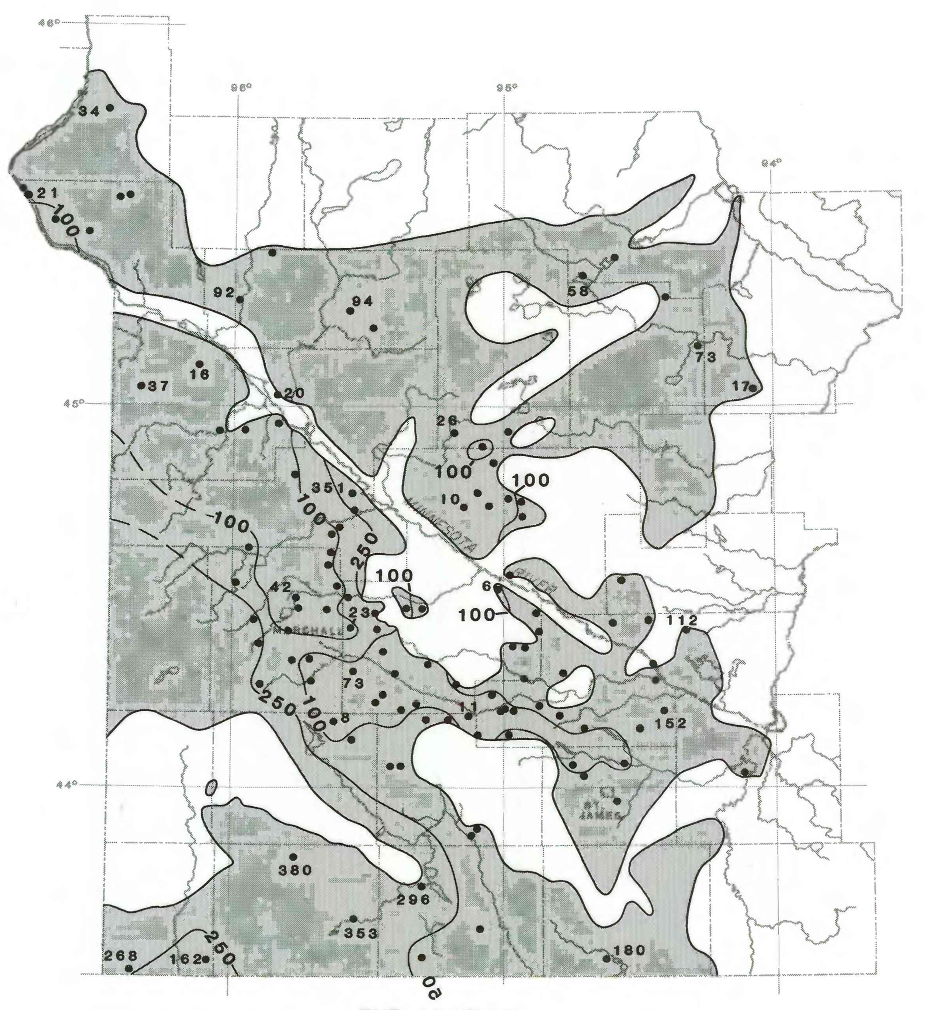
GROUND—WATER QUALITY



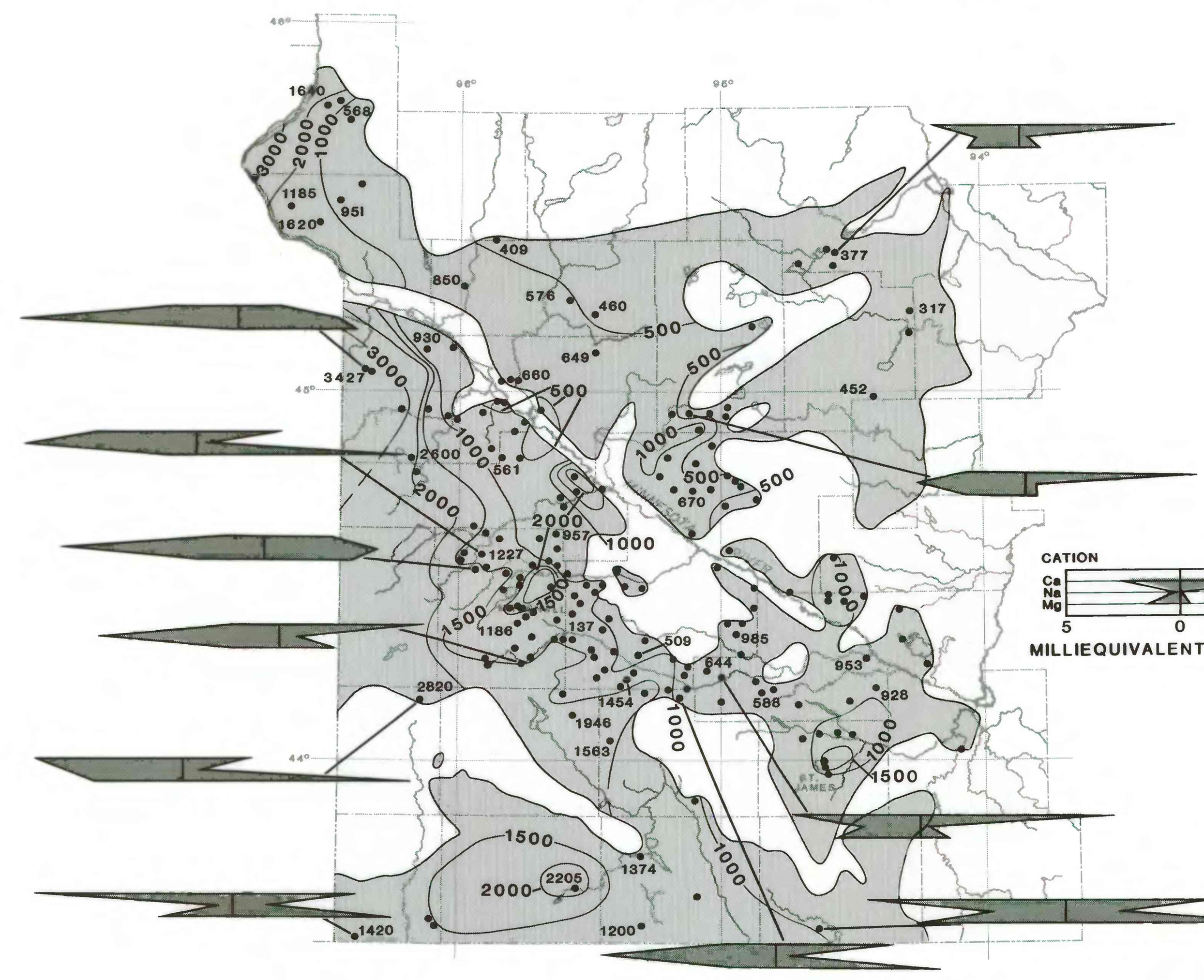
EXPLANATION

—100— — LINE OF EQUAL CALCIUM CONCENTRATION--Dashed where approximately located. Interval 100 and 150 milligrams per liter

AQUIFER

73 SAMPLING SITE--Number is value of representative concentration

Figure 10.--Concentration of calcium



EXPLANATION

—500— — LINE OF EQUAL DISSOLVED-SOLIDS CONCENTRATION--Dashed where approximately located. Interval 500 and 1000 milligrams per liter

