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# PROGRESS REPORT

# CHEMICAL QUALITY OF THE SURFACE WATERS IN THE LOUP RIVER BASIN, NEBRASKA

By

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## ABSTRACT

The Loup River and its tributaries transport moderate amounts of siliceous minerals from the sand hills region of north-central Nebraska to the Platte River near Columbus, Nebr. Predominant chemical characteristics of these waters are a high percentage of silica, moderate hardness, and a low percentage of sodium. The composition of the Loup River water is influenced by the geologic formations through which ground water, a major contributor to the flows of the Loup River branches, has percolated.

Investigation of water quality at or near proposed dam sites in the Loup River basin indicates that if soil and drainage conditions are favorable, the impounded water would be satisfactory for irrigation use.

## INTRODUCTION

Because of a possible expansion of the use of water for irrigation in the Loup River basin, Nebr., by construction of proposed dams near Dunning, Boelus, Cotesfield, Erickson, and Loretto, an investigation of the quality of surface water in this basin began in March 1947 as part of a comprehensive water-resources study of the Missouri River basin by the United States Geological Survey.

Sampling points in the Loup River basin were selected to obtain the best geographical coverage of the region so that the quality of the water could be properly determined. (See fig. 1 and pl. 1.)

During the period March 1947 to September 1949, samples were collected periodically at seven stations in the basin and analyzed by the Geological Survey.

This study was made under the general direction of S. K. Love, Chief, Quality of Water Branch, Geological Survey, and under the supervision of P. C. Benedict, regional engineer, in charge of quality-of-water investigations in the Missouri River basin. Analyses of samples collected for this report were made by W. M. Barr, Robert Brennan, H. O. Bush, M. B. Florin, R. H. Langford, R. P. Orth, F. H. Rainwater, L. L. Thatcher, and J. C. Thompson.

## PHYSICAL AND GEOLOGICAL DESCRIPTION

The Loup River basin, resembling an elm leaf in shape, is in central Nebraska. It has an area of 15,724 square miles or about one-fifth the area of the State. (See fig. 1.) The basin is 325 miles in length and 80 miles at its widest point and narrows to 4 miles in width at its confluence with the Platte River.

The Loup River flows in a general southeastward direction and empties into the Platte River just below Columbus, Nebr. Three main branches--the Middle Loup, the South Loup, and the North Loup Rivers--converge to form the Loup River proper. The Middle Loup River, which is considered to be the main stem, is joined by the South Loup approximately 4 miles northeast of St. Michael and by the North Loup 4½ miles east of St. Paul, Nebr. The principal tributaries are the Dismal River, the Calamus River, the Cedar River, and Beaver Creek. The Dismal River joins the Middle Loup River near Dunning; the Calamus River enters the North Loup River near Burwell; the Cedar River and Beaver Creek join the Loup River downstream from St. Paul. A canal 25 miles upstream from Columbus diverts most of the normal flow of the Loup River for generation of hydroelectric power.

Geologically, the Loup River basin is blanketed by loess and dune sand, which are underlain by bedrock at varying depths. Loess overlies the southeastern one-third of the basin, and dune sand covers the remainder of the basin. Alluvium is present along all the larger drainage ways.

The sandy soil readily absorbs rainfall and stores large quantities of water in underground reservoirs. These reservoirs feed the streams of the basin through various underground routes and are effective in stabilizing stream flows. Precipitation records show that the upper half of the basin lies in a

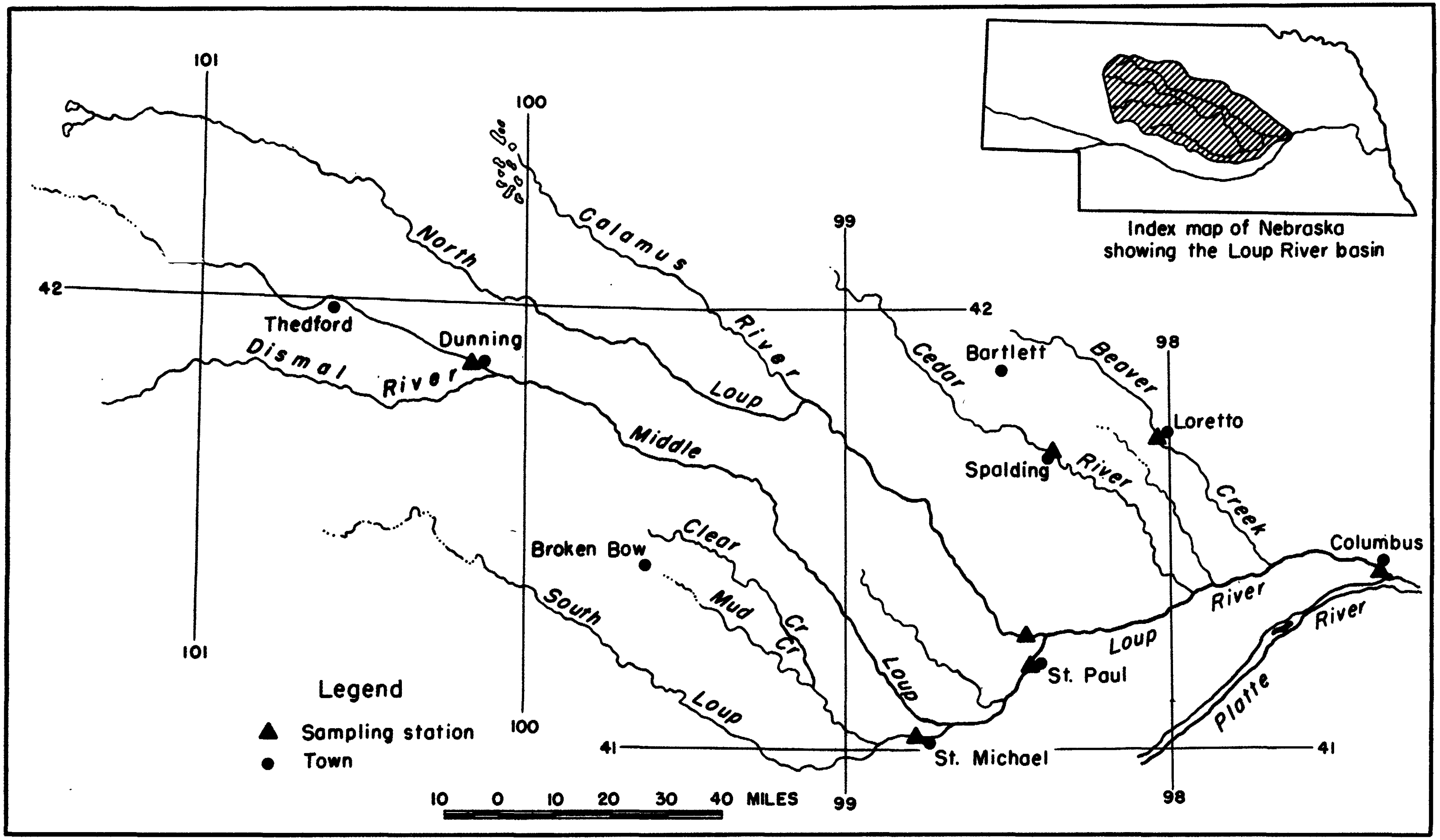
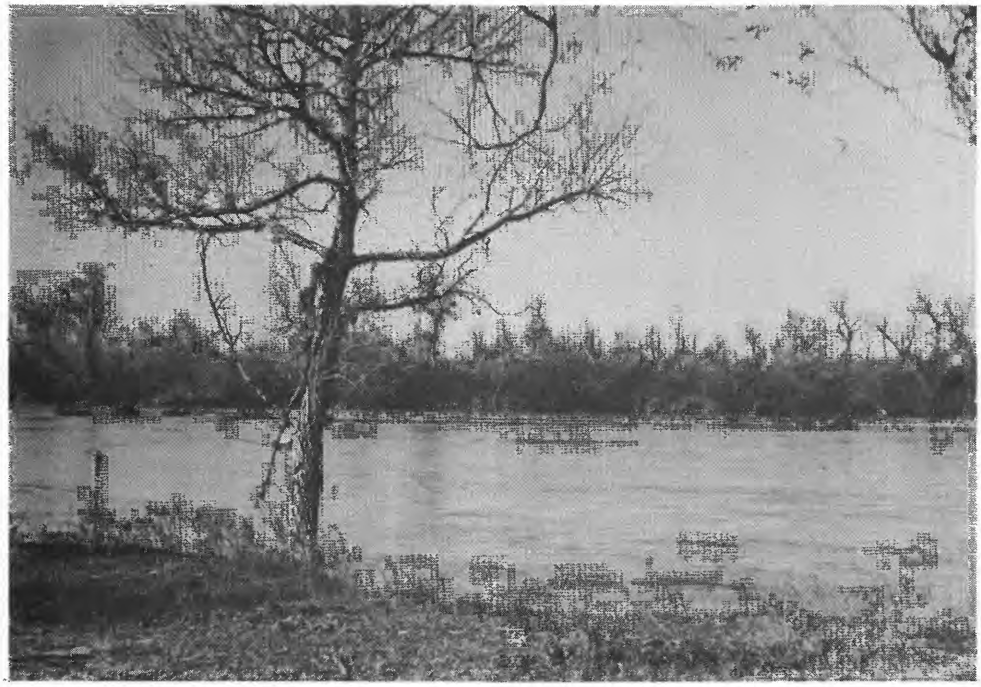



Figure I.--Map of the Loup River basin showing sampling stations for quality of water studies.

A. Sampling station at Dunning, from right bank



B. View across river below Dunning

VIEWS OF THE MIDDLE LOUP RIVER

flood-producing storm area; however, the area has very little runoff because of the pervious mantle rock.

## METHODS OF ANALYSIS

The analyses of samples collected in 1943 include results for specific conductance, pH, sodium, bicarbonate, sulfate, chloride, nitrate, and calculated total hardness. Analyses for samples collected since November 1, 1945, include the following determinations: specific conductance, pH, dissolved solids, silica, iron, calcium, magnesium, sodium, potassium, bicarbonate, sulfate, chloride, fluoride, nitrate, boron, percentage of sodium, total hardness, and noncarbonate hardness. For one sample, sodium and potassium were reported separately, and for the remaining samples, sodium and potassium were calculated and reported as sodium.

All analyses were made by methods commonly used by the Geological Survey (Collins, 1928 and Am. Public Health Assoc., 1946).1/ Boron was determined by an electrometric method, on the basis of methods developed by Foote and Wilcox (1932).

