U. S. DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

WATER RESOURCES DIVISION

PROGRESS REPORT

CHEMICAL CHARACTER OF SURFACE WATERS IN THE DEVILS LAKE BASIN, NORTH DAKOTA

By

Herbert A. Swenson

PRELIMINARY DRAFT
OF PROPOSED REPORT
FOR OFFICIAL REVIEW ONLY
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Missouri River Basin

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PROGRESS REPORT ON THE CHEMICAL CHARACTER OF SURFACE WATERS IN DEVILS LAKE BASIN, NORTH DAKOTA

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ABSTRACT

Devils Lake in northeastern North Dakota was at one time the most popular summer resort in the state. With decline in lake level the lake has become a shallow body of very saline water, with scenic value and recreational appeal completely destroyed. Under the Missouri River development program, it is proposed to restore the lake level to an altitude of 1,425 feet by diversion of Missouri River water.

The chemical character of the water in Devils Lake and in other surface bodies in Devils Lake Basin is determined from the analyses of 95 samples. The physical and chemical properties of lake bed deposits are also shown. Lake waters in the basin vary considerably in both concentration and composition, ranging from fresh bicarbonate waters of 300 parts per million dissolved solids to sulfate waters of over 100,000 parts per million of soluble salts. Twenty-four samples indicate the chemical character of water in the Red River of the North and its tributaries.

The probable concentration of dissolved solids in water of Devils Lake at altitude 1,425 feet has been estimated as ranging from 3,000 to 7,600 parts per million. Final concentration will largely depend upon the percentage of deposited salts reentering solution and the quality of the inflow water.

The possible effects of lake effluents on downstream developments, with particular reference to sanitation and pollution problems, are also discussed in the report.

INTRODUCTION

Purpose and Scope of Investigation

A study of the chemical character of surface waters in the Devils Lake Basin was undertaken by the Quality of Water Branch of the United States Geological Survey during the summer of 1949. It was hoped that as a result of this study, certain contributions could be made to the hydrology of the region with particular consideration to the chemical quality of the lake waters. The investigation was prompted by proposed plans of the Bureau of Reclamation for restoring Devils Lake to its former level by diversion of Missouri River waters. As part of the preliminary planning to revive the recreational value of the lake, a better understanding was necessary of the following factors: the present salt content and composition of Devils and Stump Lakes; properties of lake bed deposits; estimated mineral concentrations to be expected of Devils Lake water after restoration of lake level; and effects of flushing the saline lake waters on downstream municipal supplies in the Sheyenne and Red River of the North Valleys.

This report includes data on cross-sectional sampling of Devils Lake, East Devils Lake, West Stump Lake, and East Stump Lake. Results are given for chemical analysis, temperature, density, and depth of the lake waters. Single water samples from approximately 30 smaller lakes and coulees were also collected for analysis. Lake bed deposits were treated with distilled and Missouri River water, and the leached salts analyzed. Organic matter and density were also determined on the bed samples. Limited data on the chemical character of water in the Red River of the North and its tributaries are presented. The area of present-day Devils Lake was measured planimetrically from preliminary topographic maps, and estimates made as to the total tonnage of salts in solution. Preliminary estimates are also shown on the probable concentration of Devils Lake water upon restoration of the lake to an altitude of 1,425 feet.

The investigation was under the general direction of S. Kenneth Love, Chief, Quality of Water Branch, and under the immediate supervision of Paul C. Benedict, regional engineer, in charge of quality of water studies, Missouri River Basin. Jay M. Stow, chemist, assisted in the field collection of samples, and B. R. Colby and R. B. Vice, engineers, critically

reviewed the report.

Acknowledgments

Acknowledgments are made to Harrell F. Mosbaugh, supervisor, and Russell L. Bagwell, aquatic biologist, United States Fish and Wildlife Service, for their cooperation during the investigation.

Many residents of the city of Devils Lake gave helpful information concerning lakes in the region and otherwise assisted in the study. Particular thanks are given to C. M. Gonser, who furnished valuable information on early lake history, and to E. A. Thompson, who provided a boat with outboard motor for use in collection of water samples.

The writer is indebted to Professor G. A. Abbott, of the University of North Dakota, for his contributions and suggestions concerning the chemistry of Devils Lake water.

G. A. LaRocque, Jr., and P. D. Akin, district engineers, Ground Water Branch, reviewed the report and made many helpful suggestions.

Field Work

Ten days were spent in the field during June 1949. During this period 107 water samples were collected for chemical analysis, 12 of which represent river waters in the Sheyenne and Red River of the North Basins. Representative lake bed samples were collected for mechanical analysis and leaching tests. Both surface and bottom samples of major lake waters were obtained to note any change in chemical quality with depth. Soundings and water temperatures were recorded. Although Devils and Stump Lakes received the major attention, the investigation included study of many other lakes in the region where information on the chemical quality would be of value.

Laboratory Work

Laboratory work was performed by chemists of the Quality of Water Branch, United States Geological Survey at Lincoln, Nebr. The samples were analyzed according to methods regularly used by the Geological Survey. These methods [1] are essentially the same or are modifications of methods described in recognized authoritative publications for the mineral analysis of water samples. Analytical results for waters that contain in excess of 10,000 parts per million (1 percent) of dissolved solids were corrected for density.

Analyses of samples were made by J. E. Adams, W. M. Barr, M. B. Florin, L. R. Kister, R. A. Krieger, R. H. Langford, R. P. Orth, and F. H. Rainwater.

GENERAL FEATURES OF DEVILS LAKE BASIN

Location and Extent

Devils Lake Basin extends from the southern slopes of the Turtle Mountains and the Canadian boundary to a series of prominent hills that lie between Devils and Stump Lakes and the Sheyenne River. (See pl. 1.) In describing the extent of the basin, Simpson [2] points out that the eastern and western boundaries are more vague and indistinct, but that the area of the entire drainage basin is estimated at about 3,500 square miles. The area occupied by Devils Lake and the smaller adjoining lakes comprises but a small fraction of what may be called Devils Lake drainage basin.

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1 Collins, W. D., Notes on practical water analysis: U. S. Geol. Survey Water-Supply Paper 596-H, pp. 235-261, 1928; Am. Public Health Assoc., Standard methods for the examination of water and sewage, 9th ed., pp. 1-111, 1946.

2 Simpson, H. E., Geology and ground-water resources of North Dakota: U. S. Geol. Survey Water-Supply Paper 598, p. 9, 1929.

Physiography

There is a gradual southward slope throughout the drainage basin to Devils and Stump Lakes; however, gradients are so slight and the surface so irregular that the drainage pattern has been imperfectly developed. The lakes have very irregular outlines, with numerous windings and long bays or arms, and are considered by Upham [3] to lie in the valley of a preglacial river, the tributaries of which are filled with drift. An unbroken ridge of prominent and typical morainal hills appears along the south shore of Devils Lake in strong contrast to the level farm land that borders its northern extent. Devils Lake and Stump Lake are remnants of glacial Lakes Minnewaukan and Wamduska, respectively. The recession of Devils Lake has resulted in the development of several smaller lakes, besides the separation of the glacial Lakes Minnewaukan and Wamduska into the present Devils and Stump Lakes. For a complete discussion of the physiography of the Devils-Stump Lake region, the reader is referred to a report by Simpson.[4]

Drainage

Prior to 1889, the Mauvais Coulee (see pl. 1) drained the Sweetwater chain of lakes through Lake Irvine and emptied considerable water into Devils Lake. Several converging coulees then transported excess water to Stump Lake. Mauvais Coulee is the largest drainage line in the system. In subsequent years, flow in the coulee has been intermittent and largely in response to the spring snow melt or excessive precipitation. During 1949 Mauvais Coulee discharged considerable water to Devils Lake, a flow of 385 second-feet being measured on May 10 at a point 9 miles northeast of the

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3 Upham, Warren, The glacial Lake Agassiz: U. S. Geol. Survey Mon. 25, pp. 170-171, 1895.

4 Simpson, H. E., Physiography of the Devils-Stump Lake region of North Dakota: North Dakota Geol. Survey 6th Bienn. Rept., pp. 105-157, 1912.

Figure 1.--Mauvais Coulee looking upstream from U. S. Highway No. 2 near Churchs Ferry. Width approximately 150 feet. June 17, 1949.

town of Minnewaukan. Considerable flow in the coulee was also noted on June 17, as seen in figure 1.

According to Simpson [5] the inflow to the lake of surface runoff from the marginal lands is small and very irregular. He believes that comparatively little water enters the lake as surface inflow from marginal lands, because of the morainal character of the topography, and mentions the many undrained depressions common to the adjacent hills and prairies. It is possible, however, that Simpson underestimated the runoff from the area, as there is considerable organized drainage into the lake along the northwest part of West Bay.

Both Devils and Stump Lakes may receive ground-water inflow from the glacial drift of the large drainage basin, the ground waters of which move slowly down the slope from the north through the lower sandy portions of the drift over the floor of Pierre shale.

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5 Simpson, H. E., Physiography of the Devils-Stump Lake region of North Dakota: North Dakota Geol. Survey 6th Bienn. Rept., p. 115, 1912.

The reduction in salinity of Devils Lake water in 1949, as a result of mixing with the much more dilute runoff waters discharged by Mauvais Coulee, is discussed under the heading "Chemical character of the waters."

Climate

The mean annual temperature of the Devils Lake Basin is between 36° and 42° F. Figure 2 shows the mean annual air temperatures for the period 1905 to 1949 at the United States Weather Bureau Station in the city of Devils Lake. Maximum and minimum temperatures of above 100° F. and below -30° F., respectively, are not unusual. January is the coldest month, with mean temperatures slightly above zero. July is the warmest month, with mean temperatures of about 67° F., and August is only about 2° cooler.

Most of the precipitation occurs during the summer months, often as storms of cloudburst intensities, accompanied by thunder and lightning. In most years, some part of the basin is visited by a storm with a rainfall of 2 to 3 inches in 24 hours, and from 5 to 6 inches of rainfall in 24 hours is not unknown. The average annual precipitation for a 78-year period (1870 to 1948) at the city of Devils Lake is 17.78 inches. A 5-year moving average of precipitation for this period is shown in figure 3. From 75 to 80 percent of the average annual precipitation falls during the growing season, April to September. Almost 50 percent falls during the 3-month period, May, June, and July. The normal precipitation for the driest months, November, December, January, and February, is about one-half inch each. (See fig. 4.)

The average annual snowfall is slightly more than 30 inches. The first light snow may fall in September, but usually very little snow falls even in October. The greatest amount of snow falls during March, and light snows often occur during May.

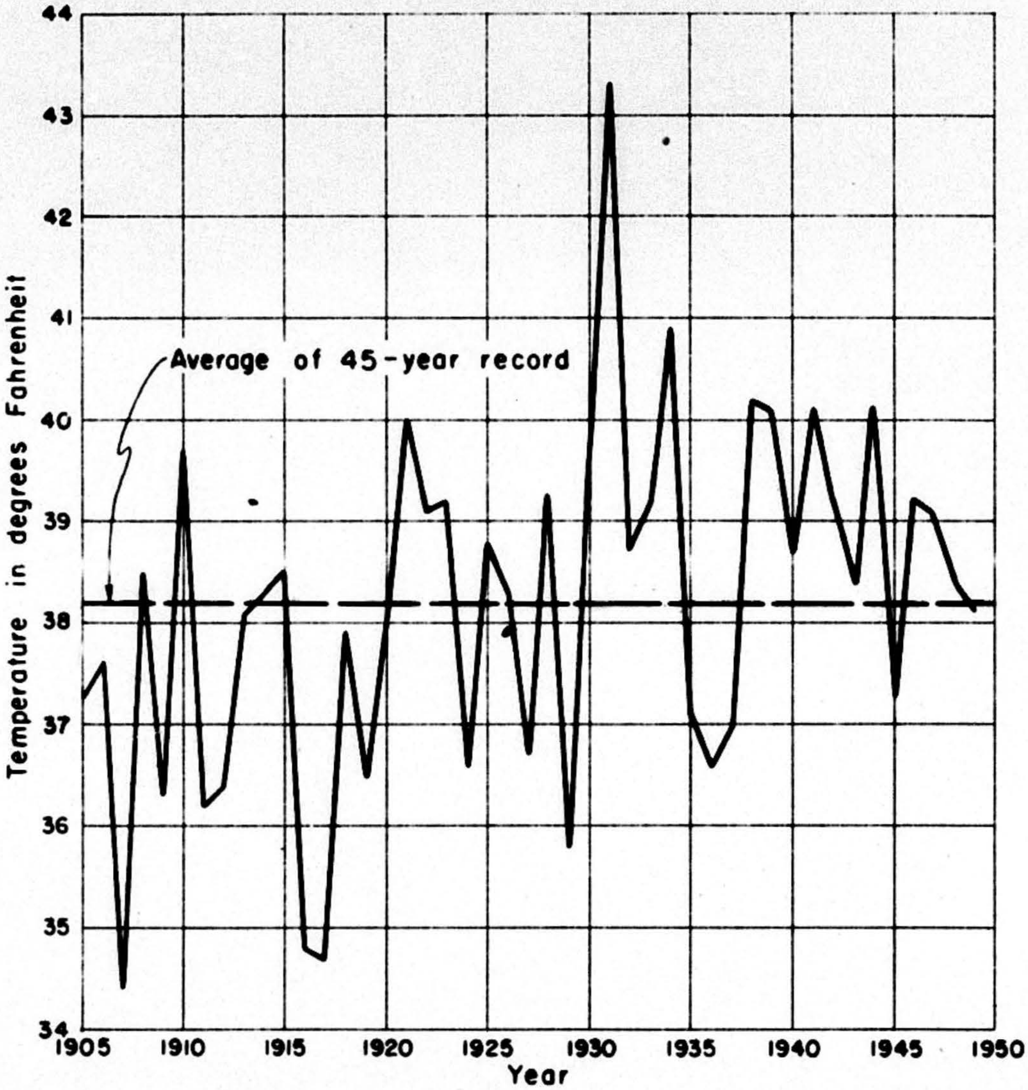

Figure 2.—— Mean annual air temperature for City of Devils Lake.

