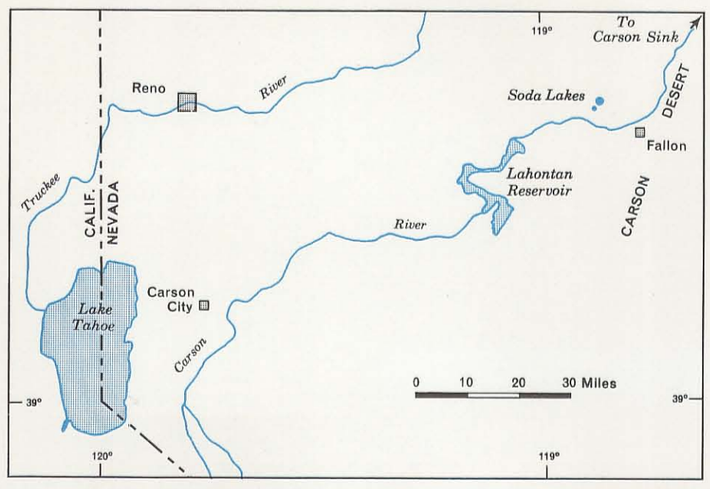


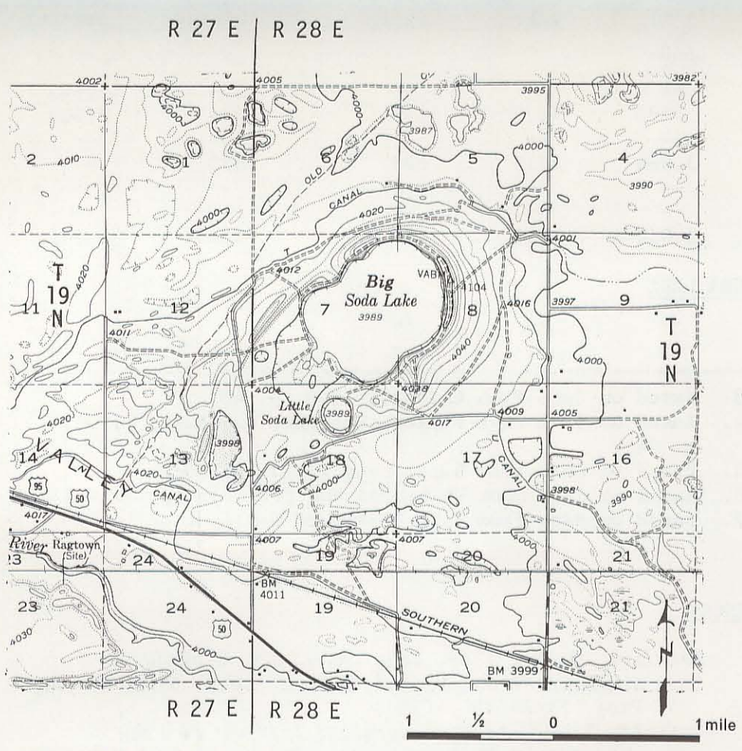
Figure 1.– *Index map of the Reno-Fallon area of northwestern Nevada showing the location of the Soda Lakes*

INTRODUCTION

Big and Little Soda Lakes are about 7 miles northwest of Fallon, Nev. (fig. 1), and about 50 miles east of Reno on the floor of Carson Desert. The two lakes occupy small craters composed of volcanic, basaltic sand (Morrison, 1964, p. 71 and Willden and Speed, 1968), surrounded by a broad expanse of alluvium. The form of the craters is shown in figure 2. On June 29, 1971, the stage of Big Soda Lake was at an altitude of 3,989.3 feet and Little Soda Lake, at 3,989.8 feet. The surrounding valley floor is generally at an altitude of about 4,000 feet. Regional ground-water flow is generally northeastward toward Carson Sink.

