GROUND-WATER QUALITY IN WYOMING

By L. R. Larson

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CONVERSION FACTORS

For use of readers who prefer to use metric units, conversion factors for terms used in this report are listed below:

Multiply	By	To obtain
foot	0.3048	meter
acre-foot	1,233	cubic meter

Temperature in degrees Fahrenheit (°F) can be converted to degrees Celsius (°C) by the following equation:

$$°C = 5/9(°F - 32)$$

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ABSTRACT

Chemical-quality data for selected constituents in the U.S. Geological Survey water-quality file (WATSTORE) for about 2,300 ground-water sample sites in Wyoming are summarized. Dissolved-solids, nitrate, fluoride, arsenic, barium, cadmium, chromium, lead, mercury, selenium, iron, and manganese concentrations are summarized on a statewide basis. The major chemical-quality problem limiting the use of Wyoming ground water is excessive dissolved-solids concentrations. Water from about 62 percent of the ground-water sites sampled exceeded the U.S. Environmental Protection Agency's (1979) secondary drinking-water standard of 500 milligrams per liter for dissolved solids. Consequently, dissolved-solids concentrations also are summarized by aquifer on a county-wide basis.

Although dissolved-solids concentrations generally vary greatly within an aquifer, there is, nonetheless, a considerable difference in water quality among the more than 100 aquifers from which samples have been collected. Based on the median dissolved-solids concentrations of water in aquifers with 20 or more sampling sites, aquifers yielding water of the best quality are the Holocene lacustrine deposits, the upper Miocene Ogallala Formation, the lower Miocene Arikaree Formation, the Mississippian Madison Limestone, and the Oligocene White River Formation. Aquifers yielding the most mineralized water are the Paleocene Ferris Formation, the Lower Cretaceous Cloverly Formation, the Eocene Tipton Shale and Laney Members of the Green River Formation, and the Paleocene Hanna Formation.

The counties with the best quality water based on median dissolved-solids concentrations are Teton and Laramie Counties. The counties with the highest median dissolved-solids concentrations are Hot Springs and Natrona Counties. However, all counties do have some ground-water samples with dissolved-solids concentrations less than the U.S. Environmental Protection Agency's (1979) drinking-water standard.

Nitrate contamination is an uncommon but potentially dangerous ground-water problem. About 3 percent of the nitrate concentrations in Wyoming ground-water samples exceeded the U.S. Environmental Protection Agency's (1975) primary drinking-water standard of 10 milligrams per liter (for nitrate, as nitrogen). A nitrate problem generally is caused by septic tank, feedlot, or barnyard drainage into shallow aquifers.

Fluoride concentrations exceeded the primary drinking-water standard in 14 percent of the ground-water samples. All counties had at least one sample with a fluoride concentration greater than the drinking-water standard. The highest fluoride concentration (90 milligrams per liter) was in water from a well completed in the Tipton Shale Member of the Green River Formation.

Toxic trace elements generally have not been found in concentrations greater than the primary drinking-water standards in ground-water samples, except for selenium. Poisoning of livestock by selenium in forage is a known problem in some areas of Wyoming.

Concentrations in about 19 percent of the iron analyses and about 30 percent of the manganese analyses exceeded the secondary drinking-water standards (U.S. Environmental Protection Agency, 1979) of 300 micrograms per liter for iron and 50 micrograms per liter for manganese. Iron and manganese concentrations greater than the drinking-water standards commonly cause esthetic problems when used for domestic supplies.

Many activities of man in Wyoming such as waste disposal, coal mining, uranium mining and milling, oil refining, and crop irrigation and fertilization may have the potential for ground-water contamination. However, most of the data in the water-quality file of the U.S. Geological Survey represent natural ground-water conditions. In order to ascertain the impact of man-caused activities, a sensitive ground-water chemical-quality data network needs to be established. In addition, in order to more adequately define the ground-water quality of the State, a computerized data base containing data contributed by interested State and Federal agencies as well as private organizations would be advantageous.

1.0 INTRODUCTION

REPORT SUMMARIZES SELECTED GROUND-WATER CONSTITUENTS IN WYOMING

Dissolved-solids, nitrate, fluoride, toxic trace elements, iron, and manganese concentrations are summarized by aquifer on a statewide basis. Dissolved solids also are summarized by aquifer on a county-wide basis.

The general public and water users and managers have difficulty obtaining and evaluating the voluminous ground-water-quality data for Wyoming. Many of the published county and basin ground-water reports are out of print, require updating, or both. A single report presenting and assessing the ground-water quality of the State is needed. In addition, the need to plan for future requirements for ground-water-quality data in order to properly develop, manage, and protect the ground-water resources of Wyoming has been recognized.

The primary objectives of the report include the following: (1) To summarize the chemical-quality data collected from more than 2,300 wells and springs in the State, and (2) to assess the ground-water quality of the State using currently available data. An additional objective is to identify future needs for future collection of ground-water-quality data in the State.