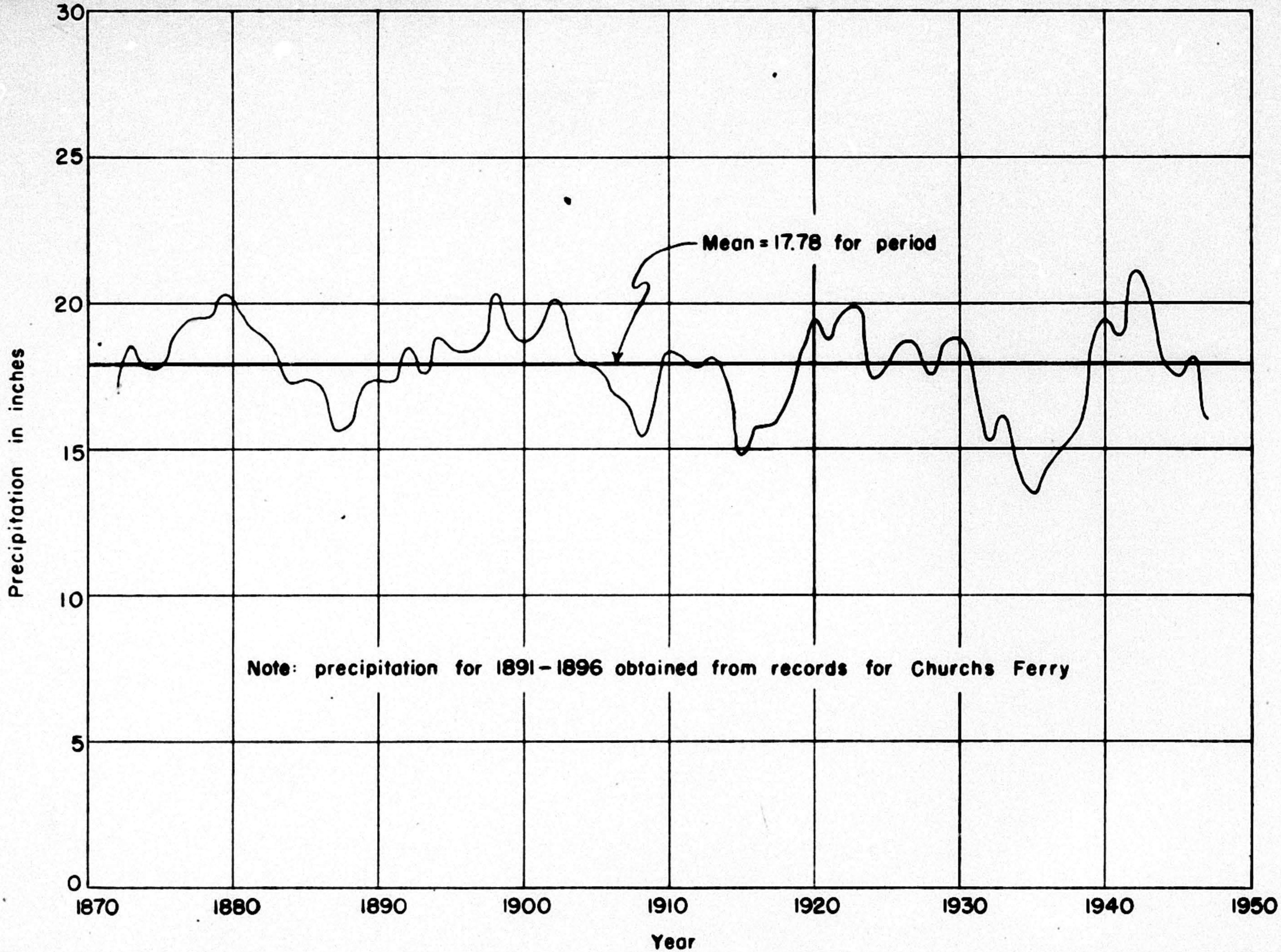

Figure 3.-- Five-year moving average of precipitation for city of Devils Lake

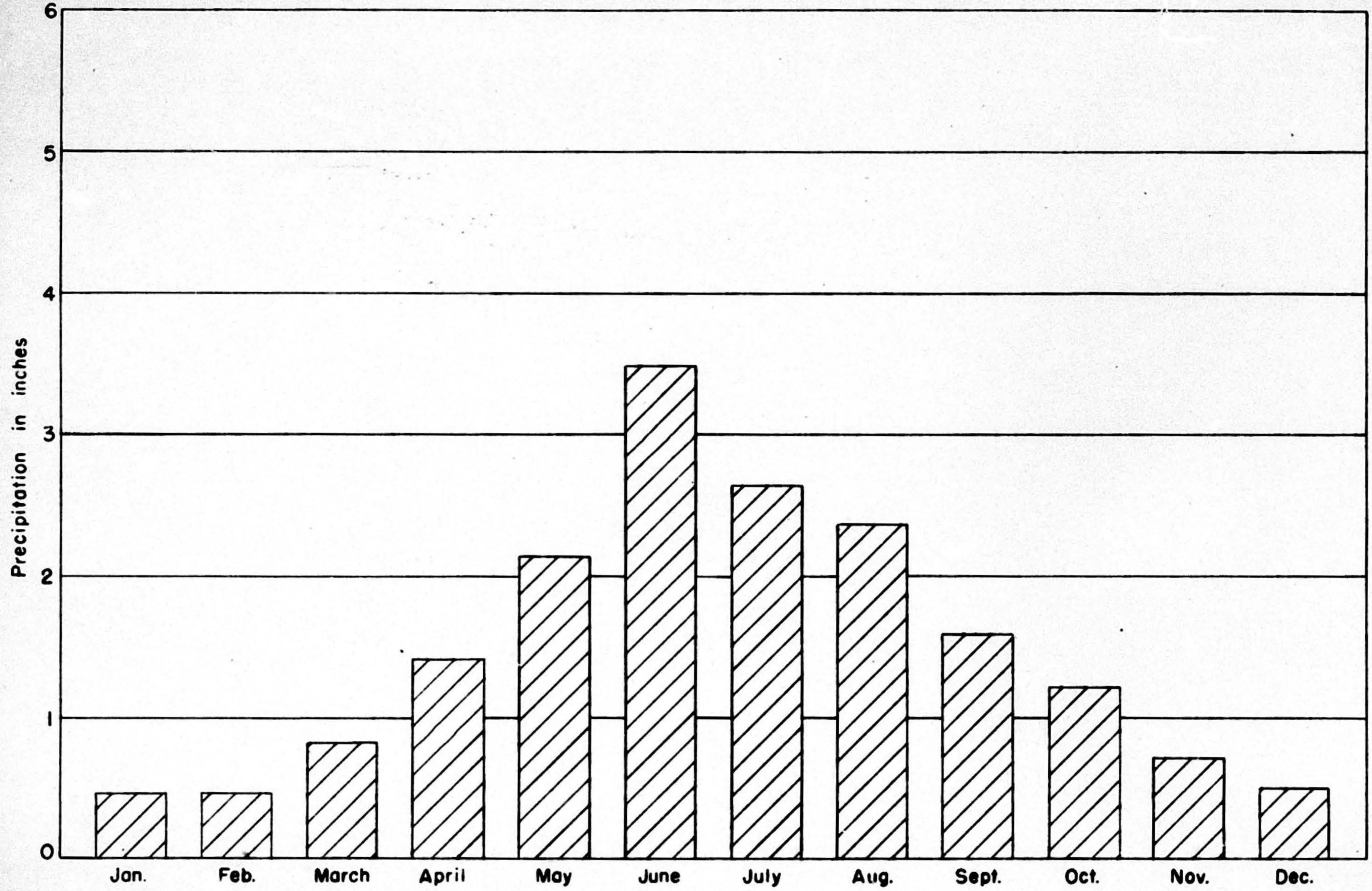

Figure 4.__Mean monthly precipitation for Devils Lake, 1870–1949 (record for 1891-1896 obtained from Churchs Ferry)

The prevailing direction of the wind for all months of the year is from the northwest unless influenced by local conditions. More southerly winds are observed during the summer months than during the winter. The average annual wind velocity for the basin is about 10 miles per hour, and the wind movement is greatest in the spring and least during August.

The average relative humidity is nearly 78 percent throughout the basin. The humidity, however, is frequently very low during the summer; sometimes it is below 25 percent.

Evaporation in the vicinity of Devils Lake is practically twice the amount of the mean annual rainfall. The gross amount of evaporation has been closely estimated as averaging between 33 and 36 inches.[6] This estimate is in good agreement with the 41 year average of 34.636 inches at Dickinson and the 34 year average of 33.311 inches at Mandan, N. Dak.

Transportation

The transcontinental Great Northern Railroad crosses the basin from east to west. Branch lines of the Minneapolis, St. Paul, and Sault Sainte Marie Railroad also enter the region. North and south transportation facilities, however, are limited. Paved highways cross the basin east and west and to a less extent in a north and south direction.

Recreation

Devils Lake, the largest lake in the state, was a well-known recreational area at one time and was considered the most attractive summer resort in North Dakota. With the decline in lake surface since 1860, the recreational value of the lake has been completely destroyed. Since the disappearance of pickerel from Devils Lake about 1889, no species of food

6 North Dakota State Eng. 5th Bienn. Rept. to the Governor of North Dakota, p. 24, 1911-12.

or game fish has been found in the waters.[7] With restoration of lake level to altitude 1,425 feet, it is expected that this region will again become a popular resort area.

FLUCTUATIONS OF LAKE LEVEL

Interest in the recent history of Devils Lake centers in its fluctuation and decline. Upham [8] believes that the lake altitude was 1,446 feet above mean sea level about the year 1830. This is 45 feet above the low stage reported in 1940. A few miles south of the city of Devils Lake along State Highway 57 may be seen a wooden marker, shown in figure 5, on which previous lake altitudes are indicated. Early residents recall the period when the lake waters reached the limits of Devils Lake City, which is now approximately 5 miles from the nearest shore. Beginning in 1867 occasional but well-authenticated records of lake levels are available.

The decline in lake level, as indicated in table 1 and shown graphically in figure 6, is not fully understood. It has been suggested that the lowering of the lake level is the result of lowering of the ground water levels. However, it does not appear that there has been sufficient withdrawal of ground water through wells to affect materially the water table. It has also been reasoned that the development of farm lands in the region has caused a decrease in runoff to the streams and lakes in the area, but no tenable relationship has been definitely established. The decline in lake level seems most likely due to general changes in climatic conditions, and the answer may lie in a combination of such factors as: (1) a general decrease in precipitation during the winter months when evaporation is low; (2) a general increase in total evaporation during the summer duc to slightly increased

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7 Pope, T. E. B., Devils Lake, North Dakota, A study of physical and biological conditions with a view to the acclimatization of fish: U. S. Bur. of Fisheries Doc. 634, p. 3, 1908.

8 Upham, Warren, op. cit., p. 595.

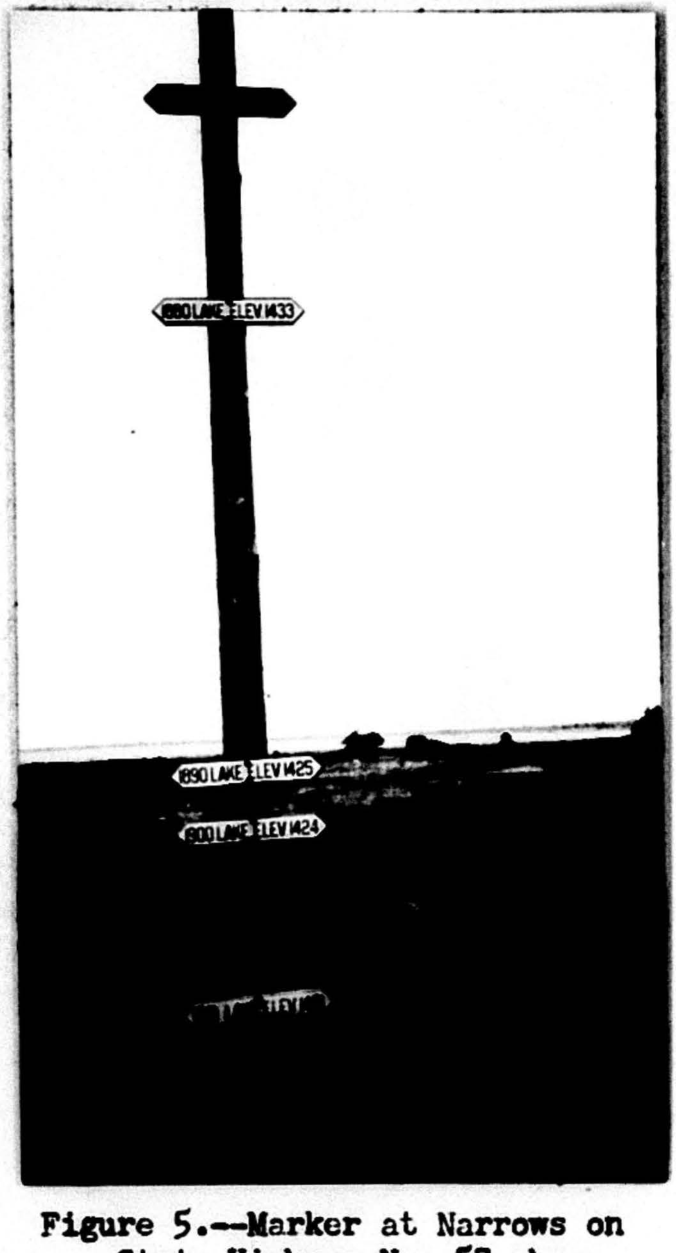

Figure 5.--Marker at Narrows on State Highway No. 57 showing previous elevations of lake level. Devils Lake in background.

Table 1.--Altitudes for maximum and minimum stages of Devils Lake (referred to datum of 1929)

Year	Maximum	Minimum	Year	Maximum	Minimum
1867	1,438.3		1923	1,416.3	
1879	1,434.6		1924	1,416.2	
1883	1,434.4		1925	1,414.8	
1887	1,427.0		1926	1,413.7	
1890	1,424.6		1927	1,413.6	
1896	1,424.6		1928	1,412.8	
1901	1,424.0	1,423.2	1929	1,412.2	1,411.3
1902	1,425.8	1,424.6	1930	1,411.4	1,411.0
1903	1,424.8	1,423.4	1931	1,411.4	1,410.0
1904	1,425.0	1,424.2	1932	1,410.9	1,409.4
1905	1,425.2	1,424.2	1933	1,410.2	1,408.2
1906	1,424.6	1,423.2	1934	1,408.3	1,406.5
1907	1,424.2	1,423.0	1935	1,406.9	1,406.1
1908	1,423.4	1,421.8	1936	1,406.7	1,404.5
1909	1,422.6	1,421.6	1937	1,404.3	1,403.2
1910	1,421.4	1,420.2	1938	1,403.4	1,402.1
1911	1,420.4	1,420.2	1939	1,402.7	1,401.5
1912	1,421.4	1,420.4	1940	1,402.3	1,400.9
1913	1,421.8	1,420.4	1941	1,402.8	1,402.2
1914	1,420.6	1,419.6	1942	1,404.5	1,404.0
1915	1,419.2	1,418.4	1943	1,404.7	1,403.4
1916	1,419.6	1,418.6	1944	1,404.0	1,403.0
1917	1,418.8	1,417.2	1945	1,404.7	1,403.5
1918	1,417.4	1,416.4	1946	1,405.0	1,403.3
1919	1,418.0		1947	1,403.6	1,403.0
1920	1,417.6	1,416.2	1948	1,405.2	1,404.2
1921	1,416.7	1,416.6	1949	1,407.2	1,405.0
1922	1,417.2				

Note.--Where only one altitude shown, reading is for single observation.

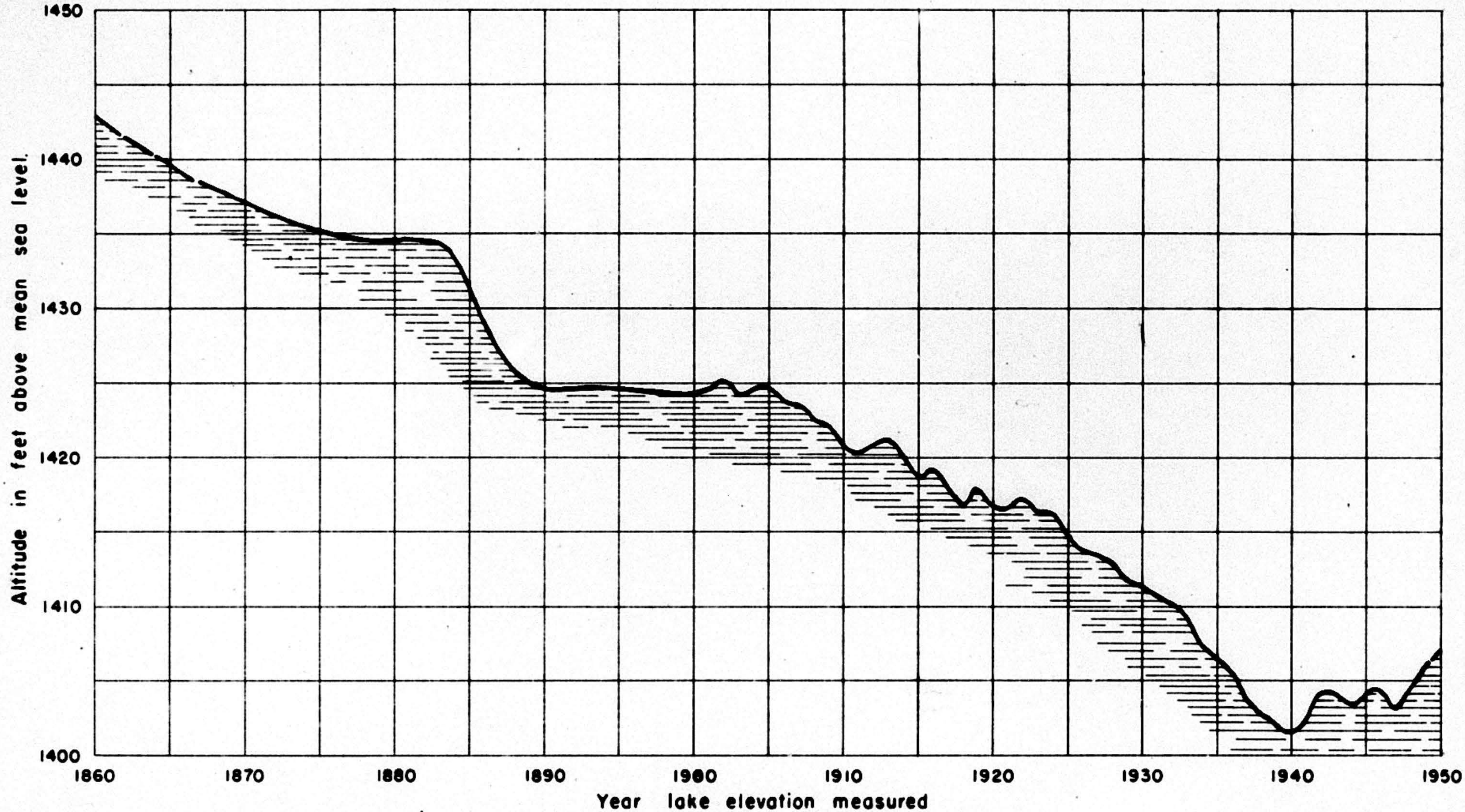

Figure 6.--Fluctuation in level of Devils Lake.

average temperatures; (3) length of warm seasons; and (4) increased air movement. Because precipitation, runoff, changes in stage of the lake surface, and temperature are so interwoven, it is difficult to establish definite relations between one factor and another.

The area of the water surface of Devils Lake has been estimated or calculated for certain years. Lake areas for the period 1867 to 1949 are reported in table 2, and the relationship with altitudes is shown graphically in figure 7.

Table 2.—Area of Devils Lake, 1867-1949

Year	Area		Altitude	Source
	Sq. miles	Acres		
1867	142	90,880	1,438.9	North Dakota State Eng. 21st Bienn. Rept.
1882	120	76,800	1,434	Do.
1928	a/ 35	22,400	1,413.4	Do.
1941	4.5	2,880	1,400.9	Do.
1949	15.7	10,050	1,406.4	Preliminary U. S. Geol. Survey topographic map.

a/ Main part of lake measured from U. S. Geol. Survey topographic map as 17.2 square miles.

CHEMICAL CHARACTER OF THE WATERS

General

Few early records of sampling of the major lake waters for chemical analysis are available. Several analyses of Devils Lake water have been reported from time to time, and in most instances these results are for single observations for certain years. A survey of the literature reveals little information on the areal distribution of soluble salts in Devils and Stump Lakes and no data on the concentration of the waters in the vertical section. The sampling program followed during the field study of 1949 included collection of samples from the major lakes at many points and at

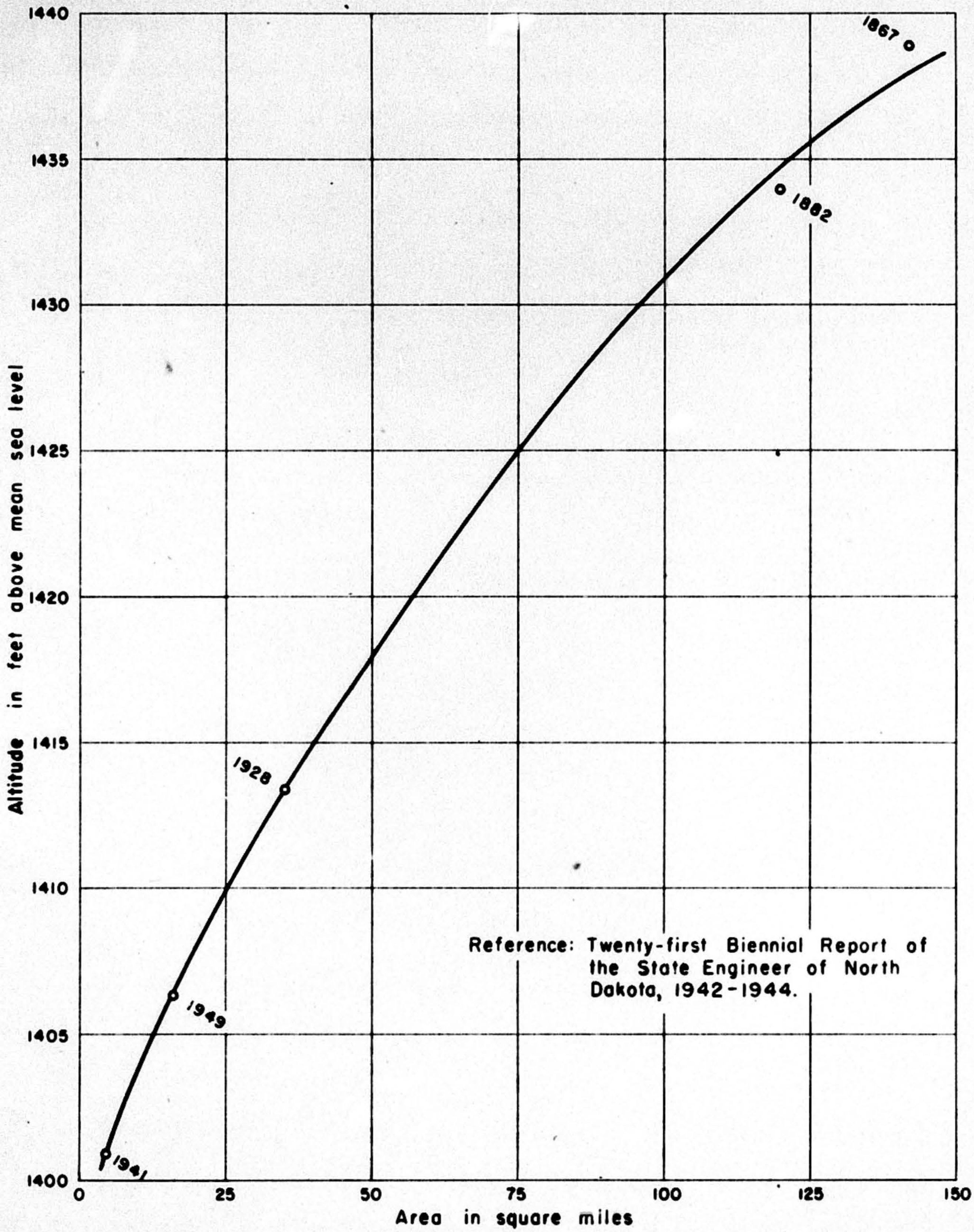

Figure 7.—— Relation between Devils Lake altitude and area.

