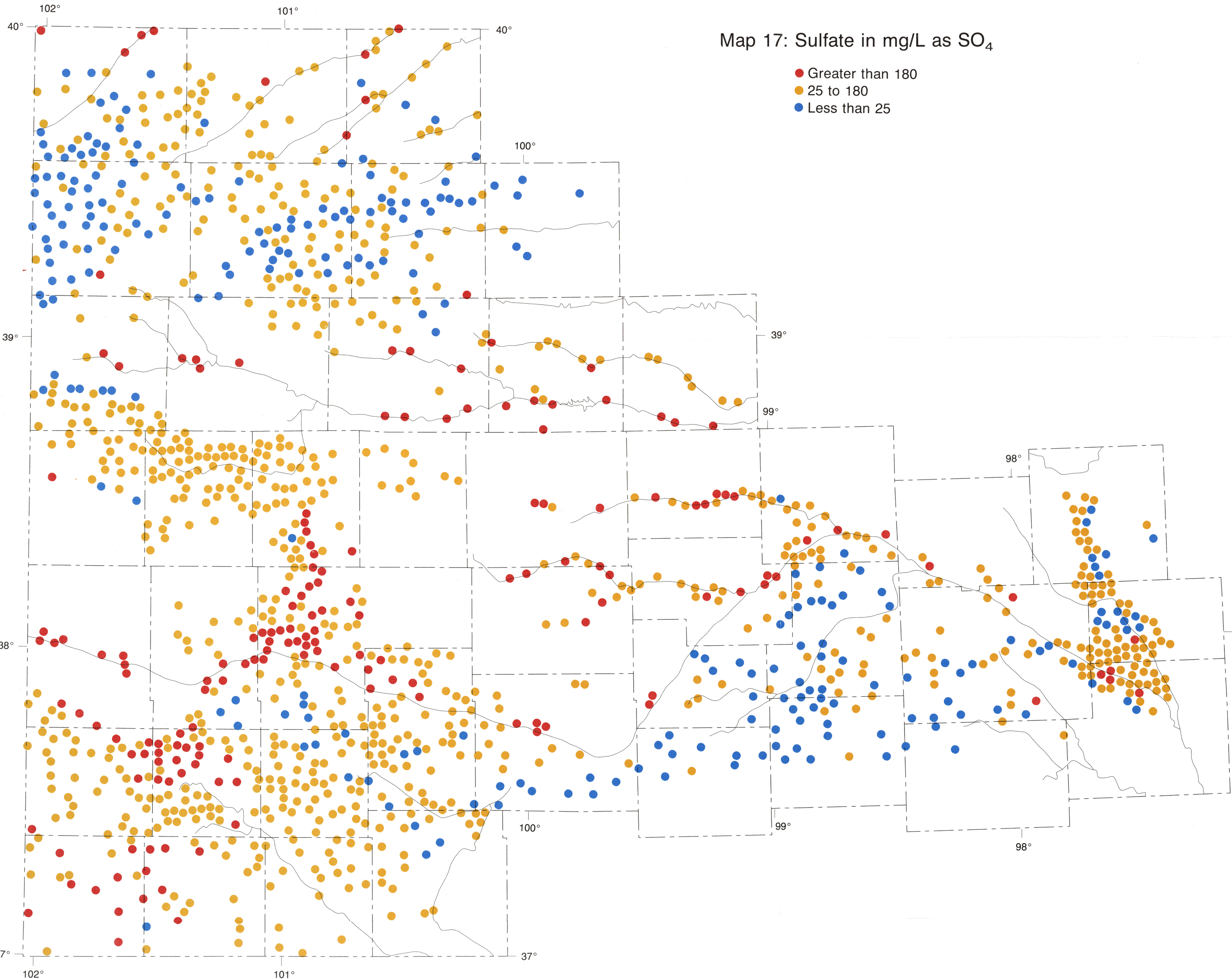


by
L. R. Hathaway and L. M. Magnuson
Kansas Geological Survey