The scope of the report is limited to data that were retrieved in September, 1983 from the water-quality file (WATSTORE) of the U.S. Geological Survey and is further limited to constituents that commonly restrict the use of ground water. These critical constituents were selected because of water-quality standards, especially drinking-water standards (U.S. Environmental Protection Agency, 1975, 1979), the availability of data, and the magnitude of the problem created by certain constituents. The most prevalent ground-water-quality problem in Wyoming is excessive dissolved-solids concentrations. Dissolved-solids concentrations are, therefore, emphasized by summarizing the data by aquifer on a county-wide basis as well as on a statewide basis. Nitrate, fluoride, toxic trace elements, iron, and manganese concentrations are summarized by aquifer on a statewide basis.

The chemical-quality data in the water-quality file of the Survey generally reflect natural conditions. Contamination problems caused by man generally are not reflected by the data in the Survey file; the wells for which data are included generally are not monitored for potential ground-water contaminants introduced by the activities of man. Also, many potential contaminants are not the commonly found and analyzed constituents in ground water.

Although the water-quality data generally do not reflect ground-water contamination problems, such problems do exist in Wyoming. "The booming energy industry is creating potential sources of aquifer contamination at a very rapid pace" (Wyoming Department of Environmental Quality, 1982, p. 51). Potential contamination sources include a railroad-tie treatment plant, 4,000 petroleum-related injection wells, oil refineries, leaky gasoline storage tanks, 350 uranium in situ injection wells, uranium mines and mills, underground coal gasification sites, trona mines and mills, city landfills, and proliferating septic-tank leach fields.

The ground-water-quality data available in the Survey file are statistically biased to some extent. Most of the wells from which samples were collected yield water suitable for either livestock, domestic, or irrigation use. A well unsuitable for the intended use generally would be abandoned and not sampled. Samples collected from springs, however, generally are without this bias. In some areas, samples from flowing wells from oil-field tests are biased because often these oil-related deep wells generally yield very poor quality water. However, the data also are biased because many areas lack data for deep aquifers.

The data summaries presented in this report also introduce biases to the data analysis. The summaries are presented by aquifer, as defined in the water-quality file. Some of the aquifers are thousands of feet thick and, therefore, can vary significantly in lithology. The samples identified from the same aquifer may be from different lithologic layers within that aquifer, which may not be hydrologically connected. Within the same aquifer, coal layers tend to have different water quality than sandstone layers, especially if shale layers separate them. Although in the same named aquifer, samples may have been collected in different structural basins, which are not hydrologically connected. The water quality in the same aquifer in various basins may be quite different.

A large number of published reports pertaining to ground-water quality in Wyoming are available. Among the more recent reports containing sections on ground-water quality are eight U.S. Geological Survey Hydrologic Investigation Atlases that cover eight of the nine major structural basins in the State (Cox, 1976; Hodson and others, 1974; Lines and Glass, 1975; Lowry and others, 1974; Lowry and others, 1976; Welder, 1968; Welder and McGreevy, 1966; and Whitcomb and Lowry, 1968). The remaining structural basin includes the southeastern part of the State and has been studied in county ground-water reports published as U.S. Geological Survey Water-Supply Papers (Lowry and Crist, 1967; Morris and Babcock, 1960; and Rapp and others, 1957). A selenium study in Natrona County (Crist, 1974) and a Niobrara County report (Whitcomb, 1965) also are available.

2.0 GROUND-WATER USE

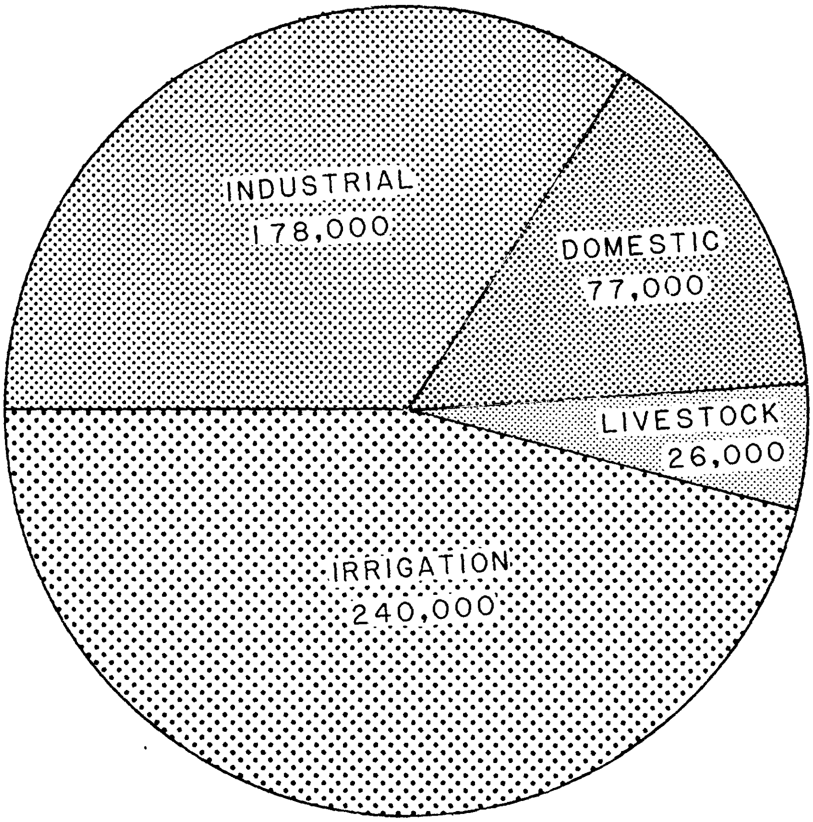
GROUND WATER USED THROUGHOUT WYOMING

Ground water is a major source of water for agriculture, domestic, and industrial use. Use of ground water in Wyoming is increasing but has some restrictions.