## QUALITY OF THE WATER

An indication of the acceptable quality of the Loup Basin streams may be seen in tables 1 and 2, in which the mineral constituents of the water samples are expressed in parts per million. The water was hard and siliceous; the range in hardness and silica of 44 samples collected during high, medium, and low stages was 62 to 198 and 16 to 64 parts per million, respectively. The concentration of dissolved solids was less than 300 parts per million for all samples, and the percentage of sodium was less than 46.

In order to define the chemical quality of the Loup River water more accurately, samples were collected at various discharges. Some concept of the relative discharges at sampling time may be realized in viewing the hydrographs of daily mean discharge for each station for the period January 1947 to September 1948. (See pls. 2-4.) The results of chemical analyses, in equivalents per million, are shown graphically above the daily mean discharge of the date on which the sample was collected. Instantaneous discharges for these samples are shown in tables 1 and 2. Samples collected in 1949 are included in this report but are not shown on the hydrographs.

Analytical results, in equivalents per million, for samples collected during high and low discharges are shown in bar-graph form in figures 2-4. The principal acids and bases are represented by component sections of two columns; the height of each section is proportional to the quantity, as equivalents, of the ion it represents. The sum of the acids (acid column) is equal to the sum of the bases (base column); and the height of the double column, multiplied by two, is equal to the equivalent amount of all major ions in solution at the time of sampling.

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1/ See page 15 for list of references cited.

Hardness values, in parts per million, of calcium carbonate ($CaCO_3$) may be read to the right of the bar-graphs. A horizontal line drawn from the top of the magnesium section to the vertical line on the right will indicate the total hardness of that sample. Noncarbonate hardness (permanent hardness) is absent in samples shown by bar-graphs. Only three samples had permanent hardness, and the maximum value observed was 8 parts per million. (See tables 1 and 2.)

It is readily seen from the bar-graphs and tables 1 and 2 that the Loup River waters vary somewhat in mineral content. For the period of investigation, the South Loup River at St. Michael had the largest quantities of dissolved solids, which varied from 204 to 298 parts per million during high and low flows. Downstream increases in mineral content are evident from results obtained at the two Middle Loup River stations (Dunning and St. Paul). The dilution effect of high discharge is illustrated in figures 2-4. For the most part, samples collected during periods of highest discharge had the smallest amount of dissolved solids and the least hardness.

An over-all comparison of the hydrologic information for each sampling station is given in table 3.

### Geochemical Relationships and Salinity Characteristics

As rain falls to the surface of the earth, it picks up varying amounts of dissolved gases and impurities. Carbon dioxide ($CO_2$), present in the atmosphere, imparts to the rain water an acidic property that permits solution of various minerals, particularly limestone, as the water percolates to the water table. Any discharge of ground water thus stored should reflect to some extent the types of soils, minerals, and geologic beds through which the water percolated. The degree of solution of these various substances is dependent on such factors as time in contact, type of material, nature of infiltrating water, temperature, and base exchange.

The three branches of the Loup River generally carry siliceous, calcium bicarbonate waters. This would be expected of ground water that discharges from the dune-sand and loess areas that mantle the basin. The results of analyses of 19 samples from wells 31 to 180 feet deep in the alluvium along the Middle Loup and South Loup Rivers indicate similarities to surface waters. Ranges in several mineral constituents and in other physical properties of the ground water are as follows:

| | Maximum (parts per million) | Minimum (parts per million) |
|---|---|---|
| Silica | 58 | 35 |
| Calcium | 114 | 32 |
| Magnesium | 15 | 4.8 |
| Bicarbonate | 396 | 127 |
| Dissolved solids | 516 | 186 |
| Hardness | 371 | 100 |

Generally, the ground water is more highly mineralized and harder than the surface

Table 1.—Mineral constituents and related physical measurements for sampling stations on the main stem, Loup River
[Analytical results in parts per million except as indicated]

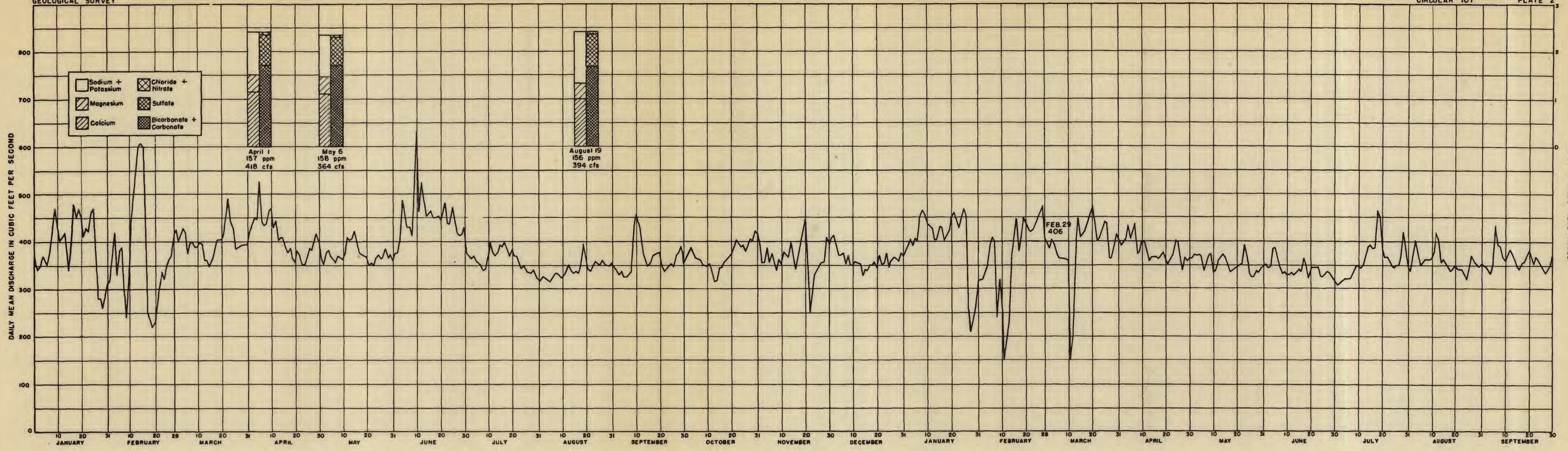
| Date of collection | Discharge (second-feet) | pH | Specific conductance (micromhos/cm. at 25° C.) | Silica ($SiO_2$) | Iron (Fe) | Calcium (Ca) | Magnesium (Mg) | Sodium (Na) | Potassium (K) | Bicarbonate ($HCO_3$) | Sulfate ($SO_4$) | Chloride (Cl) | Fluoride (F) | Nitrate ($NO_3$) | Boron (B) | Dissolved solids: Parts per million | Dissolved solids: Tons per acre-foot | Hardness as $CaCO_3$: Total | Hardness as $CaCO_3$: Noncarbonate | Percent sodium |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Middle Loup River at Dunning, Nebr.** | | | | | | | | | | | | | | | | | | | | |
| Apr. 1, 1947 - - | 418 | 7.1 | 199 | 60 | 0.08 | 23 | 4.4 | 21 | | 104 | 31 | 0 | 0.4 | 2.2 | 0.02 | 157 | 0.21 | 76 | 0 | 37 |
| May 6 - - - - - | 1/364 | 8.1 | 198 | 62 | .01 | 22 | 4.4 | 20 | | 104 | 29 | 0 | .3 | 1.4 | .25 | 158 | .21 | 73 | 0 | 38 |
| Aug. 19 - - - - | 394 | 7.1 | 193 | 61 | .06 | 20 | 3.9 | 25 | | 102 | 33 | 0 | .3 | 2.2 | .07 | 156 | .21 | 66 | 0 | 45 |
| Sept. 21, 1949 - | 1/344 | 7.3 | 178 | 56 | .04 | 25 | 3.7 | 9.0 | | 106 | 6.8 | .6 | .3 | 1.5 | — | 154 | .21 | 78 | 0 | 20 |
| **Middle Loup River at St. Paul, Nebr.** | | | | | | | | | | | | | | | | | | | | |
| Dec. 1, 1943 - - | — | 8.0 | 244 | — | — | — | — | 6.2 | | 148 | 7.0 | 2.2 | — | 2.0 | — | — | — | 120 | — | — |
| Mar. 26, 1947 - | 1,150 | 7.7 | 284 | 58 | .05 | 35 | 5.9 | 17 | | 151 | 22 | 0 | .4 | 2.2 | .20 | 197 | .27 | 112 | 0 | 25 |
| May 8 - - - - - | 1,060 | 8.3 | 286 | 61 | .02 | 36 | 6.6 | 19 | | 2/156 | 27 | 0 | .4 | 1.1 | .42 | 207 | .28 | 117 | 0 | 26 |
| Sept. 2 - - - - | 623 | 8.1 | 288 | 62 | .02 | 34 | 5.9 | 26 | | 150 | 40 | 0 | .3 | 1.4 | .02 | 195 | .27 | 109 | 0 | 35 |
| June 8, 1948 - - | 941 | 8.3 | 272 | 62 | .08 | 38 | 4.9 | 12 | | 3/162 | 3.2 | 1.0 | .2 | 3.2 | .01 | 230 | .31 | 115 | 0 | 18 |
| June 22 - - - - | 3,880 | 8.3 | 191 | 34 | .07 | 23 | 2.0 | 16 | | 4/103 | 8.8 | 1.0 | .2 | 5.4 | — | 165 | .22 | 66 | 0 | 34 |
| July 20 - - - - | 2,020 | 7.5 | 235 | 33 | .08 | 34 | 4.4 | 9.2 | | 138 | 5.6 | 1.0 | .3 | 2.3 | .04 | 182 | .25 | 103 | 0 | 16 |
| July 29 - - - - | 2,990 | 7.1 | 157 | 31 | .02 | 22 | 2.9 | 8.2 | | 92 | 6.4 | 1.0 | .1 | 1.3 | .12 | 129 | .18 | 67 | 0 | 21 |
| Aug. 13 - - - - | 5,070 | 7.5 | 174 | 28 | .02 | 22 | 2.0 | 12 | | 101 | 3.2 | 1.0 | .1 | 1.4 | .03 | 142 | .19 | 63 | 0 | 29 |
| Mar. 5, 1949 - - | 5/8,000 | 7.5 | 198 | 32 | .12 | 29 | 4.2 | 5.5 | | 112 | 4.8 | 2.0 | .3 | 1.3 | .07 | 158 | .21 | 90 | 0 | 12 |
| Mar. 6 - - - - - | 3,030 | 7.5 | 198 | 32 | .10 | 31 | 5.3 | 4.6 | | 120 | 7.2 | 1.5 | .3 | .9 | .04 | 162 | .22 | 100 | 2 | 9 |
| June 7 - - - - - | 7,250 | 7.2 | 242 | 35 | .10 | 32 | 4.7 | 14 | | 148 | 6.4 | .5 | .3 | .2 | — | 173 | .24 | 100 | 0 | 23 |
| June 9 - - - - - | 7,940 | 7.2 | 242 | 29 | .10 | 35 | 4.2 | 12 | | 140 | 12 | 1.0 | .3 | .3 | — | 167 | .23 | 105 | 0 | 19 |
| **Loup River near Columbus, Nebr.** | | | | | | | | | | | | | | | | | | | | |
| Nov. 8, 1945 - - | 208 | 7.9 | 240 | 50 | .05 | 33 | 6.5 | 7.6 | 6.2 | 144 | 11 | 1.8 | .2 | 1.1 | .04 | 196 | .27 | 109 | 0 | 12 |

1 Mean daily discharge.
2 Includes 4.9 parts per million carbonate ($CO_3$).
3 Includes 14 parts per million carbonate ($CO_3$).
4 Includes 2.0 parts per million carbonate ($CO_3$).
5 Discharge approximate—ice conditions.