AQUIFER

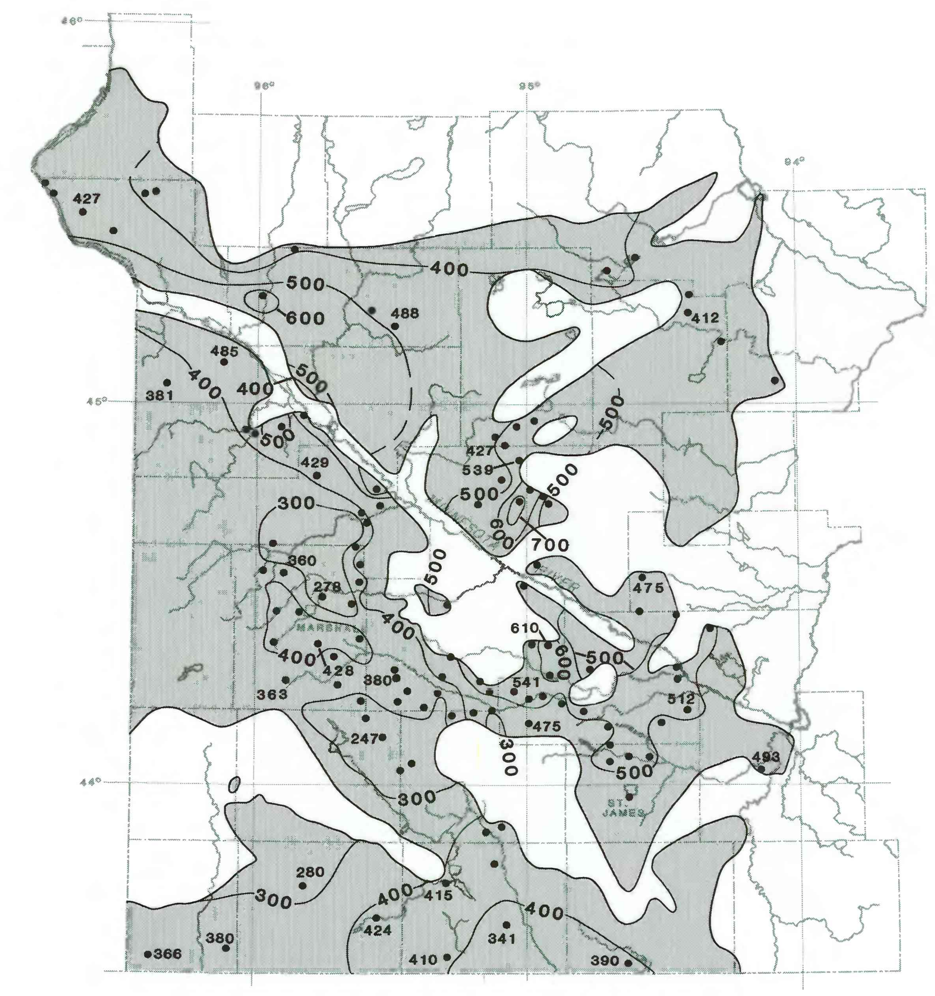
WATER-ANALYSIS PATTERN--Pattern is based on water analysis from indicated observation wells. Concentrations, in milliequivalents per liter, are plotted for calcium (Ca), sodium (Na), magnesium (Mg), bicarbonate (HCO_3), chloride (Cl), and sulfate (SO_4). The larger the area of the pattern, the greater the dissolved-solids concentration

CATION — ANION: Ca, Na, Mg — HCO_3, Cl, SO_4; 5 0 5 MILLIEQUIVALENTS PER LITER

953 SAMPLING SITE--Number is value of representative concentration

0 10 20 30 40 MILES
0 10 20 30 40 50 60 KILOMETERS

Figure 9.--Dissolved—solids concetrations and water—type patterns



EXPLANATION

—300— — LINE OF EQUAL BICARBONATE CONCENTRATION--Dashed where approximately located. Interval 100 milligrams per liter

AQUIFER

424 SAMPLING SITE--Number is value of representative concentration

Figure 13.--Concentration of bicarbonate

WATER QUALITY CHARACTERISTICS

Results of inorganic chemical analyses of 154 water samples collected primarily during the 1970's from wells in the Cretaceous aquifer were compiled from U.S. Geological Survey studies and WATSTORE files, National Uranium Resource Evaluation (NURE) records of the U.S. Department of Energy, and Minnesota Department of Health records of municipal water supplies. All analyses were checked for cation-anion balance, and only those that balanced within 10 percent were used for statistical evaluation. The mean, median, and range of concentrations of selected chemical constituents and specific conductance from the analyses, and selected U.S. Environmental Protection Agency criteria for public supply are given in table 1.

Maps showing the dissolved-solids concentration and concentrations of calcium, sodium, magnesium, bicarbonate, chloride, and sulfate in water from the Cretaceous aquifer are presented in figures 9 through 15.

Concentrations of sodium, chloride, and sulfate (figs. 11, 14, and 15) are generally highest in the western part of the aquifer between the Coteau and the Minnesota River. Ground water with high concentrations of these ions moves into the Cretaceous aquifer in Minnesota as inflow from adjacent areas in South Dakota. In the area between the Sioux Quartzite ridge and the Minnesota River, concentrations of calcium and magnesium (figs. 10 and 12) generally increase to the southwest and toward the Minnesota River. Concentrations of bicarbonate generally increase toward the Minnesota River (fig. 13).

Dissolved Solids

Dissolved-solids concentration--the weight of substances dissolved in a given volume of water--is a commonly used guideline in evaluating water quality and in comparing waters from different areas. Water with less than 500 mg/L dissolved solids generally is considered to be satisfactory for domestic and industrial uses, and the U.S. Environmental Protection Agency (1979) has proposed that 500 mg/L be the recommended maximum concentration of dissolved solids for drinking water. Furthermore, the U.S. Geological Survey (Robinove and others, 1958) has assigned terms for waters of high dissolved solids, as follows: slightly saline, concentrations between 1,000 and 3,000 mg/L; moderately saline, concentrations between 3,000 and 10,000 mg/L.