Ground water is an important resource to Wyoming, providing about 12 percent of the total water used. Current ground-water use is about 521,000 acre-feet annually, about one-half of which is used for irrigation, as shown in figure 2.0-1. Sixty-five percent of Wyoming residents obtain drinking water from wells or springs. Major industrial uses include secondary and tertiary oil recovery, trona mining, uranium mining and milling, and cooling water for electrical-power generation. Wells and springs commonly are used for livestock watering.

The use of ground water increased from 216,000 acre-feet during 1973 to about 521,000 acre-feet during 1981 (Wyoming Department of Environmental Quality, 1982, p. 49). Future use of ground water will increase as demand for water increases, because in many areas of the State, surface water is not physically available or has been fully appropriated.

Availability, quality, and cost are three restrictions limiting ground-water use in Wyoming. The availability of ground water is not within the scope of this report; however, availability is a definite limitation. Some areas in the State are not underlain by aquifers that can be reached by drilling at a reasonable cost. Also, some aquifers have such small yields of water to wells that the usefulness of the aquifer is restricted. Only a few Wyoming counties are endowed with widespread, relatively shallow aquifers that yield large volumes of high quality water that is chemically suitable for most uses. The cost, not only of the drilling and constructing of wells, but also of the power for pumping is increasingly becoming an important factor in determining the suitability of Wyoming ground water for large-volume uses such as irrigation. Despite these restrictions ground-water use in Wyoming is predicted to increase (Wyoming Department of Environmental Quality, 1982, p. 52).



(Modified from Wyoming Department of Environmental Quality, 1982)

Figure 2.0-1.--Ground-water use (statewide), in acre-feet per year.

3.0 WATER QUALITY

WATER QUALITY COMMONLY LIMITS USE OF WYOMING GROUND WATER

Criteria for evaluating water quality for three major uses of ground water (domestic, livestock watering, and irrigation) are presented.

Water quality is the characteristic of water that determines the suitability of water for various uses. Water quality commonly is a problem in Wyoming and usually prevents or limits the use of the water. The quality of water primarily is determined by the concentration of various solids, liquids, or gases dissolved or suspended in the water. Although treatment of water to improve the quality usually is technically possible, the cost generally is prohibitive.

Criteria for evaluating water quality for three common uses of ground water--drinking water, livestock watering, and irrigation--are presented in table 3.0-1. The table includes most of the constituents in the U.S. Environmental Protection Agency (1975, 1979) drinking-water standards except for organic and radioactive constituents. Data for these constituents either are not in the Survey file or are too few to summarize. For livestock and irrigation water, only dissolved-solids criteria are included (National Academy of Sciences and National Academy of Engineering, 1973), as this usually is the dominant factor in Wyoming for determining the suitability of ground water for these two uses.

Table 3.0-1.--Criteria for selected constituents used to evaluate water quality

[µg/L, micrograms per liter; mg/L, milligrams per liter; fluoride standard is based on an annual average maximum daily air temperature of 54° to 58° Fahrenheit]

DRINKING WATER

Primary standards[1] (mandatory)		Secondary standards[2] (recommended)	
Constituent	Concentration	Constituent	Concentration
Arsenic	50 µg/L	Chloride	250 mg/L
Barium	1,000 µg/L	Copper	1,000 µg/L
Cadmium	10 µg/L	Dissolved solids	500 mg/L
Chromium	50 µg/L	Iron	300 µg/L
Fluoride	2.2 mg/L	Manganese	50 µg/L
Lead	50 µg/L	Sulfate	250 mg/L
Mercury	2 µg/L	Zinc	5,000 µg/L
Nitrate (as nitrogen)	10 mg/L		
Selenium	10 µg/L		

LIVESTOCK[3]

Dissolved-solids concentration (mg/L)	Remarks
Less than 1,000	Relatively low level of salinity, generally considered freshwater. Excellent for all classes of livestock and poultry.
1,000 - 2,999	Very satisfactory for all classes of livestock and poultry. May cause temporary and mild diarrhea in livestock not accustomed to the water or may cause watery droppings in poultry.
3,000 - 4,999	Satisfactory for livestock, but may cause temporary diarrhea or be refused at first by animals not accustomed to the water. Poor water for poultry, commonly causing watery feces, increased mortality, and decreased growth, especially in turkeys.
5,000 - 6,999	Can be used with reasonable safety for dairy and beef cattle, for sheep, swine, and horses. Avoid use for pregnant or lactating animals. Not acceptable for poultry.
7,000 - 10,000	Unfit for poultry and probably for swine. Considerable risk in using for pregnant or lactating cows, horses, or sheep, or for the young of these species. In general, use should be avoided although may be tolerable for older ruminants, horses, poultry, and swine under certain conditions.
More than 10,000	Risks with this highly saline water are so great that it cannot be recommended for use under any conditions.