Prior to large-scale irrigation, fresh water entered the Soda Lakes mostly by subsurface percolation (Lee and Clark, 1916, p. 666) and numerous small springs (King, 1878, v. 1, p. 512 and Russell, 1885, pl. 16) flowing from the adjacent saturated alluvium about the lakes. In addition, some thermal water (temperature, 86°F or 30°C) may be entering Big Soda Lake near its center (Breese, 1968, p. 25). Evaporation, the principal form of discharge from the lakes under native conditions, offset the inflow. The lakes functioned much like large wells or sumps below the general ground-water level of the area. Under native conditions prior to 1906, the lake stages were maintained at a fairly constant low level, as shown in figure 3. In 1906, when extensive irrigation began in the area, the lake levels began to rise, continuing until about 1930. The total rise in stage for the period was about 60 feet. The principal cause of the rise was attributed to seepage losses from the T, U, and N canals (fig. 2), which carried water from the Carson River to fields in the Fallon area as part of the Newlands Project of the U.S. Bureau of Reclamation (Lee and Clark, 1916, p. 672-675).

Big Soda Lake is highly saline, as shown in table 1, and reportedly has no fish population (Breese, 1968, p. 2). Extraction of soda (essentially equal parts of sodium carbonate and sodium sulfate, according to Russell, 1885, p. 78-79) from Big Soda Lake began in 1875 (Russell, 1885, p. 79, and Morrison, 1964, p. 116) and continued until the facilities were flooded by rising water. Little Soda Lake is much less saline, but was used for soda extraction beginning in 1867 (Russell, 1885, p. 80). Little Soda Lake was reported (King, 1878, v. 1, p. 512) to have been nearly dry in 1867.



Base from U.S. Geological Survey - Soda Lake, Nevada (1951) 1:62,500

Contour interval 20 feet. Interval for dotted lines 10 feet. Datum is mean sea level.

Figure 2.- *Topography of the Soda Lakes area*

BATHYMETRY

A continuously recording electronic fathometer was used to measure depths in the Soda Lakes in June 1971. Data were gathered along 17 traverse lines, utilizing 10 control points along the shore of Big Soda Lake. The author was assisted by his daughter, Teresa, in collecting the field data. The bathymetry, stage-area-volume relations, and a cross section are shown in figures 4, 5, 6, and 7. The deepest point surveyed in Big Soda Lake was 207 feet below the lake surface. An island that is shown on Russell's bathymetric map of 1882 (1885, pl. 16) was located at a depth of 58 feet, as shown in figures 4 and 6. Big Soda Lake (fig. 6) is within a compound crater. Below a depth of about 80 feet, a small, steep-sided crater occupies the center of the larger crater of topographic prominence, as shown in figures 2 and 6.

Little Soda Lake had a maximum depth of about 56 feet when this survey was made (fig. 4).

Lake stage, area, and volume for (1) equilibrium under near native conditions (prior to 1907) and for (2) equilibrium under irrigation conditions (since 1930) are summarized as follows:

	Near native conditions (Prior to 1907)	Irrigation conditions (Since 1930)
Big Soda Lake:		
Stage (feet)	3,930 ± 2	3,988 ± 2
Area (acres)	270 ± 5	385 ± 5
Volume (acre-feet)	15,500 ± 500	35,000 ± 500
Little Soda Lake:		
Stage (feet)	3,937 ± 4	3,989 ± 2
Area (acres)	≤6	20 ± 1
Volume (acre-feet)	≤70	770 ± 50

