

QUALITY OF GROUND WATER IN ROUTT COUNTY, NORTHWESTERN COLORADO

U. S. GEOLOGICAL SURVEY



Water-Resources Investigations
Open-File Report 80-956

Prepared in cooperation with the
Routt County Regional Planning Commission
Routt County Department of Environmental Health



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By Kenneth J. Covay and Robert L. Tobin

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GLOSSARY

aquifer.--A geologic formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs.

bacteria.--Microscopic unicellular organisms; typically spherical, rodlike, or spiral and threadlike in shape, often clumped into colonies. Some bacteria cause disease while others perform essential roles in the recycling of materials by decomposing organic matter into a form available for reuse by plants.

fecal-coliform bacteria.--Bacteria that are present in the intestines or feces of warmblooded animals. They are commonly used as indicators of the sanitary quality of the water. In the laboratory they are defined as all organisms that produce blue colonies within 24 hours when incubated at $44.5^{\circ}\text{C} \pm 0.2^{\circ}\text{C}$ on M-FC medium (nutrient medium for bacterial growth). Their concentrations are expressed as number of colonies per 100 mL (milliliters) of sample.

total-coliform bacteria.--A particular group of bacteria that are used as indicators of possible sewage pollution. This group is characterized as aerobic or facultative anaerobic, gram-negative, nonspore-forming, rod-shaped bacteria which ferment lactose with gas formation within 48 hours at 35°C . In the laboratory these bacteria are defined as all the organisms that produce colonies with a golden-green metallic sheen within 24 hours when incubated at $35^{\circ}\text{C} \pm 1.0^{\circ}\text{C}$ on M-Endo medium (nutrient medium for bacterial growth). Their concentrations are expressed as number of colonies per 100 mL of sample.

dissolved.--The material in a representative water sample that passes through a 0.45-micrometer membrane filter. This is a convenient operational definition used by Federal agencies that collect water data. Determinations of "dissolved" constituents are made on subsamples of the filtrate.

dissolved solids.--The total concentration of all determined constituents that are converted mathematically into compounds in which they would normally exist in an anhydrous state.

hardness.--The physical-chemical characteristic of water that is commonly recognized by the increased quantity of soap required to produce lather. Hardness is attributable to the presence of alkaline earths (principally calcium and magnesium) and is expressed as equivalents of calcium carbonate (CaCO_3).

micrograms per liter ($\mu\text{g/L}$).--A unit expressing the concentration of chemical constituents in solution as mass (micrograms) of solute per unit volume (liter) of water. One thousand micrograms per liter are equivalent to 1 milligram per liter.

milligrams per liter (mg/L).--A unit for expressing the concentration of chemical constituents in solution. Milligrams per liter represent the mass of solute per unit volume (liter) of water. Concentration of suspended sediment also is expressed in milligrams per liter, and is based on the mass of sediment per liter of water-sediment mixture.

sodium-adsorption ratio (SAR).--The expression of relative activity of sodium ions in exchange reactions with soil and an index of sodium or alkali hazard to the soil. This ratio should be known, especially for water used for irrigating farmland. The formula for sodium-adsorption ratio is:

$$\text{SAR} = \sqrt{\frac{\text{Sodium } (\text{Na}^+)}{\frac{\text{Calcium } (\text{Ca}^{++}) + \text{Magnesium } (\text{Mg}^{++})}{2}}}$$

The ionic concentrations are expressed in milliequivalents per liter.

specific conductance.--A measure of the ability of a water to conduct an electrical current (reciprocal of resistance) is expressed in micromhos per centimeter at 25°C . Because specific conductance is related to the number and specific chemical types of ions in solution, it can be used to approximate the dissolved-solids concentration in the water. Commonly, the amount of dissolved solids (in milligrams per liter) is about 65 percent of the specific conductance (in micromhos per centimeter at 25°C). This relation is not constant from stream to stream or from well to well, and it may even vary in the same source with changes in the composition of the water.

CONVERSION FACTORS

For those readers who may prefer to use metric units rather than inch-pound units, the conversion factors for the terms used in this report are listed below:

<i>Multiply inch-pound unit</i>	<i>By</i>	<i>To obtain metric unit</i>
foot (ft)	0.3048	meter
square mile (mi^2)	2.590	square kilometer
gallon per minute (gal/min)	0.06309	liter per second

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ABSTRACT

Chemical and bacteriological data were collected to describe the quality of water from selected geologic units in Routt County, Colo. Calcium bicarbonate was the dominant water-chemistry type; magnesium, sodium, and sulfate frequently occurred as codominant ions. Specific-conductance values ranged from 50 to 6,000 micromhos. Mean values of specific conductance, dissolved solids, and hardness from the sampled aquifers were generally greatest in waters from the older sedimentary rocks of the Lance Formation, Lewis Shale, Mesaverde Group, and Mancos Shale, and least in the ground waters from the alluvial deposits, the Browns Park Formation, and the basement complex. Direct correlations of specific conductance with dissolved solids and specific conductance with hardness were found within specified limits.

On the basis of water-quality analyses, water from the alluvial deposits, the Browns Park Formation, and the basement complex generally is the most suitable for domestic uses. Chemical constituents in water from wells or springs that exceeded State and Federal standards for public-water supplies or State criteria for agricultural uses were pH, arsenic, boron, chloride, iron, fluoride, manganese, nitrite plus nitrate, selenium, sulfate, or dissolved solids. Total-coliform bacteria were detected in water from 29 sites; fecal-coliform bacteria were detected in water from 6 of these 29 sites.

INTRODUCTION

Urban development in the mountainous and other rural lands of Colorado has resulted in an increased demand for ground water that is of suitable quality for domestic and agricultural supplies. The lack of information on the quality of the local ground-water resources is a major problem for county planners and residents. Chemical and biological characteristics of water are particularly important because contamination from septic tanks, leach fields, and natural sources may cause constituents in the water to occur in excess of standards and criteria for water use. Information about the quality of ground water in the county is needed to provide a basis for making decisions regarding land development and use.

Routt County, which has an area of 2,231 mi² (fig. 1) in northwestern Colorado, is experiencing rapid growth in population due to recreational and energy-related activities. The population of Steamboat Springs, the largest community in the county, has increased from 2,400 in 1970 to more than 4,000 in 1977 (Michael J. Zopf, Routt County Department of Environmental Health, oral commun., 1978).

In 1978, the U.S. Geological Survey, in cooperation with the Routt County Regional Planning Commission and the Routt County Department of Environmental Health, began a 1-year study to assess the quality of ground water in the county. This study extends and supplements earlier work of Brogden and Giles (1977) that was done in 1975 in parts of western Routt and eastern Moffat Counties.

Approach

Water samples were collected from 130 wells and springs (pl. 1) during May and June 1978. Sampling sites were selected from a listing of registered wells and springs provided by the Colorado Department of Natural Resources, Division of Water Resources, Office of the State Engineer. When possible, the depth to the water level was measured in each well prior to obtaining the water sample. Water temperature, specific conductance, and pH were measured at the well or spring site, and samples for bacteriological analyses were collected at all wells and springs. Samples for laboratory analyses of dissolved chemical constituents were collected from 35 of the wells and springs and analyzed in accordance with accepted procedures of the U.S. Geological Survey (Skougstad and others, 1979; Greeson and others, 1977).

In addition to the water-quality data obtained during this study, water-quality data collected from 62 wells and springs in Routt County during 1975 (Brogden and Giles, 1977) were used to assess the water quality and to correlate water chemistry with the contributing aquifers from selected geologic units. Boundaries of the geologic units shown on plate 1 are based on geologic or geohydrologic maps presented in reports by Boettcher (1972), Miller (1975), and Brogden and Giles (1977).

Acknowledgments

Appreciation is extended to the many landowners in Routt County who permitted access to their wells and springs for the purpose of collecting the data presented in this report. Appreciation also is extended to Phillip E. Stark, Michael J. Zopf, and Val Myrick, Routt County Department of Environmental Health, Steamboat Springs, Colo., for their help in organizing the data-collection program, and to Gloria Beattie for use of the laboratory and equipment at the sewage-treatment plant in Steamboat Springs.

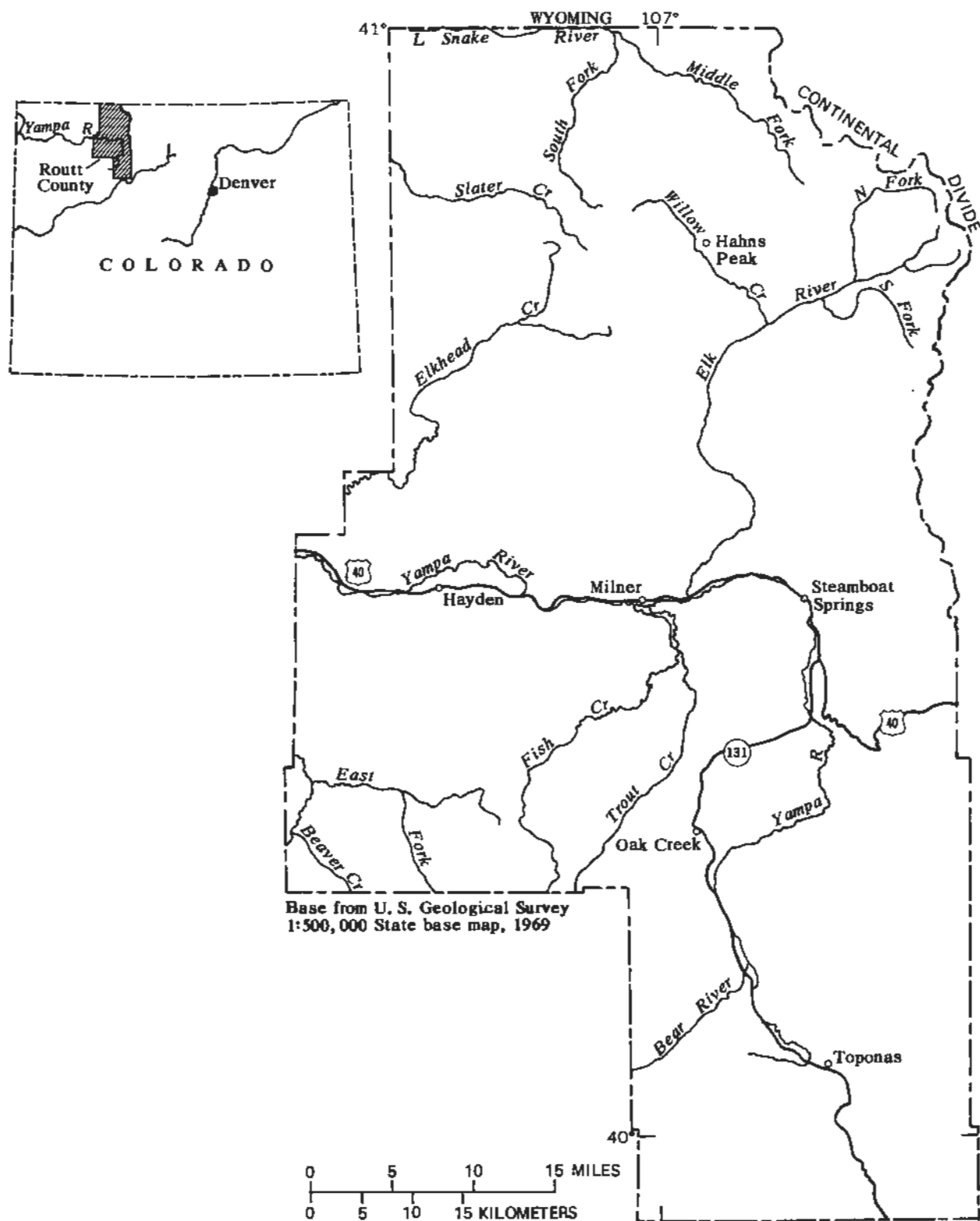


Figure 1. -- Location map of Routt County.

GEOHYDROLOGY

Precambrian crystalline rocks, which underlie the area, are exposed in the eastern one-third of the county. In the western two-thirds of the county, the crystalline rocks are overlain by younger sedimentary rocks of Tertiary to Cambrian age. In places, these sedimentary deposits were intruded during Tertiary time by dikes, sills, and other rocks of igneous origin. Alluvial deposits of Quaternary age are common in river and stream valleys (Miller, 1975).

All geologic units, with the possible exception of the extrusive and intrusive rocks of Tertiary age, will yield at least several gallons per minute of water to wells and springs and are considered aquifers (table 1 shown on plate 1). The principal aquifers, those yielding more than 10 gal/min to wells and occurring in relatively large areas in the county, are the alluvial deposits, the Browns Park Formation, and the Mesaverde Group (Steele and others, 1979, table 13). Reported yields of as much as 900 gal/min are obtained from the alluvial deposits. Because of the proximity of the alluvial deposits to urban and agricultural development, these deposits are the principal source of additional community-water supplies in the county.