IRRIGATION[4]

Dissolved-solids concentration (mg/L)	Classification
500 or less	Water for which no detrimental effects usually are noticed.
500 - 1,000	Water that can have detrimental effects on sensitive crops.
1,000 - 2,000	Water that can have adverse effects on many crops; requires careful management practices.
2,000 - 5,000	Water that can be used for salt-tolerant plants on permeable soils with careful management practices.

[1] Data from U.S. Environmental Protection Agency, 1975, p. 59570; based on health effects
[2] Data from U.S. Environmental Protection Agency, 1979, p. 42198; based on esthetic effects
[3] Data from National Academy of Sciences and National Academy of Engineering, 1973, p. 308
[4] Data from National Academy of Sciences and National Academy of Engineering, 1973, p. 335

4.0 AQUIFERS

WATER SAMPLES COLLECTED FROM MORE THAN 100 AQUIFERS

The complex geology of the State has resulted in the use of ground water from many different aquifers. However, water-quality data from the Wasatch Formation, alluvium, and Fort Union Formation are the most abundant.

The complex geology of the State has necessitated the use of many different aquifers ranging in age from Holocene alluvial deposits to Precambrian rock. The U.S. Geological Survey has collected ground-water samples from more than 100 aquifers for water-quality analysis. These aquifers, the aquifer code, geologic age, and number of analyses are listed in table 4.0-1.

The aquifers with the most water-quality analyses are the Wasatch Formation, alluvium, and Fort Union Formation, with more than 200 analyses each in the Survey file. In addition to these three aquifers, the Madison Limestone, Tensleep Sandstone, Lance Formation, and White River Formation are individually represented in the Survey file by more than 50 analyses.

The name Madison Limestone is popularly used throughout the State except in the Black Hills where the term Pahasapa Limestone is accepted by the U.S. Geological Survey. However, for consistency in this report, the term Madison Limestone is used throughout Wyoming.

Table 4.0-1.--System, series, aquifer code and name, and number of water-quality analyses for aquifers in Wyoming

[System and series: The youngest system and series are given for a rock unit that extends across more than one stratigraphic unit]

System and series	Aquifer code	Aquifer name	Number of analyses
Holocene	111ALVM	Holocene alluvium	214
	111EOLN	Eolian deposits	1
	111HLCN	Holocene Series	1
	111LCTN	Lacustrine deposits	22
	111LDLD	Landslide deposits	2
	111SNDD	Sand dune deposits	2
	111TRRC	Terrace deposits	24
Pleistocene	112BVUC	Bivouac Formation	1
	112GLCL	Glacial deposits	18
	112TRRC	Terrace deposits	6
Tertiary	120EXTV	Extrusive rock	1
	120INTV	Intrusive rock	1
	120TRTR	Tertiary System	11
Pliocene	121BRPK	Browns Park Formation[1]	9
	121NRPK	North Park Formation[1]	16
	121OGLL	Ogallala Formation[1]	20
	121PLCN	Pliocene Series	1
	121TWNT	Teewinot Formation[1]	1
Miocene	122ARKR	Arikaree Formation	33
	122BSHP	Bishop Conglomerate[2]	9
	122MOCN	Miocene Series	1
Oligocene	123BRUL	Brule Formation	13
	123CDRN	Chadron Formation	1
	123OLGC	Oligocene Series	1
	123WRVR	White River Formation or Group	52
Eocene	124BRDG	Bridger Formation	20
	124BSPG	Battle Spring Formation	11
	124CDBF	Cathedral Bluffs Tongue of Wasatch Formation	14
	124EOCN	Eocene Series	10
	124GRRV	Green River Formation	12
	124HANN	Hanna Formation[3]	29
	124LNEY	Laney Member of Green River Formation	47

Table 4.0-1.--System, series, aquifer code and name, and number of water-quality analyses for aquifers in Wyoming--Continued