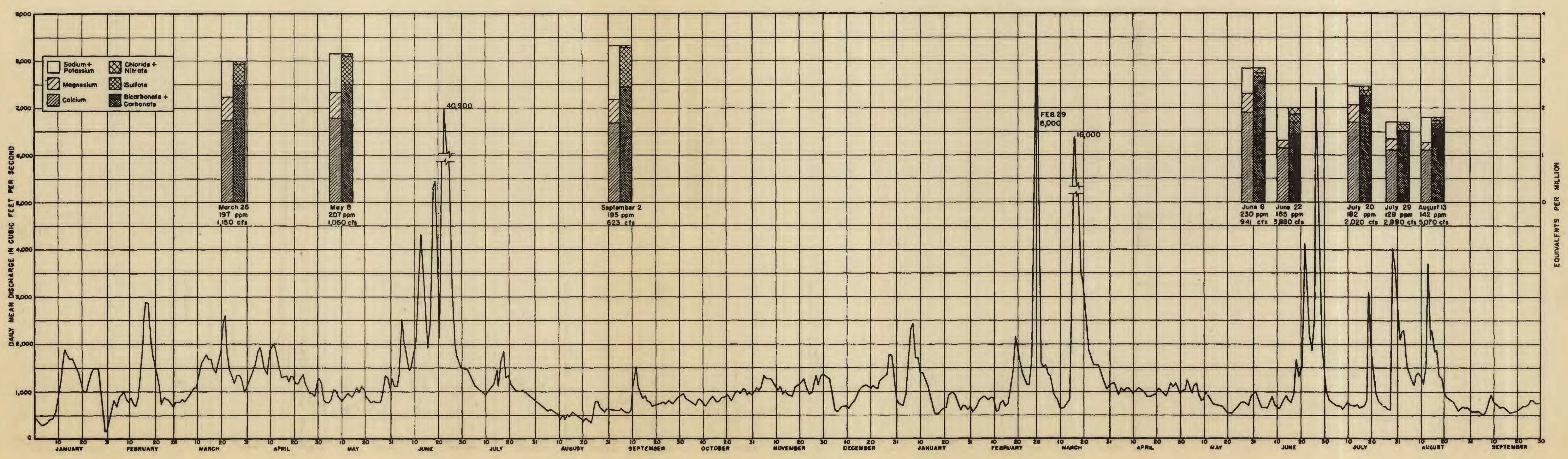
Table 2.—Mineral constituents and related physical measurements for sampling stations on tributaries to the Loup River
[Analytical results in parts per million except as indicated]

| Date of collection | Discharge (second-feet) | pH | Specific conductance (micromhos/cm. at 25° C.) | 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 | Hardness as $CaCO_3$: Total | Hardness as $CaCO_3$: Noncarbonate | Percent sodium |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **South Loup River at St. Michael, Nebr.** | | | | | | | | | | | | | | | | | | | | |
| Apr. 2, 1947 - - | 1/244 | 7.3 | 454 | 56 | 0.05 | 60 | 9.8 | 22 | | 246 | 29 | 2.0 | 0.2 | 3.1 | 0.20 | 280 | 0.38 | 190 | 0 | 20 |
| May 1 - - - - - | 208 | 8.4 | 466 | 59 | .05 | 62 | 10 | 24 | | 2/256 | 33 | 2.0 | .3 | 2.1 | .38 | 296 | .40 | 198 | 0 | 21 |
| Aug. 20 - - - - | 124 | 8.2 | 452 | 56 | .05 | 62 | 9.6 | 23 | | 244 | 38 | 2.0 | .2 | 2.8 | .19 | 298 | .41 | 194 | 0 | 21 |
| June 22, 1948 - | 1,190 | 8.5 | 285 | 38 | .04 | 40 | 6.0 | 8.8 | | 3/158 | 4.0 | 1.3 | .8 | 7.1 | — | 218 | .30 | 124 | 0 | 13 |
| July 18 - - - - | 2,000 | 7.1 | 264 | 34 | .18 | 39 | 6.0 | 9.0 | | 158 | 8.0 | 1.0 | .4 | 1.6 | .06 | 206 | .28 | 122 | 0 | 14 |
| July 29 - - - - | 1,900 | 7.2 | 258 | 36 | .30 | 32 | 5.5 | 16 | | 152 | 11 | 0 | .3 | .8 | .07 | 204 | .28 | 102 | 0 | 25 |
| Sept. 22, 1949 - | 1/168 | 7.5 | 394 | 46 | .02 | 59 | 8.9 | 17 | | 238 | 17 | 3.4 | .2 | 3.8 | — | 284 | .39 | 184 | 0 | 17 |
| **North Loup River near St. Paul, Nebr.** | | | | | | | | | | | | | | | | | | | | |
| Dec. 1, 1943 - - | — | 8.0 | 211 | — | — | — | — | 10 | | 126 | 5.0 | 2.0 | — | 2.5 | — | — | — | 120 | — | — |
| Mar. 26, 1947 - | 934 | 8.2 | 237 | 64 | .08 | 26 | 5.9 | 15 | | 120 | 19 | 0 | .4 | 2.8 | .11 | 174 | .24 | 89 | 0 | 27 |
| May 8 - - - - - | 762 | 7.4 | 232 | 49 | .11 | 31 | 6.3 | 7.1 | | 131 | 9.5 | 0 | .4 | .5 | .06 | 175 | .24 | 103 | 0 | 13 |
| Aug. 25 - - - - | 329 | 7.0 | 239 | 50 | .13 | 29 | 6.8 | 11 | | 135 | 12 | 0 | .3 | .9 | — | 182 | .25 | 100 | 0 | 20 |
| July 29, 1948 - | 1,950 | 7.5 | 255 | 40 | .40 | 43 | 5.5 | 5.1 | | 149 | 16 | 1.0 | .3 | 0 | .06 | 208 | .28 | 130 | 8 | 8 |
| Mar. 5, 1949 - - | 4/3,690 | 7.4 | 226 | 35 | .07 | 28 | 4.6 | 5.3 | | 109 | 4.0 | 3.5 | .3 | 1.0 | .06 | 176 | .24 | 89 | 0 | 11 |
| Mar. 6 - - - - - | 2,900 | 7.4 | 195 | 33 | .10 | 26 | 4.6 | 6.2 | | 107 | 5.6 | 1.5 | .3 | 1.1 | .06 | 132 | .18 | 84 | 0 | 14 |
| **Cedar River near Spalding, Nebr.** | | | | | | | | | | | | | | | | | | | | |
| Apr. 2, 1947 - - | 47 | 7.0 | 203 | 37 | .12 | 26 | 6.3 | 5.7 | | 116 | 6.6 | 0 | .2 | .9 | .02 | 147 | .20 | 91 | 0 | 12 |
| May 6 - - - - - | 123 | 7.2 | 228 | 40 | .20 | 30 | 7.4 | 5.6 | | 133 | 7.0 | 0 | .2 | .9 | .01 | 164 | .22 | 105 | 0 | 10 |
| Aug. 27 - - - - | 42 | 8.2 | 204 | 47 | .13 | 26 | 6.8 | 5.4 | | 117 | 7.4 | 0 | .2 | .7 | .14 | 165 | .22 | 93 | 0 | 11 |
| Feb. 28, 1949 - | 61 | 7.6 | 195 | 42 | .12 | 27 | 6.8 | 3.9 | | 117 | 5.6 | .5 | .2 | 1.1 | .01 | 148 | .20 | 96 | 0 | 8 |
| **Beaver Creek near Loretto, Nebr.** | | | | | | | | | | | | | | | | | | | | |
| Apr. 2, 1947 - - | 72 | 7.3 | 246 | 36 | .20 | 33 | 6.8 | 7.2 | | 144 | 5.8 | 0 | .3 | 1.4 | .09 | 171 | .23 | 110 | 0 | 12 |
| May 5 - - - - - | 44 | 7.9 | 248 | 36 | .20 | 35 | 7.0 | 5.7 | | 148 | 5.8 | 0 | .2 | .8 | .36 | 172 | .23 | 116 | 0 | 10 |
| Aug. 27 - - - - | 30 | 8.0 | 229 | 40 | .12 | 31 | 7.2 | 5.1 | | 135 | 5.8 | 0 | .3 | .8 | .12 | 164 | .22 | 107 | 0 | 9 |
| June 22, 1948 - | 311 | 8.5 | 175 | 19 | .40 | 26 | 3.8 | 7.4 | | 5/102 | 10 | 0 | .5 | 1.2 | — | 150 | .20 | 80 | 0 | 17 |
| July 29 - - - - | 419 | 7.0 | 157 | 16 | .50 | 20 | 3.0 | 9.3 | | 89 | 6.4 | 1.5 | .3 | 0 | 0 | 120 | .16 | 62 | 0 | 25 |
| Aug. 1 - - - - - | 55 | 7.6 | 233 | 42 | .16 | 35 | 4.4 | 8.8 | | 145 | 4.0 | 0 | .4 | .7 | — | 188 | .26 | 105 | 0 | 15 |
| Mar. 3, 1949 - - | 95 | 7.2 | 224 | 35 | .11 | 31 | 5.2 | 8.5 | | 132 | 5.6 | 1.0 | .3 | 1.5 | .03 | 162 | .22 | 99 | 0 | 16 |
| Mar. 7 - - - - - | 619 | 7.0 | 193 | 16 | .02 | 26 | 2.7 | 8.7 | | 102 | 4.0 | 2.0 | .1 | 5.2 | 0 | 139 | .19 | 76 | 0 | 20 |
| May 23 - - - - - | 311 | 8.0 | 225 | 27 | .03 | 35 | 4.2 | 8.5 | | 127 | 15 | .5 | .2 | 3.8 | — | 166 | .23 | 105 | 1 | 15 |
| Sept. 27 - - - - | 39 | 7.7 | 274 | 38 | .08 | 31 | 5.4 | 7.6 | | 136 | 1.6 | 1.4 | .2 | .8 | — | 158 | .21 | 100 | 0 | 14 |