QUALITY OF GROUND WATER

General Discussion

Water entering and migrating through a ground-water system has the capacity, through various chemical processes, to dissolve and transport minerals and gases (Hem, 1970). Although these activities in the water are complex, the resulting dissolved constituents generally reflect the mineralogy of the material through which the water moves. The types and amounts of dissolved constituents in the ground water are the basis for the chemical classification of the water in this report (table 2).

Table 2.--*Chemical criteria used to classify water types and hardness*

Water types (modified from Piper and others, 1953, p. 26)		Hardness (modified from Durfor and Becker, 1964, p. 27)	
Milliequivalents per liter		Classifi- cation	Bivalent cations; calcium and magne- sium (milligrams per liter as CaCO ₃)
Cations	Anions		
Single cation used when it amounts to 50 per- cent or more of the total cations; when the above does not ex- ist, the highest two cations are used.	Single anion used when it amounts to 50 per- cent or more of the total anions; when the above does not ex- ist, the highest two anions are used.	Soft----- Moderately hard----- Hard----- Very hard--	Less than 60. 61-200. 121-180. More than 180.

Ground water may be limited for use by its chemical and biological nature. Water-quality standards for public-water supplies (Colorado Department of Health, 1977; U.S. Environmental Protection Agency, 1976; 1977) and water-quality criteria for agricultural uses (Colorado Department of Health, 1978) are summarized in table 3. Included in the table are statements summarizing some potential effects of using water with constituents in excess of the standards or criteria limits. Although the standards are for public-water supplies, they may be used by individual well owners in evaluating the suitability of their water supply for domestic use. Values that exceeded water-quality standards or criteria during this study are indicated on plate 1 and in tables 5 and 6 (in Supplemental Information section at back of this report).

The assessment of ground-water quality in Routt County was based on water-quality data from 130 wells and springs sampled in 1978 (tables 5 and 6 in Supplemental Information section at back of this report) and on chemical analyses of water from 62 wells and springs sampled in 1975 and presented in Brogden and Giles (1977). The chemical analyses included determination of major ions, nutrients, and both toxic and nontoxic trace elements; densities of total- and fecal-coliform bacteria (tables 5 and 6) also were determined in 1978.

Major ions are those mineral constituents selectively dissolved from soils or rocks in relatively large quantities. Concentrations of major ions in water are reported in milligrams per liter; (one mg/L (milligram per liter) is virtually equal to one part in one million by weight). The most common major ions are listed below:

Cations (positive charge)

Calcium (Ca)
Magnesium (Mg)
Potassium (K)
Sodium (Na)

Anions (negative charge)

Bicarbonate (HCO_3)
Chloride (Cl)
Sulfate (SO_4)

Percentages of the major ions in each chemical analysis were plotted on a trilinear graph (Piper, 1944). This was done to determine the chemical type of water from each well and spring (table 2) and to establish whether or not a chemical grouping was characteristic of a given aquifer.

Correlations of values of specific conductance with concentrations of dissolved solids and values of specific conductance with hardness are presented for selected aquifers (figs. 2-6). These correlations and corresponding regressions provide a means of estimating dissolved solids and hardness only within a given range of measured specific-conductance values; they do not necessarily indicate a cause-and-effect relationship between given values. The regression curves (figs. 2-6) are shown for data points only when there exists a close correlation between specific conductance and dissolved solids and between specific conductance and hardness. Regression curves were not extended to include the entire range of the data where data scatter becomes excessive. This is evident in figure 2 where there is data scatter above 800 micromhos in the regression curve between specific conductance and hardness.

Table 3.--*Water-quality standards for public-water supplies and water-quality criteria for agricultural use*

[mg/L=milligram per liter; µg/L=microgram per liter]

Constituent	Standards for public-water supplies ¹	Criteria for agricultural use ²	Some potential effects of using water with constituents in excess of standards or criteria ³
pH (units)-----	6.5-8.5(R)	(4)	May increase toxicity of other constituents; corrosive.
Dissolved solids (mg/L)-----	500(R)	(5)	Unpleasant taste.
Chloride (mg/L)-----	250(R)	(4)	Unpleasant taste.
Fluoride (mg/L)-----	61.8(M)	(4)	May cause dental fluorosis (mottling of teeth) especially in children.
Nitrite plus nitrate as nitrogen (mg/L).	710(M)	100	May cause methemoglobinemia (blue-baby disease) in infants of warm-blooded animals.
o Sulfate (mg/L)-----	250(R)	(4)	Temporary physiological (laxative) effect on people unaccustomed to drinking the water.
Total- and fecal-coliform bacteria.	(8)	1,000	Increased possibility that disease organisms may be present.
Arsenic (µg/L)-----	50(M)	100	Accumulative toxicant.
Boron (µg/L)-----	(9)	750	Toxic to sensitive plants.
Cadmium (µg/L)-----	10(M)	10	Highly toxic; associated with itai-itai disease.
Copper (µg/L)-----	1,000(R)	200	Unpleasant taste.
Iron (µg/L)-----	300(R)	(4)	Unpleasant taste; stains laundry and porcelain fixtures.
Lead (µg/L)-----	50(M)	100	Accumulative toxicant, resulting in neurological and kidney disorders.
Manganese (µg/L)-----	50(R)	200	Unpleasant taste; stains laundry and porcelain fixtures.

Table 3.--Water-quality standards for public-water supplies and water-quality criteria for agricultural use--Continued

Constituent	Standards for public-water supplies ¹	Criteria for agricultural use ²	Some potential effects of using water with constituents in excess of standards or criteria ³
Mercury (µg/L)-----	2(M)	(⁴)	Accumulative toxicant.
Molybdenum (µg/L)-----	(⁹)	(5)	-----
Nickel (µg/L)-----	(⁹)	200	Toxic to sensitive plants.
Selenium (µg/L)-----	10(M)	20	Toxic to people and livestock.
Zinc (µg/L)-----	5,000(R)	2,000	Unpleasant taste; toxic to sensitive plants.

¹R=recommended standard established by U.S. Environmental Protection Agency, 1977; M=mandatory standard established by Colorado Department of Health, 1977; equivalent to mandatory standard established by U.S. Environmental Protection Agency, 1976b.

²Established by Colorado Department of Health, 1978.

³Adapted from U.S. Environmental Protection Agency, 1976a; 1976b.

⁴Numerical limit generally is not needed.

⁵Numerical limit may be required for certain cases; however, there are insufficient data for establishing a general criterion.

⁶Based on annual average of maximum daily air temperature. The range of fluoride concentration is from 1.4 mg/L at air temperatures ranging from 26.3°C to 32.5°C to a fluoride concentration of 2.4 mg/L at an air temperature of 12.0°C and below.

⁷Standard and criteria are for nitrate only; however, because excessive concentrations of nitrite cause the same health problems, concentrations of nitrite plus nitrate are reported by the U.S. Geological Survey.

⁸There is no standard for bacteria based on the analysis of a single sample; however, the presence of any bacteria in a water supply used for drinking is cause for concern because of the potential health hazard; disinfection of the water supply generally is required by public-health officials whenever any bacteria are present in the water.

⁹No standard.

Nutrients are substances, such as nitrogen and phosphorus compounds, generally considered beneficial for plant and animal growth. However, water that contains concentrations of nitrite plus nitrate as nitrogen greater than 10 mg/L may cause methemoglobinemia (blue-baby disease) in infants. Excessive concentrations of nitrite plus nitrate may indicate contamination of the water supply by human or animal wastes, or by commercial fertilizers.

Trace constituents in water are those mineral constituents generally present in relatively small quantities. Trace constituents in water are reported in micrograms per liter; (one $\mu\text{g/L}$ (microgram per liter) is equivalent to one part in one billion by weight). One or more trace constituents may be present in significant quantities in the rocks of certain aquifers and their detection in water may aid in identifying the source of the water. Trace constituents considered to be toxic in small concentrations include arsenic, cadmium, lead, mercury, and selenium. The toxic constituents determined for samples collected in 1978 are shown in the last five columns in table 5 (Supplemental Information section at back of this report).

Total- and fecal-coliform bacteria are used as indicator organisms; the presence of these bacteria indicate that disease-producing organisms may be present in the water (Federal Water Quality Administration, 1971). Also, the presence of these bacteria in water generally indicates a local source of contamination, such as a septic system or barnyard, rather than contamination of the entire aquifer. Contaminated water needs to be disinfected before being used for drinking. Total- and fecal-coliform bacteria were not detected in water samples when the values shown in tables 5 and 6 (Supplemental Information section at back of this report) are preceded with a < (less than) symbol.

Alluvial Deposits

Sixty-two wells and springs yielding water from the alluvial deposits in Routt County were sampled--43 in 1978 (sites 1-8 on pl. 1 and in table 5; sites 36-70 on pl. 1 and in table 6) and 19 in 1975 (Brogden and Giles, 1977). Twenty-seven samples were analyzed for major ions, nutrients, and selected trace constituents.

Specific conductance in water from 61 sites ranged from 50 to 2,200 micromhos (micromhos per centimeter at 25° Celsius) and pH in water from 58 sites ranged from 5.9 to 9.4. The water was generally a calcium bicarbonate type when the specific conductance was less than 800 micromhos. Water type varied when specific conductance was greater than 800 micromhos.

Data from the 27 chemical analyses show that dissolved-solids concentrations ranged from 46 to 1,660 mg/L and that hardness ranged from 19 to 850 mg/L. Correlations and regressions of specific conductance with dissolved solids and specific conductance with hardness are shown in figure 2. The data indicate that values of dissolved solids may be estimated from values of specific conductance within the range of 75 to 2,200 micromhos. Dissolved solids will most likely exceed 500 mg/L when specific conductance exceeds 770 micromhos. The data also indicate that water from this aquifer will be very hard (hardness greater than 180 mg/L) when specific conductance is greater than 400 micromhos.

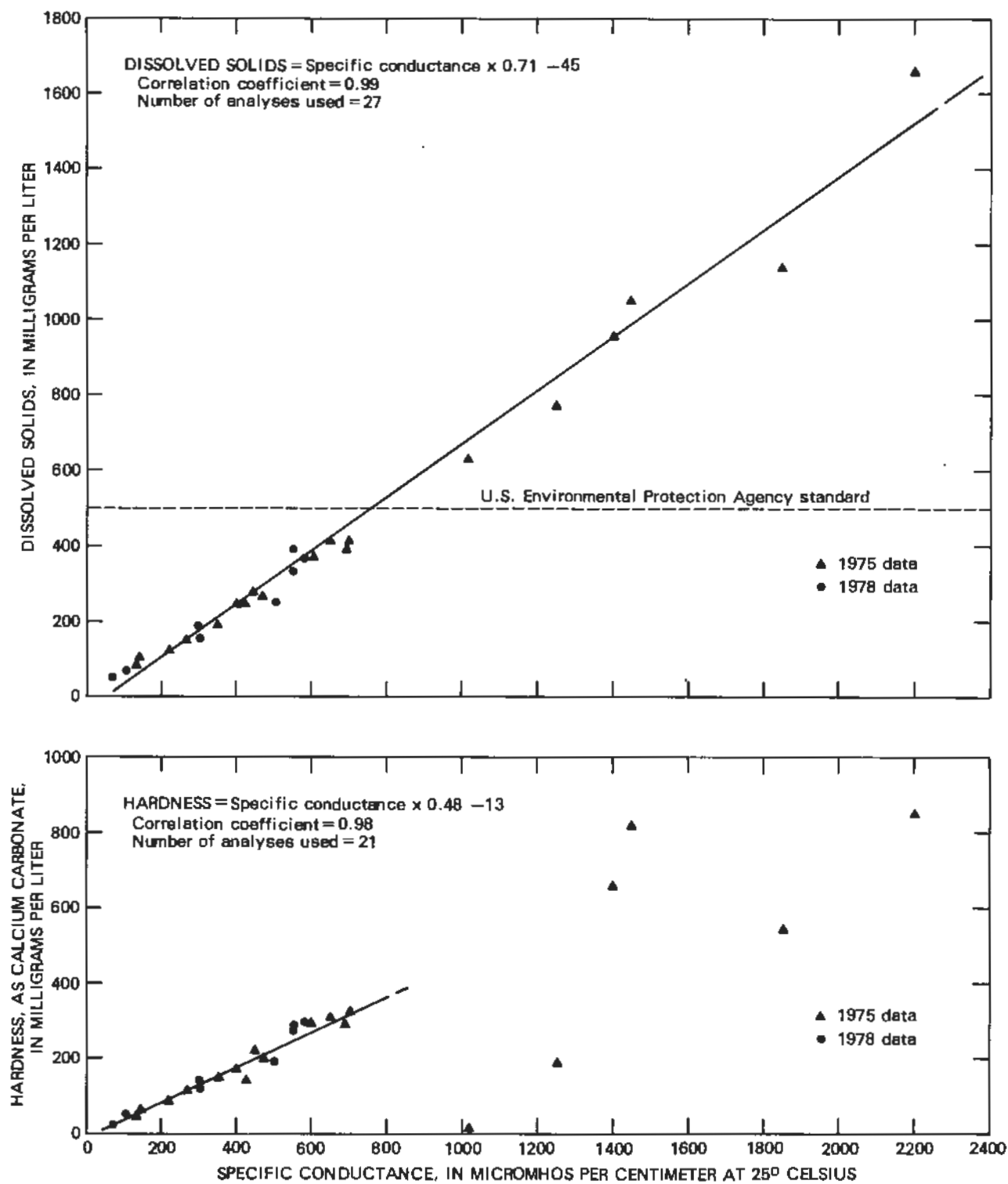


Figure 2. --Correlations and regressions between specific conductance and dissolved solids and between specific conductance and hardness in water from the alluvial deposits.