System and series	Aquifer code	Aquifer name	Number of analyses
Eocene	124TPTN	Tipton Shale Member of Green River Formation	44
	124WDRV	Wind River Formation	38
	124WKPK	Wilkins Peak Member of Green River Formation	11
	124WLWD	Willwood Formation	47
	124WSHK	Washakie Formation	2
	124WSTC	Wasatch Formation	312
Paleocene	125EVNS	Evanston Formation	1
	125FRRS	Ferris Formation	27
	125FRUN	Fort Union Formation	205
	125PLCN	Paleocene Series	2
	125TGRV	Tongue River Member of Fort Union Formation	1
	125TULK	Tullock Member of Fort Union Formation	2
Cretaceous	210CRCS	Cretaceous System	4
Upper Cretaceous	211ADVL	Adaville Formation	1
	211ALMD	Almond Formation	12
	211BLDB	Blind Bull Formation	1
	211BLIR	Blair Formation	2
	211BXTR	Baxter Shale	4
	211CODY	Cody Shale	3
	211CRCSU	Upper Cretaceous Series	2
	211ERCS	Ericson Sandstone or Formation	5
	211FRNR	Frontier Formation	35
	211FXHL	Fox Hills Formation	27
	211HLRD	Hilliard Shale or Formation	2
	211LNCE	Lance Formation	58
	211LWIS	Lewis Shale	8
	211MDCB	Medicine Bow Formation	2
	211MTTS	Meeteetse Formation	2
	211MVRD	Mesaverde Formation or Group	43
	211NBRR	Niobrara Formation	2
	211PIRR	Pierre Shale	4
	211RKSP	Rock Springs Formation	5
	211STEL	Steele Shale	5
Lower Cretaceous	217ASPN	Aspen Shale or Formation	1
	217BRRV	Bear River Formation	3
	217CLVL	Cloverly Formation	24
	217CRCSL	Lower Cretaceous Series	2
	217FLRV	Fall River Formation	4
	217GNNT	Gannett Group	2
	217INKR	Inyan Kara Group	26
	217LKOT	Lakota Formation	20
	217MDDY	Muddy Sandstone Member of Thermopolis Shale	3
	217MWRY	Mowry Shale	5
	217TMPL	Thermopolis Shale	2
Jurassic	220JRSC	Jurassic System	1
Upper Jurassic	221GPSP	Gypsum Spring Formation[4]	2
	221JRSCU	Upper Jurassic Series	1
	221MRSN	Morrison Formation	5
	221SNDC	Sundance Formation	12
Lower Jurassic	227NGGT	Nugget Sandstone	3
Upper Triassic	231ANKR	Ankareh Shale, Formation, or Red Beds	1
	231CGTR	Chugwater Formation or Group	8
Lower Triassic	237GSEG	Goose Egg Formation	13
	237SPRF	Spearfish Formation	6
	237TYNS	Thaynes Limestone	1
Paleozoic	300PLZC	Paleozoic Erathem	7
Upper Permian	311PRKC	Park City Formation	7
	311PSPR	Phosphoria Formation	3
Lower Permian	317CSPR	Casper Formation	3
	317FRLL	Forelle Limestone Member of Goose Egg Formation	6
	317MNKT	Minnekahta Limestone	7
	317MNLS	Minnelusa Formation	26
	317OPCH	Opeche Shale	1
	317STNK	Satanka Shale	4
	317TSLP	Tensleep Sandstone	59
Pennsylvanian	320PSLV	Pennsylvanian System	2
Mississippian	330MSSP	Mississippian System	1
Upper Mississippian	331MDSN	Madison Limestone	95
			4
Upper Ordovician	361BGRN	Bighorn Dolomite	2
	361RDRV	Red River Formation of Bighorn Group	4
Cambrian	370CMBR	Cambrian System	2
Upper Cambrian	371GLTN	Gallatin Limestone or Formation	1
	371GRVR	Gros Ventre Formation	2
Middle Cambrian	374FLTD	Flathead Quartzite or Sandstone	7
Precambrian	400PCMB	Precambrian Erathem	2

[1] Now designated Miocene by the U.S. Geological Survey
[2] Now designated Oligocene by the U.S. Geological Survey
[3] Now designated Paleocene by the U.S. Geological Survey
[4] Now designated Middle Jurassic by the U.S. Geological Survey

5.0 DISSOLVED SOLIDS
5.1 Statewide

HIGH DISSOLVED-SOLIDS CONCENTRATIONS - A COMMON PROBLEM

Dissolved-solids concentrations in 62 percent of the samples collected from wells and springs in Wyoming exceed the secondary drinking-water standard of 500 milligrams per liter. Concentrations in most samples, however, are suitable for livestock use.

The high dissolved-solids concentrations of Wyoming ground water frequently limit the potential usefulness of the water. Concentrations in 62 percent of the ground-water samples exceed the national drinking-water standard: The U.S. Environmental Protection Agency (1979, p. 42198) recommends a maximum dissolved-solids concentration of 500 mg/L (milligrams per liter) for drinking water (fig. 5.1-1). Unfortunately, water that meets this nonmandatory criterion is not available to many ranchers, farmers, other rural dwellers, and in some cases, municipalities. For this reason, water exceeding the recommended maximum dissolved-solids concentration commonly is used.

High dissolved-solids concentrations are objectionable for domestic supply because of adverse physiological effects, taste, and economic problems (National Academy of Sciences and National Academy of Engineering, 1973, p. 90). When dissolved-solids concentrations exceed the 500-mg/L standard, the secondary standards for sulfate (250 mg/L) or chloride (250 mg/L) also are likely to be exceeded. In addition, problems with hardness or sodium tend to increase with increased dissolved-solids concentrations.

The dissolved-solids concentrations in the water from the 2,300 ground-water sampling sites are variable. The lowest dissolved-solids concentration was 22 mg/L, which is similar to the quality of distilled water. The highest concentration was 99,400 mg/L, a brine several times more saline than seawater. The median concentration was 725 mg/L and the average was 1,430 mg/L. Fifty percent of the samples had concentrations within the range of 323 to 1,440 mg/L. Ninety percent of the samples had concentrations within the range of 167 to 3,850 mg/L.

The water from most wells and springs is satisfactory for livestock watering. Almost 97 percent of the samples had dissolved-solids concentrations less than 5,000 mg/L. Because wells yielding water that is unsatisfactory for livestock generally are abandoned, the samples may not adequately represent ground water which is unsuitable for livestock.