1985

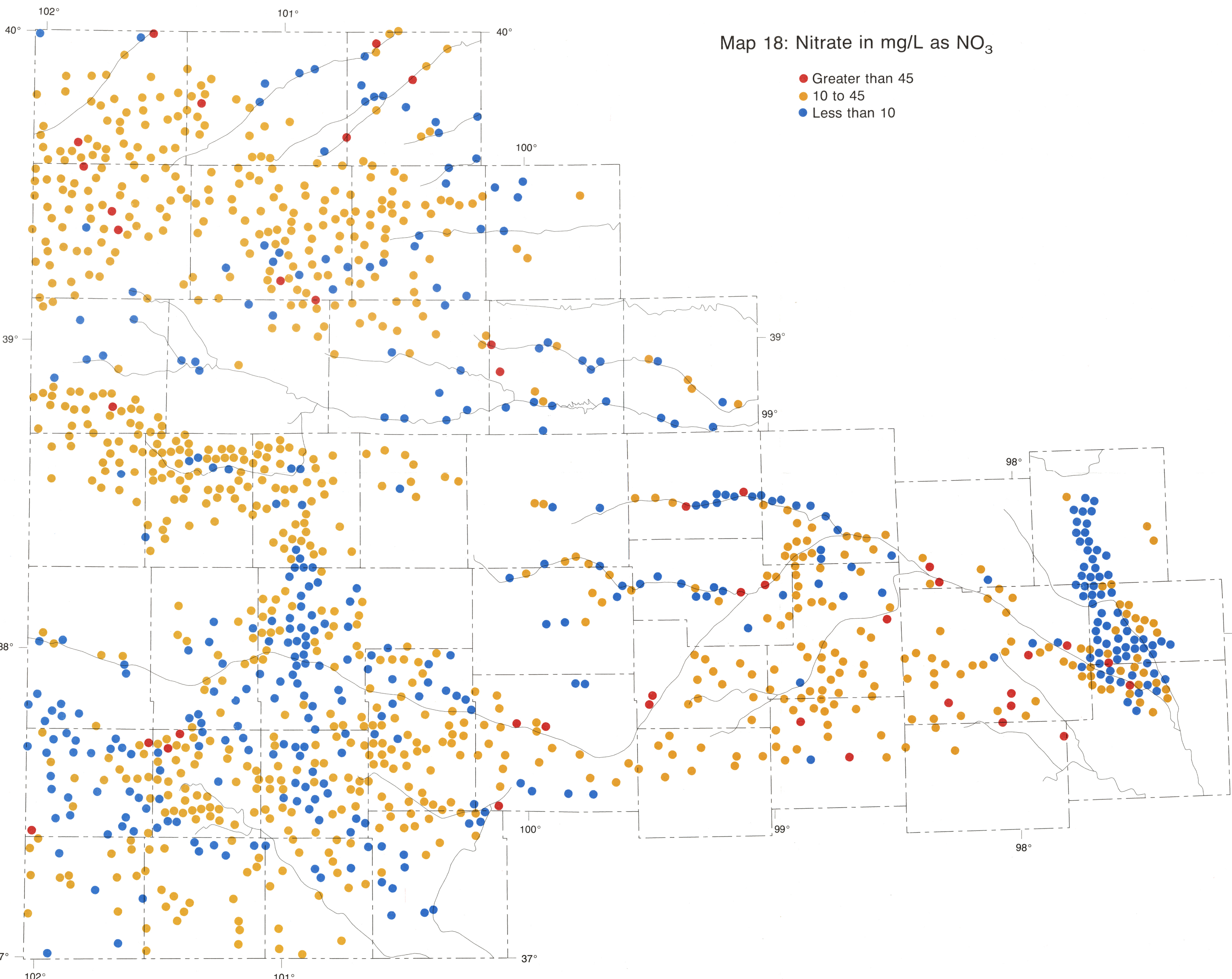
Map 17: Sulfate in mg/L as SO₄