Figure 8.—View of Devils Lake from south shore. Boat used in obtaining samples in foreground.

both top and bottom levels. (See fig. 8.)

A map of the region studied, showing sampling points, is given in plate 2 (in pocket). The waters in the basin differ considerably in both composition and concentration. This is seen in plate 3 (in pocket) where concentrations as milligram equivalents per kilogram (equivalents per million) for 11 representative waters in the region are plotted graphically. Analyses reported in equivalents per million show chemical properties to better advantage, in that the actual reactive values of the ions are considered. The concentrations of salts as tons per acre-foot vary from 0.47 for a fresh water (Lake Irvine) to 129 for a very saline water (East Stump Lake). Also, the character of water found varies considerably. Wood Lake water, for example, is essentially a bicarbonate water, East Stump Lake water is primarily a sulfate type, and water in Cranberry Lake is classed as a mixed type that contains approximately equal amounts of bicarbonate and sulfate. Maximum concentration determined for all waters that were analyzed in the region is 102,000 parts per million (10.2 percent) and represents the result for a single observation at East Stump Lake.

Devils Lake

The water in Devils Lake has been sampled for chemical analysis on an intermittent basis for at least 50 years. Young [9] records a concentration of 8,471 parts per million of dissolved solids for 1899. Between 1899 and 1949 the lake water has been analysed at infrequent intervals pursuant to biological, limnological, or academic studies. Although some exceptions are noted, the concentration of salts in the lake water has tended to increase during this period, and it is noted that concentrations in general fluctuate inversely with lake level. The relationship between salt concentration and lake altitude is shown graphically in figure 9. Prior to 1949, analyses are available only for single samples over a period of years, and no analyses are given for the interval 1923 to 1948. From figure 9 it is seen that the maximum concentration for the period of record is 25,000 parts per million, reported during November 1948. As a result of surface runoff during the following spring, at which time flow in Mauvais Coulee exceeded 350 second-feet, the concentration of salts in the lake water on May 19, 1949, was reduced to 17,500 parts per million. Further mixing during June of the lake water with the dilute runoff (approximately 400 p.p.m. salts) resulted in a water having an average concentration of 13,400 parts per million, based on 32 samples. The lake altitude in feet above mean sea level was 1 foot higher in June than in May.

During June 14 and 18, 1949, samples of the lake water were collected from 28 points in Devils Lake. The location of the sampling points is shown in figure 10, and results of analyses are given in table 3 (in appendix).

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9 Young, R. T., The life of Devils Lake, North Dakota: North Dakota Biological Sta., p. 28, 1924.

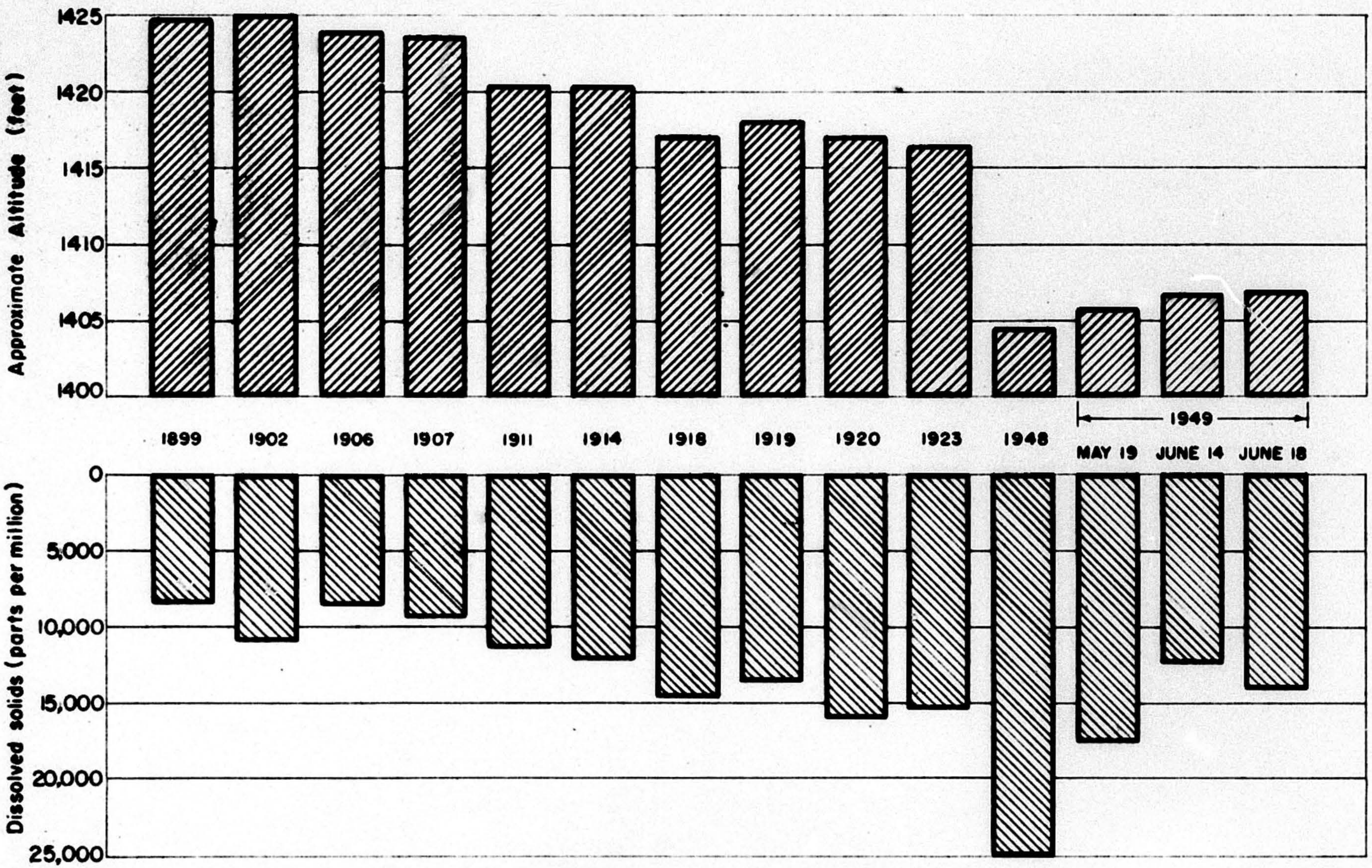


Figure 9.--Comparison of Devils Lake altitude and dissolved solids for period 1899-1949

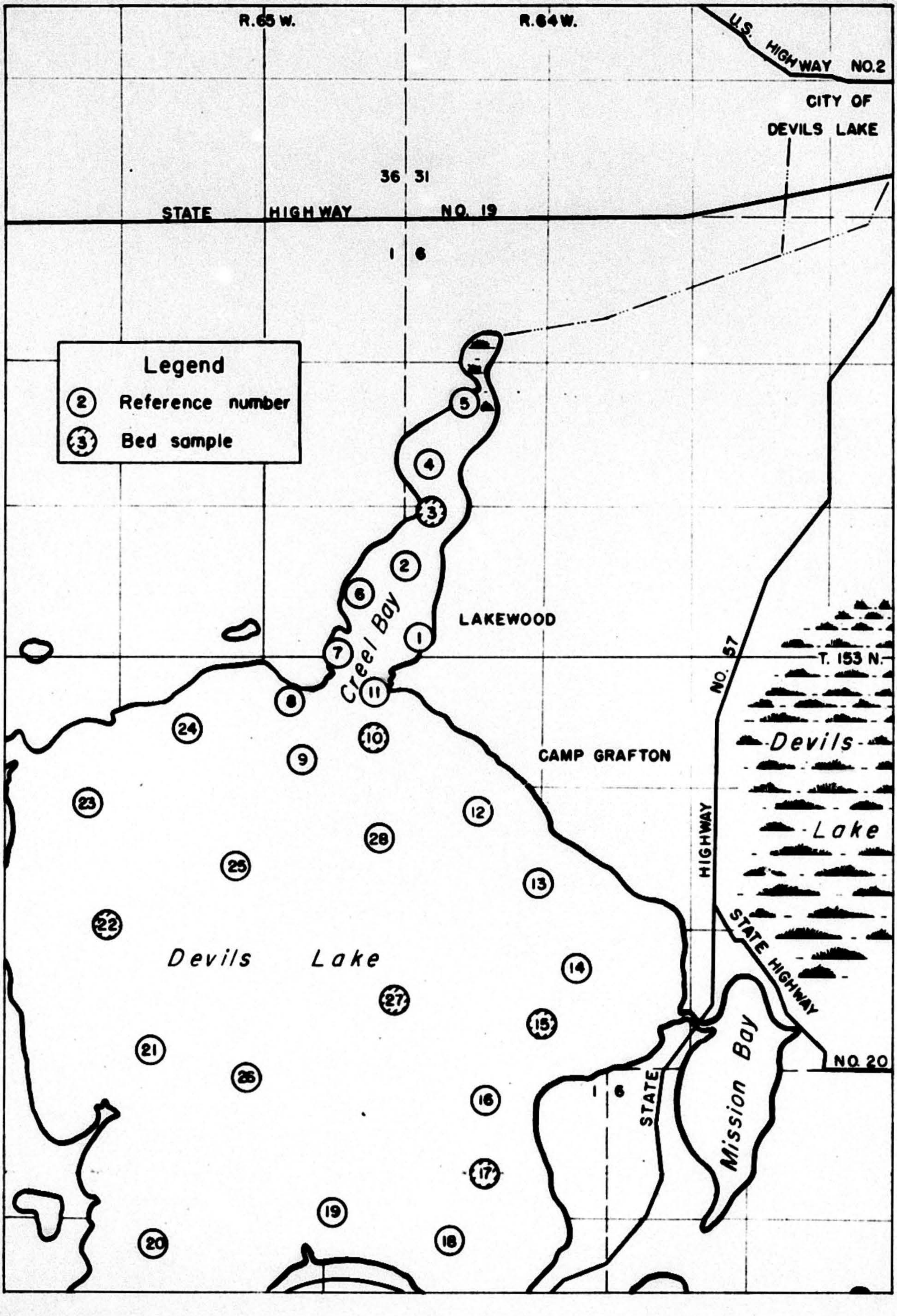


Figure 10.--Map of Devils Lake showing sampling points.

Maximum depth of water measured was 6.9 feet, which is a reduction of approximately 18 feet from the maximum depth reported by Pope [10] in 1908. The average density of the samples for 1949 was 1.0096. Differences in concentration between surface and bottom samples were found to be small, the shallow depth of the lake permitting uniform mixing of the water by wind action.

The composition of the lake water does not appreciably vary. This is seen below, where an analysis by Daudt [11] in 1911 is compared with a lake sample analyzed by the Geological Survey in 1948.

Analysis of Devils Lake water, 1911 and 1948
(percent of anhydrous residue)

	1911	1948
Sodium (Na)	25.9	24.7
Calcium (Ca)	-	0.4
Magnesium (Mg)	5.4	5.7
Carbonate (CO_3)	4.2	2.9
Sulfate (SO_4)	54.1	54.4
Chloride (Cl)	10.5	11.5
Salinity as parts per million	11,278	25,000

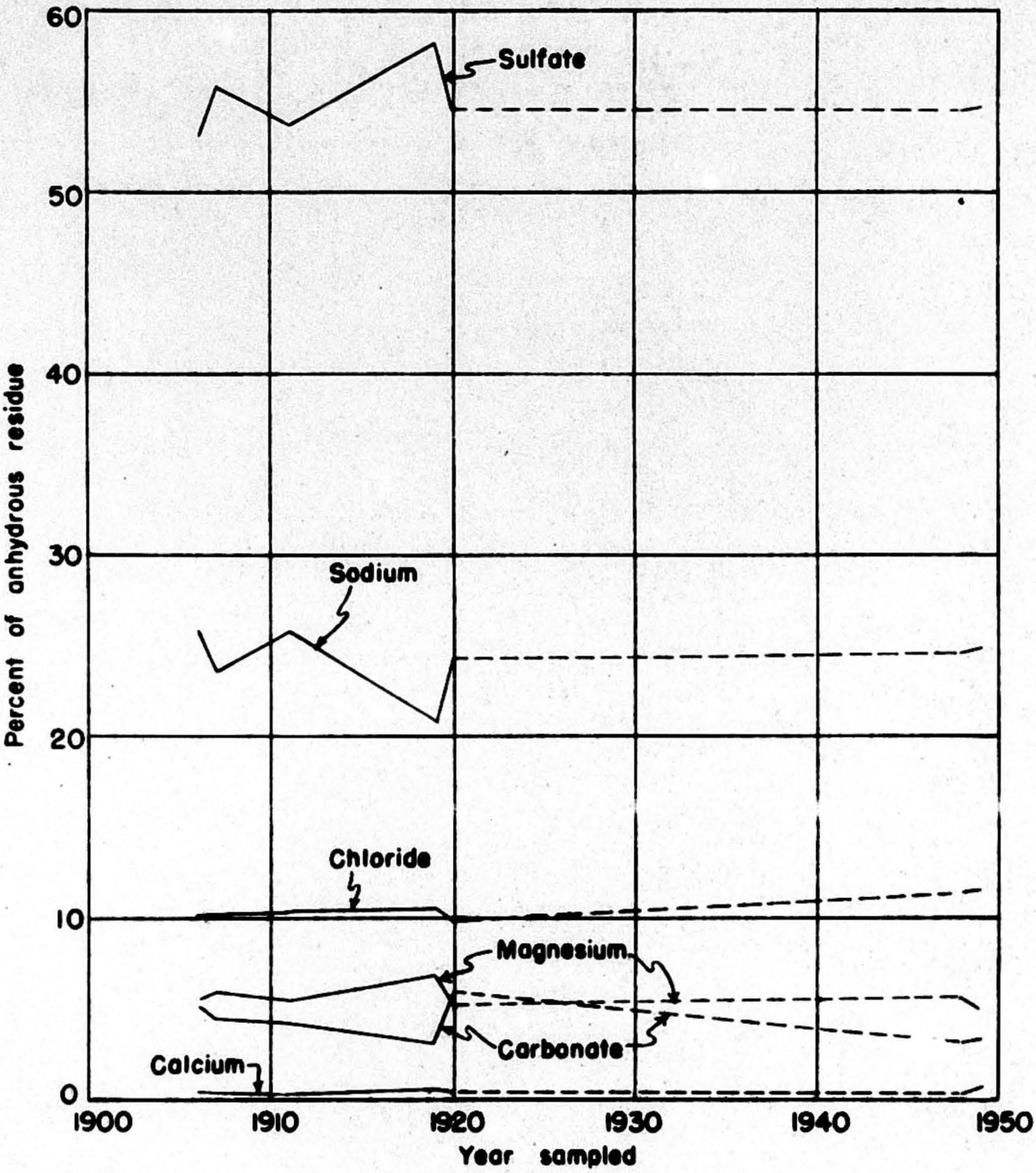
The percentage compositions corresponding to years for which complete chemical analyses are available are plotted in figure 11 for the principal constituents in solution. The variation is small, and it is seen that on a weight basis, sodium and sulfate are the cation and anion, respectively, which account for most of the mineral content. The average salinity in parts per million of this average composition is computed as 13,800.

It is interesting to note that Nerhus,[12] working under the direction of G. A. Abbott of the University of North Dakota, made a study of the

10 Pope, T. E. B., op. cit., p. 5.

11 Daudt, H. W., Quart. Jour., Univ. of North Dakota, vol. 1, p. 225, 1911.

12 Nerhus, P. T., A study of the solubility relations of the salts in Devils Lake water, Thesis for Master of Science degree, Univ. of North Dakota, pp. 40-41, June 1920.



Average percentage composition

Sodium------------------24.3

Magnesium---------------5.6

Calcium-------------------0.4

Chloride------------------10.6

Sulfate-------------------54.9

Carbonate----------------4.2

Salinity 13,800 parts per million

Figure 11.__ Percentage composition of Devils Lake water, 1906-1949

solubility relations of the salts of Devils Lake, with a view to obtaining salts in a state of purity on a commercial scale. They devised a procedure using solar evaporation and fractional crystallization for the separation of the following salts: mirabilite ($Na_2SO_4 \cdot 10H_2O$); astrakanite ($MgSO_4 \cdot Na_2SO_4 \cdot 4H_2O$); halite (NaCl); and sylvite (KCl). Abbott [13] pointed out that the chief salts present are sodium sulfate, sodium chloride, and magnesium sulfate. He also brought out the point that the composition of Devils Lake water differs strikingly from the composition of such western lake waters as those of Searles Lake and Owens Lake, Calif.; Dixie Salt Marsh, Nev.; and Jesse Lake, Nebr., all of which are high in chlorides rather than sulfates.

In his work on chemical toxicology of Devils Lake water to discover the reasons for the disappearance of fish from Devils Lake, Abbott [14] reasoned that the presence of zinc in the water was the contributing factor and, in 1924, reported concentrations of this element as high as 15 parts per million. Analyses of samples collected by the Geological Survey in 1949 do not show the presence of zinc in this concentration; the maximum found from 25 samples was 0.16 part per million. A recent analysis by Dr. Abbott [15] showed 0.20 part per million of zinc, confirming the report in 1949 of the Geological Survey. Apparently the zinc has reacted chemically with other ions in the water and precipitated on the lake floor in the form of an insoluble salt, possibly zinc carbonate.