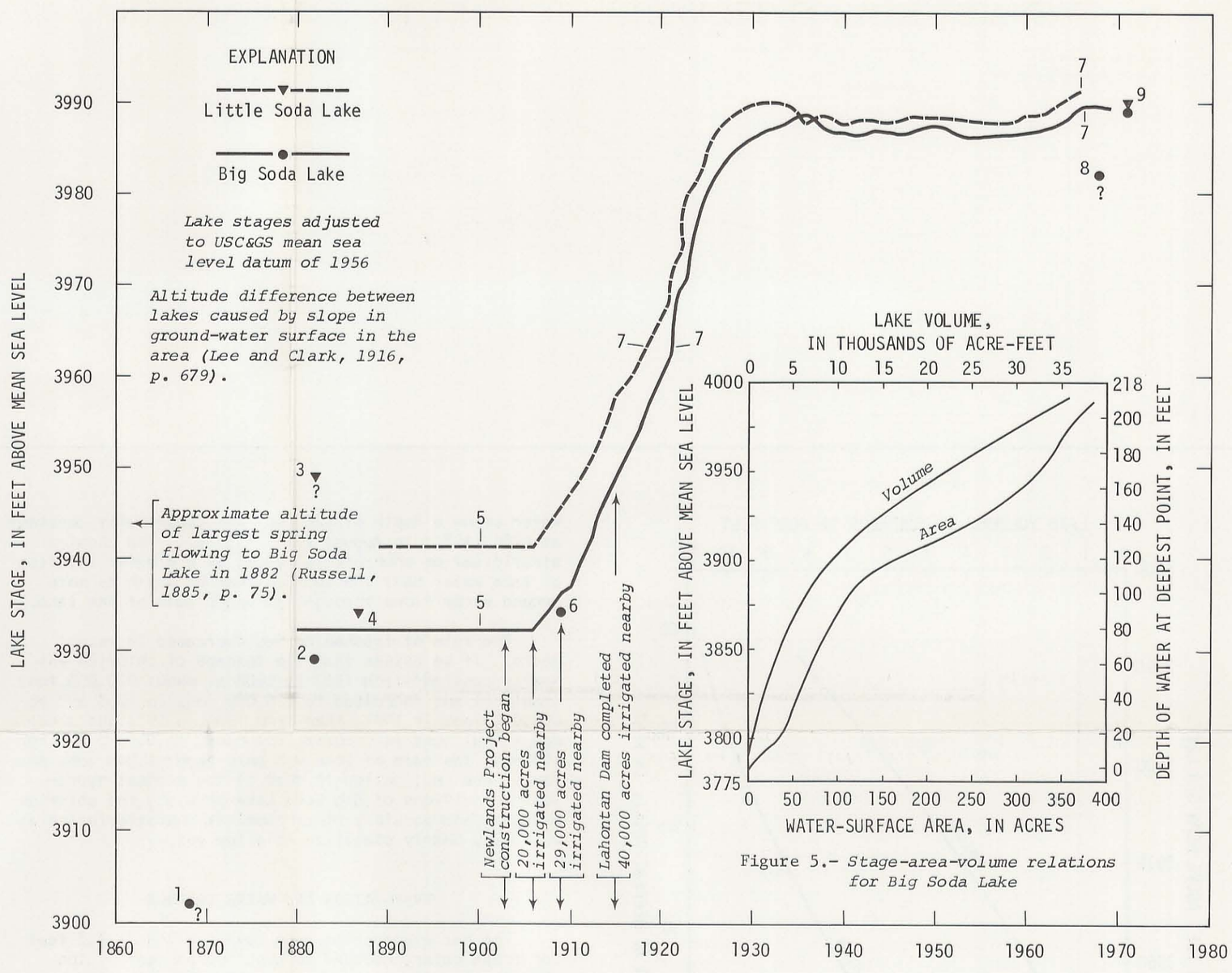


Figure 3.- *Variations in the stages, areas and volumes of the Soda Lakes*

Figure 5.- *Stage-area-volume relations for Big Soda Lake*

FOOTNOTES FOR FIGURE 3

1. *From King (1877, v. 4, p. 351); may be in error.*
2. *Based on lake area and water depth as reported by Russell (1885, p. 73).*
3. *Based on footnote by Russell (1885, p. 73). Probably not a natural stage.*
4. *As reported by Breese (1968, p. 8), Chatard (1890) observed Little Soda Lake to be dry. When first discovered, reported to have been dry (Russell, 1885, p. 79).*
5. *From Lee and Clark (1916, p. 705-706) for period 1880-1910. Data adjusted to U.S. Coast and Geodetic Survey mean sea level datum of 1956 by subtracting 3.7 feet from reported data.*
6. *From Strahorn and van Duyne (1911), as reported by Breese (1968, p. 13).*
7. *Data for period 1911-69 from U.S. Bureau of Reclamation.*
8. *From Breese (1968, p. 14). Probably in error.*
9. *Determined as part of present study in June 1971: Big Soda Lake, 3,989.3 feet; Little Soda Lake, 3,989.8 feet.*