Water in the Cretaceous aquifer generally is slightly saline southwest of the Minnesota River, but is fresher northeast and southeast of the river (fig. 9). The mean dissolved-solids concentration, determined from results of 154 analyses, was 1,070 mg/L; concentrations ranged from 251 to 3,540 mg/L (table 1). The highest concentration is in the extreme western part of the area (fig. 9) where highly mineralized water in the aquifer flows into Minnesota from South Dakota (fig. 8). The decrease in dissolved-solids concentration between the Sioux Quartzite ridge and the Minnesota River suggests recharge of fresher water through the relatively thin overlying drift. Isolated areas of higher dissolved-solids concentrations (fig. 9) primarily reflect water samples that were collected from deeper parts of the aquifer, and that, consequently, have had a longer residence time in the aquifer.

Water Types and Major Ions

Water may be classified chemically on the basis of relative concentrations of major cations and anions. In this report, a water type was defined for a water sample having at least 60 percent of the dominant cations and at least 60 percent of the dominant anion. A mixed water type has either no predominant cations or no predominant anion. Water from the Cretaceous aquifer includes five chemical types. Of the 154 water samples, 38 percent were mixed types, 21 percent were calcium-magnesium sulfate type, 20 percent were calcium-magnesium bicarbonate type, 14 percent were sodium sulfate type, 6 percent were sodium bicarbonate type, and 1 percent were sodium chloride type. The Stiff diagrams in figure 9 illustrate results of ground-water analyses. The location of water types is shown by township in figure 16. Townships containing ground water of more than one chemical type are shown by composite symbols. The mixing of water types occurs throughout the aquifer (fig. 16), particularly in lowland areas adjacent to the Minnesota River.

In southwestern Minnesota, calcium-magnesium sulfate type water is commonly found in end moraines (Novitzki and others, 1969; Broussard and others, 1973) and in clayey till (Maclay and others, 1968). In the Cretaceous aquifer, this water type occurs in the southwest (fig. 16) where the aquifer is overlain by the Bemis and Altamont moraines (fig. 6). The high concentration of sulfate in the southwestern part of the aquifer (fig. 15) probably is caused by the leaching and oxidizing of sulfate- and sulfide-rich minerals, such as gypsum and iron sulfide, from the drift (Winter, 1974), and by inflow from the west in the area north of the Sioux Quartzite ridge.

Calcium-magnesium bicarbonate type water is the most common ground-water type in Minnesota; it occurs locally in the uppermost part of the ground-water system in most recharge areas (Winter, 1974). Water from wells completed in sand and gravel and in ground-moraine deposits in southwestern Minnesota generally is a calcium-magnesium bicarbonate type (Broussard and others, 1973). In the Cretaceous aquifer, this water type is present primarily northeast and immediately southwest of the Minnesota River (fig. 16). The probable source of the calcium-magnesium bicarbonate type water in the aquifer is by leakage from overlying drift deposits.

Sodium sulfate type water is present in the Cretaceous aquifer in areas between the Coteau and the Minnesota River (fig. 16), and probably is derived from movement by sulfate type water from the drift into sodium chloride type water in the underlying Cretaceous aquifer (Winter, 1974), by ion exchange, and by underflow of sodium sulfate type water from South Dakota.

Sodium bicarbonate type water is present at depth in the Cretaceous aquifer primarily northeast of the Minnesota River (fig. 16). Calcium in water percolating through the Cretaceous aquifer from overlying drift aquifers is exchanged for sodium through cation exchange (Adolphson and others, 1981).

Sodium chloride type water is present in the Cretaceous aquifer southwest of the Minnesota River (fig. 16), partially as a result of inflow from South Dakota (Adolphson and others, 1981) and partially from unknown sources. In the area north of the Sioux Quartzite ridge, the decrease in chloride concentration downgradient (fig. 14) is an indicator of recharge through the overlying drift.

