch	5.4431	Centimeter-kilograms per centimeter
Ounce-inches	72.008	Gram-centimeters
VELOCITY		
Feet per second	30.48 (exactly)	Centimeters per second
	0.3048 (exactly)*	Meters per second
Feet per year	0.965873×10^{-6}*	Centimeters per second
Miles per hour	1.609344 (exactly)	Kilometers per hour
	0.44704 (exactly)	Meters per second
ACCELERATION*		
Feet per second^2	0.3048*	Meters per second^2
FLOW		
Cubic feet per second (second-feet)	0.028317*	Cubic meters per second
Cubic feet per minute	0.4719	Liters per second
Gallons (U.S.) per minute	0.06309	Liters per second
FORCE*		
Pounds	0.453592*	Kilograms
	4.4482*	Newtons
	4.4482×10^{-5}*	Dynes

Multiply	By	To obtain
WORK AND ENERGY*		
British thermal units (Btu)	0.252*	Kilogram calories
	1,055.06	Joules
Btu per pound	2.326 (exactly)	Joules per gram
Foot-pounds	1.35582*	Joules
POWER		
Horsepower	745.700	Watts
Btu per hour	0.293071	Watts
Foot-pounds per second	1.35582	Watts
HEAT TRANSFER		
Btu in./hr ft^2 deg F (k, thermal conductivity)	1.442	Milliwatts/cm deg C
	0.1240	Kg cal/hr m deg C
Btu ft/hr ft^2 deg F	1.4880*	Kg cal m/hr m^2 deg C
Btu/hr ft^2 deg F (C, thermal conductance)	0.568	Milliwatts/cm^2 deg C
	4.882	Kg cal/hr m^2 deg C
Deg F hr ft^2/Btu (R, thermal resistance)	1.761	Deg C cm^2/milliwatt
Btu/lb deg F (c, heat capacity)	4.1868	J/g deg C
Btu/lb deg F	1.000*	Cal/gram deg C
Ft^2/hr (thermal diffusivity)	0.2581	Cm^2/sec
	0.09290*	M^2/hr
WATER VAPOR TRANSMISSION		
Grains/hr ft^2 (water vapor transmission)	16.7	Grams/24 hr m^2
Perms (permeance)	0.659	Metric perms
Perm-inches (permeability)	1.67	Metric perm-centimeters

Table III

OTHER QUANTITIES AND UNITS

Multiply	By	To obtain
Cubic feet per square foot per day (seepage)	304.8*	Liters per square meter per day
Pound-seconds per square foot (viscosity)	4.8824*	Kilogram second per square meter
Square feet per second (viscosity)	0.092903*	Square meters per second
Fahrenheit degrees (change)*	5/9 exactly	Celsius or Kelvin degrees (change)*
Volts per mil	0.03937	Kilovolts per millimeter
Lumens per square foot (foot-candles)	10.764	Lumens per square meter
Ohm-circular mils per foot	0.001662	Ohm-square millimeters per meter
Millicuries per cubic foot	35.3147*	Millicuries per cubic meter
Milliamps per square foot	10.7639*	Milliamps per square meter
Gallons per square yard	4.527219*	Liters per square meter
Pounds per inch	0.17858*	Kilograms per centimeter

ABSTRACT

This report presents Lake Mead water quality data obtained from 1964 to 1966. The effect of filling Lake Powell on the water quality of Lake Mead is evaluated. General limnological principles and the present limnology of Lake Mead are discussed. Lake Mead has a warm monomictic annual temperature cycle characterized by spring overturn, summer stratification, and continuous circulation throughout the winter; temperatures never fall below 39 deg F (4 deg C). During stratification, lower dissolved oxygen values were recorded in the thermocline than in the epilimnion and hypolimnion. Mineral content increases from the upper to the lower end of Lake Mead. The greatest increase is in calcium and sodium sulfates and chlorides, although there is an overall decrease in bicarbonate. The filling of Lake Powell intensified the deterioration of water quality in Lake Mead during 1965, as evidenced by increased temperature, conductivity, and total dissolved solids and decreased dissolved oxygen. Las Vegas Bay reach was found to be a major source for degradation of water quality in Lake Mead because of its large input of dissolved salts and algae nutrients. The monitoring station at Hoover Dam has been a useful indicator of water quality in the lower reach of Boulder Basin.

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ABSTRACT

This report presents Lake Mead water quality data obtained from 1964 to 1966. The effect of filling Lake Powell on the water quality of Lake Mead is evaluated. General limnological principles and the present limnology of Lake Mead are discussed. Lake Mead has a warm monomictic annual temperature cycle characterized by spring overturn, summer stratification, and continuous circulation throughout the winter; temperatures never fall below 39 deg F (4 deg C). During stratification, lower dissolved oxygen values were recorded in the thermocline than in the epilimnion and hypolimnion. Mineral content increases from the upper to the lower end of Lake Mead. The greatest increase is in calcium and sodium sulfates and chlorides, although there is an overall decrease in bicarbonate. The filling of Lake Powell intensified the deterioration of water quality in Lake Mead during 1965, as evidenced by increased temperature, conductivity, and total dissolved solids and decreased dissolved oxygen. Las Vegas Bay reach was found to be a major source for degradation of water quality in Lake Mead because of its large input of dissolved salts and algae nutrients. The monitoring station at Hoover Dam has been a useful indicator of water quality in the lower reach of Boulder Basin.

ChE-70
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DESCRIPTORS-- *dissolved oxygen/ electrical conductance/ reservoirs/ water supplies/ *limnology/ pH/ temperature/ salinity/ *water quality/ multiple purpose projects/ test procedures/ chemical engineering/ chemical analysis/ chemistry/ basins/ field laboratories/ field tests/ laboratory tests/ water sampling/ field data/ water management/ *water analysis/ reservoir surveys
IDENTIFIERS-- Lake Mead/ Boulder Canyon Project/ *water chemistry/ Winkler method/ dissolved carbon dioxide/ Lake Powell/ impoundments

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