East Devils Lake

East Devils Lake was formerly a part of the main body of Devils Lake

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13 Abbott, G. A., A chemical investigation of the water of Devils Lake, North Dakota: Proc. of Indiana Acad. of Science, p. 182, vol. 34, 1924.
14 Abbott, G. A., Idem., pp. 183-184.
15 Personal communication to the writer.

and was known as Lamoreaux Bay. As previously noted, the recession of Devils Lake has resulted in the development of several smaller lakes, among which is East Devils Lake, a few miles southeast of Devils Lake.

Samples were obtained at six points on the lake, and the concentration of salts is essentially the same over the entire extent of East Devils Lake. The average concentration of dissolved solids is 41,200 parts per million--about three times the concentration of salts in Devils Lake water. East Devils Lake water upon evaporation yields mostly sodium sulfate, sodium chloride, and magnesium sulfate. Exposed rocks near the shore line of East Devils Lake show salt incrustation as seen in figure 12.

The average density of the lake waters is 1.0347. The salt content of surface and bottom samples is practically the same. An analysis of East Devils Lake water for 1919, reported by Young,[16] shows 14,932 parts per million of dissolved solids--a much more dilute water.

Figure 13 shows the location of points sampled in East Devils Lake. Analytical results are given in table 4 (in appendix). The maximum measured depth reached in the sampling of the lake waters was 6 feet.

West Stump Lake

West Stump Lake was formerly part of Stump Lake, but the latter now consists of west and east arms, the result of construction of a highway embankment across the main lake. The two Stump Lakes are approximately 10 miles southeast of East Devils Lake. Both lakes lie in the same inland drainage basin and are otherwise united physiographically with Devils Lake.

The concentration of West Stump Lake water averaged 6,040 parts per million of dissolved solids, most of which are sulfates of sodium and magnesium. The density of the water is 1.0012, and a maximum depth of 3 feet was

16 Young, R. T., op. cit., p. 28.

A. Rocks along west bank about 300 feet from present shore line.

B. Large boulder along west bank.

Figure 12.--Rocks incrusted with salt deposits, East Devils Lake.

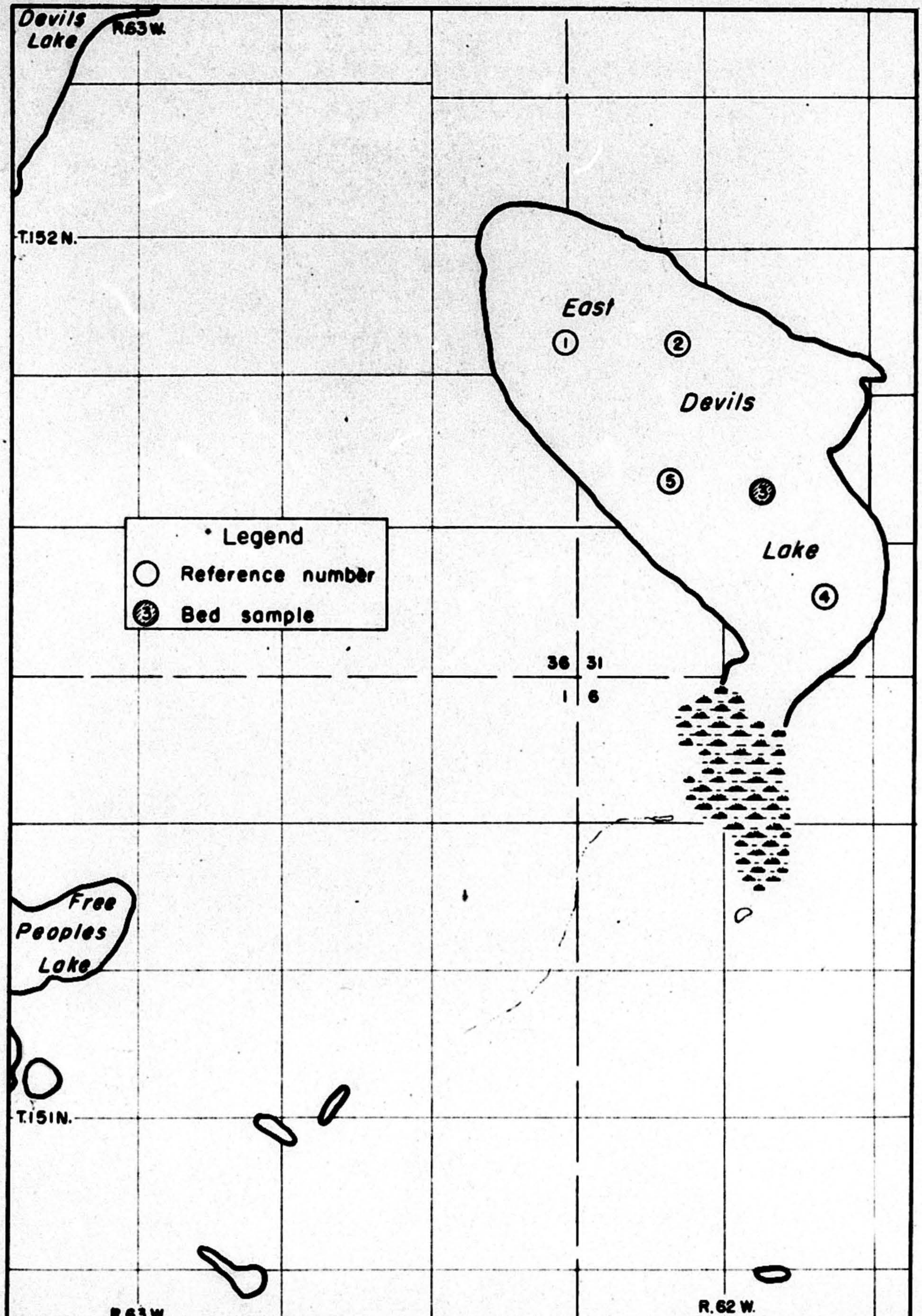

Figure 13.__ Map of East Devils Lake showing sampling points.

noted. Chemical characteristics of the waters are uniform in an areal extent and vertical profile.

Sampling points are shown in figure 14, and analytical results are given in table 5 (in appendix).

East Stump Lake

East Stump Lake water is the most saline of all surface waters sampled during the course of investigation. The average of 20 samples gave a concentration of 95,200 parts per million of dissolved solids. This lake water is more than 15 times saltier than West Stump Lake water, more than 7 times saltier than Devils Lake water, and more than twice saltier than East Devils Lake water. The lake water is almost three times more concentrated than ocean water (35,000 p.p.m.). People using the lake for swimming or bathing notice that their bodies become coated with a fine, chalky deposit.

The shore line of East Stump Lake is very irregular, the character in general being similar to that of a marine littoral. Boulders (see fig. 15) and cobbles with gravelly and sandy stretches are found along the extent of the lake. It is thought that both Stump Lakes are of glacial origin and are in a lower portion of the same valley as Devils Lake.

The density of the water is 1.0882. Maximum depth measured was 6.8 feet, although residents near the lake stated that depths of approximately 20 feet are known. The salt concentration in the lake water is evenly distributed laterally; however, bottom samples showed somewhat higher concentrations than did samples collected at the surface. Figure 16 shows the location of sampling points, and analytical results are tabulated in table 6 (in appendix).

The water in East Stump Lake contains more sulfate than chloride and is similar to Devils Lake water. Both lake waters differ markedly in this

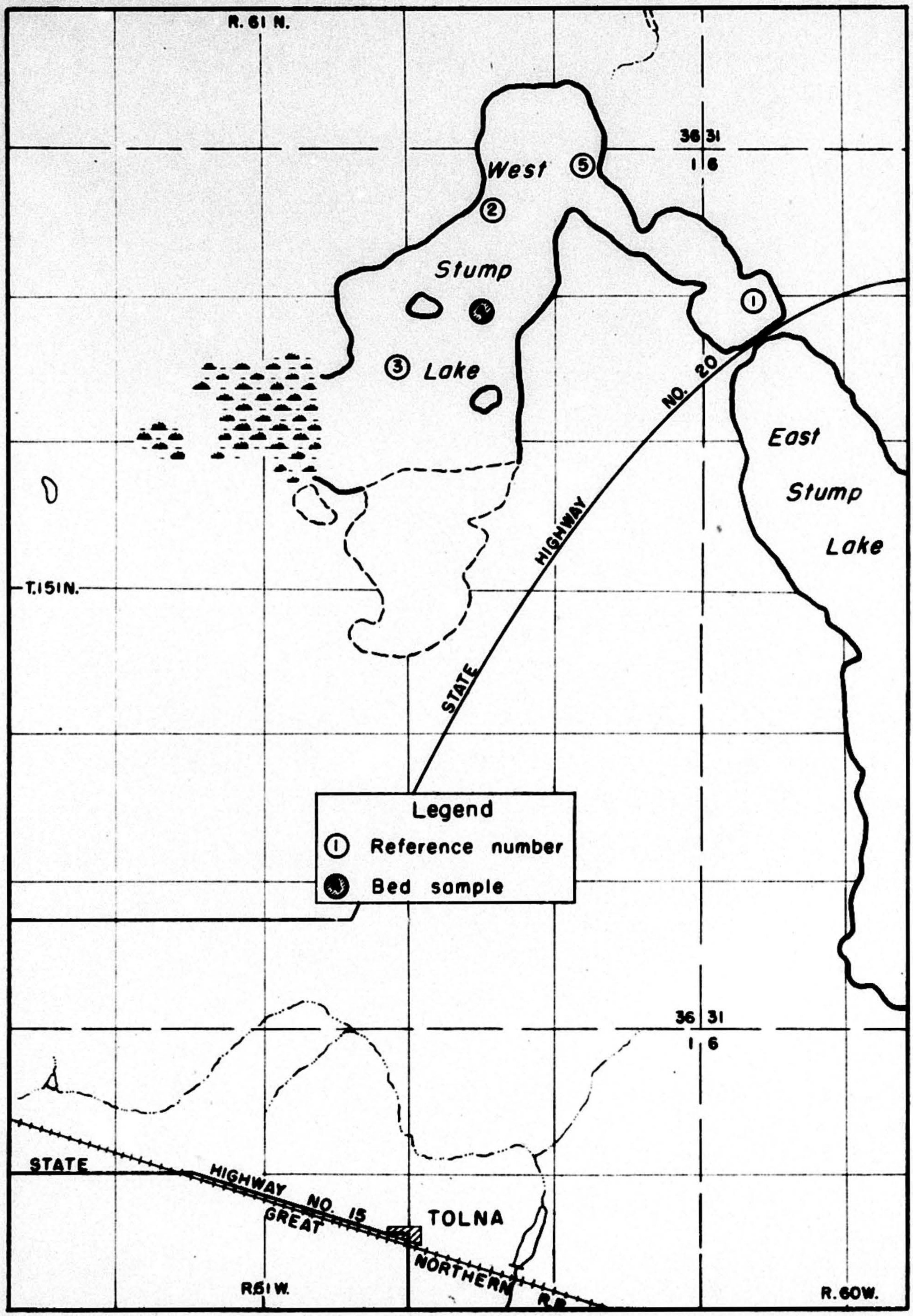

Figure 14.— Map of West Stump Lake showing sampling points.

Figure 15.--Boulders strewn along west shore, East Stump Lake. Incrustations on rocks extreme left. White material in foreground is foam.

respect from saline waters present in the ocean and Great Salt Lake. The analyses of ocean and Great Salt Lake waters show a reversal in relation of percent sulfate to percent chloride as compared with East Stump and Devils Lake waters. (See fig. 17.) The two chloride waters also contain more sodium and less magnesium than either Devils Lake or East Stump Lake water. Evaporation of East Stump Lake water yields mostly sodium sulfate, sodium chloride, and magnesium sulfate. (See pl. 3 in pocket.)

Miscellaneous Waters

In the course of the investigation, it was thought worthwhile to obtain information on the chemical character of waters in adjoining lakes, bays, and coulees, many of which were at one time a part of Devils Lake. In most instances single samples were collected by wading out to the lake or bay as far as safety permitted. The specific location of these sampling points is given in table 7 (in appendix) and also shown on the general map of the region (pl. 2 in pocket). Analytical results are given in table 8 in the appendix.

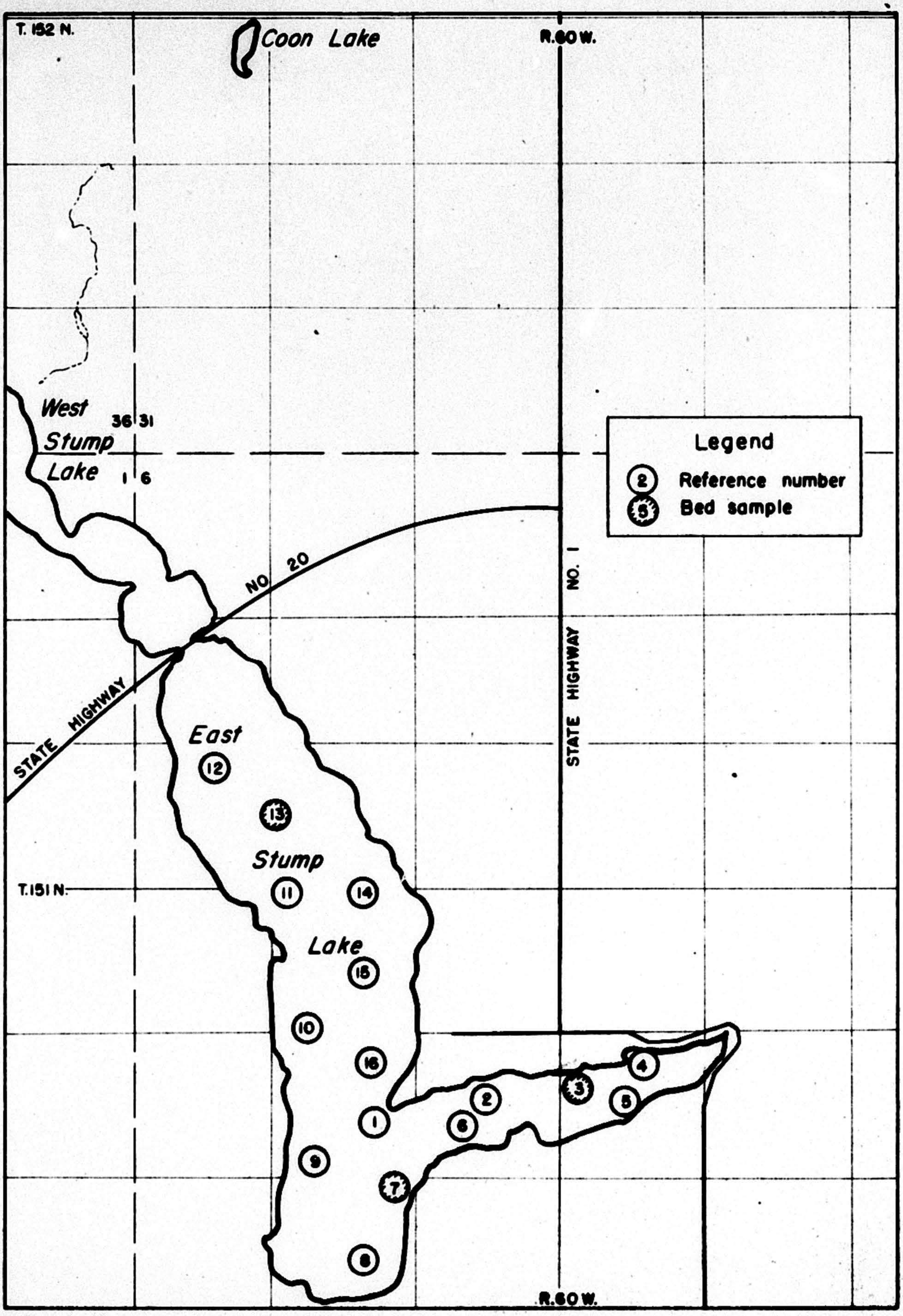

Figure 16.–Map of East Stump Lake showing sampling points

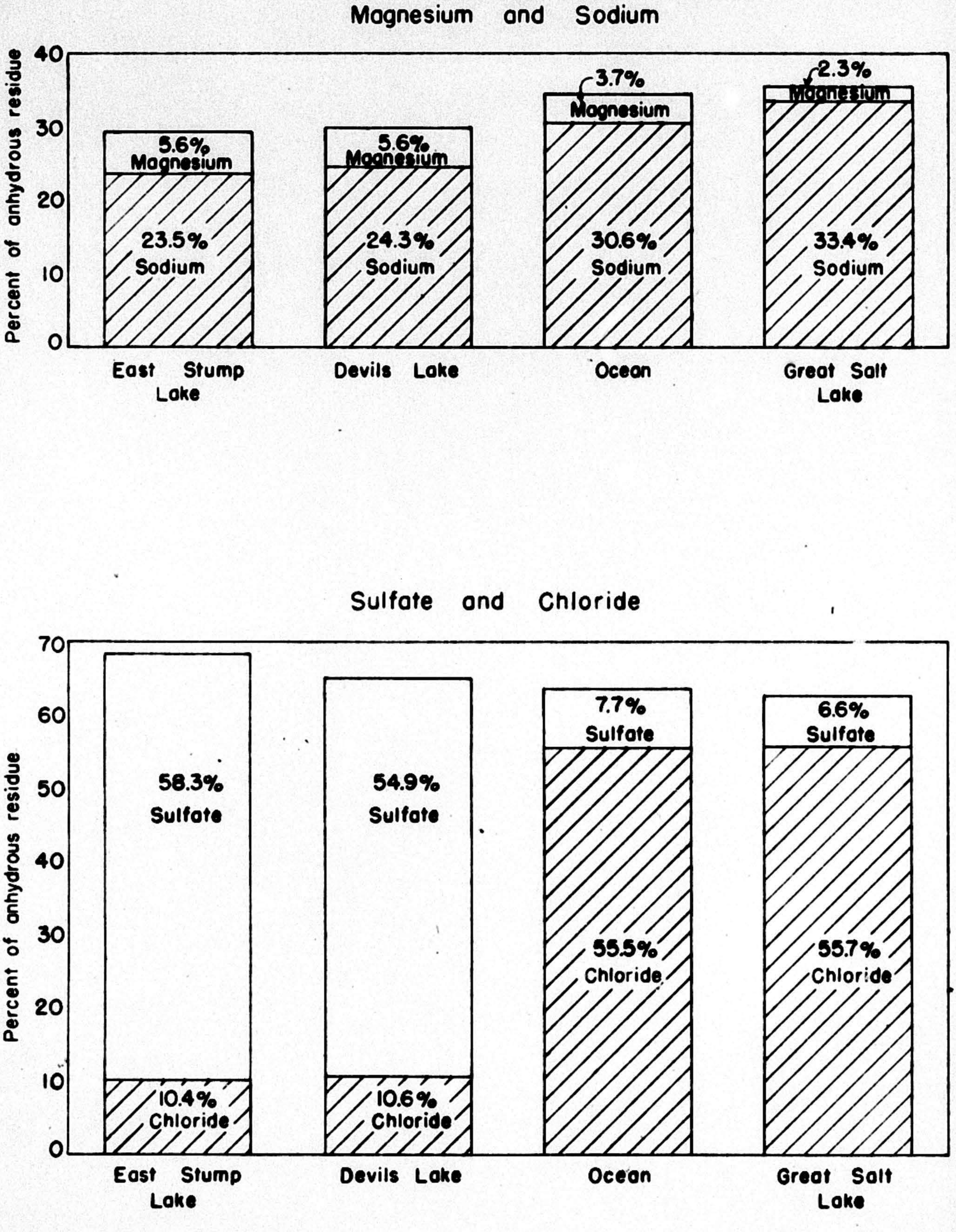

Figure 17.__Principal chemical constituents in certain saline waters

These miscellaneous waters vary considerably in concentration and type. Dry Lake, a member of the Sweetwater group of lakes north of Devils Lake, contains a bicarbonate water, having 232 parts per million of dissolved solids. On the other hand, Cranberry Lake, 40 miles west of the city of Devils Lake, has a mixed sulfate-bicarbonate water, containing 23,100 parts per million of dissolved solids. Residents in the vicinity of Cranberry Lake report that the game warden posts guards near the lake to prevent ducks from alighting on these waters. The high salt concentration lowers the freezing point of the water to a point where the lake remains open water after fresh water lakes are frozen, and late migrating ducks are thus attracted to the lake. In the opinion of Dr. G. A. Abbott [17] the ducks become weighted down with a coating of salt deposit and are unable to fly, or they swallow enough of the saline water to become poisoned.