Table 1.--Mean, median, and range in concentration of selected constituents and properties of water from the Cretaceous aquifer

[Values are given in milligrams per liter, except as indicated. micromhos per centimeter, µmhos/cm; microgram per liter, µg/L]

Constituent or property	Recommended maximum or range for public supply[1]	Number of analyses	Mean	Median	Minimum	Maximum
Specific conductance (µmho/cm at 25°C)...	---	129	1,610	1,490	445	5,360
Hardness as CaCO3 (Mg,Ca)...	---	52	570	326	22	1,600
Calcium, dissolved (Ca)...	---	154	130	93	0.7	480
Magnesium, dissolved (Mg)...	---	152	44	38	0.2	150
Sodium, dissolved (Na)...	---	154	180	120	4.5	1,200
Potassium, dissolved (K)...	---	143	8	7	0.8	73
Bicarbonate (HCO3)...	---	154	432	410	91	910
Sulfate, dissolved (SO4)...	250	154	462	380	0.5	1,300
Chloride, dissolved (Cl)...	250	68	84	10	1	1,500
Silica, dissolved (SiO2)...	---	143	11	14	0.8	61
Dissolved solids, calculated...	500	154	1,070	961	251	3,540

[1] U.S. Environmental Protection Agency, 1979.

Water-Quality Problems

Dissolved-solids, chloride, and sulfate concentrations in the Cretaceous aquifer locally exceed standards recommended by the U.S. Environmental Protection Agency for public supply (table 1), particularly in areas southwest of the Minnesota River (figs. 9, 13, and 15). Hardness and high boron concentrations also limit use of the water for municipal and industrial supplies and for irrigation (Broussard and others, 1973).

Shale in the upper part of the Dakota Formation and in the Colorado Group and thick drift deposits act as confining beds and protect the Cretaceous aquifer from contaminants on or near land surface. However, the aquifer subcrops beneath relatively thin drift southwest of the Minnesota River (fig. 6), where percolation of contaminants from the land surface to the aquifer is a potential problem. Other conditions that create the potential for contamination of the Cretaceous aquifer are faults and fractures in the overlying confining beds, and buried bedrock valleys filled with permeable deposits that intersect the aquifer. Contaminants can also enter the aquifer through multiaquifer wells and deteriorated or improperly grouted well casings.

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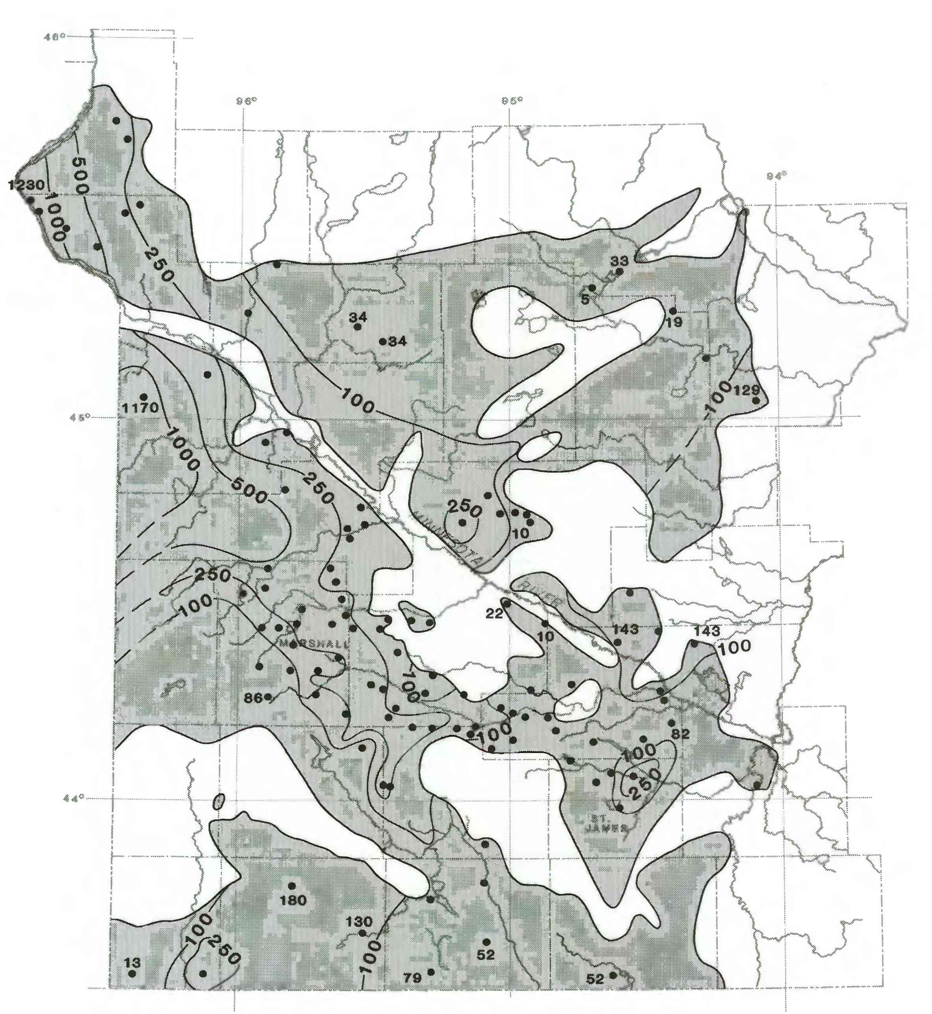