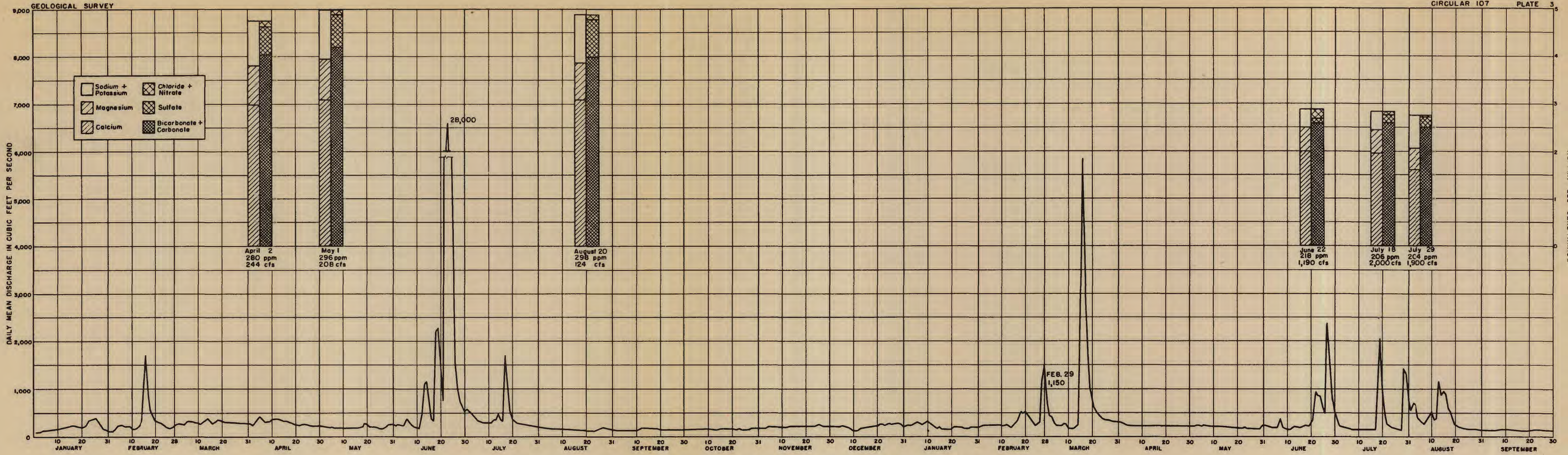
1 Mean daily discharge.
2 Includes 9.8 parts per million carbonate ($CO_3$).
3 Includes 11 parts per million carbonate ($CO_3$).
4 Discharge approximate—ice conditions.
5 Includes 12 parts per million carbonate ($CO_3$).