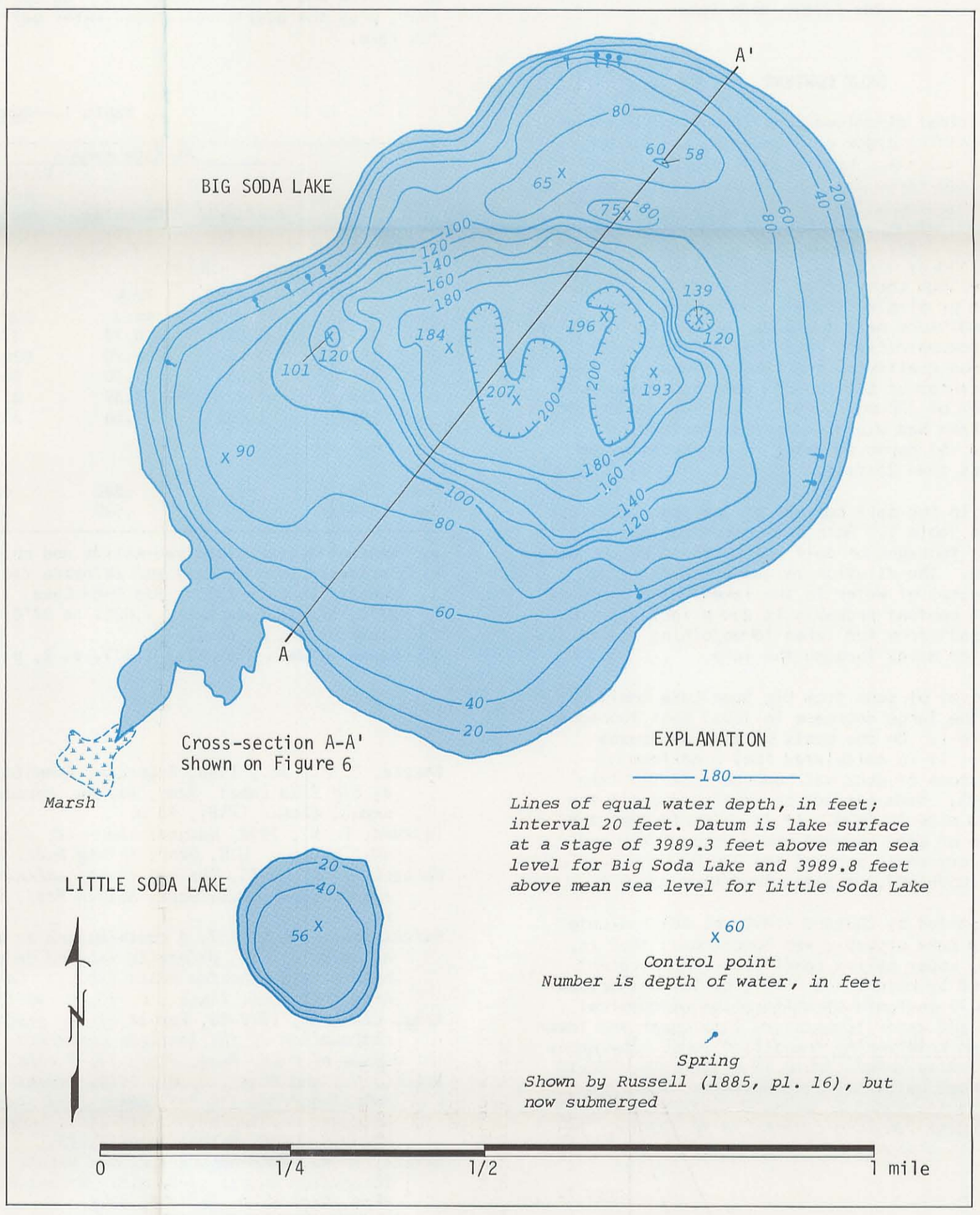


Figure 4.- *Reconnaissance bathymetry of the Soda Lakes*

Figure 6.- *Cross-section of Big Soda Lake as recorded by the fathometer*

Base from aerial photographs, 1:19,000, 1971
Cartography by C. Bosch

HYDROLOGIC RECONNAISSANCE OF BIG AND LITTLE SODA LAKES, CHURCHILL COUNTY, NEVADA

By
F. Eugene Rush

1972

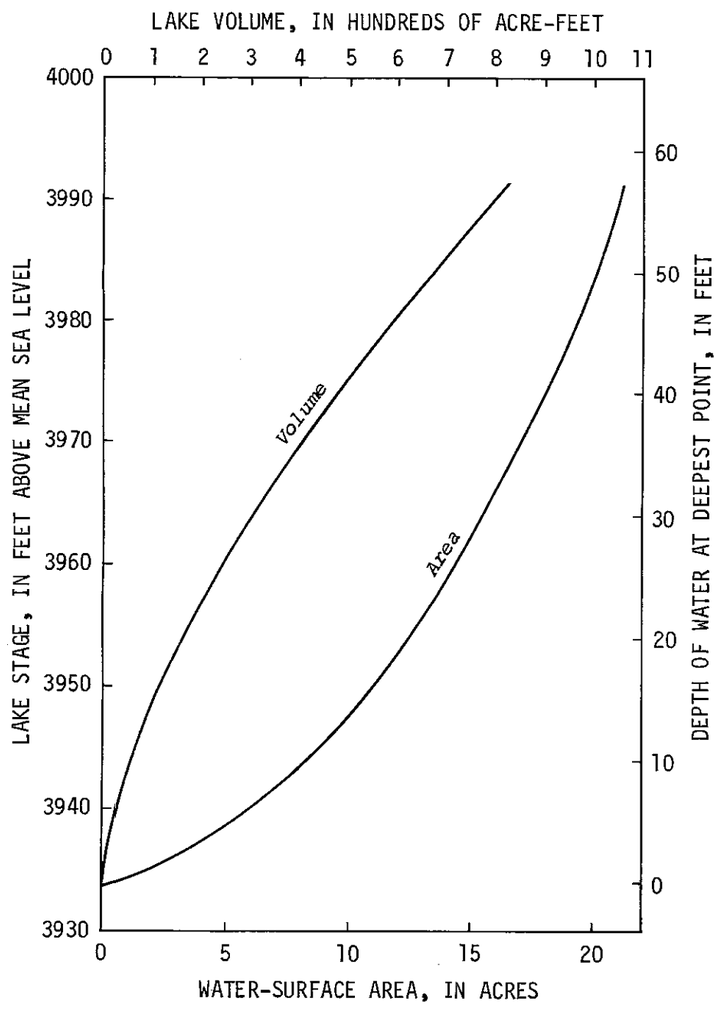


Figure 7.- *Stage-area-volume relations for Little Soda Lake*

SALT CONTENT

The principal dissolved constituents of Big Soda Lake, in descending order of abundance, are sodium, chloride, and sulfate. Little Soda Lake is different in that of these three dominant ions, sulfate has the highest concentration, followed by sodium. These ions make up approximately 90 percent of the total dissolved solids in both lakes. The naturally occurring ground water in the nearby alluvium, the principal source of water for the Soda Lakes prior to the Newlands Project, was described by Stabler (1904). He reports the following conditions near the Soda Lakes: (1) chloride and sulfate concentrations less than 100 mg/l, (2) springs of good quality in the lake craters, (3) dug well in the crater of Little Soda Lake had dissolved-solids content of 320 mg/l, (4) driven well in crater of Big Soda Lake had dissolved-solids content of 400 mg/l, and (5) depth to water in nearby alluvium generally less than 25 feet.