Wood Lake, a popular fishing resort about 15 miles south of Devils Lake City, has a bicarbonate water of low concentration (384 p.p.m. of dissolved solids). Samples collected at three different points along the Mauvais Coulee show practically the same low concentration of salts.

PROPERTIES OF LAKE BED DEPOSITS

A study on a reconnaissance level was made of bed materials that cover the floor of the major lakes considered in this report. The data presented in the following pages provide limited information on certain chemical and physical properties of the clays, silts, sands, and gravels that compose the lake bottoms.

Chemical Examination

The air-dried materials were agitated for 48 hours in distilled water, and the extracted salts analyzed, with results reported in table 9. Values

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17 Personal communication to the writer.

thus obtained afford some basis for comparison of the chemical character of the lake deposits with that of the lake water. The total leachable solids, an index to the solubility of the bed material, is also reported.

Table 9.--Analyses of distilled water extracts of bed materials

Lake	Class of material	Mg. per 100 gm. of deposited lake material							
		SiO_2	Ca	Mg	Na+K	CO_3	SO_4	Cl	Dissolved solids
Devils	Silty clay	32	110	49	950	120	1,840	300	3,700
Do.	Silty clay loam	24	240	180	1,630	190	3,700	500	7,080
Do.	Fine sand	7.5	15	15	100	65	180	10	430
Do.	Silty clay	26	290	160	1,950	100	4,320	680	8,100
Do.	Silty clay loam	32	340	150	1,800	100	4,160	620	8,060
Do.	Silty clay	30	230	260	2,540	180	5,500	810	9,550
East Devils	Silty clay	30	250	200	3,180	200	6,360	1,000	11,200
West Stump	Silty clay	53	300	120	960	160	2,540	300	4,720
East Stump	Silty clay	43	660	430	3,430	200	7,880	1,640	14,300
Do.	Silty clay	45	440	270	3,310	160	6,920	1,360	12,500
Do.	Clay	53	420	300	3,000	220	6,400	1,260	11,700
Do.1/	Coarse sand and gravel	4.2	6.5	14	139	13	278	45	520

1/ Sample from west bank.

Samples of the air-dried deposits were extracted with Missouri River water for 90 hours, and a comparison made with experimental results obtained using distilled waters. Correction for the dissolved solids (432 p.p.m.) present in the Missouri River water was made. Results are given in table 10, and it is seen that the solubilities of the bed materials are about the same in either Missouri River or distilled water. It is also noted that the bed deposits in East Stump Lake yield soluble salts in amounts greater than those measured in other lakes.

Table 10.—Solubility of lake bed material in Missouri River water

Lake	Class of material	Percent of bed material soluble (gm. per 100 gm.)	
		Missouri River water	Distilled water
Devils	Silty clay	3.7	3.7
Do.	Silty clay loam	5.7	7.1
Do.	Fine sand	.5	.4
Do.	Silty clay	7.8	8.1
Do.	Silty clay loam	6.5	8.1
Do.	Silty clay	10.3	9.6
East Devils	Silty clay	11.8	11.2
West Stump	Silty clay	4.4	4.7
East Stump	Silty clay	14.7	14.3
Do.	Silty clay	11.3	12.5
Do.	Clay	11.9	11.7

Table 11 reports values for density determinations and percent organic matter for the lake deposits. Density was determined on samples that had been dried for 1 hour at 110° C. Percent organic matter was found by decomposition of the dried samples, using a 30 percent solution of hydrogen peroxide.

Table 11.—Density and percent organic matter determinations of bed samples

Lake	Class of material	Density in grams per milliliter	Organic matter in percent
Devils	Silty clay	2.51	3.5
Do.	Silty clay loam	2.58	2.1
Do.	Fine sand	2.63	0
Do.	Silty clay	2.66	1.6
Do.	Silty clay loam	2.63	1.7
Do.	Silty clay	2.57	3.4
East Devils	Silty clay	2.60	2.6
West Stump	Silty clay	2.60	1.0
East Stump	Silty clay	2.68	1.9
Do.	Silty clay	2.66	1.6
Do.	Clay	2.66	1.6

Physical Examination

The particle size distribution for the range 1.0 millimeter to less than 0.00195 millimeter (colloidal clay) is shown in table 12.

Table 12.--Particle size distribution of bed samples

Lake	Class of material	Particle size in percent			
		Sand (1.0-.0625 mm.)	Silt (.0625-.0039 mm.)	Clay (.0039-.00195 mm.)	Colloidal clay (<.00195 mm.)
Devils	Silty clay	3.8	52.7	12.9	30.6
Do.	Silty clay loam	3.3	70.8	7.8	18.1
Do.	Fine sand	99.8	-	-	-
Do.	Silty clay	7.1	57.2	8.8	26.9
Do.	Silty clay loam	9.7	60.9	10.2	19.2
Do.	Silty clay	.9	52.9	11.3	34.9
East Devils	Silty clay	4.5	54.4	11.0	30.1
West Stump	Silty clay	2.7	50.5	12.3	34.5
East Stump	Silty clay	.6	58.7	11.5	29.2
Do.	Silty clay	1.4	55.0	14.0	29.6
Do.	Clay	2.6	49.2	14.6	33.6

DILUTION OF DEVILS LAKE WATER

A comparison of waters in the basin is given in plate 4 (in appendix) where specific conductances in micromhos for both fresh and saline waters are shown. The specific conductance of a water is a measure of its ability to conduct a current of electricity, the amount of current depending upon the concentration and degree of ionization of inorganic salts (electrolytes) in solution. Thus, conductance values are indicators of the amounts of solids in solution, the higher values representing the more saline waters.

The plan outlined by the Department of the Interior [18] for restoration of Devils Lake level proposes diversion of a portion of the return flows

18 Interior Missouri Basin Field Comm., Missouri River Basin progress report: Dept. of the Interior, pp. 33-35, October 1949.

that originate on the northern division of the Missouri-Souris project into the lake by means of Devils Lake lateral. The following paragraph is quoted from the October 1949 progress report of the Interior Missouri Basin Field Committee:

"The canal system serving Devils Lake Reservoir will leave the proposed Sheyenne Reservoir about five miles northeast of the town of Sheyenne, North Dakota, generally following a natural drainage course in a northerly direction to enter the lake about eight miles southeast of the town of Minnewaukan. The canal, to be known as the Devils Lake lateral, will have a capacity of about 1,000 second-feet. Gates will be installed at the headworks to control the flow into the lake. From the main body of Devils Lake, water will pass through a connecting canal to East Devils Lake. From East Devils Lake a canal will follow the historical outlet of the lake to a point near the north end of West Stump Lake. The canal will then follow along the shore of West Stump Lake and enter the lake near the center of the west shore. At the south end of East Stump Lake, just east of Tolna, North Dakota, an outlet canal with a capacity of about 500 second-feet will carry overflow back to the Sheyenne River. In all, there will be about 27 miles of canal. Water will flow into the lake during the period April 1 to November 30 and will be shut off during the winter months."

The question arises as to the probable concentration of the water in Devils Lake after mixing with fresh water diverted from the Missouri River. The lake has dropped in depth some 18 feet since 1899; since that time, intermittent analyses of the water has shown with some exceptions a gradual increase in concentration of dissolved solids. In table 13, concentrations corresponding to lake altitudes are shown for the period of record. Lake altitudes reported are averages of annual maximum and minimum readings; in some instances, altitudes shown are single readings for the year. The exact lake altitudes corresponding to the dates of earlier sampling of Devils Lake water cannot be determined because of insufficient lake level readings. The concentration of dissolved solids for 1902 is reported in the original source as 635.9 grains per U. S. gallon (10,874 p.p.m.).

Rough computations of volumes of water and tonnages of salts for the period of record have been made by B. R. Colby and are given in table 14.

Table 13.--Concentrations of dissolved solids, Devils Lake, 1899-1949

Date	Lake altitude in feet (datum of 1929)	Dissolved solids 1/ (p.p.m.)	Source of analytical data
1899	1,424.6	8,471	A
1902	1,425.2	10,874	B
1906	1,423.9	8,517	C
1907	1,423.6	9,448	C
1911	1,420.3	11,278	D
1914	1,420.1	12,092	E
1918	1,416.9	14,452	E
1919	1,418.0	13,462	A
1920	1,416.9	15,889	E
1923	1,416.3	15,210	A
1948	1,404.2	25,000	F
1949 (May)	1,405.7	17,500	F
1949 (June)	1,406.6	2/ 13,200	F

1/ Single samples unless otherwise indicated. 2/ Average of 32 samples.

A. Young, R. T., The life of Devils Lake, North Dakota: North Dakota Biological Sta., p. 28, 1924.

B. Babcock, E. J., Water resources of the Devils Lake region: 2d Bienn. Rept. of the State Geol. Survey of North Dakota, 2d ed., p. 234, 1903.

C. Pope, T. E. B., Devils Lake, North Dakota: A study of physical and biological conditions with a view to the acclimatization of fish: U. S. Bur. of Fisheries Doc. 634, pp. 14-15, 1908.

D. Daudt, H. W., Quart. Jour. Univ. of North Dakota, vol. 1, p. 225, 1911.

E. Nerhus, P. T., A study of the solubility relations of the salts in Devils Lake water, thesis for Master of Science degree, Univ. of North Dakota, p. 4, June 1920.

F. U. S. Geol. Survey, Lincoln, Nebr.

Table 14.--Approximate volumes of water and tonnages of salts in Devils Lake, 1899-1949

Year	Altitude of lake (feet)	Volume of water (acre-feet)	Dissolved solids	
			Parts per million	Tons
1899	1,424.6	550,000	8,471	6,400,000
1902	1,425.2	580,000	10,874	8,600,000
1906	1,423.9	520,000	8,517	6,000,000
1907	1,423.6	510,000	9,448	6,600,000
1911	1,420.3	370,000	11,278	5,700,000
1914	1,420.1	360,000	12,092	6,000,000
1918	1,416.9	260,000	14,452	5,200,000
1919	1,418.0	290,000	13,462	5,400,000
1920	1,416.9	260,000	15,889	5,700,000
1923	1,416.3	240,000	15,210	5,200,000
1948	1,404.2	38,000	25,000	1,290,000
1949 (May)	1,405.7	49,000	17,500	1,170,000
1949 (June)	1,406.6	58,000	13,200	1,040,000

It is seen from table 14 that there has been a sharp reduction in tonnages of dissolved solids in the range of altitudes between 1,406 and 1,425 feet. Some of these dissolved solids were left in smaller lakes and bays that were separated from the main lake as the elevation of the water surface fell. Also, some of the soluble salts may have been lost to ground seepage. There must be, however, a large tonnage of salts deposited on the ground surface or close below the ground surface. As early as 1908, Pope [19] observed that "Nearly all of the surrounding lands, especially the 'dried up' bays, show upon their surface a thin grayish-white efflorescence resembling frost. These accumulations, generally found in regions of deficient or irregular rainfall when the soil contains unusually large amounts of soluble salts concentrated in or near the surface, represent the residue from the evaporation of moisture."

With an increase in altitude of the water surface of Devils Lake to 1,425 feet, some of these salts, formerly in solution, will be redissolved. To what extent solution will occur is not known; any estimate of the expected salt concentration of water in the restored lake would have to include some value for salinity resulting from solution of deposited salts.

The concentration of the water to be diverted into Devils Lake may be several times greater than the concentration of water diverted from the Missouri River. The river water will be slightly concentrated by evaporation in Medicine Lake, Crosby, Des Lacs, and Sheyenne Reservoirs. Also, the Missouri River water will be used to irrigate land in the Crosby-Mohall project. The return flows from irrigation will be mixed with any surplus water from the Souris River and with water in the upper Sheyenne River; it is this water of unknown concentration and composition that will presumably be used to restore the level of Devils Lake.

In the early summer of 1949, the concentration of Devils Lake water decreased almost 50 percent from the high reading of 25,000 parts per million dissolved solids reported in 1948. This decrease is attributed to

19 Pope, T. E. B., op. cit., p. 16.

flow in Mauvais Coulee, which at this time was discharging considerable fresh water (366 p.p.m.) into the lake. Flow in the coulee on May 9 and 10, 1949, was 365 and 385 second-feet, respectively, and as late as August 22 a discharge of 6.37 second-feet was measured. It is seen that a mean daily discharge of 350 second-feet for 1 month--from May 14 to June 14 (the beginning of sampling)--would result in 21,700 acre-feet of fresh water, part or all of which reached the lake directly or indirectly. When one considers that the present (1949) calculated volume of water in Devils Lake is about 55,700 acre-feet, the flushing and diluting effects of this quantity of Mauvais Coulee water--21,700 acre-feet--flowing into the lake are understandable. The relationship between concentration and capacity for the periods 1899 to 1948 and 1948 to 1949 is shown in figure 18.

The concentration of the total volume of mixed saline and fresh water at altitude 1,425 has been roughly estimated using the equation below:

$$FC = \frac{ST_1 + (p)ST_2 + ST_3}{V}$$

where FC = final concentration of dissolved solids in tons per acre-foot of the diluted lake water

ST_1 = tonnage of dissolved solids in the lake water as of June 1949

ST_2 = tons of deposited salts available for redissolving as lake level reaches 1,425 feet

(p) = percent actually redissolving

ST_3 = tonnage of dissolved solids in water to be diverted into Devils Lake

V = total volume in acre-feet of lake water at altitude 1,425

In applying the above equation, it is realized that during the period of solution of deposited salts (period of surface water inflow) there will be certain losses of water not wholly measurable, as Devils Lake and Stump Lakes are being refilled. These losses in part will be to permanent ground-water storage and to temporary ground-water storage. There will be a loss

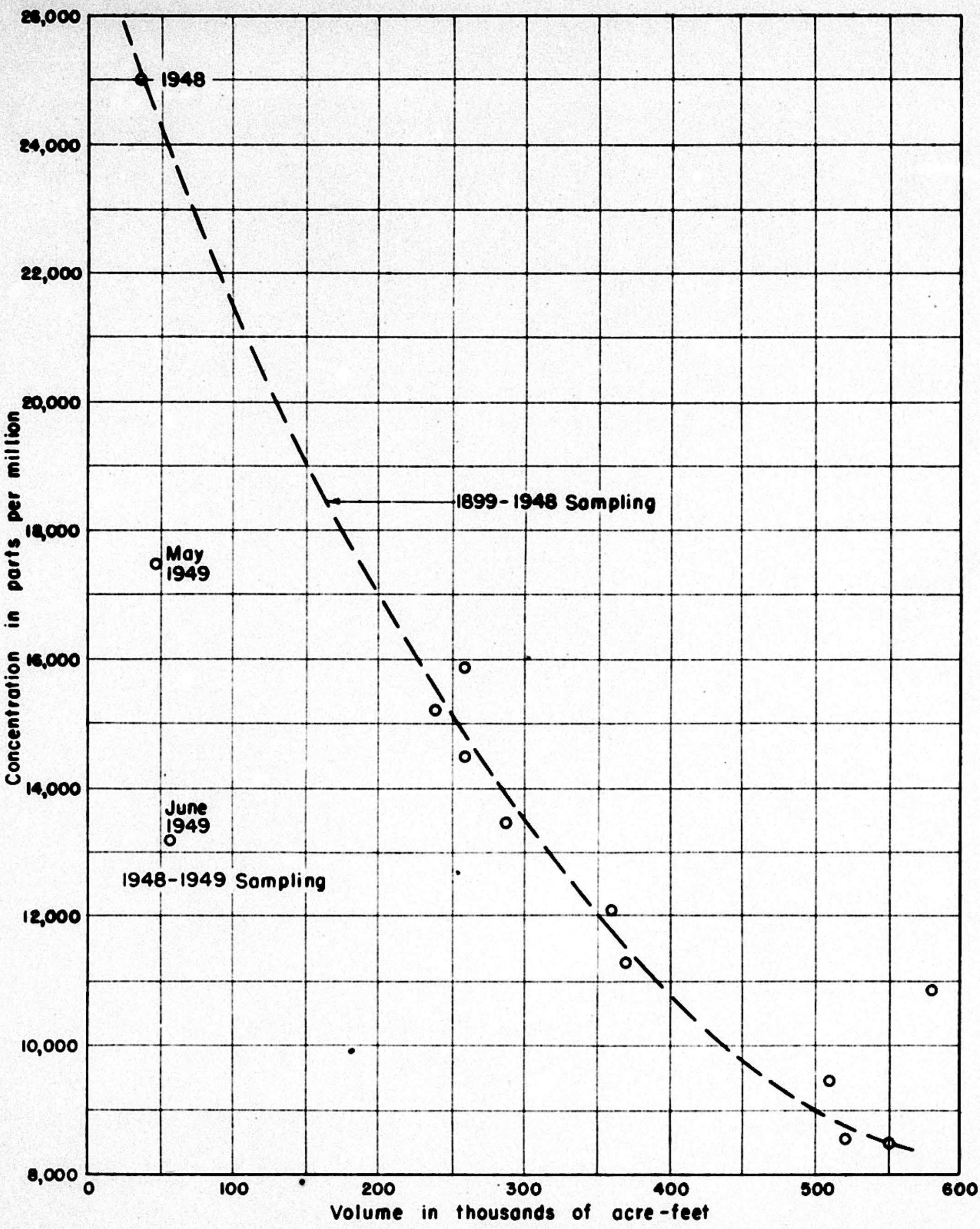


Figure 18.—— Concentration-capacity curve for Devils Lake water.

of water due to decline in ground-water inflow as a result of reduction in the inflow hydraulic gradient. Other losses will result from increases in ground-water outflow due to an increase in outflow areal extent, material thickness, and increased hydraulic gradient. Evaporation and transpiration losses may range from 2 to 3 feet per year. However, loss to ground water may be more than compensated for by the added inflow required to offset evaporation during the period of filling of the lakes.