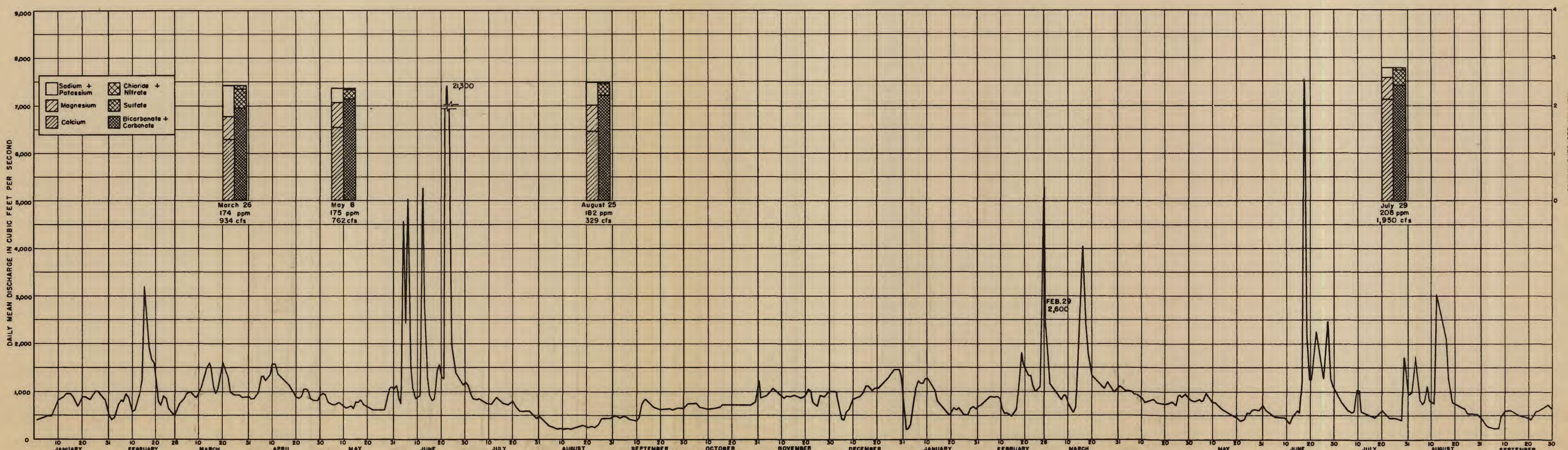

A. HYDROGRAPH OF MIDDLE LOUP RIVER AT DUNNING. JANUARY 1947 – SEPTEMBER 1948



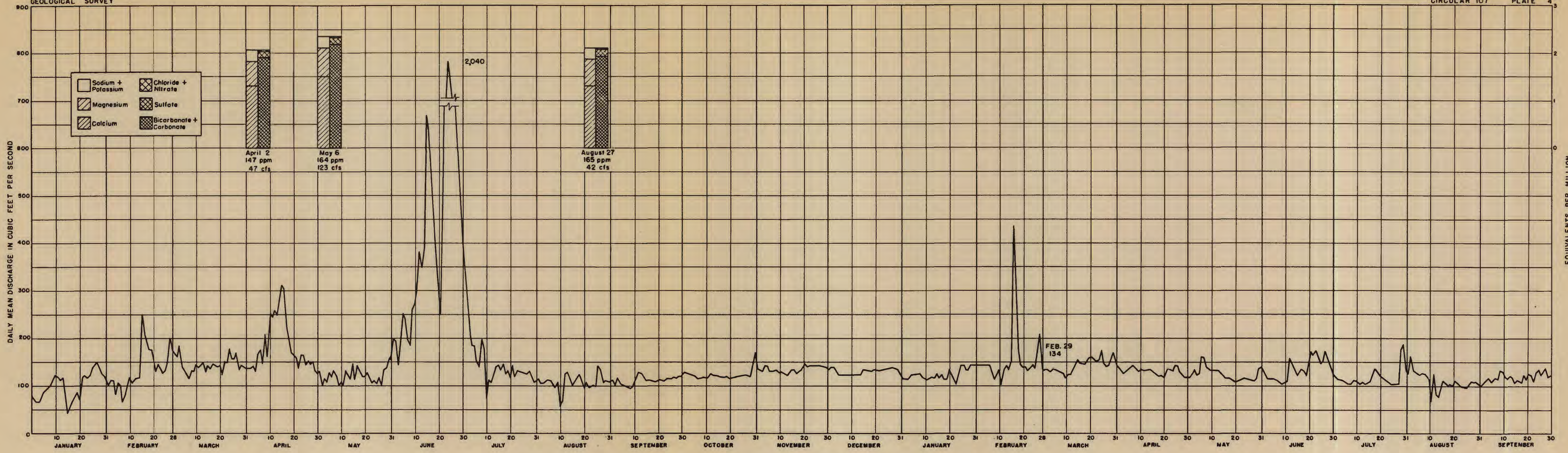

B. HYDROGRAPH OF MIDDLE LOUP RIVER AT ST. PAUL, JANUARY 1947 – SEPTEMBER 1948



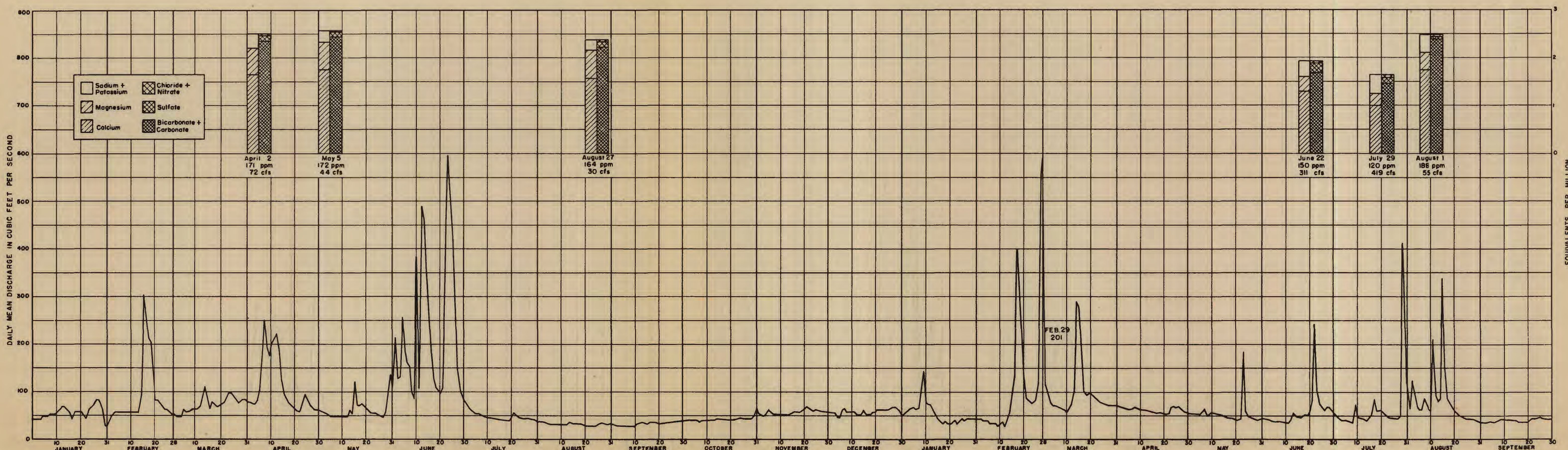

A. HYDROGRAPH OF SOUTH LOUP RIVER AT ST. MICHAEL, JANUARY 1947 - SEPTEMBER 1948




B. HYDROGRAPH OF NORTH LOUP RIVER NEAR ST. PAUL, JANUARY 1947 - SEPTEMBER 1948




A. HYDROGRAPH OF CEDAR RIVER NEAR SPALDING, JANUARY 1947-SEPTEMBER 1948




B. HYDROGRAPH OF BEAVER CREEK AT LORETTO, JANUARY 1947-SEPTEMBER 1948

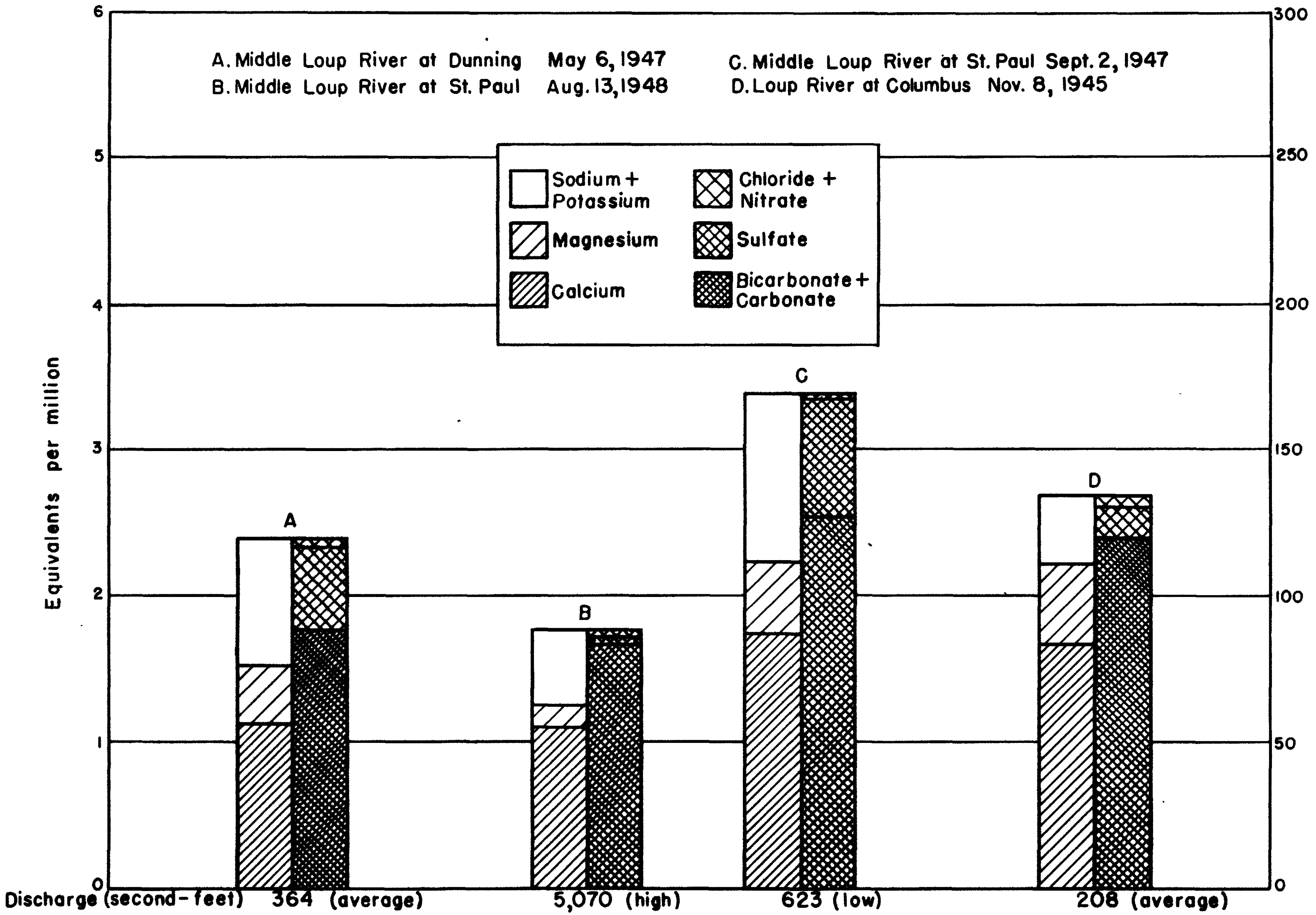



Figure 2.--Mineral constituents during high, average, and low flow--main stem, Loup River basin.

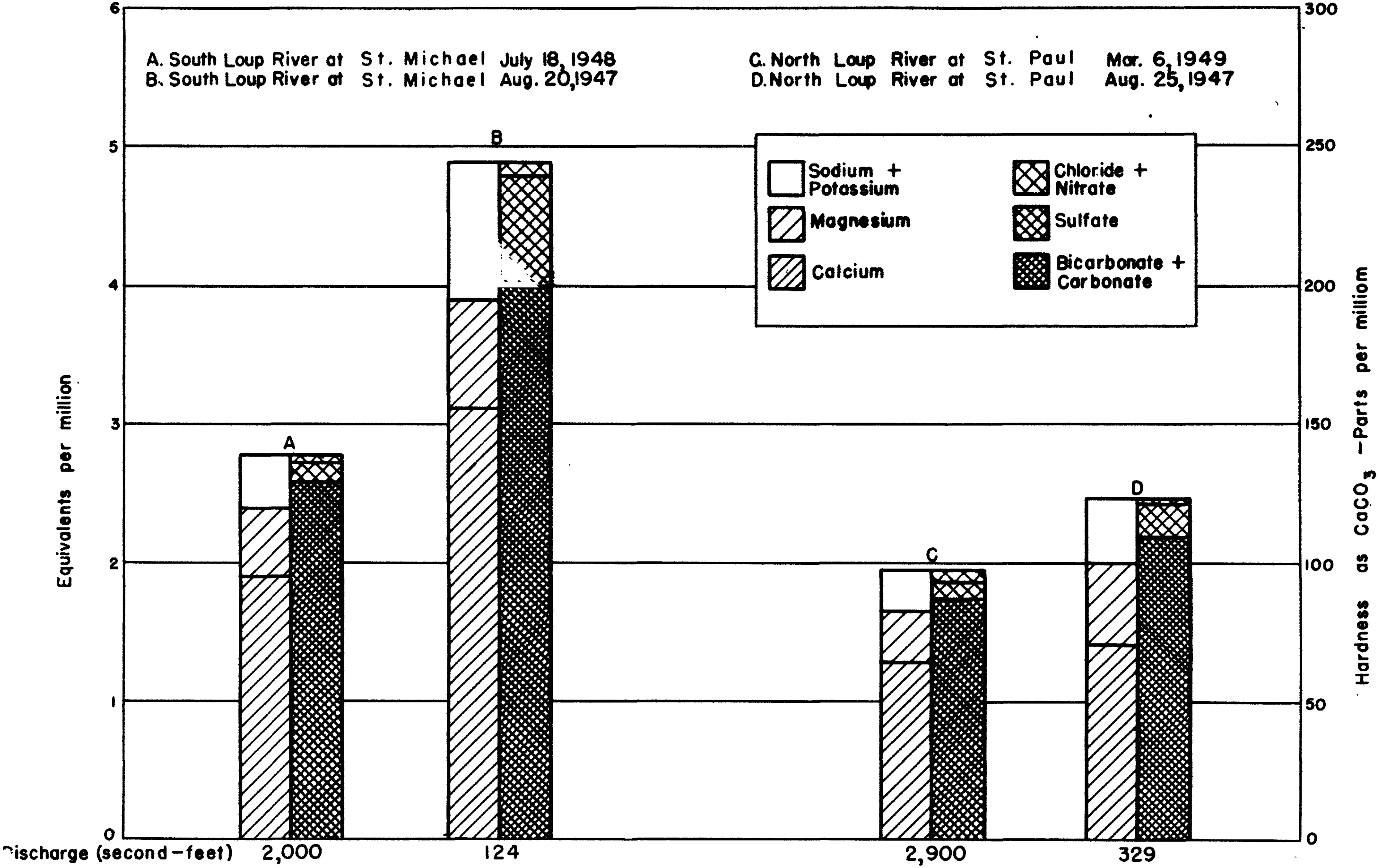



Figure 3.--Mineral constituents during high and low flow--major tributaries, Loup River basin.