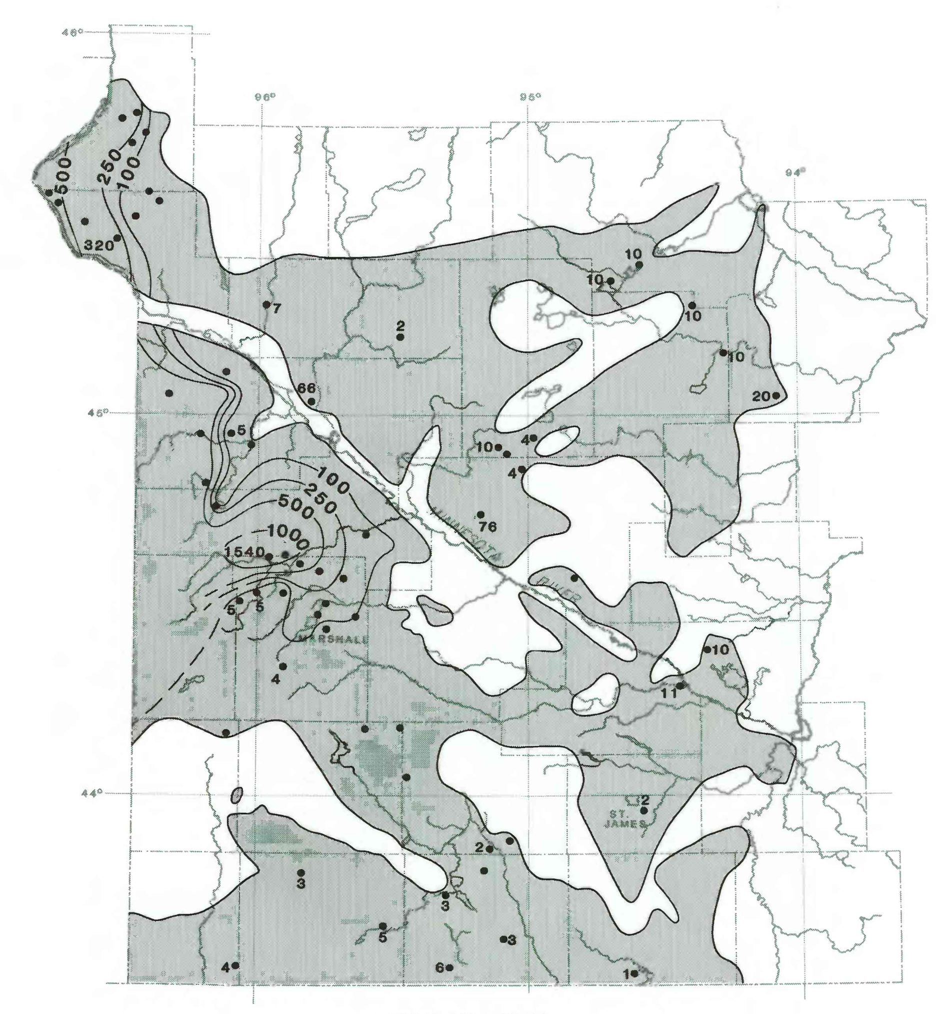
EXPLANATION

—250— — LINE OF EQUAL SODIUM CONCENTRATION--Dashed where approximately located. Interval variable, in milligrams per liter