- Greater than 180
- 25 to 180
- Less than 25



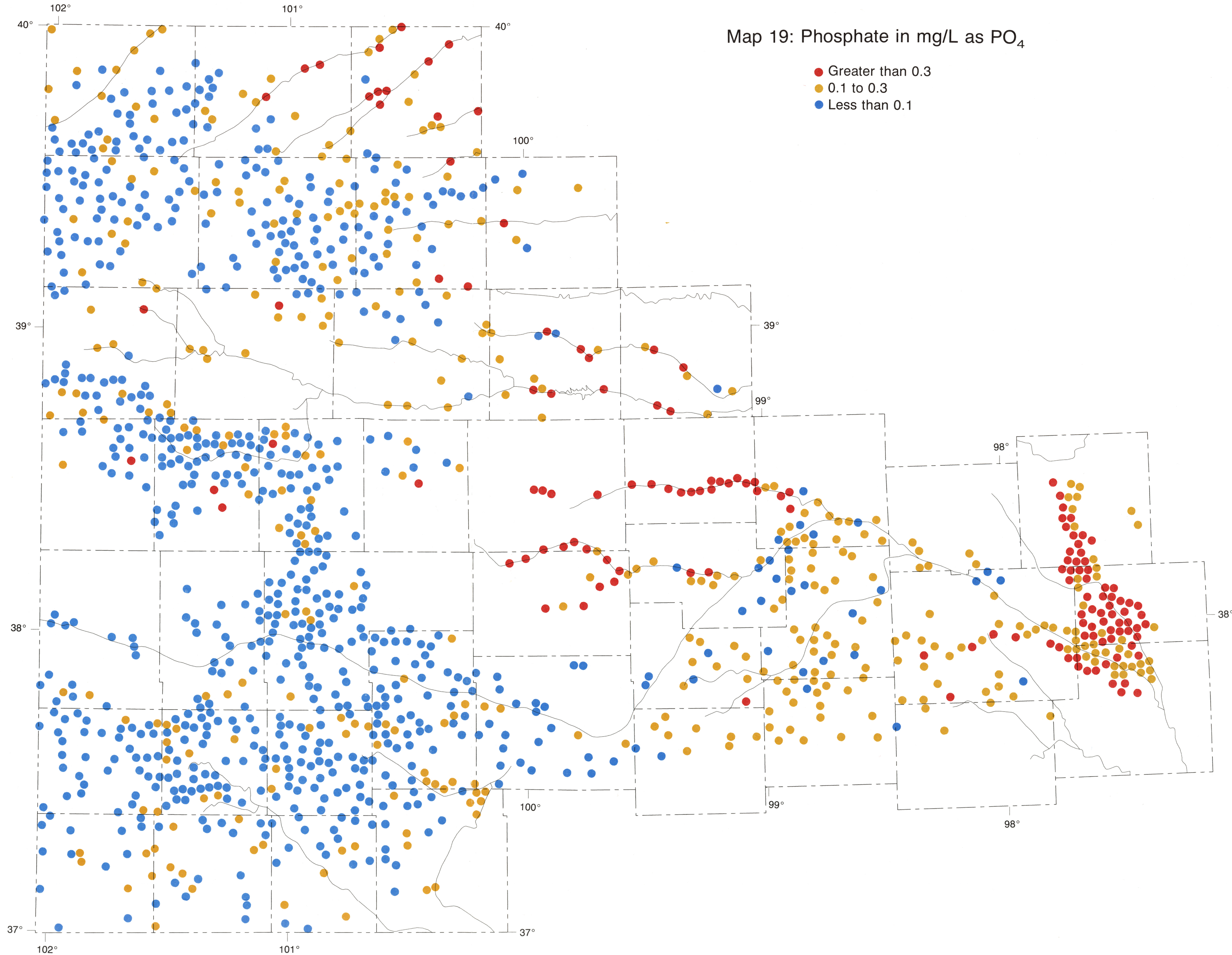