Changes in the salt content of the Soda Lakes are summarized in table 1. Both the concentrations of salt and the total tonnages of salt are shown to be decreasing with time. The dilution is due principally to increased volumes of water in the lakes. The decrease in total salt content probably is due principally to flushing of salt from the lakes to adjoining aquifers, as ground water moves through the lake.

The removal of soda from Big Soda Lake could not account for the large decrease in total salt tonnages shown in table 1. On the basis of data by Breese (1968, p. 26), it is calculated that a maximum of about 20,000 tons of soda was removed from the lake during 1868-93. Soda extraction continued until the lake began to rise in 1906. It is unlikely that the total tonnage of soda removed would account for any more than a very small part of the 900,000-ton loss of salt during 1869-1967, as determined from table 1.

Data reported by Chatard (1890, p. 48) indicate that Big Soda Lake probably was homogenous; that is, unstratified, under native conditions. More recent data collected by Hutchinson (1937, p. 75) and Breese (1968, table 7) indicate stratification of chemical constituents and water temperature into upper and lower zones, with an intervening transition zone. The upper zone of less salty water (table 1) extends to a depth of about 30 feet below the lake surface. The lower zone of more salty water is below a depth of about 120 feet. The transition zone between 30 to 120 feet is intermediate in composition. The temperature of the water below a depth of 120 feet was essentially constant at 62°F (17°C) in August 1967 (fig. 8). The chemical stratification probably is caused by a greater dilution of lake water near the surface than at depth as more ground water flows through the upper zone of the lake.

The rate of freshening has decreased in recent years. If we assume that the tonnage of chloride was nearly constant from 1867 to 1906 at about 970,000 tons (table 1) and decreased to 670,000 tons in 1933 and to 630,000 tons in 1967, then from 1906 to 1933 the average annual loss in chloride was about 11,000 tons. For 1933-67, the rate of loss was only about 1,200 tons per year. One implication is that if the present hydrologic conditions of Big Soda Lake persist, the chloride content, and possibly other chemical characteristics as well, may nearly stabilize in a few years.

EVAPORATION AND WATER BALANCE

The net evaporation rate (evaporation of 4.3 feet for fresh water, reduced to about 90 percent by the effects of salinity (Harbeck, 1955, fig. 5), minus precipitation of 0.3 foot) for Big Soda Lake under native conditions may have averaged about 1,000 acre-feet per year (that is, 3.6 feet x 270 acres). At the present stage, the evaporation may average about 1,500 acre-feet (that is, 4 feet x 385 acres). For native conditions, the net evaporation was offset by an equal amount of subsurface inflow; however, under recent equilibrium conditions and with a continuous loss of salt from the lake with high stage, a larger volume of ground water is moving into the lake; part of it leaving as subsurface outflow, carrying dissolved chemical constituents with it. The amount of thermal water entering the lake (Breese, 1968) is not known.

During the period of stage adjustment (1906-30), the volume of Big Soda Lake increased about 20,000 acre-feet, or at an average annual rate of about 800 acre-feet. During the adjustment, the average annual net inflow would have been on the order of 2,000 acre-feet, plus the additional ground-water outflow from the lake.