AQUIFER

52 SAMPLING SITE--Number is value of representative concentration

Figure 11.--Concentration of sodium



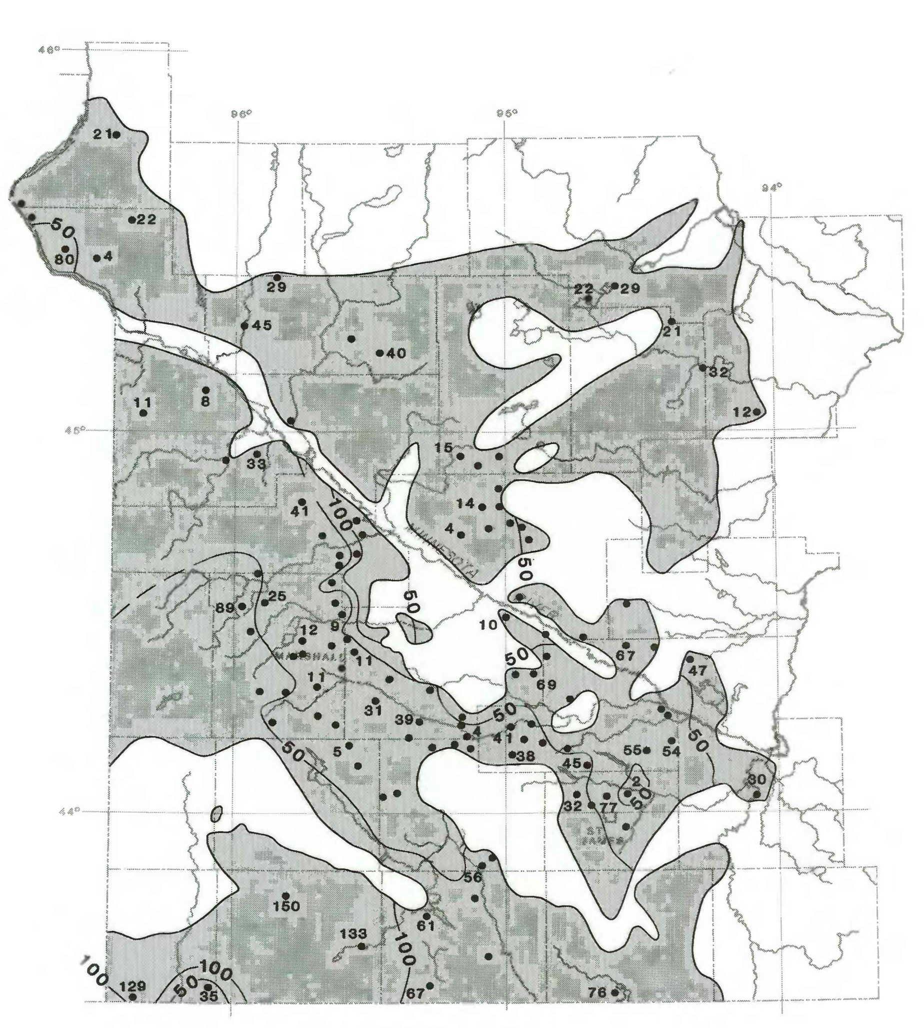
EXPLANATION

—500— — LINE OF EQUAL CHLORIDE CONCENTRATION--Dashed where approximately located. Interval variable, in milligrams per liter

AQUIFER

3 SAMPLING SITE--Number is value of representative concentration

Figure 14.--Concentration of chloride



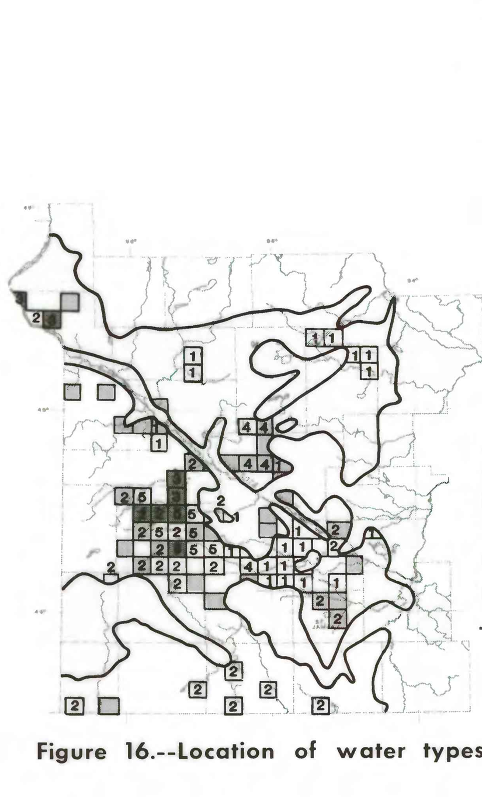
EXPLANATION

—50— — LINE OF EQUAL MAGNESIUM CONCENTRATION--Dashed where approximately located. Interval 50 milligrams per liter