Map 18: Nitrate in mg/L as NO₃

- Greater than 45
- 10 to 45
- Less than 10



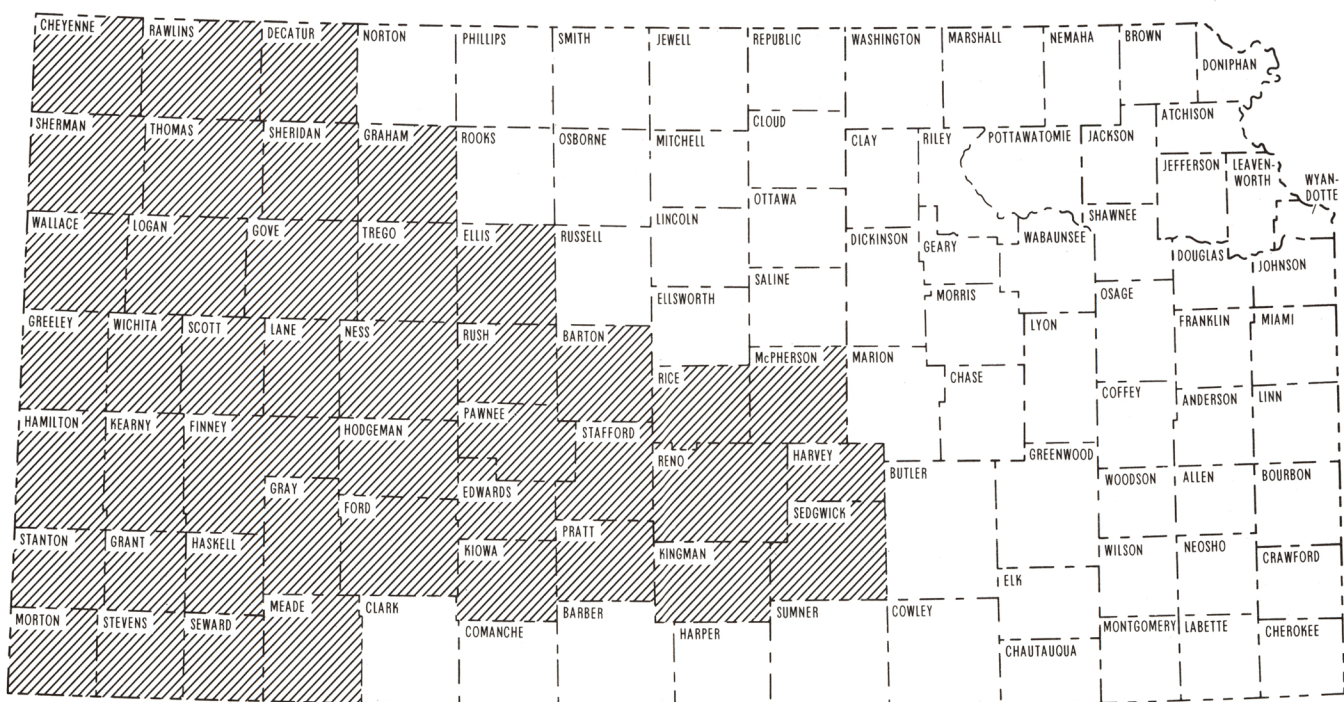