As of June 1949, the amount of dissolved solids (ST_1) in Devils Lake water is estimated as 1,040,000 tons. The total amount of deposited salts (ST_2) available for redissolving is roughly approximated as the difference between an estimated value of 7,000,000 tons at altitude of 1,425 feet and 1,040,000 tons at 1,406.6 feet, or 5,960,000 tons of salts, mostly sulfates and chlorides of sodium and magnesium. The estimated final concentration has been computed for two values (p) of ST_2—10 percent and 70 percent. The value ST_3 is computed using an average concentration of 1,000 parts per million (1.36 tons per acre-foot) and the difference between 570,000 acre-feet (the 1,425 level) and 58,000 acre-feet (the 1,406.6 level). (See fig. 19.) This difference is 512,000 acre-feet, and ST_3 is calculated as 696,300 tons. V, the total volume of the lake water at altitude 1,425 is estimated as 570,000 acre-feet, as noted from figure 19.

For a 10 percent value for ST_2:

$$FC = \frac{1{,}040{,}000 + (.1)\ 5{,}960{,}000 + 696{,}300}{570{,}000}$$

$$= 4.09 \text{ tons per acre-foot or } 3{,}000 \text{ parts per million}$$

For a 70 percent value for ST_2:

$$FC = \frac{1{,}040{,}000 + (.7)\ 5{,}960{,}000 + 696{,}300}{570{,}000}$$

$$= 10.36 \text{ tons per acre-foot or } 7{,}600 \text{ parts per million}$$

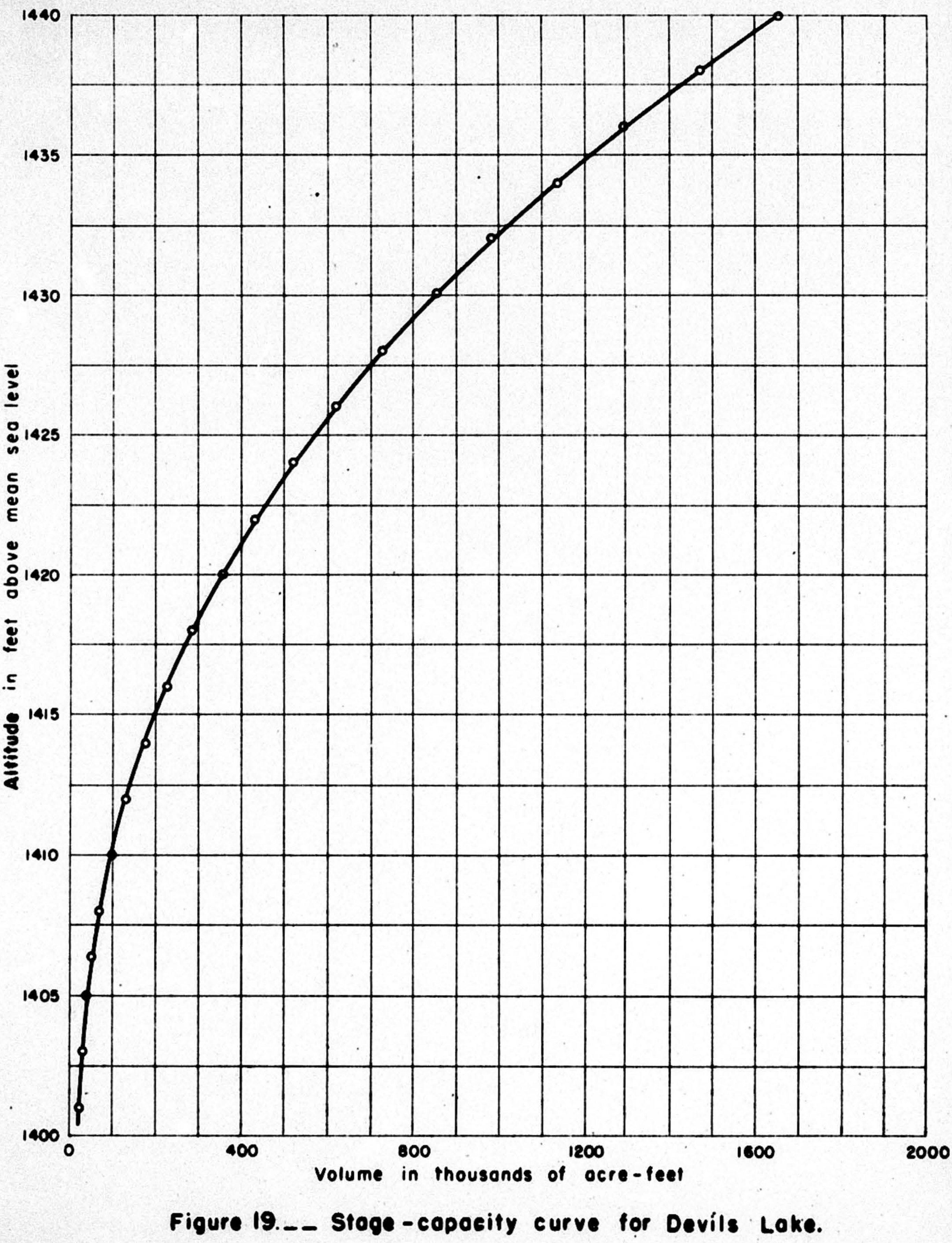


Figure 19.__ Stage-capacity curve for Devils Lake.

Thus, it is very roughly estimated that the concentration of Devils Lake water may be in the range from 3,000 to 7,600 parts per million upon restoration of lake level to 1,425 feet above mean sea level. The above figures, while necessarily crude, seem fairly reasonable in light of past concentrations of the lake water at levels approximating 1,425 feet.

Once Devils Lake is filled to the desired level and outflow adjusted to inflow, the concentration of salts in the lake water should, after an extended time, trend to approach that of the influent water, estimated as 1,000 parts per million.

No estimates are made in this report as to the probable concentration of salts in the initial outflow from restored Stump Lakes to the Sheyenne River. The concentration of the effluent Stump Lake water will of course be many times greater than that of the water leaving Devils Lake.

EFFECTS OF LAKE EFFLUENTS ON DOWNSTREAM DEVELOPMENTS

The Missouri River Basin program has revived hope that Devils Lake may be restored to early levels and the lake region again become a popular resort area. Before this is done, considerable attention must be given to the biochemical and sanitary problems attendant to flushing the saline lake waters downstream into the Sheyenne and Red River of the North Valleys. Part of the floor of Devils Lake, particularly in Creel Bay where the city of Devils Lake disposes of its sewage, is covered with a very fine, impalpable, black, foul-smelling ooze. The organic and ammoniacal nitrogen content of a sample of deposited material in Creel Bay was 5,210 parts per million, an example of the degree of organic pollution in the lake. Health authorities would be obviously alarmed over the introduction of such waters into a fresh water supply. The organic matter will make heavy demands on the oxygen supply, and the dissolved oxygen content of any mixed water downstream would no doubt be reduced, with attendant harmful results to fish life.

Available data on the chemical analyses of surface waters in the Red River of the North Basin are given in table 15 (in appendix). From the few analyses of Red River Valley waters, it is noted that concentrations of dissolved solids are much less than the probable concentrations of salts in the lake effluents.

GEOCHEMICAL PROBLEMS

No attempt has been made in this progress report to interpret the basic analytical data in terms of geochemical concepts. In a future report it is proposed to discuss some of the geochemical problems that arise in study of the waters in Devils Lake Basin. These problems include investigations as to the source of the sulfates in the lake waters; the reason for the low alkalinity of waters in the major lakes; explanations as to the high magnesium-calcium ratios noted in the saline waters as contrasted with lower ratios computed for fresh waters; the constancy of chemical composition of Devils Lake waters; the correlation of spring waters in the region with lake waters; chemical analysis of core samples of the glacial drift and the Pierre shale; the source of chlorides in the lake waters; and the cause of the remarkably high concentrations of salts in East Stump Lake.

SUMMARY

The lakes in Devils Lake Basin are unique in that they contain waters of widely varying quality, both as to concentration and composition. Devils Lake, along with many other lakes in this region, has been declining in level over a period of many years. For a number of years, during which time Mauvais Coulee was discharging only a negligible amount of water, the decline in level of Devils Lake was accompanied with increase in concentration

of dissolved solids in the lake water. During the spring and summer of 1949, Mauvais Coulee was discharging considerable fresh water, which directly or indirectly reached the lake. As a result of the mixing and flushing effects of this fresh water, the concentration of dissolved solids in the lake water decreased almost 50 percent.

The approximate range in concentration of dissolved solids in the lake water, after the lake level has been restored by Missouri River water, has been calculated for the lake altitude of 1,425 feet. This range is estimated as between 3,000 and 7,600 parts per million, depending upon the amount of deposited salts reentering solution. With restoration of lake level to 1,425 feet and lake outflow adjusted to inflow, the concentration of dissolved solids in Devils Lake water may, after a number of years, approach that estimated for the influent water diverted from Sheyenne Reservoir--about 1,000 parts per million. Accretions from surface runoff (Mauvais Coulee) would modify this estimate.

Further study would be necessary to establish the practicability of lake restoration, particularly with respect to sanitation and biochemical problems attendant with rise in lake altitude.

APPENDIX

Table 7.—Sampling data for miscellaneous lake and surface waters, Devils Lake Basin

Name	Location: Township	Location: Range	Location: Section	Date sampled June 1949	Time sampled	Temp. (°F)	Depth in feet at sampling point	Remarks
					Ramsey County			
Mission Bay	153	64	SWSW 33	20	12:10 p.m.	65	1.7	At Narrows, SE. of Devils Lake near State Highway No. 57.
Six Mile Bay	154	65	NWNW 34	20	9:00 a.m.	60	2.0	On State Highway No. 19.
Mauvais Coulee	154	66	SENE 34	20	9:20 a.m.	62	4.8	At bridge across Ramsey-Benson County line on State Highway No. 19.
Sweetwater Lake	155	64	SENW 27	19	8:30 p.m.	60	2.5	Half a mile E. of State Highway No. 20.
Dry Lake	155	65	SESE 3	19	8:05 p.m.	60	3.0	Approximately 10 miles E. of Churchs Ferry.
Mauvais Coulee	155	66	SENE 7	17	3:45 p.m.	61	3.8	SE. of Churchs Ferry on U. S. Highway No. 2.
Sweet Creek	156	63	SESE 13	19	7:15 p.m.	58	1.2	About 10 miles E. of Garske.
Lac Aux Mortes	156	66	SWNE 3	19	3:10 p.m.	59	1.0	Approximately 4 miles E. of Maza. Probably represents backwater from Mauvais Coulee.
Lake Irvine	156	66	SWSW 19	19	2:35 p.m.	58	1.1	Approximately 3 miles N. of Churchs Ferry on U. S. Highway No. 281.
					Benson County			
Free Peoples Lake	151	63	NWNW 16	20	6:20 p.m.	72	1.7	A quarter of a mile SE. of State Highway No. 20.

Table 7.—Sampling data for miscellaneous lake and surface waters, Devils Lake Basin—Continued

Name	Location			Date sampled June 1949	Time sampled	Temp. (°F)	Depth in feet at sampling point	Remarks
	Township	Range	Section					
				Benson County—Continued				
Elbow Lake	151	63	SWNW 16	20	6:25 p.m.	66	2.1	Opposite Free Peoples Lake.
Shin Bone Lake	151	63	SENW 34	20	5:45 p.m.	68	1.6	At town of Warwick.
Square Lake	151	64	SESE 11	20	7:50 p.m.	68	1.9	Approximately 1¼ miles SE. of Tokio.
Mallard Lake	151	64	SESE 14	20	8:10 p.m.	69	.8	Sample collected from marsh adjacent to lake.
Wood Lake	151	64	SENW 15	20	7:20 p.m.	71	2.3	About 2 miles SW. of Tokio.
Black Tiger Bay	152	63	SENE 19	20	8:45 p.m.	69	.5	Sample obtained at point between bay and Devils Lake.
Spring Lake	152	64	SWNE 35	20	8:30 p.m.	68	1.6	On State Highway No. 20—1½ miles N. of Tokio.
Twin Lakes	152	66	SESW 22	20	11:50 a.m.	66	1.9	About 1 mile S. of State Highway No. 57.
Long Lake	152	67	SENW 4	20	11:00 a.m.	65	2.0	Approximately 1 mile SW. of Round Lake.
Round Lake	153	67	NESE 35	20	10:45 a.m.	65	1.9	Just W. of U. S. Highway No. 281.
Pelican Lake	154	67	SESE 24	20	10:00 a.m.	65	.8	Approximately 2 miles N. of State Highway No. 19.
Cranberry Lake	154	71	NESW 27	17	8:45 p.m.	56	.6	Approximately 5 miles N. of Esmond.

Table 7.—Sampling data for miscellaneous lake and surface waters, Devils Lake Basin—Continued

Name	Location			Date sampled June 1949	Time sampled	Temp. (°F)	Depth in feet at sampling point	Remarks
	Township	Range	Section					
				Benson County—Continued				
Stink Lake	155	67	NWNW 14	17	4:45 p.m.	63	0.5	About 3 miles S. of Churchs Ferry and W. of U. S. Highway No. 281.
Silver Lake	155	67	SENW 34	17	5:35 p.m.	63	2.5	About 6 miles S. of Churchs Ferry and W. of U. S. Highway No. 281.
Pleasant Lake	156	71	SESW 9	17	7:45 p.m.	60	2.3	About 1 mile S. of U. S. Highway No. 2.
				Nelson County				
Coon Lake	152	60	NENE 19	20	3:45 p.m.	70	1.9	None.
Rose Lake	152	61	SWSW 10	20	4:30 p.m.	68	2.3	About a quarter of a mile N. of section line road.
Swan Lake	152	61	NENE 27	20	4:10 p.m.	67	2.3	NW. of West Stump Lake.
				Eddy County				
Battle Lake	150	62	SENE 17	20	5:20 p.m.	65	2.6	3 miles SW of Hamar.
Horseshoe Lake	150	64	NESW 1	20	6:50 p.m.	71	1.8	About a quarter of a mile N. of section line road.
				Towner County				
Mauvais Coulee	158	66	NESW 24	19	6:10 p.m.	62	2.0	About 4 miles E. of Cando.