AQUIFER

75 SAMPLING SITE--Number is value of representative concentration

Figure 12.--Concentration of magnesium



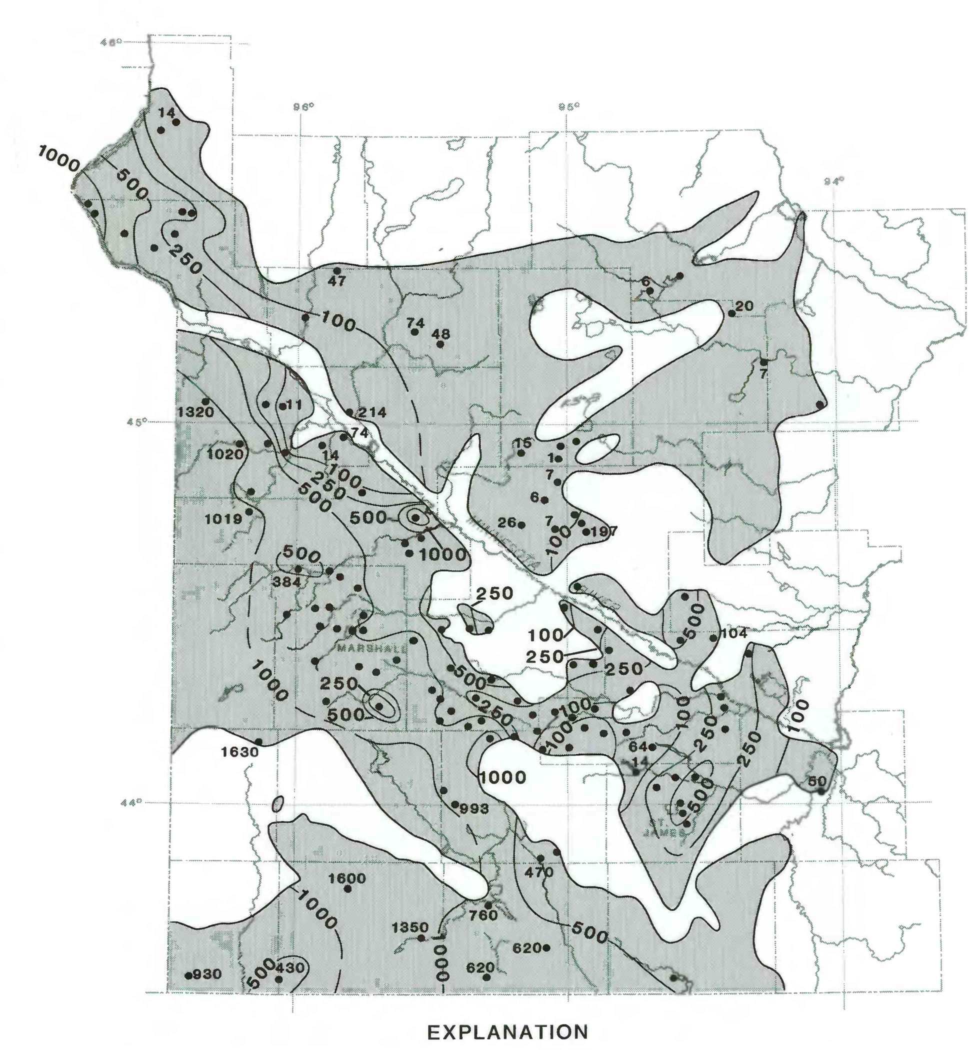
EXPLANATION

WATER TYPES IN CRETACEOUS AQUIFER, BY TOWNSHIP

1 Calcium-magnesium bicarbonate
2 Calcium-magnesium sulfate
3 Sodium chloride
4 Sodium bicarbonate
5 Sodium sulfate
Mixed types
— AQUIFER BOUNDARY

0 10 20 30 MILES
0 10 20 30 KILOMETERS

Figure 16.--Location of water types in Cretaceous aquifer



EXPLANATION

—100— — LINE OF EQUAL SULFATE CONCENTRATION--Dashed where approximately located. Interval variable, in milligrams per liter

AQUIFER

47 SAMPLING SITE--Number is value of representative concentration

Figure 15.--Concentration of sulfate

HYDROGEOLOGIC AND WATER—QUALITY CHARACTERISTICS OF THE CRETACEOUS AQUIFER, SOUTHWESTERN MINNESOTA

BY
D. G. WOODWARD AND H. W. ANDERSON JR., 1986

Base from U.S. Geological Survey State base map, 1:1,000,000, 1965

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