Constituents in water from the alluvial deposits that exceeded standards for public-water supplies and the number of occurrences are listed below:

Constituent	Standard	Number of samples in which standard was exceeded (includes pH less than 6.5)	Number of samples analyzed	Year sampled
pH-----	6.5-8.5	1 10	19 39	1975 1978
Fluoride-----	1.8 mg/L	1 0	19 8	1975 1978
Nitrite plus nitrate as nitrogen-----	10 mg/L	1 0	19 8	1975 1978
Sulfate-----	250 mg/L	4 0	19 8	1975 1978
Dissolved solids----	500 mg/L	6 0	19 8	1975 1978
Arsenic-----	50 µg/L	1 0	17 8	1975 1978
Iron-----	300 µg/L	5 1	19 8	1975 1978
Manganese-----	50 µg/L	8 2	19 8	1975 1978

Total-coliform bacteria were detected in water from 11 sites in 1978 and fecal-coliform bacteria were detected in water from 4 of the 11 sites. The agricultural criteria for copper (200 µg/L) was exceeded in water from one well in 1975.

Water from the alluvial deposits generally is suitable for use as a drinking-water supply and for agricultural use. Based on a mean value of 564 micromhos for specific conductance and using the regression function given in figure 2, the estimated mean value of dissolved solids would be 355 mg/L. Similarly, the estimated mean hardness (fig. 2) would be 258 mg/L, indicating that most water from the alluvial deposits would be very hard (table 2).

Based on the above data and analyses, water from 13 of the sites sampled could pose a health hazard to persons drinking the water. Concentrations of arsenic and fluoride (one site) and nitrite plus nitrate (one site) exceeded standards for public-water supplies. Local microbial contamination of the aquifer was indicated by the presence of total-coliform bacteria in water from 11 sites.

Browns Park Formation

Forty-three wells and springs yielding water from the Browns Park Formation were sampled--37 in 1978 (sites 9-19 on pl. 1 and in table 5, Supplemental Information at back of this report; sites 71-96 on pl. 1 and in table 6) and 6 in 1975 (Brogden and Giles, 1977). Seventeen samples were analyzed for major ions, nutrients, and selected trace constituents.

Specific conductance in water from 41 sites ranged from 50 to 1,720 micromhos and pH in water from 40 sites ranged from 6.3 to 9.2. The water was a calcium bicarbonate type when the specific conductance was less than 600 micromhos. Water type varied when specific conductance was greater than 600 micromhos.

Data from the 17 chemical analyses show that concentrations of dissolved solids ranged from 89 to 2,140 mg/L and that hardness ranged from 10 to 1,300 mg/L. Correlations and regressions of specific conductance with dissolved solids and specific conductance with hardness are shown in figure 3. The data indicate that values of dissolved solids may be estimated from specific conductance within the range of 135 to 1,700 micromhos. Dissolved solids will most likely exceed 500 mg/L when specific conductance exceeds 810 micromhos. The data also indicate that water from this aquifer will be very hard (hardness greater than 180 mg/L) when specific conductance is greater than 260 micromhos.

Constituents in water from the Browns Park Formation that exceeded standards for public-water supplies and the number of occurrences are listed below:

Constituent	Standard	Number of samples in which standard was exceeded (includes pH less than 6.5)	Number of samples analyzed	Year sampled
pH-----	6.5-8.5	0 3	6 34	1975 1978
Chloride-----	250 mg/L	1 0	6 11	1975 1978
Fluoride-----	1.8 mg/L	1 2	6 11	1975 1978
Nitrite plus nitrate as nitrogen-----	10 mg/L	0 3	6 11	1975 1978
Sulfate-----	250 mg/L	1 0	6 11	1975 1978
Dissolved solids----	500 mg/L	1 4	6 11	1975 1978
Manganese-----	50 µg/L	0 1	6 11	1975 1978

Total-coliform bacteria were detected in water from six sites in 1978.

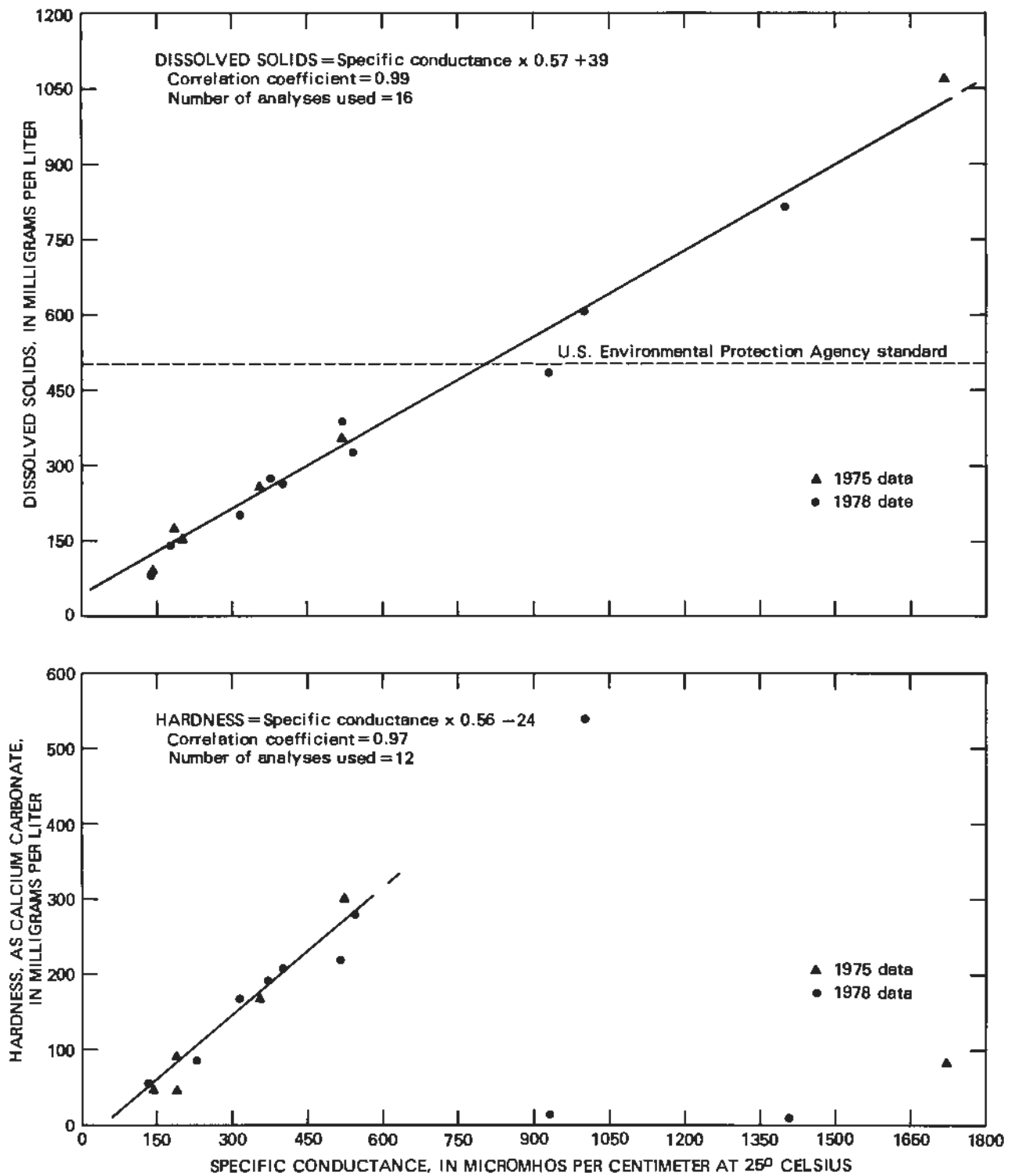


Figure 3.--Correlations and regressions between specific conductance and dissolved solids and between specific conductance and bardness in water from the Browns Park Formation.

Water from the Browns Park Formation generally is suitable for use as a drinking-water supply and for agricultural use. Based on a mean value of 497 micromhos for specific conductance and using the regression function given in figure 3, the estimated mean value of dissolved solids would be 322 mg/L. Similarly, the estimated mean hardness (fig. 3) would be 254 mg/L, indicating that most water from the Browns Park Formation would be very hard (table 2).

Based on the above data and analyses, water from 11 sites could pose a health hazard to persons drinking the water. Concentrations of fluoride (three sites) and nitrite plus nitrate (three sites) exceeded standards for public-water supplies. Local microbial contamination of the aquifer was indicated by the presence of total-coliform bacteria in water from six sites. Water from one of these sites also contained excessive fluoride.

Lance Formation

Six wells and springs yielding water from the Lance Formation were sampled--four in 1978 (sites 97-100 on pl. 1 and in table 6, Supplemental Information at back of this report) and two in 1975 (Brogden and Giles, 1977). Two samples were analyzed for major ions, nutrients, and selected trace constituents.

Specific conductance in water from the six sites ranged from 750 to 6,000 micromhos and pH ranged from 7.2 to 8.1. On the basis of the two samples collected in 1975, the water was a calcium bicarbonate type. Dissolved-solids concentrations were 501 and 569 mg/L and hardness concentrations were 350 and 370 mg/L.

Constituents in water from the Lance Formation that exceeded standards for public-water supplies and the number of occurrences are listed below:

Constituent	Standard	Number of samples in which standard was exceeded	Number of samples analyzed	Year sampled
Nitrite plus nitrate as nitrogen-----	10 mg/L	1 0	2 0	1975 1978
Dissolved solids----	500 mg/L	2 0	2 0	1975 1978
Manganese-----	50 µg/L	1 0	2 0	1975 1978

Total- and fecal-coliform bacteria were not detected at any of the sites.

Data are too few to evaluate the suitability of water from the Lance Formation for use as a drinking-water supply. On the basis of the limited water-quality data, excessive concentrations of dissolved solids and hardness may be prevalent and could affect the esthetic quality of the water.

Lewis Shale

Nine wells yielding water from the Lewis Shale were sampled--three in 1978 (sites 101-103 on pl. 1 and in table 6, Supplemental Information section at back of this report) and six in 1975 (Brogden and Giles, 1977). Six samples were analyzed for major ions, nutrients, and selected trace constituents.

Specific conductance in water from the nine wells ranged from 455 to 4,000 micromhos and pH ranged from 7.0 to 9.0. Calcium and bicarbonate were the most common ions in solution, but the water types generally were mixed.

Data from the six chemical analyses show that dissolved-solids concentrations ranged from 272 to 904 mg/L and that hardness ranged from 170 to 630 mg/L. Correlations and regressions of specific conductance with dissolved solids and specific conductance with hardness are given in figure 4. The regression-analysis results indicate that values of dissolved solids may be estimated from specific conductance within the range of 455 to 1,300 micromhos. Dissolved solids will most likely exceed 500 mg/L when specific conductance exceeds 770 micromhos. The data also indicate that water from this aquifer will be very hard (hardness greater than 180 mg/L) when specific conductance is greater than 450 micromhos.

Constituents in water from the Lewis Shale that exceeded standards for public-water supplies and the number of occurrences are listed below:

Constituent	Standard	Number of samples in which standard was exceeded (includes pH less than 6.5)	Number of samples analyzed	Year sampled
pH-----	6.5-8.5	1 1	6 3	1975 1978
Nitrite plus nitrate as nitrogen-----	10 mg/L	2 0	6 0	1975 1978
Sulfate-----	250 mg/L	1 0	6 0	1975 1978
Dissolved solids----	500 mg/L	3 0	6 0	1975 1978
Manganese-----	50 µg/L	1 0	6 0	1975 1978
Selenium-----	10 µg/L	1 0	6 0	1975 1978

Total-coliform bacteria were detected in water from two sites in 1978.