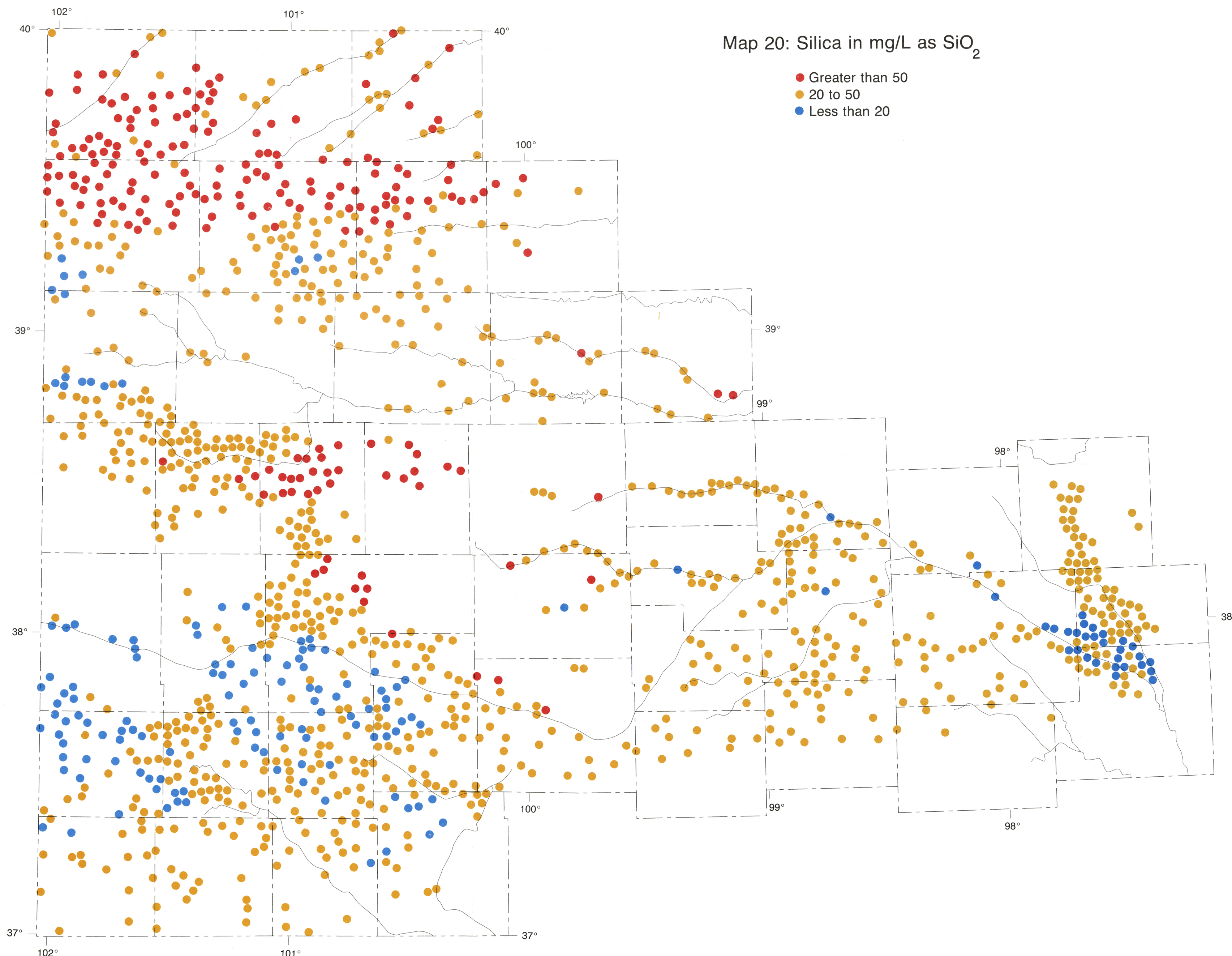
Map 19: Phosphate in mg/L as PO₄