NUMBER OF ANALYSES	CUMULATIVE NUMBER OF ANALYSES	PERCENT OF ANALYSES	CUMULATIVE PERCENT OF ANALYSES
907	907	38.71	38.71
557	1464	23.77	62.48
331	1795	14.13	76.61
180	1975	7.68	84.29
108	2083	4.61	88.90
78	2161	3.33	92.23
55	2216	2.35	94.58
17	2233	0.73	95.31
20	2253	0.85	96.16
13	2266	0.55	96.71
10	2276	0.43	97.14
5	2281	0.21	97.35
6	2287	0.26	97.61
9	2296	0.38	97.99
3	2299	0.13	98.12
7	2306	0.30	98.42
3	2309	0.13	98.55
1	2310	0.04	98.59
2	2312	0.09	98.68
4	2316	0.17	98.85
27	2343	1.15	100.00

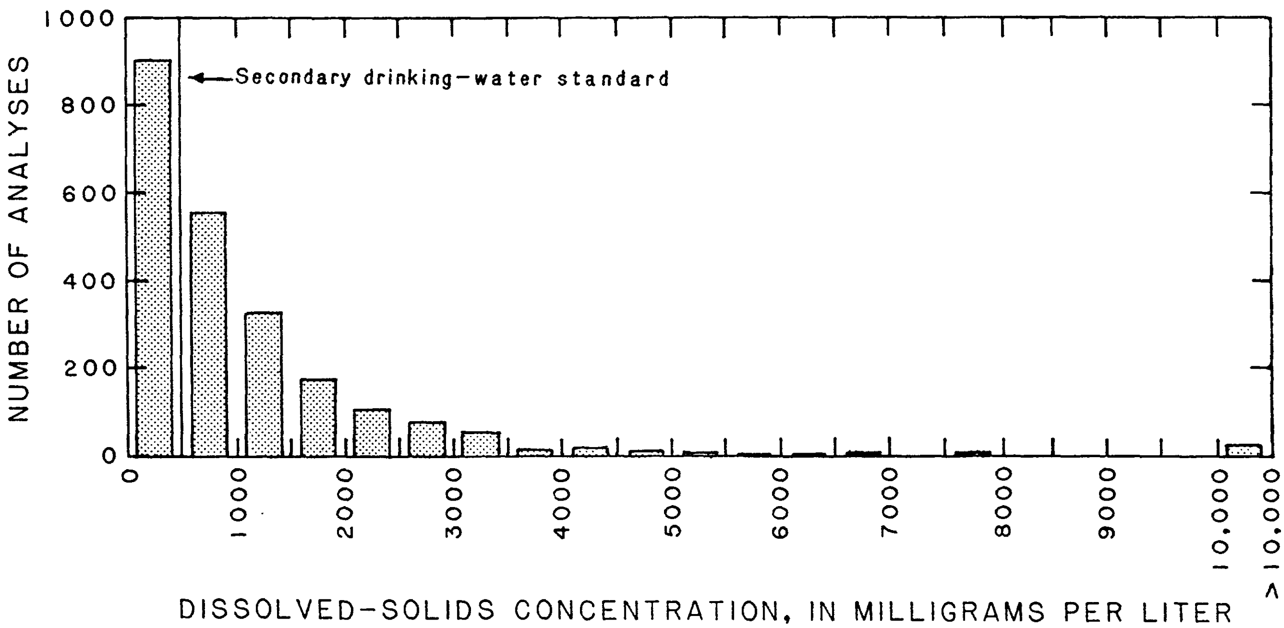


Figure 5.1-1--Histogram of dissolved-solids concentrations in water from wells and springs (statewide).

MOST AQUIFERS YIELD WATER OF VARIABLE QUALITY

Dissolved-solids concentrations in the widely used Wasatch Formation ranged from 141 to 9,710 milligrams per liter.

Ground-water samples from most of the 107 aquifers in Wyoming shown in figure 5.2-1 represent a wide range in dissolved-solids concentrations. Nearly all of the aquifers yield some water that is suitable for drinking. Of these 107 aquifers, only 24 aquifers have had samples collected at 20 or more different sites. Of these 24 aquifers, 21 aquifers had at least one sample with a dissolved-solids concentration less than 500 mg/L (milligrams per liter) and had at least one sample with a dissolved-solids concentration greater than 2,000 mg/L. Ground-water samples from only 2 of the 24 aquifers consistently had dissolved-solids concentrations of less than 500-mg/L secondary drinking-water standard (U.S. Environmental Protection Agency, 1979): Samples from the Holocene lacustrine deposits had a maximum concentration of 275 mg/L and samples from the Ogallala Formation had a maximum concentration of 290 mg/L. The Ogallala Formation is an aquifer of major economic importance to southeastern Wyoming, especially to agriculture, because wells completed in it commonly yield large volumes of excellent quality water.

Based on the median dissolved-solids concentration of each aquifer with 20 or more sampling sites, the aquifers that yielded the best quality water (the lowest median dissolved-solids concentrations) are the Holocene lacustrine deposits (100 mg/L), upper Miocene Ogallala Formation (192 mg/L), lower Miocene Arikaree Formation (271 mg/L), Mississippian Madison Limestone (338 mg/L), and the Oligocene White River Formation (342 mg/L). On the same basis, the aquifers that yielded the poorest quality water (highest median dissolved-solids concentrations are the Paleocene Ferris Formation (2,840 mg/L), the Lower Cretaceous Clovery Formation (1,600 mg/L), the Eocene Tipton Shale Member of the Green River Formation (1,575 mg/L), the Eocene Laney Member of the Green River Formation (1,560 mg/L), and the Paleocene Hanna Formation (1,550 mg/L).