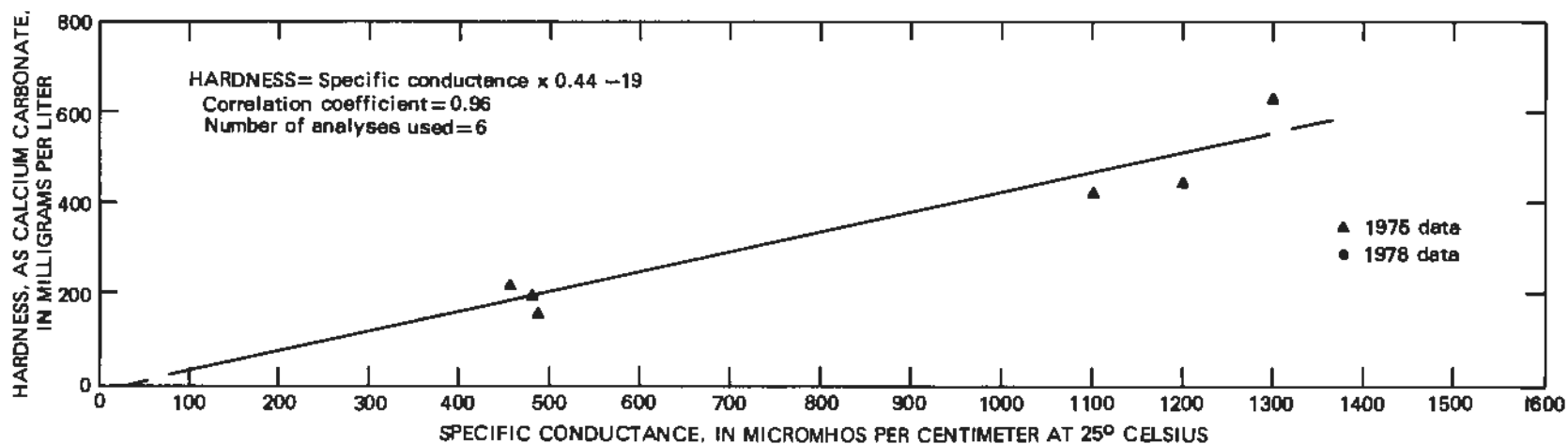
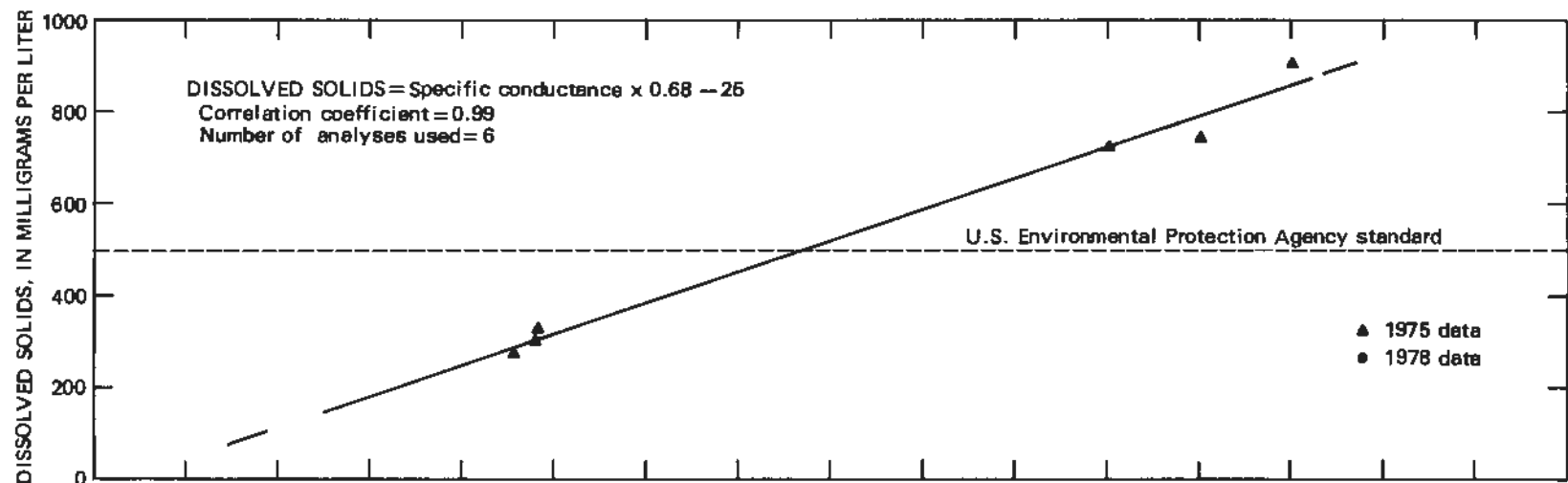


Figure 4 -- Correlations and regressions between specific conductance and dissolved solids and between specific conductance and hardness in water from the Lewis Shale.

Water from the Lewis Shale generally is not as suitable for use as a drinking-water supply as is water from the alluvial deposits or the Browns Park Formation. Excessive dissolved-solids concentrations and hardness, which impair the esthetic quality of the water, were prevalent. Based on a mean of 1,210 micromhos for specific conductance and using the regression function given in figure 4, the estimated mean value of dissolved solids would be 798 mg/L. Similarly, the estimated mean hardness (fig. 4) would be 513 mg/L, indicating that most water from the Lewis Shale would be very hard (table 2).

Based on the above data and analyses, water from five of the sites sampled could pose a health hazard to persons drinking the water. Concentrations of nitrite plus nitrate (two sites) and selenium (one site) exceeded standards for public-water supplies. Local microbial contamination of the aquifer was indicated by the presence of total-coliform bacteria in water from two sites.

Mesaverde Group

Thirty-three wells and springs yielding water from the Mesaverde Group were sampled--nine in 1978 (sites 20-22 on pl. 1 and in table 5, Supplemental Information at back of this report; sites 104-109 on pl. 1 and in table 6, Supplemental Information at back of this report) and 24 in 1975 (Broghden and Giles, 1977). Twenty-seven samples were analyzed for major ions, nutrients, and selected trace constituents.

Specific conductance in water from the 33 sites ranged from 225 to 2,100 micromhos and pH in water from 30 sites ranged from 5.3 to 8.8. Chemical analyses indicate that calcium and bicarbonate were the most common ions although magnesium, sodium, and sulfate ions were dominant or codominant in some samples.

Data from the 27 chemical analyses show that concentrations of dissolved solids ranged from 133 to 1,460 mg/L and that hardness ranged from 12 to 1,100 mg/L. Correlations and regressions of specific conductance with dissolved solids and specific conductance with hardness are given in figure 5. The data indicate that values of dissolved solids may be estimated from specific conductance within the range of 225 to 2,100 micromhos. Dissolved solids will most likely exceed 500 mg/L when specific conductance exceeds 780 micromhos. The data also indicate that the water from this aquifer would be very hard (hardness greater than 180 mg/L) when specific conductance is greater than 380 micromhos.

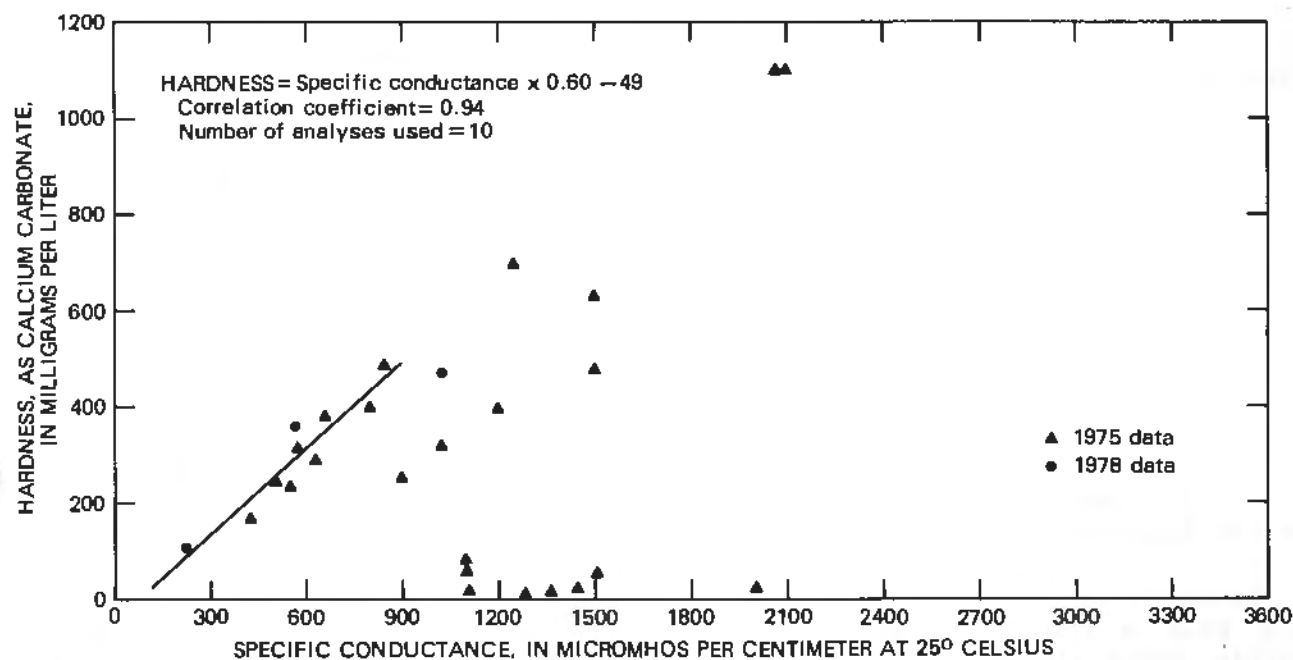
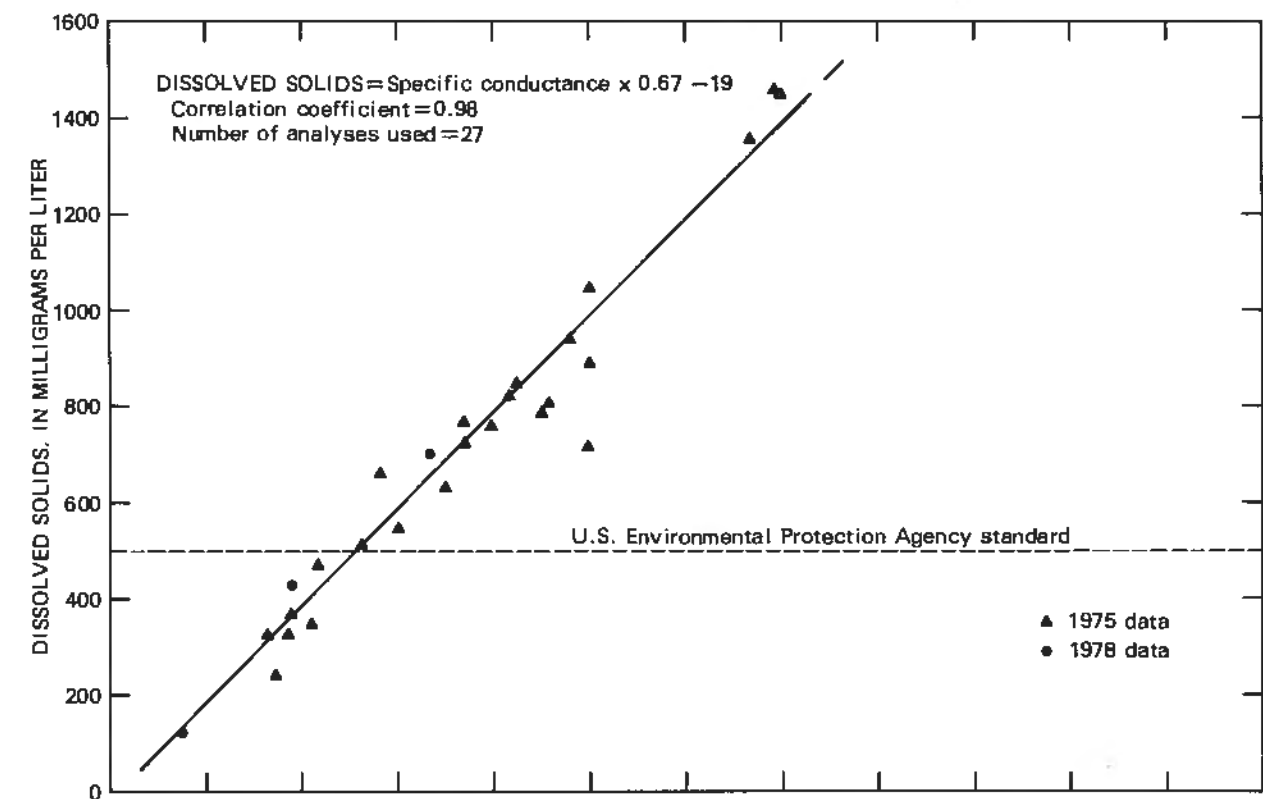


Figure 5. -- Correlations and regressions between specific conductance and dissolved solids and between specific conductance and hardness in water from the Mesaverde Group.