- Greater than 0.3
- 0.1 to 0.3
- Less than 0.1



Map 20: Silica in mg/L as SiO₂

- Greater than 50
- 20 to 50
- Less than 20



Index map of study area.

Sulfur is widely distributed in the geochemical environment. It is present in reduced form in metallic sulfide minerals which are found in both igneous and sedimentary rocks. Sulfur is present also in some sedimentary units in an oxidized form as sulfate minerals such as gypsum (CaSO₄·2H₂O) and anhydrite (CaSO₄). Sulfate anion (SO₄²⁻) is the dominant sulfur species in the hydrogeochemical environment where it tends to form ion-pair complexes with cations present. Metal sulfides in contact with aerated water are oxidized, yielding acidic sulfate-rich solutions. However, certain types of bacteria in a reducing environment containing a suitable food supply can reduce sulfate, producing in solution H₂S below pH7 or HS⁻ above pH7. No evidence of soluble-reduced sulfur species was found for ground water from the unconsolidated aquifer of the study area.

Map 17 displays sulfate concentrations in ground water of the study area. Concentrations in excess of 180 ppm are associated with ground water near drainageways and in areas of restricted surface drainage and shallow water tables. In these areas sulfate often becomes the dominant anion of the dissolved-solids load of the ground water. Saline soils in these environs often reflect regions where the concentrations of calcium and sulfate locally may have exceeded the solubility conditions for gypsum. Scattered low-sulfate concentrations, like low-chloride levels (Map 15), are present in ground water from upland areas in the northwestern part of the study area. The low-concentration zone south of the Arkansas River which trends south and eastward from Kearny County is a feature of the sulfate map which has counterparts in other maps of this atlas. Sulfate concentrations in excess of 180 ppm in ground water of Morton and western Stevens counties are problematic, but may be related to factors responsible for Mg/Ca mole ratios > 1.0 and fluoride concentrations > 2 ppm (Map 16) in ground water of the southwestern portion of the study area.

Both nitrogen and phosphorus belong to the same chemical family of elements and exhibit a multiplicity of oxidation states from -3 to +5 in their compounds. A major difference exists in the occurrence of these two elements at the earth's surface. Nitrogen in the free gaseous state makes up about 80% of the volume of the earth's atmosphere and is the principal source of the element. Phosphorus, as phosphate (PO₄³⁻), is widely distributed in igneous rocks as a component of the mineral apatite and is concentrated in phosphorite deposits in sedimentary units. Both elements are essential to biological activity and are present in the waste of such activity.

In the hydrogeochemical environment, chemical species of nitrogen and phosphorus in the +5 oxidation state are of greatest importance. Nitrogen exists as nitrate anions (NO₃⁻); in the 7 to 8 pH range of most ground water of the study area, phosphorus is distributed between the phosphate anions HPO₄²⁻ and H₂PO₄⁻. Differences in chemical behavior lead to a separation of nitrate and phosphate in natural waters. Nitrate has little tendency to form complexes with cations common to natural waters and nitrate salts are noted for their solubility. In contrast, phosphate tends to form polymeric and ionic complexes and many of its compounds exhibit low solubility. Accordingly, in most ground water of the study area, nitrate concentrations exceed phosphate concentrations by a large margin. Certain types of bacteria in soil can fix atmospheric nitrogen as nitrate. Other bacteria in suitable environments are capable of reducing nitrate, with ammonium ion (NH₄⁺) being one possible end product. Nitrogen present in natural water as ammonium ion may be retained on clay minerals through ion-exchange reactions.

Nitrate-concentration data for ground water of the study area are presented in Map 18. Nitrate levels in excess of 45 ppm are mostly found in ground water associated with drainageways of the study area. 45 ppm NO₃ corresponds approximately to the 10 ppm nitrate as nitrogen-primary-pollutant limit set for drinking water by the U.S. Environmental Protection Agency. Ingestion of high-nitrate water may lead to methemoglobinemia in infants and produce adverse effects in farm animals. Only about 3.5% of the collection sites used in this study produced water which exceeded this limit and 75% have NO₃ levels below 20 ppm. The practice of injecting liquid fertilizer into the flow stream of an irrigation well provides the potential for local pollution of the aquifer as well as possible contamination of water samples collected at the well. Nitrate-containing leachate from animal lots also poses a threat to shallow ground-water regimes. At the other end of the spectrum, ground water from a number of wells in McPherson and Harvey counties is conspicuous for its low nitrate content of less than 1 ppm. An ammonium-ion concentration of 0.8 ppm and the presence of 5.5 ppm iron, 1.1 ppm manganese, and 2.0 ppm phosphate in water from one of these wells indicate a reducing environment in this part of the aquifer system.

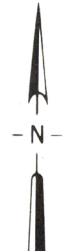
The total concentration of all soluble phosphate species in ground water of the study area is reported in terms of ppm PO₄ in Map 19. Phosphate levels in ground water from upland areas in the western half of the study area are typically below 0.1 ppm. In this same region phosphate concentrations above 0.3 ppm are found in near proximity to drainageways which are located north of the Arkansas River; the area south of the Arkansas River being devoid of high-phosphate levels. The general phosphate concentration of the ground water increases upon moving into the eastern half of the study area and reaches an average concentration of about 0.5 ppm in ground water from McPherson, Harvey, and Sedgwick counties along the eastern boundary of the study area. Reasons for these north-south and west-east variations in phosphate concentration are not readily apparent.