The Wasatch Formation, the Fort Union Formation, and the Holocene alluvium were the most commonly sampled aquifers in the State, each having more than 200 analyses in the file. Dissolved-solids concentrations for water from the Wasatch Formation ranged from 141 to 9,710 mg/L and had a median concentration of 825 mg/L. Concentrations for water from the Fort Union ranged from 209 to 5,620 mg/L and had a median concentration of 1,160 mg/L. Concentrations for water from the Holocene alluvium ranged from 52 to 10,300 mg/L and had a median concentration of 610 mg/L.

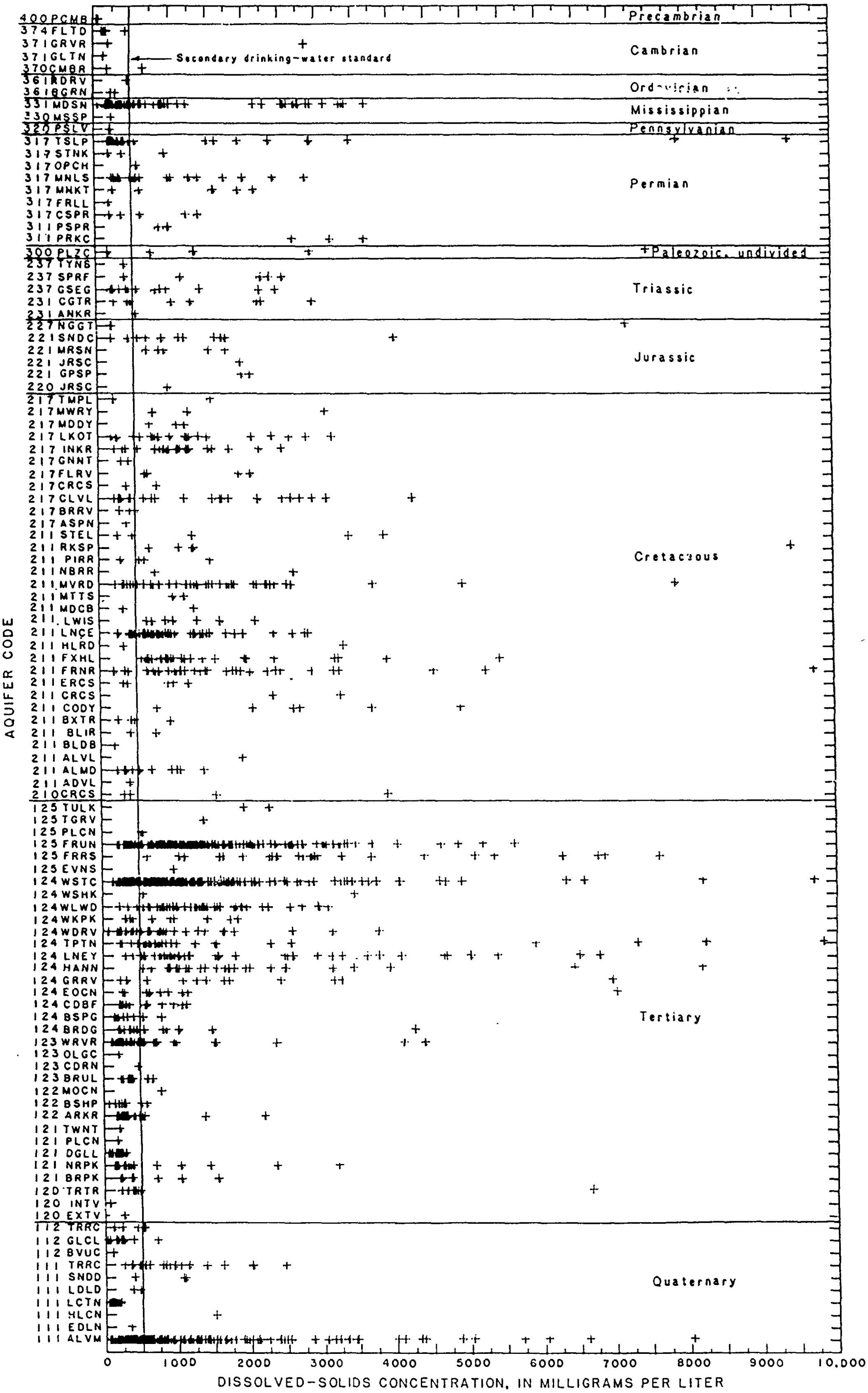


Figure 5.2-1--Dissolved-solids concentrations in ground-water samples from aquifers (statewide).
(For explanation of aquifer codes see section 4.0.)

GROUND-WATER QUALITY VARIES GREATLY AMONG COUNTIES

The median dissolved-solids concentrations in ground water ranged from 176 to 1,850 milligrams per liter in the counties.