Constituents in water from the Mesaverde Group that exceeded standards for public-water supplies and the number of occurrences are listed below:

Constituent	Standard	Number of samples in which standard was exceeded (includes pH less than 6.5)	Number of samples analyzed	Year sampled
pH-----	6.5-8.5	1	22	1975
		2	8	1978
Fluoride-----	1.8 mg/L	3	24	1975
		0	3	1978
Nitrite plus nitrate as nitrogen-----	10 mg/L	0	24	1975
		2	3	1978
Sulfate-----	250 mg/L	5	24	1975
		0	3	1978
Dissolved solids----	500 mg/L	18	24	1975
		1	3	1978
Iron-----	300 µg/L	7	24	1975
		0	3	1978
Manganese-----	50 µg/L	6	24	1975
		0	3	1978

Total-coliform bacteria were detected in water from one site in 1978. The agricultural-use criteria for manganese (200 µg/L) was exceeded in water from three sites in 1975.

Water from the Mesaverde Group generally is not as suitable for use as a drinking-water supply as is water from the alluvial deposits or the Browns Park Formation. Excessive concentrations of dissolved solids and hardness, which impair the esthetic quality of the water, were prevalent. Based on a mean of 1,040 micromhos for specific conductance and using the regression function given in figure 5, the estimated mean value of dissolved solids would be 678 mg/L. Similarly, the estimated mean hardness (fig. 5) would be 575 mg/L, indicating that most water from the Mesaverde Group would be very hard (table 2).

Based on the above data and analyses, water from six of the sites sampled could pose a health hazard to persons drinking the water. Concentrations of fluoride (three sites) and nitrite plus nitrate (two sites) exceeded standards for public-water supplies. Local microbial contamination of the aquifer was indicated by the presence of total-coliform bacteria in water from one site.

Mancos Shale

Thirty-three wells and springs yielding water from the Mancos Shale were sampled--28 in 1978 (sites 23-32 on pl. 1 and in table 5, Supplemental Information at back of this report; sites 110-127 on pl. 1 and in table 6, Supplemental Information at back of this report) and 5 in 1975 (Brogden and Giles, 1977). Fifteen samples were analyzed for major ions, nutrients, and selected trace constituents.

Specific conductance in water from the 33 sites ranged from 75 to 3,970 micromhos and pH ranged from 6.1 to 8.7. The water generally was a calcium bicarbonate type, although sodium was the dominant cation in five samples.

Data from the 15 chemical analyses show that concentrations of dissolved solids ranged from 121 to 3,290 mg/L and that hardness ranged from 10 to 1,800 mg/L. Correlations and regressions of specific conductance with dissolved solids and specific conductance with hardness are given in figure 6. The data indicate that values of dissolved solids may be estimated from specific conductance within the range of 240 to 4,000 micromhos. Dissolved solids will most likely exceed 500 mg/L when specific conductance exceeds 800 micromhos. The data also indicate that water from this aquifer would be very hard (hardness greater than 180 mg/L) when specific conductance is greater than 460 micromhos.

Constituents in water from the Mancos Shale that exceeded standards for public-water supplies and the number of occurrences are listed below:

Constituent	Standard	Number of samples in which standard was exceeded (includes pH less than 6.5)	Number of samples analyzed	Year sampled
pH-----	6.5-8.5	1	5	1975
		1	28	1978
Chloride-----	250 mg/L	1	5	1975
		1	10	1978
Fluoride-----	1.8 mg/L	2	5	1975
		1	10	1978
Nitrite plus nitrate as nitrogen-----	10 mg/L	0	5	1975
		1	10	1978
Sulfate-----	250 mg/L	0	5	1975
		1	10	1978
Dissolved solids----	500 mg/L	4	5	1975
		5	10	1978
Iron-----	300 µg/L	0	5	1975
		4	10	1978
Manganese-----	50 µg/L	1	5	1975
		2	10	1978

Total-coliform bacteria were detected in water from seven sites in 1978. The agricultural-use criteria for boron (750 µg/L) was exceeded in water from one site in 1975.

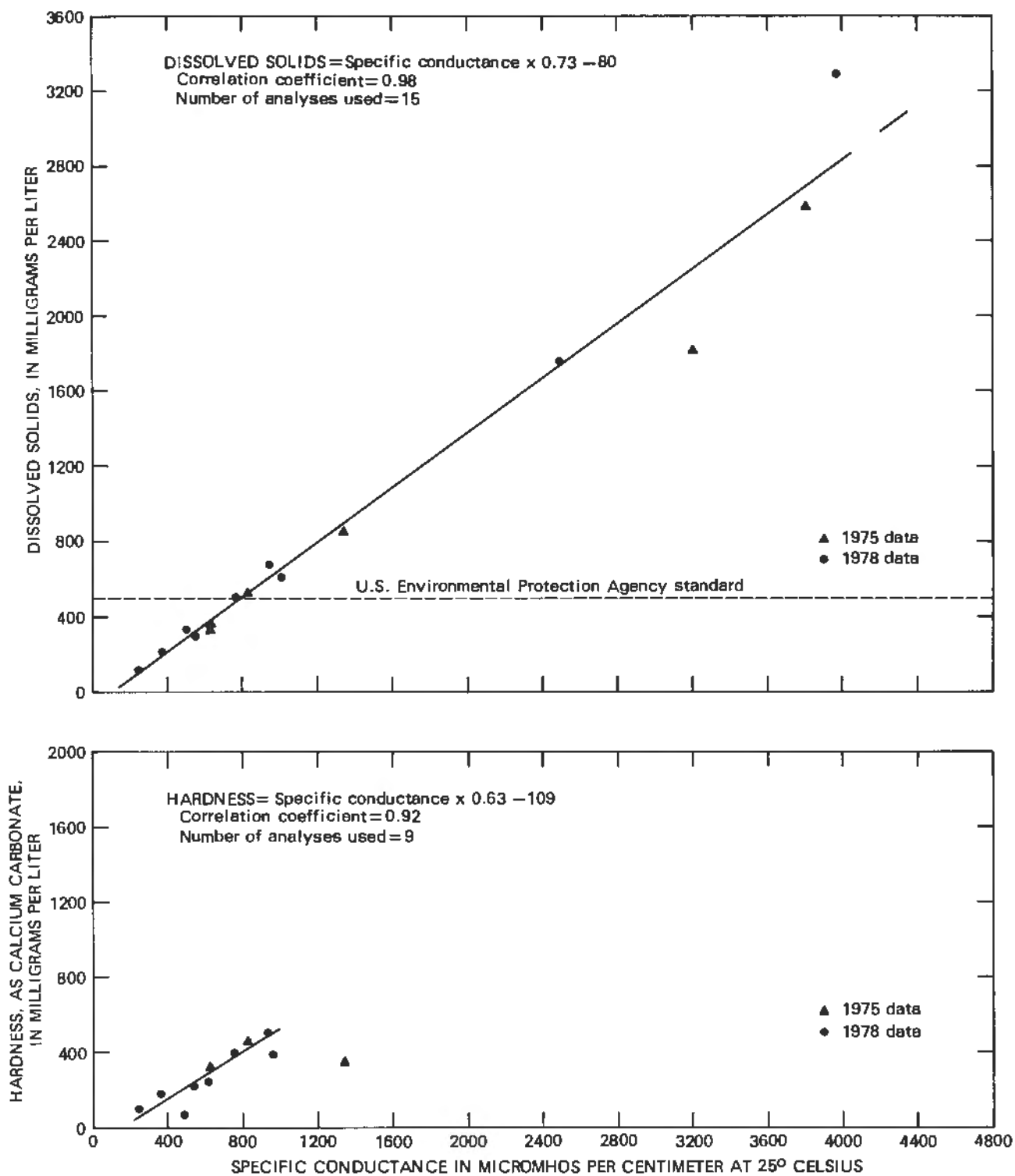


Figure 6. -- Correlations and regressions between specific conductance and dissolved solids and between specific conductance and hardness in water from the Mancos Shale.

Water from the Mancos Shale is not as suitable for use as a drinking-water supply as is water from the alluvial deposits or the Browns Park Formation. Excessive concentrations of dissolved solids and hardness, which impair the esthetic quality of the water, were prevalent. Based on a mean value of 1,060 micromhos for specific conductance and using the regression function given in figure 6, the estimated mean value of dissolved solids would be 694 mg/L. Similarly, the estimated mean hardness (fig. 6) would be 559 mg/L, indicating that most water from the Mancos Shale would be very hard (table 2).

Based on the above data and analyses, water from 11 of the sites sampled could pose a health hazard to persons drinking the water. Concentrations of fluoride (three sites) and nitrite plus nitrate (one site) exceeded standards for public-water supplies. Local microbial contamination of the aquifer was indicated by the presence of total-coliform bacteria in water from seven sites.

Basement Complex

Six wells yielding water from the basement complex (Lower Cretaceous to Precambrian age rocks) were sampled in 1978 (sites 33-35 on pl. 1 and in table 5, Supplemental Information section at back of this report; sites 128-130 on pl. 1 and in table 6, Supplemental Information section at back of this report). Three samples were analyzed for major ions, nutrients, and selected trace constituents.

Specific conductance in water from the six wells ranged from 105 to 1,450 micromhos and pH ranged from 7.1 to 8.0. The waters were a calcium bicarbonate or calcium magnesium bicarbonate type. Data from the three chemical analyses show that concentrations of dissolved solids ranged from 64 to 263 mg/L and that hardness ranged from 40 to 180 mg/L.

Constituents in water from the basement complex that exceeded standards for public-water supplies and the number of occurrences are listed below:

Constituent	Standard	Number of samples in which standard was exceeded	Number of samples analyzed	Year sampled
Iron-----	300 µg/L	0 1	0 3	1975 1978
Manganese-----	50 µg/L	0 1	0 3	1975 1978

Both total- and fecal-coliform bacteria were detected in water from two wells in 1978.

Data are too few to evaluate the suitability of water from the basement complex for use as a drinking-water supply. Analyses of the chemical data does indicate, however, that the ground water most likely would be suitable for domestic use. Local potential health hazards are indicated by the presence of bacteria in water from two wells.

SUMMARY AND DISCUSSION

The assessment of ground-water quality in Routt County was based on water-quality data from 130 wells and springs sampled in 1978 and on chemical analyses of water from 62 wells and springs presented in Brogden and Giles (1977). The data were evaluated to determine the suitability of the water for public-water supplies and agricultural use.

Summaries of water-quality data by aquifer source are presented in table 4 and figure 7. Specific conductance, pH, dissolved solids, and hardness varied between and within individual aquifers. Arithmetic mean values of specific conductance, dissolved solids, and hardness generally were greatest in water from the Lance Formation, Lewis Shale, Mesaverde Group, and Mancos Shale, and were least in water from the alluvial deposits, the Browns Park Formation, and the basement complex. Estimates of dissolved solids and hardness can be made within defined ranges of specific conductance, using regression functions derived from available data for water samples from each formation.

Calcium and bicarbonate were the most common dominant ions in the ground water. However, the frequency distribution of major-ion dominance (fig. 7) shows that the cations, magnesium, and sodium, were present to a greater degree in water from the Browns Park Formation, Lance Formation, Lewis Shale, Mesaverde Group, and Mancos Shale than in water from the alluvial deposits and the basement complex. Chloride was significant only in water from the Browns Park Formation; bicarbonate was the only dominant anion in water from the Lance Formation and the basement complex. The absence of other major-ion dominance in water from the Lance Formation and the basement complex, however, may be due to the limited number of samples obtained from these units.

Analysis of the chemical data indicates that water from the alluvial deposits, the Browns Park Formation, and the basement complex would be the most suitable for general domestic use in Routt County. The large range in concentrations of chemical constituents in water within individual aquifers, however, indicates that the degree of suitability could vary locally within all aquifers. Concentrations of dissolved solids, hardness, chloride, iron, manganese, or sulfate, which exceeded criteria for public-water supplies or agricultural use, occurred locally in water from all aquifers.

Potential health hazards from chemical or bacterial sources were detected in water from 48 of the 130 wells and springs sampled. Concentrations of arsenic, fluoride, nitrite plus nitrate, or selenium in excess of mandatory standards for public-water supplies occurred locally in water from all rock units except the basement complex.

The presence of total-coliform bacteria, which most likely reflects local sources of microbial contamination, was detected in water from 29 wells and springs sampled during 1978. Fecal-coliform bacteria also were present in water from 6 of the 29 wells and springs.