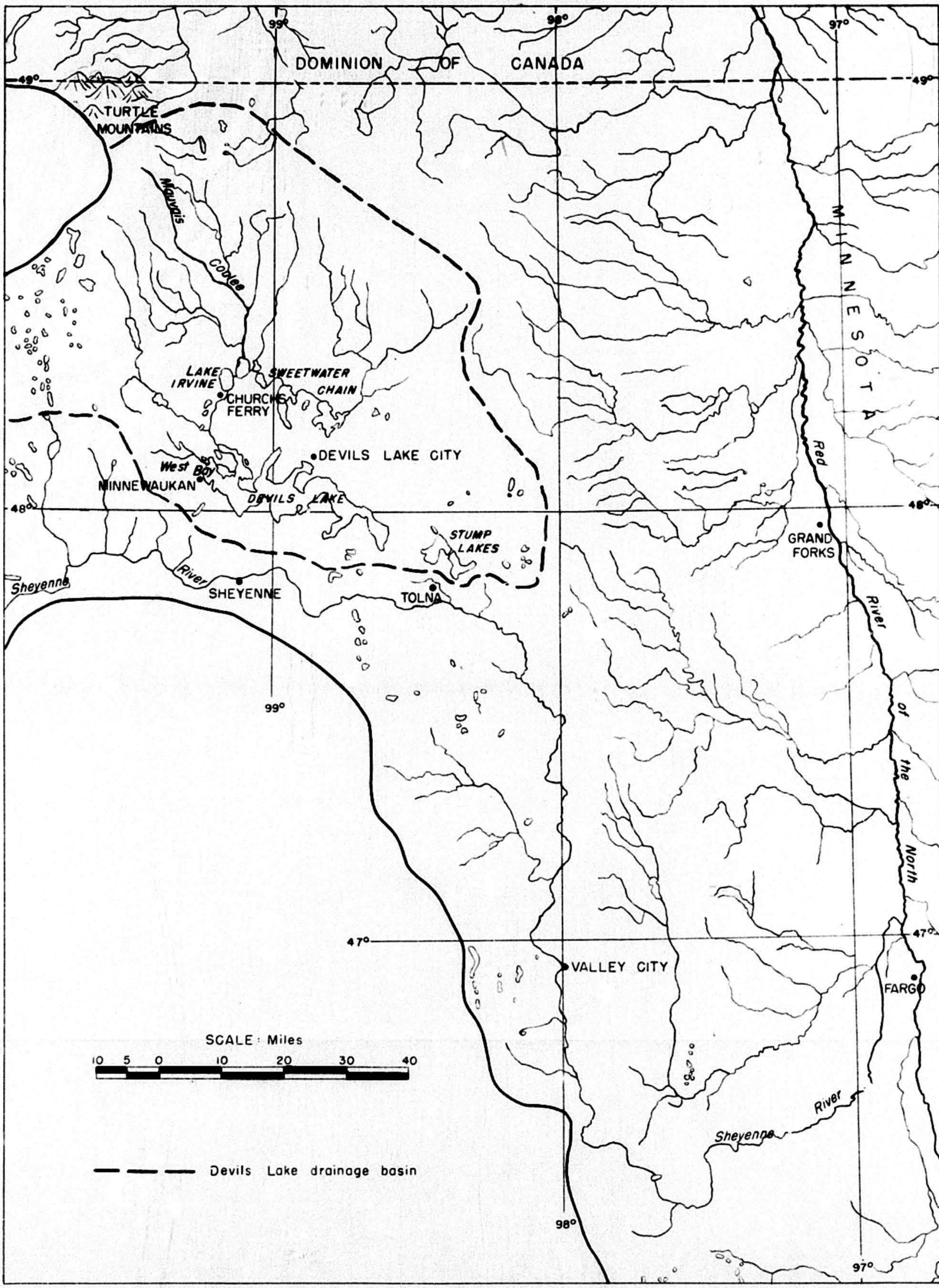
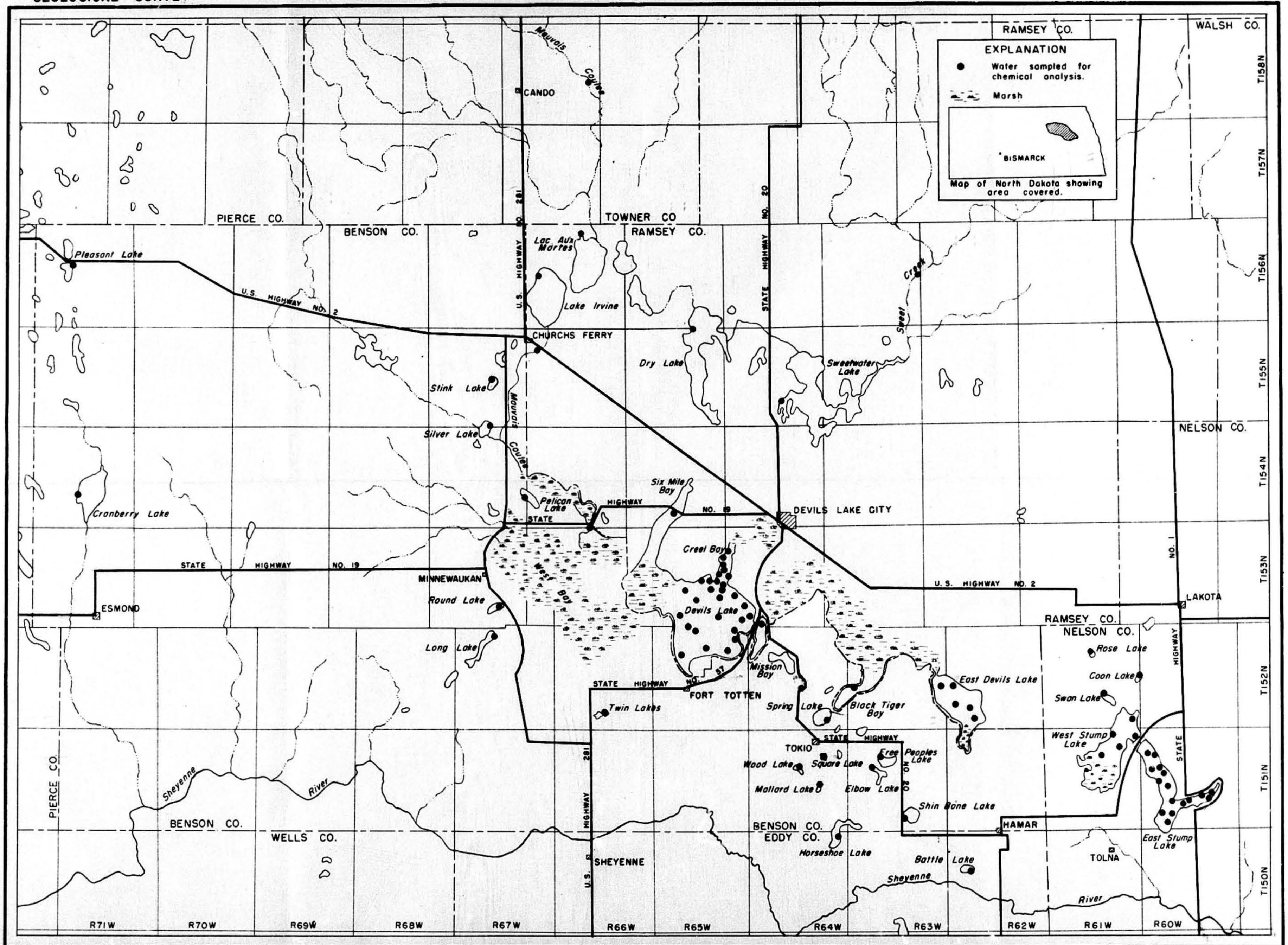


PLATE I

MAP OF EASTERN NORTH DAKOTA SHOWING DEVILS LAKE DRAINAGE BASIN

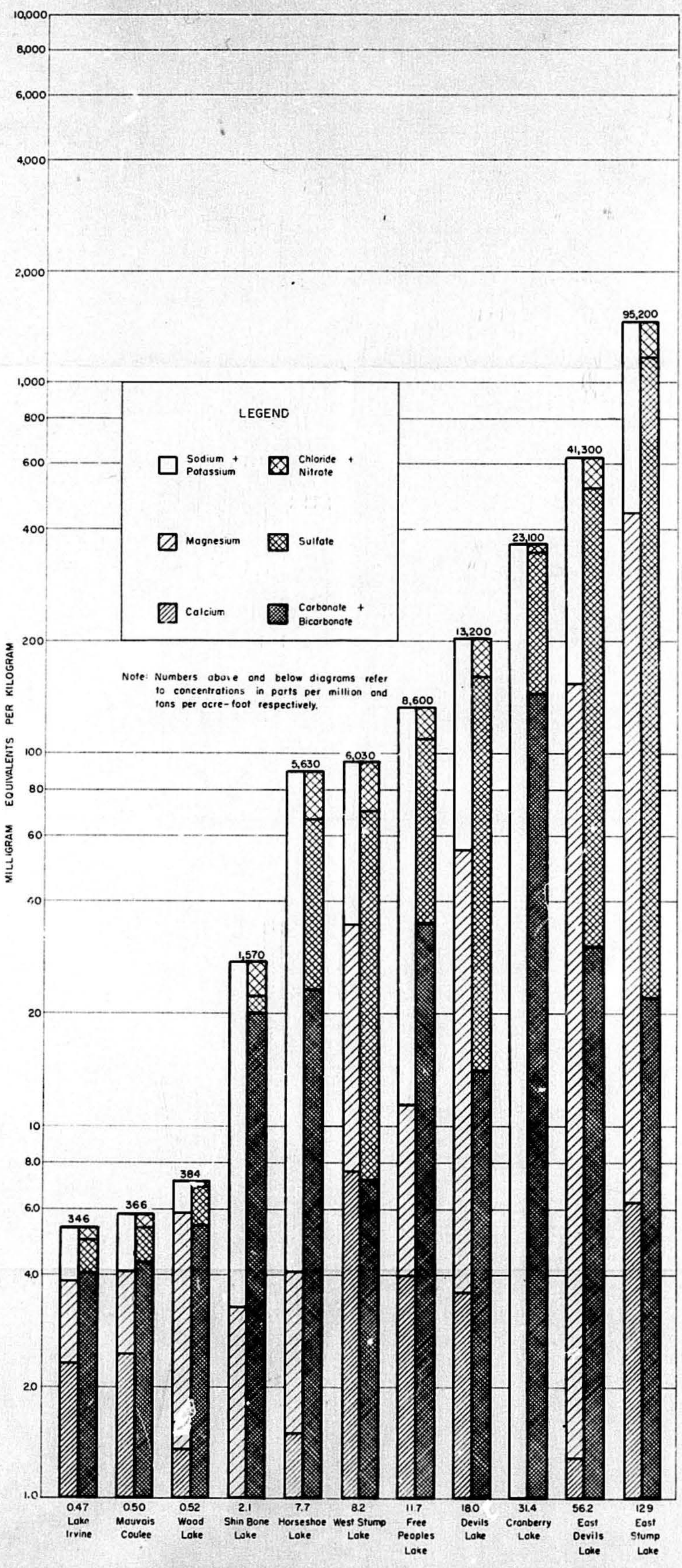
50-98

50-98



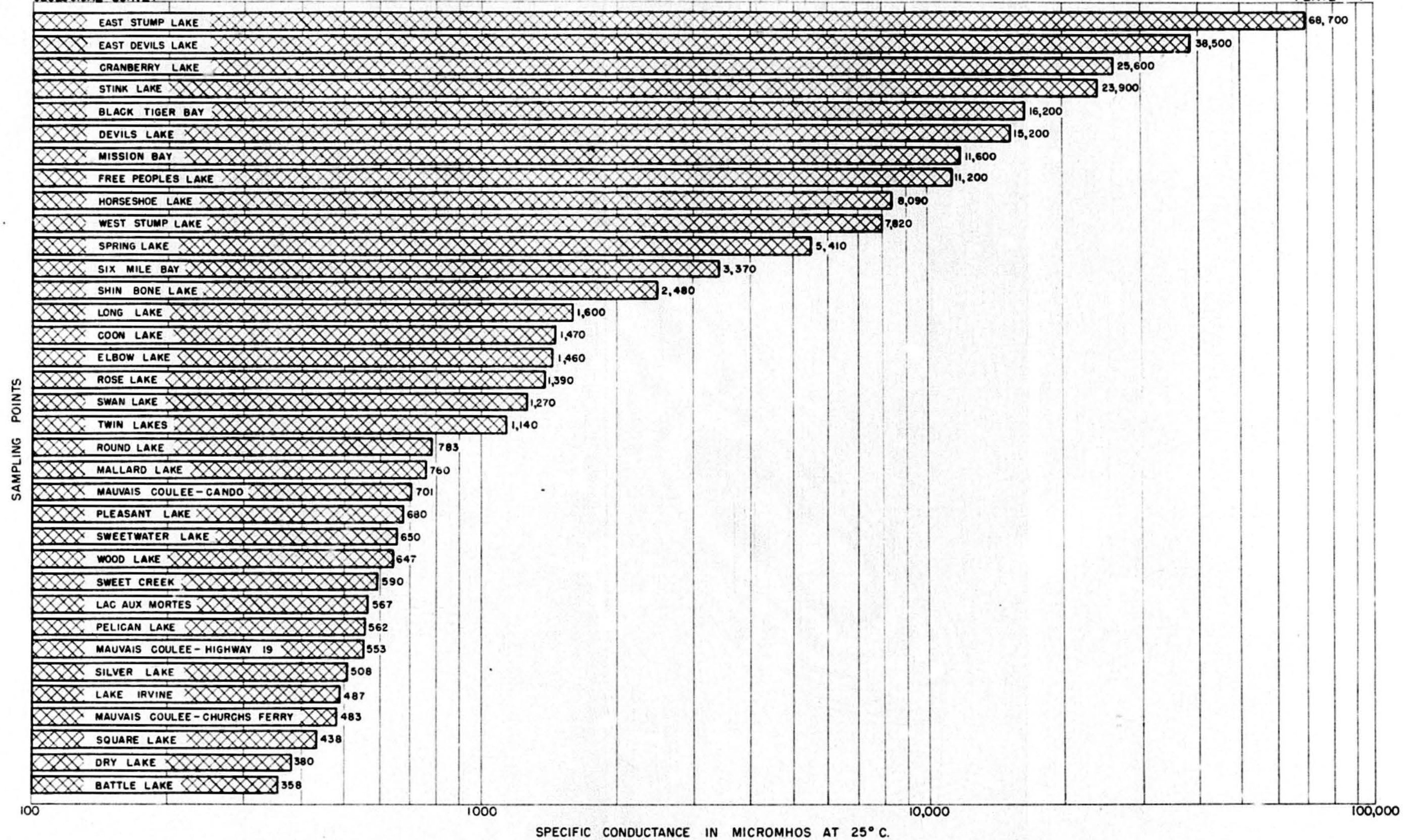
MAP OF DEVILS LAKE AND VICINITY, NORTH DAKOTA

50-98



CHEMICAL COMPOSITION OF LAKE AND COULEE WATERS,

DEVILS LAKE BASIN



CONDUCTANCE VALUES FOR SURFACE WATERS IN THE VICINITY OF DEVILS LAKE, NORTH DAKOTA

UNITED STATES DEPARTMENT OF THE INTERIOR-GEOLOGICAL SURVEY-Water Resources Division

Devils Lake ~~River Creek~~ At ~~Near~~ North Dakota Drainage area ________ square miles

TABLE 3

Mineral constituents, in parts per million, and related physical measurements, water year October, ____, to September, ____

Reference number	Date of Collection	Mean discharge (second-feet)	Temperature (°F)	pH	Specific conductance (Micromhos)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved Solids			Hardness as $CaCO_3$		Percent Sodium
																		Parts per million	Tons per acre-foot	Tons per day	Total	Non-Carbonate	
1	June 14, 1949	--	70	8.4	13,800	14	0.20	79	605	2,870	242	830	6,380	1,330	2.0	19	--	12,000	--	--	2,680	2,000	68
2	June 14	--	70	8.4	14,300	12	.30	85	615	3,050	246	845	6,460	1,350	2.0	25	--	12,300	--	--	2,740	2,050	68
3	June 14	--	70	8.3	15,000	13	.24	89	656	3,260	262	877	7,020	1,450	2.0	18	--	13,200	--	--	2,920	2,200	69
4	June 14	--	71	8.4	14,400	15	.16	83	614	3,090	246	867	6,780	1,390	2.0	16	--	12,700	--	--	2,730	2,020	69
5	June 14	--	72	8.6	14,000	23	.10	73	551	2,940	198	882	6,260	1,430	2.0	2.9	--	11,900	--	--	2,450	1,730	70
6 T	June 14	--	70	8.3	14,500	22	.10	75	584	3,120	214	832	6,660	1,450	1.0	5.8	--	12,500	--	--	2,590	1,910	70
6 B	June 14	--	70	8.3	14,300	20	.10	71	584	3,010	198	844	6,420	1,410	1.0	5.9	--	12,100	--	--	2,580	1,890	70
7	June 14	--	70	8.3	14,100	23	.10	73	571	2,990	206	828	6,420	1,390	1.0	6.1	--	12,100	--	--	2,530	1,850	70
8	June 14	--	70	8.2	13,600	17	.10	71	555	2,900	182	808	6,300	1,310	2.0	3.9	--	11,700	--	--	2,460	1,800	70
9	June 14	--	69	8.2	14,500	22	.10	71	588	3,150	190	844	6,810	1,430	1.0	5.9	--	12,700	--	--	2,600	1,910	71
10	June 14	--	71	8.0	13,900	26	.10	73	553	3,110	190	816	6,500	1,370	1.0	7.7	--	12,200	--	--	2,460	1,790	71
11	June 14	--	70	8.2	13,900	20	.14	73	553	2,990	190	822	6,260	1,370	1.0	5.7	--	11,900	--	--	2,460	1,790	71
12	June 18	--	62	8.2	16,300	25	.14	75	683	3,630	246	919	7,650	1,640	1.0	6.7	--	14,400	--	--	3,000	2,250	70
13	June 18	--	63	8.4	16,200	22	.14	75	678	3,600	222	925	7,530	1,620	1.0	5.0	--	14,200	--	--	2,930	2,220	71
14	June 18	--	63	8.6	16,300	6.0	.20	79	687	3,570	333	887	7,730	1,600	2.0	4.4	--	14,500	--	--	3,020	2,290	69
15	June 18	--	63	8.7	15,800	4.2	.16	75	672	3,430	309	903	7,490	1,560	2.0	2.4	--	14,000	--	--	2,950	2,210	69
16	June 18	--	63	8.2	15,900	17	.16	73	656	3,420	317	883	7,570	1,560	2.5	6.3	--	14,100	--	--	2,880	2,160	69
17 T	June 18	--	64	8.3	16,300	9.9	.16	69	672	3,480	317	915	7,690	1,600	2.0	5.4	--	14,300	--	--	2,940	2,190	69
17 B	June 18	--	64	8.4	16,400	16	.20	69	685	3,600	317	922	8,000	1,660	1.5	6.6	--	14,800	--	--	2,990	2,230	70
18	June 18	--	63	8.5	16,300	6.3	.20	79	695	3,520	317	999	7,840	1,620	1.5	3.8	--	14,600	--	--	3,050	2,230	69
19	June 18	--	62	8.5	15,400	7.2	.12	79	646	3,320	293	879	7,370	1,490	1.5	4.7	--	13,700	--	--	2,850	2,130	69
20	June 18	--	63	8.4	14,500	7.1	.16	75	574	2,940	285	839	6,420	1,430	1.5	5.3	--	12,200	--	--	2,550	1,860	69
21	June 18	--	64	8.5	15,500	13	.20	79	650	3,230	293	887	7,370	1,530	1.5	5.9	--	13,700	--	--	2,870	2,140	69
22 T	June 18	--	65	8.4	15,000	19	.20	73	630	3,200	285	863	7,090	1,510	1.5	5.3	--	13,200	--	--	2,770	2,060	69
22 B	June 18	--	65	8.3	16,100	7.9	.19	63	674	3,650	376	900	7,730	1,740	2.0	8.0	--	14,700	--	--	2,930	2,190	70
23	June 18	--	65	8.2	15,800	8.5	.14	65	674	3,460	376	891	7,570	1,660	2.0	8.3	--	14,300	--	--	2,930	2,200	69
24	June 18	--	62	8.5	14,500	4.4	.15	61	594	3,190	297	839	6,740	1,560	2.5	4.0	--	12,900	--	--	2,590	1,900	70
25	June 18	--	63	8.4	15,600	4.4	.16	67	648	3,480	228	899	7,410	1,620	2.4	4.0	--	13,900	--	--	2,830	2,090	71
26	June 18	--	63	8.6	15,800	3.0	.12	57	674	3,560	228	914	7,530	1,720	2.0	2.0	--	14,200	--	--	2,910	2,160	71
27 T	June 18	--	63	8.4	15,800	7.9	.17	65	683	3,440	258	903	7,410	1,680	2.0	5.7	--	14,000	--	--	2,970	2,230	69
27 B	June 18	--	63	8.2	16,200	12	.13	69	683	3,610	327	917	7,920	1,720	2.5	10	--	14,800	--	--	2,980	2,230	70
28	June 18	--	63	8.2	15,800	8.3	.14	61	681	3,520	267	903	7,690	1,700	3.9	7.9	--	14,400	--	--	2,950	2,210	70

T - Top
B - Bottom

UNITED STATES DEPARTMENT OF THE INTERIOR - GEOLOGICAL SURVEY - Water Resources Division

East Devils Lake River Creek At Near North Dakota Drainage area ______ square miles

TABLE 4

Mineral constituents, in parts per million, and related physical measurements, water year October, ____, to September, ____