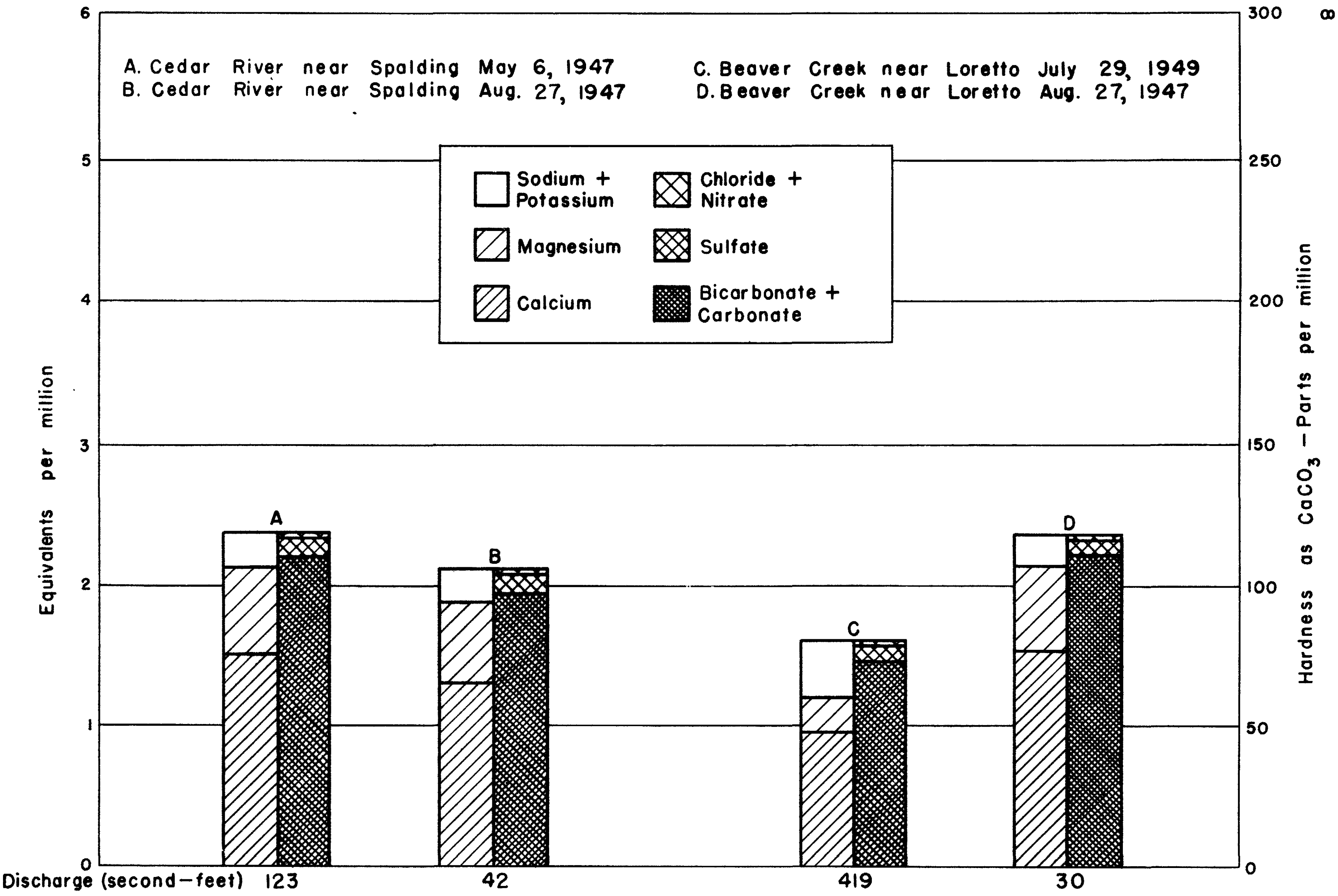



Figure 4.--Mineral constituents during high and low flow--minor tributaries, Loup River basin.

Table 3.--Comparative hydrologic information for the Loup River and its tributaries

| Sampling station | Drainage area (square miles) | Annual mean daily discharge Water year 1947 | 1948 | Predominant chemical characteristics |
|---|---|---|---|---|
| Middle Loup River at Dunning - - - | 1,760 | 392 | 368 | Highly siliceous; moderately hard; practically chloride-free. |
| Middle Loup River at St. Paul - - - | 7,720 | 1,433 | 1,232 | Siliceous; hard. |
| Loup River near Columbus - - - - - | 15,230 | 1,322 | 1,139 | Siliceous; hard. |
| South Loup River at St. Michael - - | 2,560 | 182 | 300 | Moderately siliceous; very hard. |
| North Loup River near St. Paul - - | 4,460 | 979 | 908 | Siliceous; moderately hard. |
| Cedar River near Spalding - - - - - | 794 | 170 | 125 | Siliceous; moderately hard. |
| Beaver Creek at Loretto - - - - - - | 311 | 74.2 | 62.5 | Moderately siliceous; moderately hard. |

water. Dissolved solids in ground waters ranged from 186 to 516 parts per million and averaged 312 parts per million. Hardness ranged from 100 to 371 parts per million and averaged 197 parts per million. A noticeable downward trend in the percentage of silica in ground water sampled between Dunning and St. Paul was also observed in the surface water. The average silica was 16.4 percent of the anhydrous residue.

Although more mineralized, the ground water is similar in composition to the surface water. This relationship is seen in table 4.

According to Lugn (1935) most of the dune sand of the sand-hills region of north-central Nebraska is underlain by the Arikaree, Harrison, and Sheep Creek formations of Miocene age, all of which are more siliceous than calcareous.

Palmer (1911) states in his description of the properties of natural waters,

> Nearly all terrestrial waters have two general properties, salinity and alkalinity, on whose relative proportions their fundamental characters depend. Salinity is caused by salts that are not hydrolyzed; alkalinity is attributed to free alkaline bases produced by the hydrolytic action of water on solutions of bicarbonates and on solutions of salts of other weak acids.

In the study of surface water quality of the streams in the Loup Basin, the use of Palmer's formula is helpful in classifying the water by expressing chemical proportions of the ions in solution as well as variations in the proportions themselves. The factor of concentration is eliminated in this method of expression, and the properties of the solution are expressed in percentage proportion. The percentage of reacting value is computed from equivalents per million and plotted on a trilinear diagram, as proposed by Hill (1942), to show the character of each water.

The trilinear diagram (see fig. 5) used in this report is a modification of Hill's diagram with the diamond expressing salinity and alkalinity set apart from the positive-ion and negative-ion triangles. Primary salinity may be described as sodium and potassium (alkali) salinity, secondary salinity as calcium and magnesium (permanent hardness) salinity, primary alkalinity as sodium and potassium (permanent) alkalinity, and secondary alkalinity as calcium and magnesium (temporary) alkalinity. Water is classified according to the proportions of the above properties.

It is noted from a study of figure 5 that all the Loup River waters are essentially secondary alkaline in character, and that each stream exhibits individual deviations. The character of the Middle Loup River water is noticeably changed below the confluence with the South Loup River above St. Paul. From this point on downstream to Columbus, the character of the water in the main stem is influenced by salt contributions from the North Loup River and tributaries.

Secondary salinity (permanent hardness) is noticeably absent in all the waters, as may be seen in the following comparative table, which shows the salinity and alkalinity characteristics of the Loup River and its tributaries:

Salinity and alkalinity percentages, Loup River and its tributaries

| Sampling station | A | B | C |
|---|---|---|---|
| Middle Loup River at Dunning - | 65 | 25 | 10 |
| Middle Loup River at St. Paul - | 78 | 12 | 10 |
| Loup River at Columbus - - - - | 82 | 12 | 6 |
| South Loup River at St. Michael | 81 | 11 | 8 |
| North Loup River near St. Paul | 85 | 12 | 3 |
| Cedar River near Spalding - - - | 73 | 7 | 20 |
| Beaver Creek at Loretto - - - - | 85 | 8 | 7 |

A--Secondary alkalinity.
B--Primary salinity.
C--Primary alkalinity.

The percentages expressed in figure 5 are calculated from the data in tables 1 and 2 and are the median of all analyses for each station studied. The following characteristics and trends are observed: (1) an increase of 13 percent in secondary alkalinity and a corresponding decrease of 13 percent in primary salinity between Dunning and St. Paul on the Middle Loup River; (2) the Cedar River near Spalding contributes water of 13 percent more primary alkalinity than Beaver Creek at Loretto; (3) the North Loup River near St. Paul has less primary alkalinity than any of the streams studied; and (4) the Middle Loup River at Dunning has a greater proportion of primary salinity than any of the streams studied.

Table 4.--Percentages of reacting values of ions for waters in the Loup River basin

| Date | Cation (+) percentages | | | Anion (-) percentages | | |
|---|---|---|---|---|---|---|
| | Calcium (Ca) | Magnesium (Mg) | Sodium and potassium (Na + K) | Bicarbonate ($HCO_3$) | Sulfate ($SO_4$) | Chloride, fluoride, and nitrate (Cl + F + $NO_3$) |
| SURFACE WATER | | | | | | |
| Middle Loup River - Dunning | | | | | | |
| Apr. 1, 1947 - | 47.7 | 14.9 | 37.4 | 71.3 | 27.1 | 1.6 |
| May 6 - - - - | 46.8 | 15.3 | 37.9 | 73.4 | 25.8 | .8 |
| Aug. 19 - - - | 41.5 | 13.3 | 45.2 | 69.6 | 28.8 | 1.6 |
| Sept. 21, 1949 | 64.4 | 15.5 | 20.1 | 89.7 | 7.2 | 3.1 |
| Middle Loup River - St. Paul | | | | | | |
| Mar. 26, 1947 | 58.4 | 16.3 | 25.3 | 83.2 | 15.4 | 1.4 |
| May 8 - - - - | 57.0 | 17.1 | 25.9 | 81.5 | 17.8 | .7 |
| Sept. 2 - - - | 50.9 | 14.7 | 34.4 | 74.3 | 25.1 | .6 |
| June 8, 1948 - | 67.4 | 14.2 | 18.4 | 94.7 | 2.5 | 2.8 |
| June 22 - - - | 57.5 | 8.0 | 34.5 | 84.9 | 9.0 | 6.1 |
| July 20 - - - | 69.1 | 14.6 | 16.3 | 92.2 | 4.9 | 2.9 |
| July 29 - - - | 64.7 | 14.1 | 21.2 | 89.3 | 7.7 | 3.0 |
| Aug. 13 - - - | 61.8 | 9.0 | 29.2 | 93.3 | 3.9 | 2.8 |
| Mar. 5, 1949 - | 71.1 | 17.2 | 11.7 | 91.1 | 5.0 | 3.9 |
| Mar. 6 - - - - | 70.8 | 20.1 | 9.1 | 90.8 | 6.9 | 2.3 |
| June 7 - - - - | 61.8 | 15.1 | 23.1 | 93.8 | 5.0 | 1.2 |
| June 9 - - - - | 67.3 | 13.5 | 19.2 | 88.1 | 9.6 | 2.3 |
| South Loup River - St. Michael | | | | | | |
| Apr. 2, 1947 - | 62.9 | 17.1 | 20.0 | 85.0 | 12.7 | 2.3 |
| May 1 - - - - | 62.0 | 17.3 | 20.7 | 84.3 | 13.9 | 1.8 |
| Aug. 20 - - - | 63.1 | 16.1 | 20.8 | 81.6 | 16.1 | 2.3 |
| June 22, 1948 | 69.7 | 17.1 | 13.2 | 91.9 | 2.8 | 5.3 |
| July 18 - - - | 68.9 | 17.3 | 13.8 | 91.8 | 6.0 | 2.2 |
| July 29 - - - | 58.2 | 16.3 | 25.5 | 91.2 | 8.4 | .4 |
| Sept. 22, 1949 | 66.5 | 16.5 | 17.0 | 88.2 | 7.9 | 3.9 |
| North Loup River - St. Paul | | | | | | |
| Mar. 26, 1947 | 53.3 | 20.1 | 26.6 | 81.4 | 16.5 | 2.1 |
| May 8 - - - - | 65.1 | 21.9 | 13.0 | 91.1 | 8.5 | .4 |
| Aug. 25 - - - | 58.0 | 22.4 | 19.6 | 89.5 | 10.1 | .4 |
| July 29, 1948 | 76.2 | 16.0 | 7.8 | 87.1 | 11.8 | 1.1 |
| Mar. 5, 1949 - | 69.7 | 18.9 | 11.4 | 89.9 | 4.0 | 6.1 |
| Mar. 6 - - - - | 66.7 | 19.5 | 13.8 | 90.7 | 6.2 | 3.1 |
| Cedar River - Spalding | | | | | | |
| Apr. 2, 1947 - | 62.8 | 25.1 | 12.1 | 92.7 | 6.8 | .5 |
| May 6 - - - - | 63.6 | 25.8 | 10.6 | 93.2 | 6.4 | .4 |
| Aug. 27 - - - | 61.9 | 26.7 | 11.4 | 92.3 | 7.2 | .5 |
| Feb. 28, 1949 | 64.9 | 26.9 | 8.2 | 92.8 | 5.8 | 1.4 |
| Beaver Creek - Loretto | | | | | | |
| Apr. 2, 1947 - | 65.5 | 22.2 | 12.3 | 94.4 | 4.8 | .8 |
| May 5 - - - - | 68.0 | 22.4 | 9.6 | 94.9 | 4.7 | .4 |
| Aug. 27 - - - | 65.7 | 25.0 | 9.3 | 94.4 | 5.1 | .5 |
| June 22, 1948 | 67.4 | 16.0 | 16.6 | 88.0 | 11.0 | 1.0 |
| June 29 - - - | 60.2 | 15.1 | 24.7 | 89.6 | 8.0 | 2.4 |
| Aug. 1 - - - - | 70.3 | 14.5 | 15.2 | 96.4 | 3.2 | .4 |
| Mar. 3, 1949 - | 66.0 | 18.3 | 15.7 | 92.7 | 5.2 | 2.1 |
| Mar. 7 - - - - | 68.4 | 11.6 | 20.0 | 87.9 | 4.2 | 7.9 |
| May 23 - - - - | 70.8 | 14.2 | 15.0 | 84.2 | 12.6 | 3.2 |
| Sept. 27 - - - | 66.8 | 19.0 | 14.2 | 96.1 | 1.3 | 2.6 |
| Loup River - Columbus | | | | | | |
| Nov. 8, 1945 - | 61.8 | 19.9 | 18.3 | 88.4 | 8.6 | 3.0 |
| GROUND WATER | | | | | | |
| Average (19 samples) | | | | | | |
| | 66.6 | 17.3 | 16.1 | 84.9 | 6.7 | 8.4 |