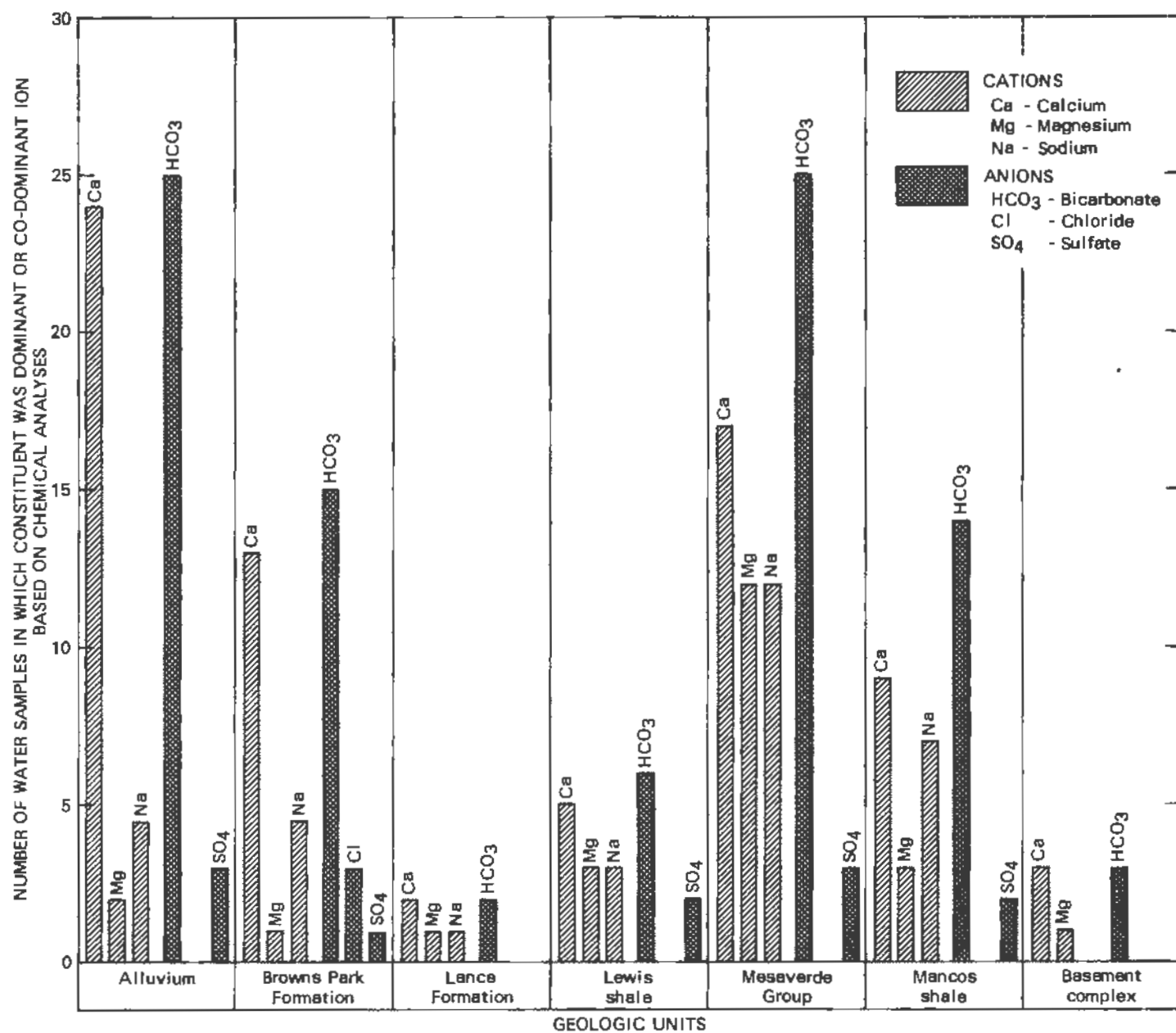


Figure 7. -- Relative frequency of major-ion dominance in water from selected geologic units.

Table 4.--Summary of water-quality characteristics of

Geologic unit	pH (units) ¹			Specific conductance (micromhos per centimeter at 25°C) ¹			Dissolved solids, sum of constituents (milligrams per liter) ²		
	Number of samples	Median	Range	Number of samples	Mean	Range	Number of samples	Mean	Range
Alluvial deposits.	58	7.3	5.9-9.4	61	564	50-2,200	27	417	72-1,660
Browns Park Formation.	40	7.4	6.3-9.2	41	497	50-1,720	17	463	89-2,140
Lance Formation.	6	7.7	7.2-8.1	6	1,970	750-6,000	2	⁵ 535	501-569
Lewis Shale.	9	8.0	7.0-9.0	9	1,210	455-4,000	6	544	272-904
Mesaverde Group.	30	7.4	5.3-8.8	33	1,040	225-2,100	27	709	133-1,460
Mancos Shale.	33	7.4	6.1-8.7	33	1,060	75-3,970	15	959	121-3,290
Basement complex.	6	7.7	7.1-8.0	6	492	105-1,450	3	⁵ 143	64-263

¹Measured at well or spring site.²Laboratory analyses.³Ion(s) used to define water-chemistry type (table 2).⁴Colorado Department of Health, 1977; U.S. Environmental Protection Agency,⁵Data too few for accurate statistical analyses.

water from selected geologic units sampled in 1975 and 1978

Number of samples	Hardness as calcium carbonate (milligrams per liter) ²		Water type Dominant ions ³		Constituents that exceeded standards ⁴ for public-water supplies in some samples (includes pH values less than 6.5)
	Mean	Range	Cations	Anions	
27	256	19-850	Calcium	Bicar- bonate	pH, fluoride, nitrite plus nitrate, sulfate, dissolved solids, arsenic, iron, manganese.
17	233	10-1,300	Calcium	Bicar- bonate	pH, chloride, fluoride, nitrite plus nitrate, sulfate, dissolved solids, manganese.
2	⁵ 360	350-370	Calcium	Bicar- bonate	Nitrite plus nitrate, dissolved solids, manganese.
6	348	120-630	Calcium, magne- sium, or sodium.	Bicar- bonate	pH, nitrite plus nitrate, sulfate, dissolved solids, manganese, selenium.
27	321	12-1,100	Calcium	Bicar- bonate	pH, fluoride, nitrite plus nitrate, sulfate, dissolved solids, iron, manganese.
15	334	10-1,800	Calcium	Bicar- bonate	pH, chloride, fluoride, nitrite plus nitrate, sulfate, dissolved solids, iron, manganese.
3	⁵ 93	40-180	Calcium	Bicar- bonate	Iron, manganese.

1977.

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SUPPLEMENTAL INFORMATION

Systems of Locating and Numbering Wells and Springs

Two systems are used to locate and number wells and springs. One system (fig. 8) uses the 14-character code of the U.S. Bureau of Land Management's land-subdivision system. The first character is an S, which indicates that the well is located in the area covered by the Sixth Principal Meridian. The next letter denotes the quadrant formed by the intersection of the base line (parallel) with the principal meridian. The quadrants are designated A, B, C, or D in a counterclockwise manner with the northeast quadrant being A. The first three numbers designate the township, the next three designate the range, and the last two designate the section. Each section is then divided into quarters designated A, B, C, or D in a counterclockwise rotation, with the northeast quarter being A. This is done again for the quarter-quarter section and the quarter-quarter-quarter section. The three letters following the number designation of township, range, and section indicate the well or spring position first in the quarter section, then in the quarter-quarter section, and then in the quarter-quarter-quarter section. The final number is the order in which the well or spring in the designated quarter-quarter-quarter section was inventoried. A well or spring numbered SB00508515CAB1 would be the first one located in the NW $\frac{1}{4}$ NE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 15, T. 5 N., R. 85 W.

The second method is a 15-digit number derived from latitude and longitude. The first six digits represent degrees, minutes, and seconds of latitude, and the next seven digits represent degrees, minutes, and seconds of longitude. The remaining two digits indicate the sequence in which wells or springs with the same latitude-longitude designations were inventoried.

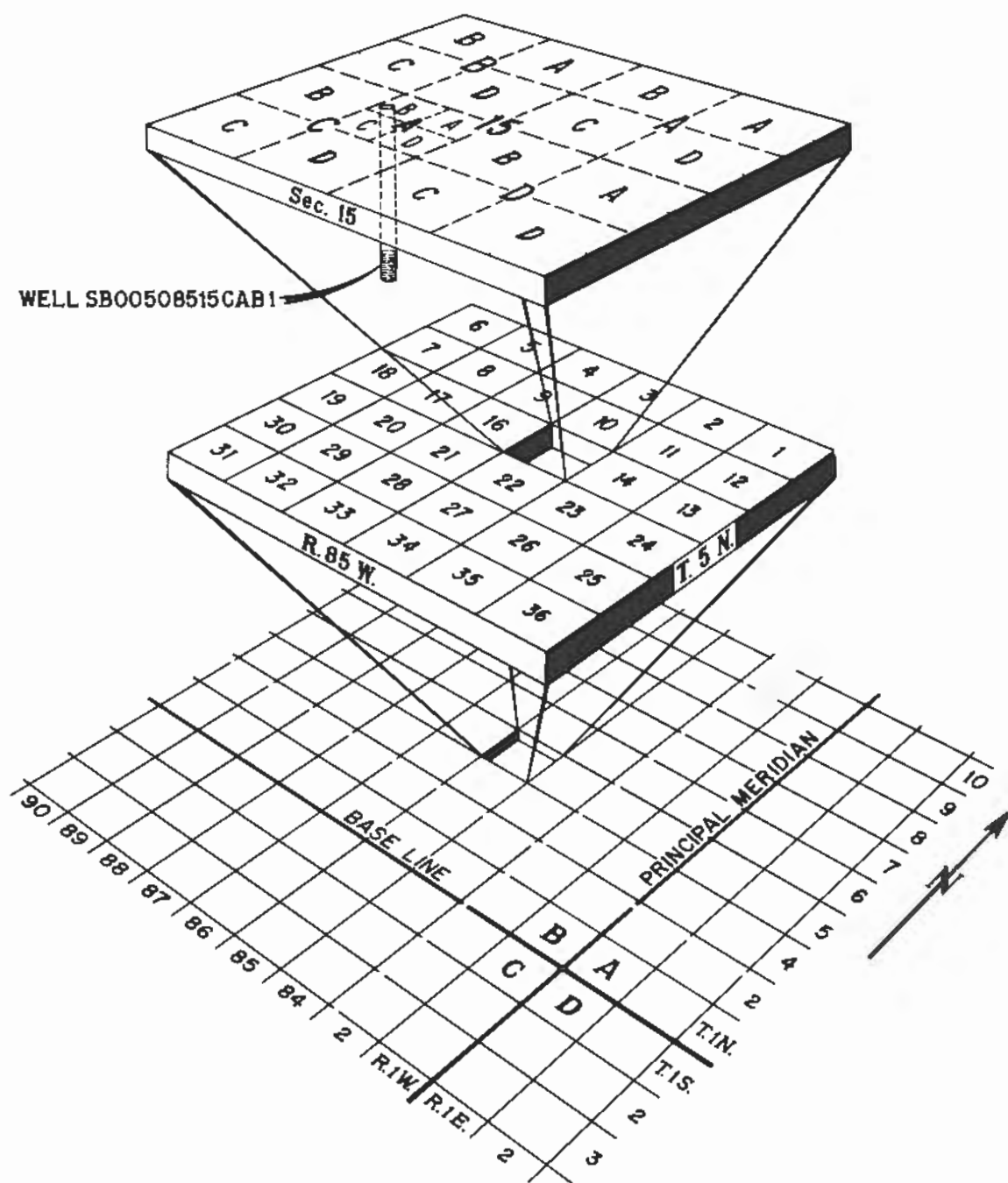


Figure 8. -- System of locating and numbering wells and springs by township, range, and section.