Reference number	Date of Collection	Mean discharge (second-feet)	Temperature (°F)	pH	Specific conductance (Micromhos)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved Solids: Parts per million	Dissolved Solids: Tons per acre-foot	Dissolved Solids: Tons per day	Hardness as $CaCO_3$: Total	Hardness as $CaCO_3$: Non-Carbonate	Percent Sodium
1	June 18, 1949 - - -	- -	65	8.7	38,800	7.0	0.21	16	2,060	10,300	755	1,870	23,200	4,030	3.4	3.0	- -	41,300	- -	- -	8,510	6,980	70
2	June 18 - - - - - - -	- -	64	8.7	38,400	6.8	.20	18	2,040	10,300	791	1,870	23,200	4,030	3.9	3.7	- -	41,300	- -	- -	8,430	6,900	70
3 T	June 18 - - - - - - -	- -	64	8.8	38,500	5.6	.11	18	1,950	10,300	851	1,880	24,000	3,860	3.4	.8	- -	41,900	- -	- -	8,060	6,520	71
3 B	June 18 - - - - - - -	- -	64	8.7	38,500	7.7	.15	21	1,890	10,300	754	1,890	22,900	3,860	3.4	.8	- -	40,700	- -	- -	7,820	6,270	72
4	June 18 - - - - - - -	- -	64	8.7	38,300	5.9	.08	19	1,860	10,300	832	1,870	22,700	3,810	3.4	1.0	- -	40,500	- -	- -	7,700	6,170	72
5	June 18 - - - - - - -	- -	64	8.7	38,300	9.2	.09	26	1,870	10,300	832	1,860	23,500	3,790	3.4	1.3	- -	41,300	- -	- -	7,750	6,220	72

T - Top
B - Bottom

50-98

UNITED STATES DEPARTMENT OF THE INTERIOR-GEOLOGICAL SURVEY-Water Resources Division

West Stump Lake North Dakota Drainage area ______ square miles

TABLE 5

Mineral constituents, in parts per million, and related physical measurements, water year October, ____, to September, ____

Reference number	Date of Collection	Mean discharge (second-feet)	Temperature (°F)	pH	Specific conductance (Micromhos)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved Solids: Parts per million	Dissolved Solids: Tons per acre-foot	Dissolved Solids: Tons per day	Hardness as $CaCO_3$: Total	Hardness as $CaCO_3$: Non-Carbonate	Percent Sodium
1	June 16, 1949	--	65	7.8	7,940	11	0.20	156	310	1,350	80	440	2,980	880	1.0	3.4	--	5,990	--	--	1,660	1,300	62
2	June 16	--	65	7.8	7,810	17	.40	156	323	1,400	80	438	3,000	885	1.0	5.4	--	6,090	--	--	1,720	1,360	63
3	June 16	--	65	7.6	7,840	18	.20	150	318	1,380	68	416	3,020	890	1.0	3.6	--	6,060	--	--	1,680	1,340	63
4 T	June 16	--	65	8.0	7,770	18	.20	156	330	1,340	72	442	3,020	872	1.0	4.7	--	6,030	--	--	1,750	1,390	61
4 B	June 16	--	65	8.0	7,790	14	.20	152	323	1,330	76	438	3,100	875	1.0	5.9	--	6,100	--	--	1,710	1,350	62
5	June 16	--	65	8.0	7,760	15	.20	156	320	1,310	120	444	2,920	880	1.0	5.4	--	5,950	--	--	1,710	1,350	61

T - Top
B - Bottom

LQW-1

UNITED STATES DEPARTMENT OF THE INTERIOR - GEOLOGICAL SURVEY - Water Resources Division

50-98

East Stump Lake North Dakota Drainage area ______ square miles

TABLE 6

Mineral constituents, in parts per million, and related physical measurements, water year October, ___, to September, ___

Reference number	Date of Collection	Mean discharge (second-feet)	Temperature (°F)	pH	Specific conductance (Micromhos)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved Solids: Parts per million	Dissolved Solids: Tons per acre-foot	Dissolved Solids: Tons per day	Hardness as $CaCO_3$: Total	Hardness as $CaCO_3$: Non-Carbonate	Percent Sodium
1 T	June 16, 1949 - - -	- -	64	8.4	69,900	26	0.10	129	5,350	21,200	2,280	1,360	55,100	9,830	1.1	3.7	- -	94,600	- -	- -	22,300	21,200	65
1 B	June 16 - - - - - -	- -	64	8.3	71,500	26	.08	140	5,280	23,800	2,580	1,360	58,800	10,700	.7	3.7	- -	102,000	- -	- -	22,100	21,000	67
2	June 16 - - - - - -	- -	64	8.4	68,600	26	.10	143	5,350	21,400	1,690	1,360	54,900	9,920	.9	4.1	- -	94,100	- -	- -	22,400	21,300	65
3	June 16 - - - - - -	- -	64	8.4	68,800	- - -	- - -	133	6,160	21,300	663	1,390	55,500	9,700	4.6	13	- -	94,500	- -	- -	25,700	24,560	64
4	June 16 - - - - - -	- -	63	8.4	68,000	26	.10	138	5,350	21,500	1,320	1,360	54,400	9,920	1.1	4.1	- -	93,300	- -	- -	22,300	21,200	66
5	June 16 - - - - - -	- -	63	8.4	68,000	24	.16	138	5,330	21,800	1,510	1,360	55,300	9,920	1.1	4.1	- -	94,800	- -	- -	22,500	21,400	65
6 T	June 16 - - - - - -	- -	64	8.3	68,000	28	.18	136	5,350	22,000	2,100	1,360	55,300	9,830	.9	3.7	- -	95,400	- -	- -	22,300	21,200	66
6 B	June 16 - - - - - -	- -	64	8.3	68,800	28	.10	130	5,350	22,300	1,800	1,360	55,300	9,830	1.1	3.7	- -	95,400	- -	- -	22,300	21,200	66
7	June 16 - - - - - -	- -	64	8.3	68,600	27	.14	127	5,280	22,300	1,320	1,360	55,500	9,920	.6	3.2	- -	95,200	- -	- -	22,000	20,900	67
8	June 16 - - - - - -	- -	64	8.3	68,300	22	.16	140	5,350	22,200	1,320	1,350	55,300	9,830	.9	3.9	- -	95,000	- -	- -	22,300	21,200	67
9	June 16 - - - - - -	- -	64	8.4	68,200	15	.20	37	5,590	22,000	1,180	1,380	55,100	9,880	1.2	8.3	- -	94,500	- -	- -	23,100	22,000	66
10	June 16 - - - - - -	- -	64	8.3	68,600	15	.20	33	5,660	21,900	1,070	1,370	55,100	9,870	1.3	9.2	- -	94,400	- -	- -	23,400	22,300	66
11 T	June 16 - - - - - -	- -	64	8.3	68,600	15	.20	53	5,700	22,400	883	1,370	54,800	9,860	.7	7.3	- -	94,400	- -	- -	23,600	22,500	66
11 B	June 16 - - - - - -	- -	64	8.3	68,800	17	.20	37	5,700	22,700	1,130	1,360	55,900	9,840	.8	10	- -	96,100	- -	- -	23,500	22,400	66
12	June 16 - - - - - -	- -	64	8.3	68,800	15	.10	40	5,880	22,100	1,100	1,370	55,500	9,920	1.0	9.2	- -	95,300	- -	- -	24,300	23,200	65
13	June 16 - - - - - -	- -	64	8.3	68,800	17	.10	33	5,920	22,100	1,070	1,370	55,100	10,000	.9	9.2	- -	94,900	- -	- -	24,400	23,300	65
14	June 16 - - - - - -	- -	64	8.3	68,600	20	.10	32	5,700	22,400	809	1,380	55,100	9,950	.9	9.2	- -	94,700	- -	- -	23,500	22,400	66
15 T	June 16 - - - - - -	- -	65	8.3	68,300	15	.10	39	5,790	22,000	883	1,370	54,400	9,880	1.0	8.3	- -	93,700	- -	- -	23,900	22,800	66
15 B	June 16 - - - - - -	- -	65	8.3	68,600	17	.10	38	5,790	22,600	993	1,380	57,000	9,980	.9	9.2	- -	97,100	- -	- -	23,900	22,800	66
16	June 16 - - - - - -	- -	65	8.3	68,600	16	.10	33	5,710	21,900	956	1,380	55,500	9,890	1.3	7.3	- -	94,700	- -	- -	23,600	22,500	66

T = Top
B = Bottom

LQW 1

UNITED STATES DEPARTMENT OF THE INTERIOR-GEOLOGICAL SURVEY-Water Resources Division

Miscellaneous lake and other surface waters — North Dakota — Drainage area ______ square miles

TABLE 8

Mineral constituents, in parts per million, and related physical measurements, water year October, ____, to September, ____

Reference number	Date of Collection 1949		Mean discharge (second-feet)	Temperature (°F)	pH	Specific conductance (Micromhos)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved Solids: Parts per million	Dissolved Solids: Tons per acre-foot	Dissolved Solids: Tons per day	Hardness as $CaCO_3$: Total	Hardness as $CaCO_3$: Non-Carbonate	Percent Sodium
1	Mission Bay	6/20	--	65	8.9	11,600	13	0.11	26	421	2,290	228	403	4,990	1,170	1.0	0.9	--	9,340	--	--	1,800	1,470	70
2	Spring Lake	6/20	--	68	8.2	5,410	13	.06	112	280	819	55	455	2,300	380	.4	1.3	--	4,190	--	--	1,430	1,060	54
3	Black Tiger Bay	6/20	--	69	8.4	16,200	49	.40	120	708	3,470	216	856	7,360	1,600	1.4	3.0	--	14,000	--	--	3,210	2,510	68
4	Wood Lake	6/16	--	71	8.2	647	13	.08	27	55	27	9.6	332	72	7.5	.2	1.5	--	384	--	--	294	22	16
5	Square Lake	6/20	--	68	7.7	438	12	.08	33	22	22	11	208	60	4.0	.2	1.8	--	282	--	--	173	2	20
6	Mallard Lake	6/20	--	69	7.9	760	15	.08	78	34	52	5.6	524	14	1.5	.2	2.7	--	498	--	--	335	0	25
7	Horseshoe Lake	6/20	--	71	8.9	8,090	20	.08	30	31	1,890	78	1,420	2,100	770	.8	1.4	--	5,630	--	--	203	0	93
8	Battle Lake	6/20	--	65	9.0	358	29	.06	14	28	19	8.8	211	18	10	.2	1.0	--	320	--	--	150	0	20
9	Shin Bone Lake	6/20	--	68	8.8	2,480	33	.06	16	30	536	50	1,230	109	180	.2	2.6	--	1,570	--	--	164	0	84
10	Elbow Lake	6/20	--	66	8.5	1,460	13	.08	20	41	268	22	703	160	50	.2	1.2	--	944	--	--	219	0	70
11	Free Peoples L	6/20	--	72	9.0	11,200	38	.60	80	92	2,810	104	2,140	3,600	800	.8	3.0	--	8,600	--	--	578	0	90
12	Rose Lake	6/20	--	68	7.4	1,390	19	.02	76	45	153	14	268	434	47	.7	6.5	--	929	--	--	375	155	46
13	Swan Lake	6/20	--	67	7.3	1,270	14	.02	74	48	118	14	247	402	39	.6	3.3	--	888	--	--	382	179	39
14	Coon Lake	6/20	--	70	7.6	1,470	25	.02	108	78	97	15	358	504	20	.8	6.1	--	1,030	--	--	590	296	26
15	Stink Lake	6/17	--	63	8.3	23,900	17	.09	41	590	6,370	185	551	13,000	1,670	3.4	2.1	--	22,200	--	--	2,530	2,080	83
16	Silver Lake	6/17	--	63	7.3	508	11	.02	48	17	27	9.6	222	54	18	.6	4.9	--	324	--	--	190	8	22
17	Pelican Lake	6/20	--	65	7.5	562	20	.02	56	24	27	10	293	42	12	.6	3.8	--	362	--	--	238	0	19
18	Round Lake	6/20	--	65	7.4	783	25	.02	45	36	71	15	223	194	21	.6	6.6	--	538	--	--	261	78	36
19	Long Lake	6/20	--	65	7.9	1,600	5.0	.02	73	82	144	30	305	536	55	.6	3.8	--	1,080	--	--	519	269	36
20	Six Mile Bay	6/20	--	60	7.9	3,370	16	.02	64	120	488	52	409	1,150	219	.8	4.1	--	2,320	--	--	653	318	60
21	Cranberry Lake	6/17	--	56	9.8	25,600	22	.02	4.0	5.0	8,220	65	8,890	9,730	591	---	3.8	--	23,100	--	--	31	0	99
22	Pleasant Lake	6/17	--	60	7.6	680	26	.02	46	35	39	8.0	296	108	2.0	.5	5.1	--	486	--	--	259	16	24
23	Twin Lakes	6/20	--	66	8.4	1,140	7.6	.04	37	65	101	26	289	312	43	.2	2.3	--	802	--	--	360	123	36
24	Sweetwater Lake	6/19	--	60	7.4	650	29	.04	60	26	23	9.6	258	94	13	.2	4.5	--	450	--	--	257	45	16
25	Dry Lake	6/19	--	60	7.4	380	12	.04	42	14	8.2	14	230	8.4	1.5	.2	1.6	--	232	--	--	163	0	9
27	Lac aux Mortes	6/19	--	59	7.5	567	24	.04	66	23	21	6.4	309	50	6.0	.2	6.2	--	390	--	--	259	6	15
28	Irvine Lake	6/19	--	58	7.3	487	27	.04	46	19	34		245	46	10	.2	3.6	--	346	--	--	193	0	28
29	Mauvais Coulee 1/	6/19	--	62	7.5	701	11	.04	64	35	34	6.8	350	83	14	.2	1.0	--	468	--	--	304	17	19
30	Mauvais Coulee 2/	6/17	--	61	7.5	483	24	.04	49	15	18	12	236	36	9.0	.2	5.0	--	324	--	--	184	0	16
31	Sweet Creek	6/19	--	58	7.3	590	23	.04	55	23	35	6.4	302	58	9.5	.2	1.9	--	390	--	--	232	0	24
32	Mouvais Coulee 3/	6/20	--	62	7.3	553	18	.04	49	20	27	16	264	51	14	.2	1.4	--	366	--	--	205	0	21

1/ Near Condo.
2/ Below Churchs Ferry.
3/ At Benson-Ramsey County line on Highway No. 19.

UNITED STATES DEPARTMENT OF THE INTERIOR - GEOLOGICAL SURVEY - Water Resources Division

Red River of the North Basin ~~River~~ ~~Creek~~ At Near ______ Drainage area ______ square miles

TABLE 15

Mineral constituents, in parts per million, and related physical measurements, water year October, ____, to September, ____

Date of Collection	Mean discharge (second-feet)	Temperature (°F)	pH	Specific conductance (Micromhos)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved Solids: Parts per million	Dissolved Solids: Tons per acre-foot	Dissolved Solids: Tons per day	Hardness as $CaCO_3$: Total	Hardness as $CaCO_3$: Non-Carbonate	Percent Sodium
Red River of the North at Fargo, N. Dak.																						
May 16, 1949		--	7.4	645	9.0	0.08	58	38	22		274	107	8.0	0.1	1.2	0.18	499	--	--	301	76	14
June 21		76	7.6	497	9.6	.10	49	34	2.5		252	52	4.4	.1	1.2	.14	291	--	--	263	56	2
Red River of the North at Grand Forks, N. Dak.																						
May 28		--	7.8	602	13	.10	66	31	17		260	101	7.0	.1	1.5	.11	405	--	--	292	79	11
June 22		69	8.3	612	16	.02	52	26	18	1.6	186	108	7.0	.1	.7	.63	372	--	--	237	84	14
Sheyenne River at Sheyenne, N. Dak.																						
Mar. 31		--	7.6	2,170	30	.06	103	96	304		1,120	316	45	.2	1.1	.72	1,460	--	--	652	0	50
Apr. 7		--	6.9	169	10	.04	14	5.5	11		62	25	2.0	.0	2.5	.00	111	--	--	58	7	30
May 2		--	7.4	647	21	.02	36	21	78		276	102	9.0	.2	1.6	.32	444	--	--	177	0	49
June 13		75	8.6	980	13	.02	25	40	138		422	146	19	.2	1.3	.40	678	--	--	227	0	59
Sheyenne River at Valley City, N. Dak.																						
May 12		63	7.4	760	22	.02	67	30	59		303	140	16	.2	2.2	.23	520	--	--	291	43	31
June 21		68	7.7	813	18	.02	67	34	66		310	166	16	.2	1.3	.24	567	--	--	307	53	32
Sheyenne River at West Fargo, N. Dak.																						
May 16		--	7.3	695	22	.02	68	25	48		271	122	19	.2	1.4	.23	467	--	--	273	51	25
June 21		67	7.4	901	19	.02	78	35	72		356	146	35	.2	1.6	.29	606	--	--	339	48	32
Goose River near Portland, N. Dak.																						
May 19		--	7.5	1,170	18	.10	139	52	58		362	348	18	.2	1.1	.25	867	--	--	561	264	18
June 21		64	7.6	1,030	22	.10	139	51	12		310	292	16	.1	1.6	.23	748	--	--	557	303	4
Goose River at Hillsboro, N. Dak.																						
May 19		--	7.5	1,380	19	.02	158	58	97		360	456	50	.8	1.6	.42	1,020	--	--	633	338	25
June 21		67	7.5	1,190	24	.10	122	52	64		294	340	43	.1	1.5	.35	876	--	--	519	278	21
Maple River at Mapleton, N. Dak.																						
May 16		--	7.5	1,290	14	.12	105	47	109		342	298	71	.2	1.0	.33	836	--	--	456	176	34
June 21		67	7.6	1,310	10	.10	64	51	143		256	325	92	.2	1.2	.42	879	--	--	369	159	46
Buffalo River near Dilworth, Minn.																						
May 18		--	7.7	836	27	.02	100	50	15		333	204	.5	.1	2.0	--	615	--	--	455	182	7
June 21		68	7.5	664	12	.02	70	51	4.1		334	106	5.2	.2	1.2	.20	455	--	--	384	110	2
Wild Rice River at Hendrum, Minn.																						
June 21		67	7.4	564	18	.02	67	40	8.3		316	82	2.4	.2	1.4	.19	393	--	--	332	73	5
Marsh River near Shelby, Minn.																						
June 21		67	7.4	567	16	.05	67	36	3.0		280	86	.5	.2	1.8	.14	400	--	--	316	86	11
Red Lake River at Crookston, Minn.																						
May 18		--	7.5	502	11	.10	63	26	2.3		222	82	.0	.1	1.2	.02	323	--	--	264	82	2
June 21		67	8.3	575	21	.02	67	25	21	.8	212	139	.0	.1	.9	.48	379	--	--	270	96	14