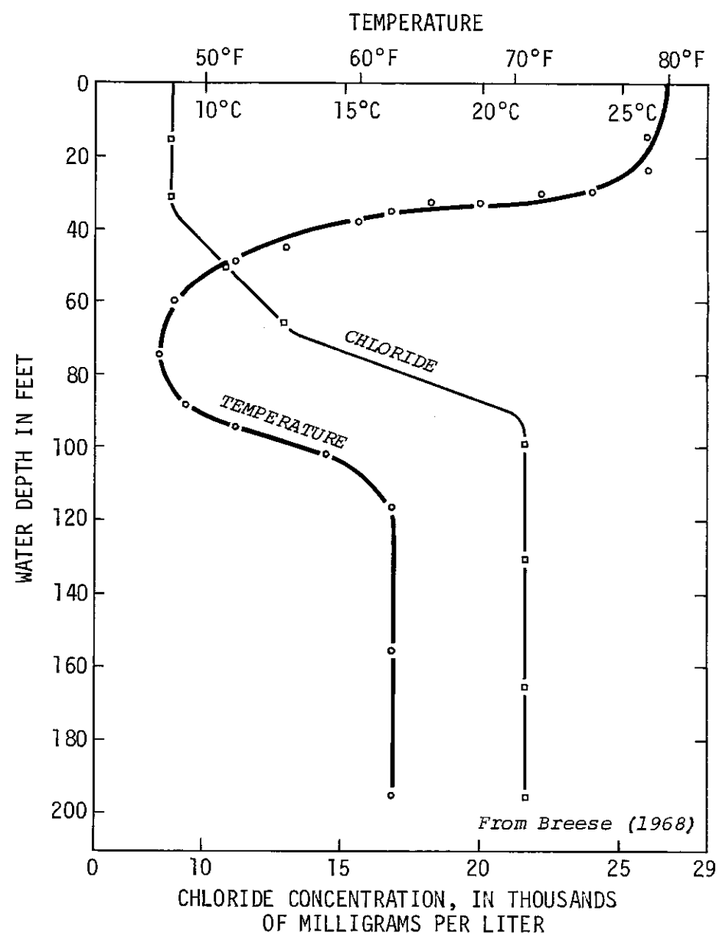


Figure 8.- *Variations in water temperature and chloride concentration with depth of Big Soda Lake, August 1967*

Table 1.--Summary of water-quality changes for the Soda Lakes

Date	Surface sample: Density[1] (g/ml)	Surface sample: Chloride (g/l)	Surface sample: Dissolved-solids content (g/l)	Deep sample: Depth (feet)	Deep sample: Density (g/ml)	Deep sample: Chloride (g/l)	Deep sample: Dissolved-solids content (g/l)	Total lake content (thousands of tons): Chloride	Total lake content (thousands of tons): Dissolved-solids content
BIG SODA LAKE									
Aug. 1867[2]	1.0975	39.4	125	--	--	--	--	960	2,800
Sept. 1882[3]	1.0995	45.7	129	100	1.098	44.3	126	970	2,800
-- 1927[4]	a1.02	8.77	27.4	--	--	--	--	--	--
July 1933[5]	1.022	8.20	b26	192	1.066	27.3	b87	670	--
Aug. 1958[6]	1.017	7.70	24.7	--	--	--	--	--	--
Oct. 1963[7]	a1.02	7.39	25.7	--	--	--	--	--	--
-- 1967[7]	1.021	7.60	25.3	197	1.050	21.5	61.8	630	1,900
LITTLE SODA LAKE									
Oct. 1963[7]	--	.880	6.33	--	--	--	--	.93	6.7
Jan. 1967[7]	--	.699	5.51	--	--	--	--	.78	6.2

a. Estimated from dissolved-solids and chloride data.
b. Estimated from density and chloride data.
1. Density in July 1915: Big Soda Lake, 1.0563 at 27°C; Little Soda Lake, 1.0051 at 27°C (Lee and Clark, 1916, p. 666).
2. Based on data from King (1877, v. 2, p. 747).
3. Based on data from Chatard (1890, p. 48).
4. Based on data from Miller, Hardman, and Mason (1953, p. 34).
5. Based on data from Hutchinson (1937, p. 75).
6. Based on data from Whitehead and Feth (1961, table 1).
7. Based on data from U.S. Bureau of Reclamation.

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