Water-Quality Data Obtained at Wells and Springs

Table 5.--Water-quality data obtained at wells or springs and laboratory

[mg/L=milligram per liter; $\mu\text{g/L}$ =microgram per liter. Underlined values exceed standards Environmental Protection Agency (1977)--pH (6.5-8.5), chloride (250 mg/L), sulfate (250 $\mu\text{g/L}$), and zinc (5,000 $\mu\text{g/L}$); and mandatory standards, established by the Colorado (1.8 mg/L), nitrite plus nitrate as nitrogen (10 mg/L), arsenic (50 $\mu\text{g/L}$), cadmium (10

Site number on plate 1	Latitude and longitude	Location within township, range, and section	Geologic unit	Date of sample (Y-M-D)	Depth to water (feet below land surface)
1	400220106494800	SB00108420ADC1	Alluvium	78-05-15	Surface
2	400339106482900	SB00108416AAA1	Alluvium	78-05-19	-----
3	400930106542100	SB00208510ADD1	Alluvium	78-05-10	18
4	402957107103300	SB00608708BAA1	Alluvium	78-05-15	6
5	403106106492000	SB00708433CBC1	Alluvium	78-05-16	4
6	403712107030200	SB00808629DAD1	Alluvium	78-05-19	4
7	404318106533400	SB00908523CCB1	Alluvium	78-05-11	12
8*	404404106553100	SB00908516DCC1	Alluvium	78-05-15	-----
9	400357106481600	SB00108410CBD1	Browns Park FM	78-05-11	22
10	401210106555400	SB00308528ACC2	Browns Park FM	78-05-10	15
11	401330106562000	SB00308516CCD1	Browns Park FM	78-05-10	10
12	401959106510100	SB00408407DBB1	Browns Park FM	78-05-11	180
13	402514106561500	SB00508505ADD1	Browns Park FM	78-05-16	-----
14	402924106532300	SB00608511CAD1	Browns Park FM	78-05-16	5.4
15	403205106492000	SB00708428CBB1	Browns Park FM	78-05-12	54
16	403207106490600	SB00708428CBA1	Browns Park FM	78-05-16	270
17*	403821107011400	SB00808622BDA1	Browns Park FM	78-05-18	-----
18	404446106574500	SB00908518ABC1	Browns Park FM	78-05-16	2.7
19	404834106563600	SB01008520DBC1	Browns Park FM	78-05-15	55
20	401801107015100	SB00408622CDB1	Mesaverde Group	78-05-09	3.9
21	402609107124800	SB00608836DDC1	Mesaverde Group	78-05-11	21.5
22	411911107221800	SB00408915ABC1	Mesaverde Group	78-05-11	-----
23	400716106555900	SB00208521CDD1	Mancos Shale	78-05-09	18
24	400921106534600	SB00208511CAB1	Mancos Shale	78-05-09	8.8
25	401053107005200	SB00308635CCD1	Mancos Shale	78-05-11	50
26	401418106560300	SB00308509BDC1	Mancos Shale	78-05-18	130
27	401611106575000	SB00408531DDC2	Mancos Shale	78-05-11	2
28	402810106551000	SB00608509DDD1	Mancos Shale	78-05-11	7.4
29	403219106531100	SB00708526ACD1	Mancos Shale	78-06-01	29.8
30	403536106564700	SB00708505CAA1	Mancos Shale	78-05-17	2.2
31	403516107422500	SB00708606DCD1	Mancos Shale	78-05-19	120
32	403810106563000	SB00808520DAC1	Mancos Shale	78-05-11	7.5
33	400809106574300	SB00208518DDC1	Basement complex	78-05-11	Flowing
34	400437106415800	SB00108304DCC1	Basement complex	78-05-15	10
35	403211106465400	SB00708426BCD1	Basement complex	78-05-19	12

analyses of dissolved constituents, sites 1-35, sampled in 1978

for public-water supplies, as follows: Recommended standards, as established by the U.S. Department of Health (1977) and the U.S. Environmental Protection Agency (1977)--fluoride (50 mg/L), lead (50 µg/L), mercury (2 µg/L), and selenium (10 µg/L)

Well depth (feet)	Water temperature (degrees Celsius)	pH (units)	Specific conductance (micromhos per centimeter at 25°C)	Total-coliform bacteria (colonies per 100 milliliters) ¹	Fecal-coliform bacteria (colonies per 100 milliliters) ¹	Calcium, dissolved (mg/L as Ca)
17	10.0	7.3	550	<2	<2	87
12	5.0	8.0	500	<4	<4	61
25	11.0	7.2	300	<2	<2	30
11	10.0	7.1	550	<2	<2	72
30	5.0	5.9	75	<2	<2	7.5
17	9.0	---	300	150	60	34
50	10.0	6.4	105	<2	<2	15
-----	5.0	7.1	580	<2	<2	71
50	8.0	7.5	1,000	<2	<2	180
52	9.0	7.8	-----	<2	<2	250
53	6.5	7.3	400	<2	<2	60
260	8.0	7.2	375	<2	<2	58
91	10.0	7.4	520	<2	<2	75
300	15.0	9.2	1,400	<2	<2	3.7
97	8.0	7.5	315	<2	<2	59
320	9.0	7.8	930	22	<2	5.5
-----	6.0	6.8	180	<2	<2	21
44	7.0	7.2	540	212	<2	87
70	4.0	6.3	135	<2	<2	18
12	6.0	7.6	225	42	<2	26
60	11.5	8.0	1,030	<2	<2	120
-----	15.0	8.8	570	<2	<2	71
41	5.0	7.5	240	28	<2	23
110	6.0	7.3	625	<2	<2	66
112	11.0	7.3	550	<2	<2	50
263	13.0	7.3	950	<2	<2	140
25	8.0	7.0	360	<2	<2	44
95	9.0	7.8	766	212	<2	110
180	8.0	7.3	1,000	<2	<2	100
80	8.0	7.1	3,970	<2	<2	360
235	12.0	7.1	500	<2	<2	16
225	9.5	7.7	2,500	<2	<2	2.7
2,500	38.0	7.3	430	110	212	51
56	6.0	8.0	150	<2	<2	18
47	5.0	7.1	105	216	26	9.2

Table 5.--Water-quality data obtained at wells or springs and laboratory

Site number on plate 1	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Bicarbonate (mg/L as HCO ₃)	Carbonate (mg/L as CO ₃)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)
1	18	10	1.6	300	0	5.0	0.2
2	8.0	4.6	5.1	210	0	.5	.2
3	11	4.5	1.2	140	0	2.7	.1
4	24	29	3.0	270	0	13	.2
5	1.7	2.6	.6	23	0	2.6	.2
6	14	7.7	3.2	140	--	4.8	.1
7	3.1	2.2	1.0	49	0	1.8	.1
8*	27	28	2.0	370	0	4.1	.2
9	21	7.0	5.0	260	0	90	.1
10	160	230	7.1	430	0	27	.2
11	15	9.6	2.0	220	0	4.1	.1
12	11	6.4	7.2	250	0	2.1	.1
13	6.7	35	9.3	260	0	11	.2
14	.2	340	.7	720	67	26	<u>3.5</u>
15	4.7	7.6	.7	210	0	1.9	.6
16	.2	190	1.2	180	0	91	<u>15</u>
17*	8.0	6.4	.8	100	0	10	.1
18	14	13	3.8	370	0	3.2	.1
19	1.4	6.1	.5	56	0	1.9	.1
20	10	3.7	1.1	120	0	1.2	.1
21	42	56	7.9	390	0	44	.2
22	45	13	3.6	340	--	2.6	.2
23	7.5	5.6	1.1	100	0	1.8	.1
24	16	35	5.6	230	0	3.5	.2
25	24	27	3.4	300	0	4.9	.3
26	36	36	1.6	350	0	38	.2
27	15	11	3.0	160	0	19	.1
28	27	25	1.8	320	0	3.8	.2
29	32	94	2.0	490	0	15	.2
30	210	410	3.8	540	0	<u>320</u>	.3
31	8.4	110	1.8	290	--	6.9	.3
32	1.8	740	4.3	1,990	0	19	<u>3.8</u>
33	13	27	1.3	260	0	1.5	.1
34	3.1	6.2	2.5	53	0	13	.1
35	4.2	3.2	1.4	60	0	4.2	.2

analyses of dissolved constituents, sites 1-35, sampled in 1978--Continued

Sulfate, dissolved (mg/L as SO ₄)	Silica, dissolved (mg/L as SiO ₂)	Nitrogen, NO ₂ +NO ₃ , dissolved (mg/L as N)	Phospho- rus, ortho, dissolved (mg/L as P)	Dissolved solids, sum of constitu- ents (mg/L)	Hardness (mg/L as CaCO ₃)	Hardness, noncar- bonate, (mg/L as CaCO ₃)	Sodium- adsorp- tion ratio
54	11	0.05	0.05	336	290	46	0.3
11	41	1.6	.10	243	190	13	.1
7.7	18	.48	.02	147	120	6	.2
97	12	.01	.01	386	280	58	.8
3.8	7.0	2.0	.01	46	26	7	.2
25	13	1.9	.03	181	140	28	.3
6.0	8.7	2.2	.01	72	50	10	.1
34	14	.09	.01	364	290	0	.7
32	38	<u>23</u>	.06	604	540	320	.1
<u>1,100</u>	12	<u>32</u>	.00	<u>2,140</u>	1,300	930	2.8
49	19	.34	.01	269	210	32	.3
4.6	60	.40	.00	275	190	0	.2
21	45	<u>13</u>	.02	390	220	2	1.0
5.9	10	.04	.10	<u>813</u>	10	0	47
5.2	18	.12	.01	<u>203</u>	170	0	.3
110	10	.11	.01	<u>513</u>	15	0	22
10	38	.43	.01	<u>146</u>	86	4	.3
4.9	12	1.8	.01	329	280	0	.3
8.6	18	1.5	.04	89	51	5	.4
15	15	.43	.01	133	110	8	.2
140	35	<u>14</u>	.00	<u>700</u>	470	150	1.1
94	12	<u>12</u>	3.2	<u>424</u>	360	85	.3
7.7	22	.43	.03	121	89	7	.3
100	16	.09	.01	358	230	42	1.0
25	18	2.0	.00	310	220	0	.8
170	14	<u>17</u>	.00	<u>689</u>	500	210	.7
39	11	.13	.18	<u>223</u>	170	41	.4
160	15	.22	.01	<u>503</u>	390	120	.6
130	13	.34	.00	<u>632</u>	380	0	2.1
<u>1,700</u>	13	.01	.01	<u>3,290</u>	1,800	1,300	4.2
37	9.0	3.3	.01	350	75	0	5.5
11	6.3	.02	.03	<u>1,770</u>	14	0	86
23	17	.13	.00	263	180	0	.9
4.7	18	1.7	.01	101	58	14	.4
2.7	8.6	.00	.02	64	40	0	.2

Table 5.--Water-quality data obtained at wells or springs and laboratory

Site number on plate 1	Alkalinity (mg/L as CaCO ₃)	Boron, dissolved (µg/L as B)	Copper, dissolved (µg/L as Cu)	Iron, dissolved (µg/L as Fe)	Manganese, dissolved (µg/L as Mn)	Molybdenum, dissolved (µg/L as Mo)	Nickel, dissolved (µg/L as Ni)
1	250	40	2	120	50	0	0
2	170	10	3	40	0	0	1
3	110	0	9	70	30	0	0
4	220	700	3	350	450	1	0
5	19	-----	---	60	10	--	-
6	110	40	6	100	20	0	0
7	40	10	24	40	0	0	0
8*	300	80	0	20	60	0	0
9	210	30	6	0	0	0	1
10	350	140	26	30	0	0	0
11	180	30	2	50	0	0	1
12	210	20	16	30	0	0	0
13	210	50	6	0	0	0	0
14	700	520	0	0	0	0	0
15	170	5	40	0	0	0	0
16	150	260	27	20	10	20	0
17*	82	20	8	10	0	0	0
18	300	30	6	10	110	0	0
19	46	30	21	90	0	0	0
20	98	30	0	0	10	0	3
21	320	90	10	50	30	3	5
22	280	70	15	30	0	0	0
23	82	30	1	50	20	0	0
24	190	380	4	360	16	1	1
25	250	30	100	20	0	0	8
26	290	90	4	160	0	0	1
27	130	120	7	10	0	0	1
28	260	70	4	310	20	2	0
29	400	130	27	920	80	74	0
30	440	280	1	3,100	230	2	0
31	240	130	22	180	30	0	2
32	1,630	1,000	0	80	10	0	1
33	210	30	5	20	20	5	0
34	43	0	3	300	30	0	0
35	49	2	1	660	110	0	0

*Spring.

¹"Less than" values indicate the maximum colonies that could have been detected with²Colonies determined from nonideal count.

analyses of dissolved constituents, sites 1-35, sampled in 1978--Continued

Strontium, dissolved (µg/L as Sr)	Vanadium, dissolved (µg/L as V)	Zinc, dissolved (µg/L as Zn)	Arsenic, dissolved (µg/L as As)	Cadmium, dissolved (µg/L as Cd)	Lead, dissolved (µg/L as Pb)	Mercury, dissolved (µg/L as Hg)	Selenium, dissolved (µg/L as Se)
510	0	60	1	-	-	0	0
220	5.0	50	3	-	-	0	0
220	1.0	170	0	-	-	0	0
410	0	270	0	-	-	0	0
-----	-----	-----	-	-	-	-	-
190	0	980	1	-	-	0	0
110	0	70	0	0	-	0	0
450	0	10	1	-	-	0	0
590	3.0	50	1	1	2	0	0
1,700	0	30	0	-	-	0	0
350	1.0	20	1	1	5	0	0
280	4.0	510	1	-	-	0	0
380	3.0	700	2	-	-	0	0
90	0	30	0	-	-	0	0
200	1.0	830	0	-	-	0	0
120	76	8	3	-	-	0	6
170	3.0	80	0	1	4	0	0
520	0	20	1	1	4	0	0
120	1.0	100	1	-	-	0	0
190	0	10	0	-	-	0	0
800	1.0	80	2	-	-	0	0
730	0	50	1	-	-	0	1
190	2.0	330	1	-	-	0	0
330	1.0	220	1	2	5	0	0
330	0	100	0	-	-	0	0
1,900	0	3,400	0	-	-	0	5
260	0	210	1	1	3	0	0
1,100	0	310	0	-	-	0	0
1,500	0	50	2	-	-	0	0
3,900	10	30	0	-	-	0	0
210	1.0	2,200	1	-	-	0	0
70	1.0	200	0	-	-	0	0
560	0	10	1	0	5	0	0
110	0	900	1	-	-	0	0
20	0	260	0	-	-	0	0

the size sample used when no colonies were found.