Silicon and carbon are members of the same chemical family of elements. The importance of carbon as a fundamental building unit in the biochemical realm is matched by the importance of silicon in tetrahedral SiO₄⁴⁻ to the structure of many minerals making up rocks and soils in the geochemical environment. Concentrations of silicon in natural waters are usually reported in terms of ppm silica (SiO₂), but the element probably is present in solution as a hydrated species such as H₄SiO₄. Concentrations of silica in natural waters typically lie between the solubility values of quartz (6 ppm at 25°C) and amorphous silica (115 ppm at 25°C).

Map 20 indicates that silica concentrations above 50 ppm in ground water of the study area are only to be found north of the Arkansas River. A small cluster of high-silica values is found in the west-central part of the study area, but the principal region of high ground-water silica concentration is north of the Smoky Hill River valley in the northwestern corner of the state. Silica concentrations in ground water south of the Arkansas River, where areas of dunes and sandy soils exist, average about 25 ppm. Uncertainty exists regarding sources responsible for the high silica content of ground water from the northwestern part of the study area, but volcanic ash disseminated in aquifer sediments of the area is one possibility. Previous movement of silica-rich fluids in this area is inferred today from local exposures of silicified sediments along drainageways.

Selected readings

1. Berendsen, P., and Hathaway, L. R., 1981, Uranium in unconsolidated aquifers of western Kansas: Kansas Geological Survey, Mineral Resources Series 9, 43 p.
2. Hathaway, L. R., Carr, B. L., Flanagan, M. A., Galle, O. K., Waugh, T. C., and Dickey, H. P., 1978, Chemical quality of irrigation waters in southwestern Kansas: Kansas Geological Survey, Chemical Quality Series 6, 33 p.
3. Hathaway, L. R., Carr, B. L., Galle, O. K., Magnuson, M. L., Waugh, T. C., and Dickey, H. P., 1977, Chemical quality of irrigation waters in Hamilton, Kearny, Finney, and northern Gray counties: Kansas Geological Survey, Chemical Quality Series 4, 33 p.
4. Hathaway, L. R., and Dickey, H. P., 1978, Soil associations of southwestern Kansas: Kansas Geological Survey, Map M-84.
5. ———, 1980, Soil associations of northwestern Kansas: Kansas Geological Survey, Map M-88.
6. ———, 1982, Soil associations of south-central Kansas: Kansas Geological Survey, Map M-90.
7. Hathaway, L. R., Galle, O. K., Waugh, T. C., and Dickey, H. P., 1978, Chemical quality of irrigation waters in Ford County and the Great Bend Prairie of Kansas: Kansas Geological Survey, Chemical Quality Series 7, 41 p.
8. Hathaway, L. R., Magnuson, L. M., Carr, B. L., Galle, O. K., and Waugh, T. C., 1975, Chemical quality of irrigation waters in west-central Kansas: Kansas Geological Survey, Chemical Quality Series 2, 45 p.
9. Hathaway, L. R., Waugh, T. C., Galle, O. K., and Dickey, H. P., 1979, Chemical quality of irrigation waters in northwestern Kansas: Kansas Geological Survey, Chemical Quality Series 8, 45 p.
10. ———, 1981, Chemical quality of irrigation waters in the Equis Beds area, south-central Kansas: Kansas Geological Survey, Chemical Quality Series 10, 45 p.
11. Chemical-quality data for ground waters from the Smoky Hill River, Pawnee River, and Walnut Creek valleys: Kansas Geological Survey, Open-File Report 80-18 (available from L. R. Hathaway).



Scale 1:1,000,000
0 10 20 30 40 mi
0 10 20 30 40 50 km

The county boundaries, streams, contours of saturated thickness shown on Plate 1, and color-separated dot symbols on all five plates were produced by computer in the Automated Cartography Laboratory of the Kansas Geological Survey. Dot symbols were generated from supplied locations. Software used to perform these tasks is a part of GIMMAP (Geodata Interactive Management: Map Analysis and Production), a computer-assisted cartography system developed at the Kansas Geological Survey. All other preparation and layout by Renate Hensiek.