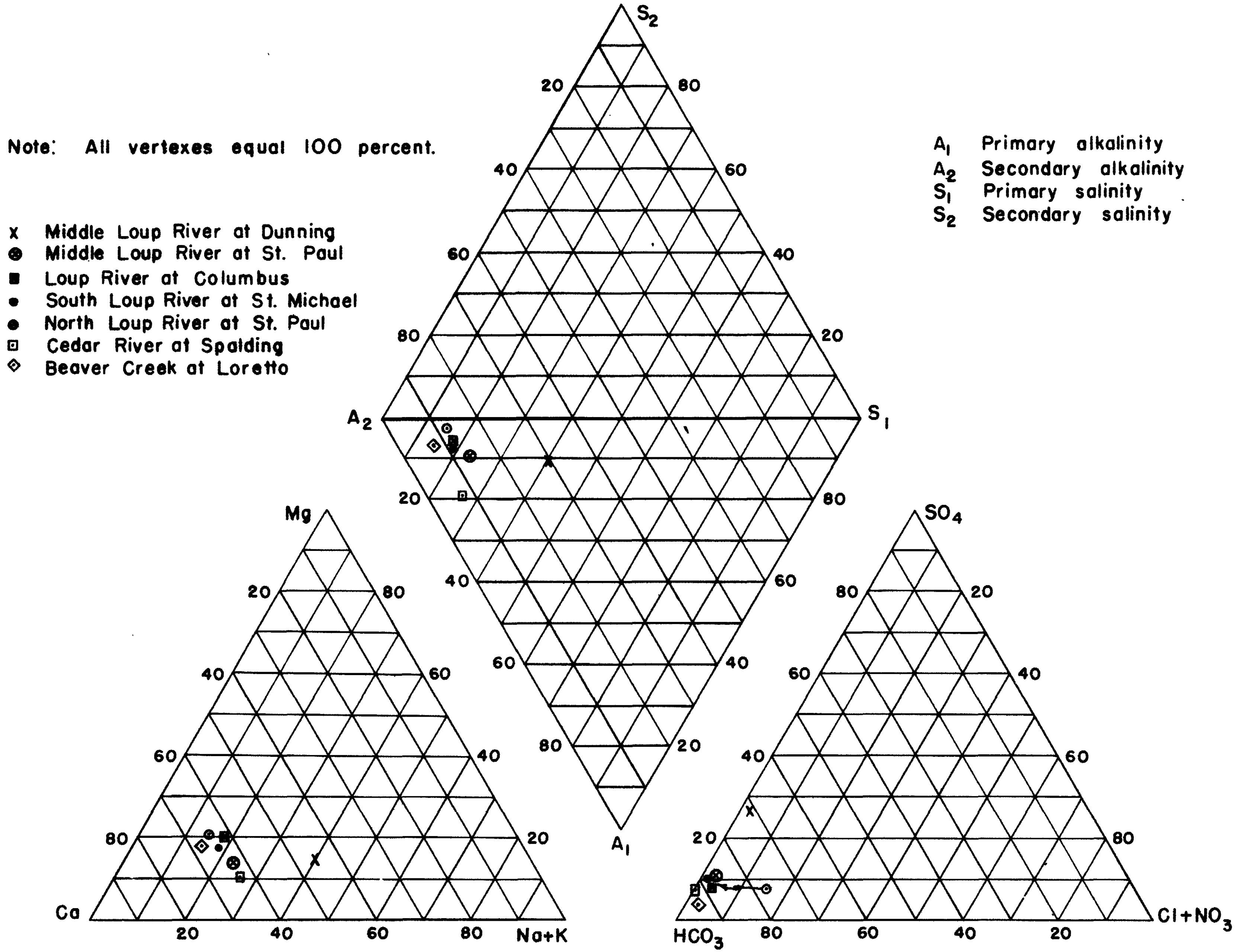



Figure 5.--Geochemical classification of Loup River waters (Palmer-Hill-Piper).

The reacting value of calcium in the Middle Loup River at St. Paul (see table 4) increased from approximately 51 to 71 percent between September 2, 1947, and March 5, 1949, and there was a corresponding decrease for sodium and potassium (considered together) from 34 to 12 percent. For this same period the percentage of reacting value of bicarbonate increased from 74 to 91; whereas the percentage of sulfate decreased from 25 to 5. (See fig. 6.) A similar, but less pronounced, trend occurred in water of the North Loup River at St. Paul.

Considerable variation is also found in the silica content of the Loup River streams. This variation is evident if the silica is expressed as a percentage of anhydrous residue. During the period studied, the Middle Loup River at Dunning had the highest and the South Loup at St. Michael the lowest average percentage of silica. The average percentages of silica in decreasing order for each sampling station are shown in the following table and are illustrated in figure 7.

| Sampling station | Silica Percent of anhydrous residue |
|---|---|
| Middle Loup River at Dunning - - | 38.1 |
| Cedar River at Spalding - - - - | 26.6 |
| North Loup River near St. Paul - | 26.1 |
| Loup River at Columbus - - - - - | 25.5 |
| Middle Loup River at St. Paul - | 23.3 |
| Beaver Creek at Loretto - - - - | 19.2 |
| South Loup River at St. Michael | 18.2 |

The Middle Loup River at St. Paul shows the following decreasing trend in percentage of silica for the period of sampling:

| Date | Percent $SiO_2$ |
|---|---|
| Mar. 26, 1947 - - - | 29.4 |
| May 8 - - - - - - - | 29.5 |
| Sept. 2 - - - - - - | 31.8 |
| June 8, 1948 - - - | 27.0 |
| June 22 - - - - - - | 20.6 |
| July 20 - - - - - - | 18.1 |
| July 29 - - - - - - | 24.0 |
| Aug. 13 - - - - - - | 19.7 |
| Mar. 5, 1949 - - - | 20.3 |
| Mar. 6 - - - - - - | 19.8 |
| June 7 - - - - - - | 20.9 |
| June 9 - - - - - - | 17.7 |

## Quality of Water in Relation to Use

The waters of the Loup River and its tributaries (see fig. 1) are satisfactory for irrigation in areas of average soil and drainage conditions. For streams studied, the waters would be termed "good" or "excellent" by Wilcox's classification of irrigation waters (1948). (See table 5.)

The specific characteristics during high and low discharges at the six sampling points are shown in table 6.

Table 5.--Permissible limits for electrical conductance, percent sodium, and boron in several classes of irrigation water

| Classes of water: Rating | Classes of water: Grade | Electrical conductivity (micromhos/cm. at 25° C.) | Percent sodium | Boron 1/ (p.p.m.) |
|---|---|---|---|---|
| 1 | Excellent | < 250 | < 20 | < 0.33 |
| 2 | Good | 250 - 750 | 20 - 40 | 0.33 - 0.67 |
| 3 | Permissible | 750 - 2,000 | 40 - 60 | 0.67 - 1.00 |
| 4 | Doubtful | 2,000 - 3,000 | 60 - 80 | 1.00 - 1.25 |
| 5 | Unsuitable | > 3,000 | > 80 | > 1.25 |

1/ For crops sensitive to boron.