Table 6.--Water-quality data obtained at wells or springs, sites 36-130, sampled in 1978

[Underlined pH values are those values that were less than 6.5 or greater than 8.5 recommended for public-water supplies by the U.S. Environmental Protection Agency, 1977]

Site number on plate 1	Latitude and longitude	Location within township, range, and section	Date of sample (Y-M-D)	Depth to water (feet below land surface)	Well depth (feet)	Water temperature (degrees Celsius)	pH (units)	Specific conductance (micromhos per centimeter at 25°C)	Total coliform bacteria (colonies per 100 milliliters) ¹	Fecal coliform bacteria (colonies per 100 milliliters) ¹
<u>Alluvium</u>										
36	400245106495600	SB00108420ABA1	78-05-19	Surface	18	13.0	8.0	335	48	--
37*	400300106515000	SB00108418CCB1	78-05-12	-----	-----	4.0	7.3	240	<2	<2
38	400637106563600	SP00208529DAD1	78-05-09	20	59	8.0	7.5	220	<2	<2
39*	400819106541000	SB00208514CCB1	78-05-10	9.0	12	10.0	7.5	330	28	<2
40*	400902106543900	SB00208510DCD1	78-05-10	-----	-----	7.0	7.8	450	46	<2
41	401355106563600	SB00308517ADD1	78-01-20	8.6	12.6	7.0	7.6	700	--	--
42*	401418106561200	SB00308516BBA1	78-05-18	-----	-----	9.5	7.4	420	<2	<2
43	401425107052300	SB00308618BBA1	78-05-11	4.5	12	5.0	<u>9.2</u>	170	<2	<2
44	402049106485500	SB00508433DBB1	78-05-10	13.0	16	9.0	<u>6.6</u>	500	216	<2
45	402146106543400	SB00508527ACC1	78-05-16	Flowing	17	13	7.2	170	<2	<2
46	402324106485700	SB00508416DBB1	78-05-09	20	29	8.5	6.8	280	<2	<2
47	402351106482200	SB00508516AAA1	78-05-15	-----	50	11.0	6.5	105	216	<u>2</u>
48	402517106590700	SB00508601BDA1	78-05-18	Flowing	-----	11.5	<u>8.7</u>	980	2?	<2
49	402535106582300	SB00608531CCC1	78-05-18	10	-----	10.0	<u>8.8</u>	760	<2	<2
50	402904106595700	SB00608614ABA1	78-05-12	8	50	11.0	<u>9.3</u>	340	<2	<2
51	402912107020900	SB00608609DCD1	78-05-12	1.2	-----	7.5	<u>9.4</u>	410	98	<2
52	402920107543000	SB00608809CBD1	78-05-16	4.5	12.5	9.0	---	1,750	80	<u>26</u>
53	402938107155200	SB00608809ACD1	78-05-16	-----	-----	10.0	7.5	1,750	<2	<2
54	402942107152500	SB00608809ADA1	78-05-16	-----	35	12.0	7.5	1,080	<2	<2
55	402942107154400	SB00608809ACA1	78-05-18	-----	12	6.0	---	1,800	--	<2
56	403005106512100	SB00608406CCA1	78-05-09	30	42	9.0	6.8	370	<2	<2
57*	403012107115000	SB00608706CCA1	78-05-15	-----	-----	10.0	7.5	540	<2	<2
58	403031107121600	SB00608801ADC1	78-05-15	-----	15	9.0	6.8	360	<2	<2
59	403202106485600	SB00708428CAD1	78-05-17	-----	-----	10.0	8.2	580	<2	<2
60	403210106520800	SB00708525ACC1	78-05-18	14	20	10.5	7.3	380	<2	<2
61	403211106484000	SB00708428ACD1	78-05-17	30	48	7.0	7.3	180	<2	<2
62	403702106591900	SB00808529DDD1	78-05-12	15.8	75	10.0	7.3	275	<2	<2
63	403903106564300	SB00808517DBC1	78-05-12	4.3	70	4.0	<u>6.2</u>	290	<2	<2
64*	403958106560400	SB00808509CBA1	78-05-18	-----	-----	10.0	<u>7.4</u>	360	<2	<2
65	404233106555400	SB00908528CBD1	78-05-15	Surface	60	----	---	-----	28	<2

Alluvium--Continued

66	404302106545200	SB00908527BBB1	78-05-14	4	41	6.0	6.2	235	<2	<2
67	404309106543000	SB00908522CDD1	78-02-08	46.8	75	8.0	6.5	105	--	--
68	404414106515100	SB00908513DAD1	78-05-18	15.1	51	5.0	6.9	120	40	22
69	404402106521000	SB00908513CDC1	78-05-11	26	53	6.0	6.1	180	<2	<2
70	402902106470400	SB00608514BBC1	78-05-11	2	12	3.0	7.2	50	<2	<2

Browns Park Formation

71*	400647106524900	SB00208525CBA1	78-05-10	-----	---	6.0	7.3	350	28	<2
72	401007106442100	SB00208306DBC1	78-05-18	21	30	7.0	8.2	400	<2	<2
73	401210106555600	SB00308528ACC1	78-05-10	8	15	8.0	6.8	700	<2	<2
74	401349106565500	SB00308517DBB1	78-05-10	44.1	83	10.0	7.5	1,480	--	<2
75	401352106564200	SB00308517ADC1	78-01-20	26.9	33	12.0	7.6	750	--	--
76	401355106563500	SB00308517ADD2	78-05-10	-----	90	9.0	7.9	850	<2	<2
77	401521106495900	SB00308405DCB1	78-05-10	10.4	800	-----	---	-----	--	--
78	401931106492300	SB00408416BBB1	78-05-17	20	48	10.0	7.1	630	<2	<2
79	402007106513000	SB00408407BDB1	78-05-11	30	195	9.0	7.3	380	<2	<2
80	402023106515200	SB00408512AAD1	78-05-10	107	237	22.0	7.3	280	<2	<2
81	402121106515300	SB00408525DDD1	78-05-15	24	51	10.0	7.6	450	<2	<2
82	402132106515000	SB00508525DAD1	78-05-10	35.1	210	12.5	---	390	<2	<2
83	402237106530700	SB00508523ADC1	78-05-16	.9	---	10.5	7.5	480	22	<2
84*	402239106484300	SB00508421ACD1	78-05-15	-----	---	8.0	7.1	235	<2	<2
85	402259106501500	SB00508420BAB1	78-05-09	60	270	7.0	7.3	680	<2	<2
86	402324106545000	SB00508515CAB1	78-05-15	183.5	302	10.0	8.4	300	<2	<2
87	402324106545500	SB00508515CBA1	78-05-16	-----	---	10.0	7.4	340	24	<2
88	402345106503600	SB00508417BBC1	78-05-11	6.7	170	13.0	7.8	405	<2	<2
89	402349106535200	SB00508514BBB1	78-05-11	-----	320	9.0	7.5	280	<2	<2
90	402357106535800	SB00508511CCC1	78-05-15	55.8	150	12.0	7.3	460	<2	<2
91	402329106541000	SB00508515ADC1	78-05-15	20.2	200	10.0	7.5	270	22	<2
92	402436106510100	SB00508407ABD1	78-05-09	104	130	9.0	8.2	550	<2	<2
93	402545106481900	SB00508503BBB1	78-05-15	13.5	45	9.0	6.4	120	<2	<2
94	402551106505200	SB00608431DDB1	78-05-09	125	525	12.0	7.6	390	--	<2
95	403136106491400	SB00708433BBB1	78-05-12	4.3	75	5.0	7.1	50	<2	<2
96	404932106194500	SB00408408DDB1	78-05-10	15.4	240	15.0	---	270	<2	<2

Lance Formation

97	402843107150600	SB00608815BDC1	78-05-11	2.5	9	18.5	8.0	2,500	<2	<2
98	402930107203000	SB00608911DBB1	78-05-10	3.3	200	13.5	8.1	6,000	<2	<2
99	403233107858000	SB00708924DD1	78-05-15	-----	---	12.0	7.4	880	<2	<2
100*	403453107174800	SB00708807ADA1	78-05-18	-----	---	10.0	7.2	750	<2	<2

Lewis Shale

101	402415107184400	SB00508807CBB1	78-05-10	7.7	85	11.0	8.1	4,000	84	<2
102	402842107120000	SB00608813ADD1	78-05-10	16	60	21.0	8.3	750	<2	<2
103	402713107321000	SB00608811DDC1	78-05-10	.7	15	12.0	9.0	1,130	130	<2

Table 6.--Water-quality data obtained at wells or springs, sites 36-130, sampled in 1978--Continued

Site number on plate 1	Latitude and longitude	Location within township, range, and section	Date of sample (Y-M-0)	Depth to water (feet below land surface)	Well depth (feet)	Water temperature (degrees Celsius)	pH (units)	Specific conductance (micromhos per centimeter at 25°C)	Total coliform bacteria (colonies per 100 milliliters) ¹	Fecal coliform bacteria (colonies per 100 milliliters) ¹
<u>Mesaverde Group</u>										
104	402055106591100	SB00508636BD01	78-05-18	-----	560	10.5	8.5	1,420	<2	<2
105	402217107113600	SB00508719CDA1	78-05-18	-----	18	9.0	---	580	<2	<2
106	402334106574600	SB00508518ACA1	78-05-18	50	80	14.0	7.3	705	<2	<2
107	402710106591400	SB00608625BAC1	78-05-18	48.7	116	9.0	7.5	995	<2	<2
108	402809106595500	SB00608623ABA1	78-05-18	150	260	9.0	7.2	600	<2	<2
109	402929107015900	SB006086090A81	78-05-12	1.8	150	10.0	5.3	570	<2	<2
<u>Mancos Shale</u>										
110*	400120106500000	SB00108429DAD1	78-05-15	-----	-----	12.0	7.8	250	<2	<2
111*	400156106563100	SB00108529AAA1	78-05-11	-----	-----	5.0	7.3	560	<2	<2
112*	400202106550200	SB00108422CDB1	78-05-12	-----	-----	5.0	7.5	275	<2	<2
113*	400304106532000	SB00108514BBD1	78-05-12	-----	-----	8.0	7.6	210	² 16	<2
114*	400707106594700	SB00208625BBC1	78-05-11	-----	-----	10.0	7.7	325	<2	<2
115	401941107222100	SB004089100BC1	78-05-11	21.1	210	11.5	8.2	2,300	<2	<2
116	402158106570700	SB00408529BAC1	78-05-18	-----	40	7.5	7.6	880	<2	<2
117	402920106550700	SB006085090AD1	78-02-07	96.1	400	15.0	8.1	1,500	---	--
118	402941106523100	SB00608512BCA1	78-05-16	30	265	12.0	8.3	950	<2	<2
119	402949106491800	SB00608509BBC1	78-05-09	190	466	14.0	7.7	450	<2	<2
120*	403153106592800	SB00708625CCB1	78-05-17	-----	-----	7.0	7.2	1,300	62	<2
121	403224106521500	SB00708525BAD1	78-06-01	4.4	60	9.5	6.9	570	90	<2
122	403242106520300	SB00708525ABD1	78-05-09	50	240	8.0	8.5	2,150	1,100	<2
123	403351106594200	SB00708614DAB1	78-05-17	1.0	12	10.0	6.9	705	² 2	<2
124	403843106581500	SB00808519BBA	78-05-17	6.0	40	6.0	6.9	390	<2	<2
125	403843106583500	SB00808613DDC1	78-05-09	9.3	75	6.0	6.7	515	<2	<2
126	403855106563400	SB00808517DCA1	78-05-12	47	135	10.0	6.5	310	<2	<2
127	404259106542300	SB00908527BBC1	78-05-11	5.6	60	9.0	6.1	75	<2	<2
<u>Basement complex</u>										
128	395534106463600	SC00108435CAB1	78-05-17	-----	-----	11.0	7.9	590	<2	<2
129	395537106463200	SC00108435CAB2	78-05-17	3	7	17.0	7.4	1,450	<2	<2
130	403127106583500	SB00708433ABD1	78-05-16	10	200	7.0	8.0	225	<2	<2

*Spring.

¹"Less than" values indicate the maximum number of colonies that could have been detected with the size sample used when no colonies were detected.²Colonies determined from a nonideal count.