Table 6.--Classification for irrigation use of Loup River streams during high and low discharges

| Sampling point | Discharge (sec.-ft.) | Electrical conductivity (micromhos/cm. at 25° C.) | Percent sodium | Boron (p.p.m.) | Class |
|---|---|---|---|---|---|
| Middle Loup River at Dunning - - | 418 | 199 | 37 | 0.02 | Good. |
| | 344 | 178 | 20 | -- | Good. |
| Middle Loup River at St. Paul - - | 8,000 | 198 | 12 | .07 | Excellent. |
| | 623 | 288 | 35 | .02 | Good. |
| South Loup River at St. Michael - | 2,000 | 264 | 14 | .06 | Good. |
| | 124 | 452 | 21 | .19 | Good. |
| North Loup River near St. Paul - | 3,690 | 226 | 11 | .06 | Excellent. |
| | 329 | 239 | 20 | -- | Good. |
| Cedar River near Spalding - - - - | 123 | 228 | 10 | .01 | Excellent. |
| | 42 | 204 | 11 | .14 | Excellent. |
| Beaver Creek at Loretto - - - - - | 619 | 193 | 20 | .00 | Good. |
| | 30 | 229 | 9 | .12 | Excellent. |

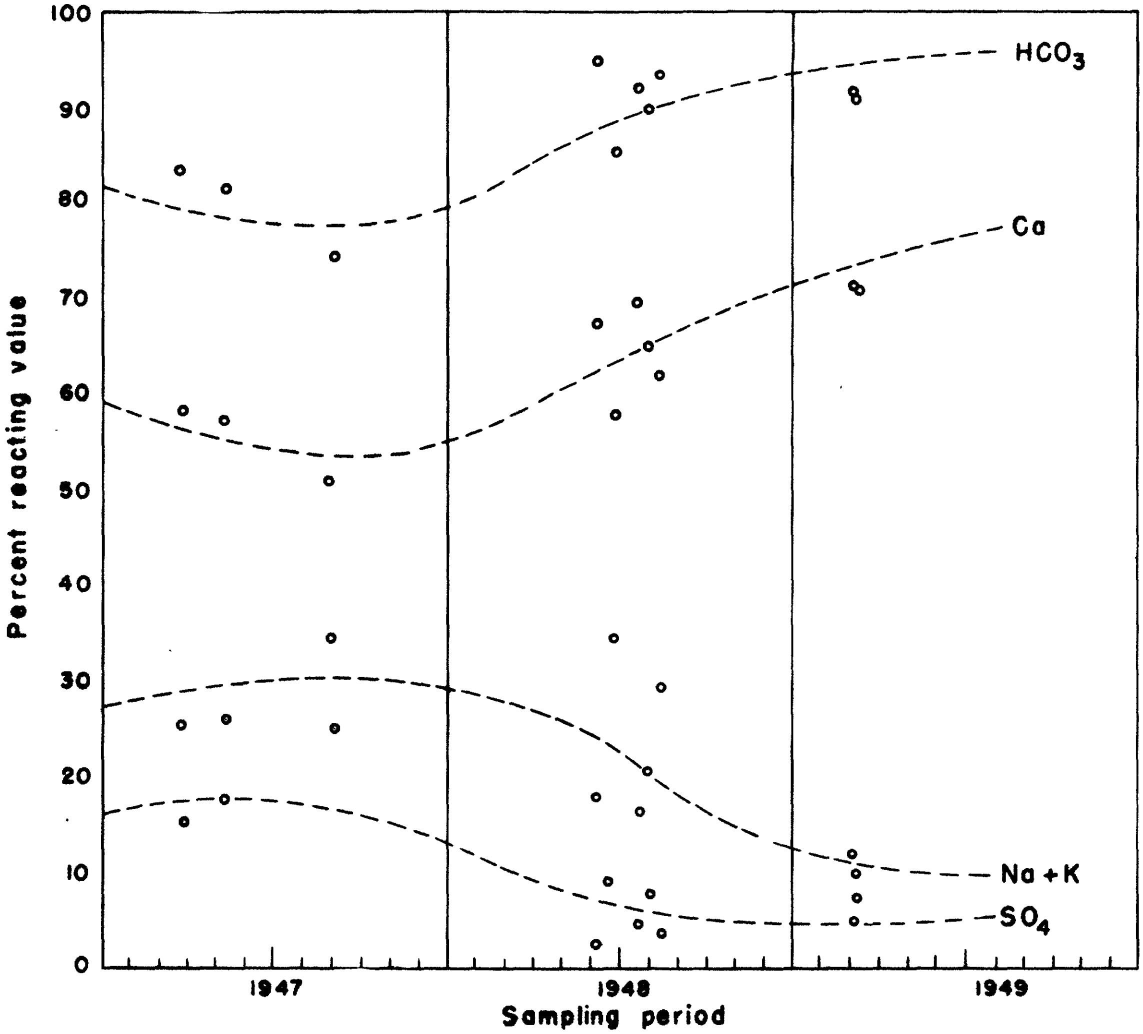



Figure 6.--Percentage of reacting value of several major ions, Middle Loup River at St. Paul.

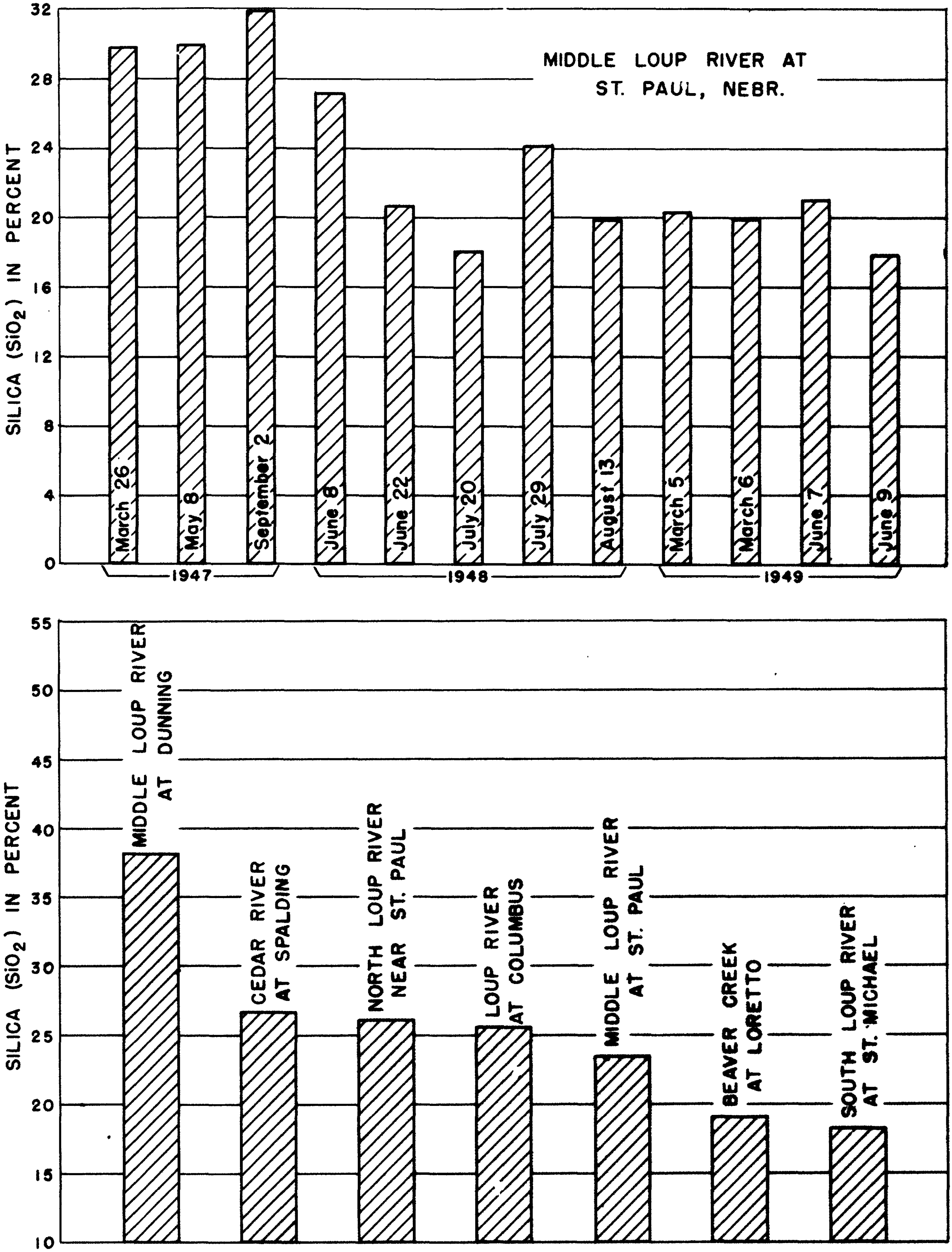



Figure 7.— — Trends in content of silica in waters, Loup River basin.

## SUMMARY

The chemical characteristics of surface waters in the Loup River basin indicate a substantial ground-water inflow from known subterranean formations. These waters are moderately mineralized and hard. The concentration of dissolved solids, composed largely of calcium bicarbonate and silica, ranged from 120 to 298 parts per million; hardness, as calcium carbonate, ranged from 62 to 198 parts per million.

Waters in the Middle Loup River at Dunning and the Cedar River at Spalding carry higher percentages (by weight) of silica than are found in other surface waters in the basin. Similarly, the waters at these two stations have higher percentages of primary alkalinity. This correlation supports evidence of other investigators that the primary alkalinity and the silica content in a water are related.

Concentrations of boron and percentages of sodium in the waters were low, and water impounded from any or all of these streams for irrigation should be suitable for crops under most conditions.

## LIST OF REFERENCES

Am. Public Health Assoc., 1946, Standard methods for the examination of water and sewage: 9th ed. 286 pp.

Collins, W. D., 1928, Notes on practical water analysis: U. S. Geol. Survey Water-Supply Paper 596-H, pp. 236-261.

Foote, F. J., 1932, Determination of boron in water: Ind. and Eng. Chemistry, Anal. ed., vol. 4, pp. 39-42.

Hill, R. A., 1942, Salts in irrigation water: Am. Soc. Civil Eng. Trans., vol. 68, no. 107, pt. 2, pp. 1478-1493.

Lugn, A. L., 1935, The Pleistocene geology of Nebraska: Nebraska Geol. Survey Bull. 10, 2d ser., p. 164.

Palmer, Chase, 1911, The geochemical interpretation of water analyses: U. S. Geol. Survey Bull. 479, p. 11.

Wilcox, L. V., 1932, Electrometric titration of boric acid: Ind. and Eng. Chemistry, Anal. ed., vol. 4, pp. 38-39.

Wilcox, L. V., 1948, The quality of water for irrigation use: U. S. Dept. Agr. Tech. Bull. 962, p. 27.