Considerable disparity exists in the quality of ground water among the 23 Wyoming counties based on the median dissolved-solids concentration (fig. 5.3-1). The counties with the lowest median concentrations were Teton (176 mg/L) (milligrams per liter), Laramie (241 mg/L), Lincoln (334 mg/L), and Uinta (399 mg/L). The counties with the highest median concentrations were Hot Springs (1,850 mg/L), Natrona (1,390 mg/L), and Campbell (1,220 mg/L).

The average dissolved-solids concentrations of a county whose samples include oil-field brines from test wells and saline springs is greatly increased by such samples. For this reason the relative water quality of each county is better determined by the median concentration rather than the average concentration. The U.S. Environmental Protection Agency's (1979, p. 42198) recommended maximum dissolved-solids concentration for drinking water, 500 milligrams per liter, will be referred to in this report as the secondary drinking-water standard. The percentage of samples with dissolved-solids concentrations less than the drinking-water standard also is used in assessing the quality of available ground water in each county.

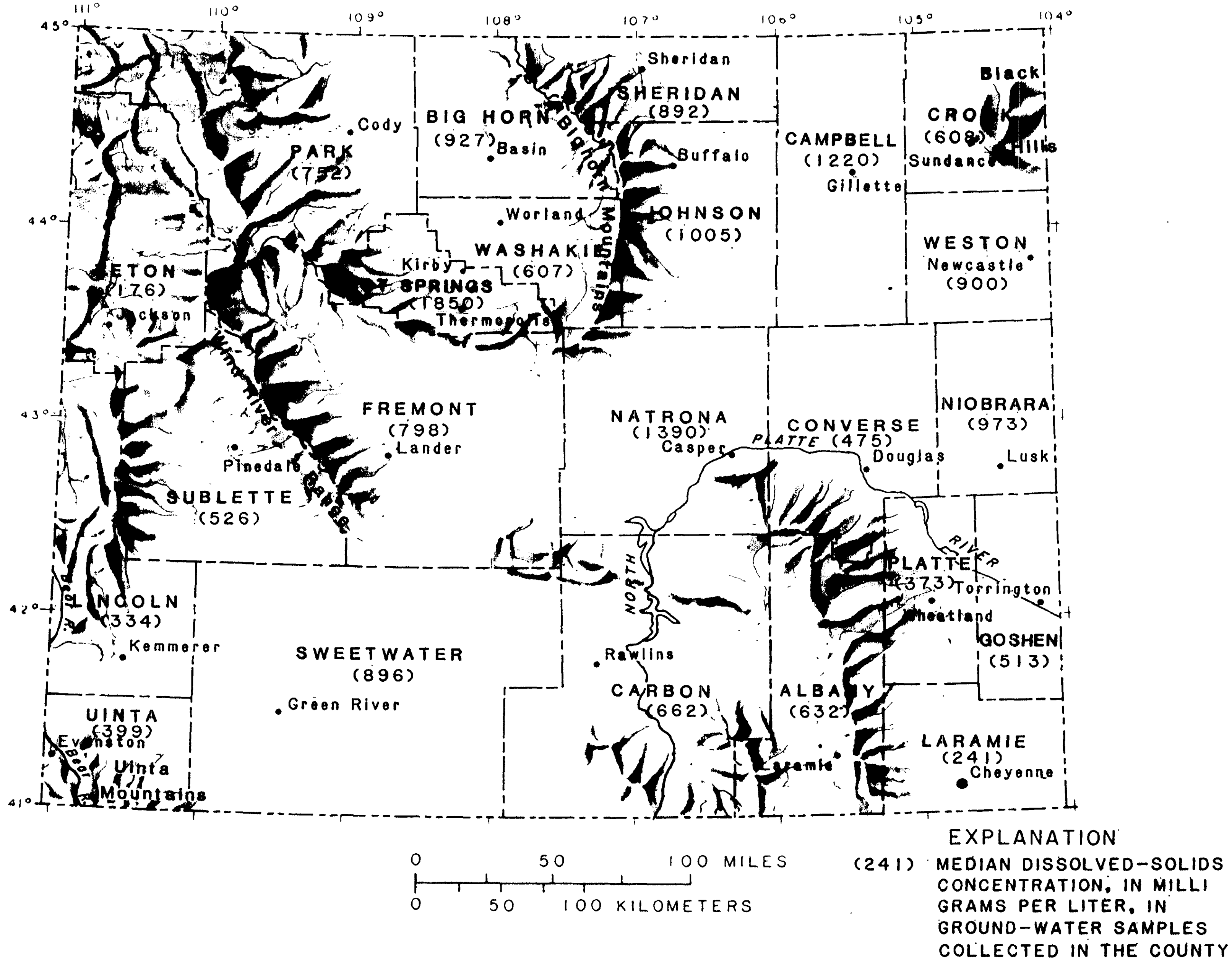


Figure 5.3-1--Location of counties and median dissolved-solids concentrations in ground-water samples collected in each county.

5.3.1 Albany County

MEDIAN DISSOLVED-SOLIDS CONCENTRATION - 632 MILLIGRAMS PER LITER

Dissolved-solids concentrations of ground-water samples were slightly less than the statewide median and ranged from 55 to 9,730 milligrams per liter.

The dissolved-solids concentrations in the 98 ground-water samples collected in Albany County were extremely variable, ranging from 55 to 9,730 mg/L (milligrams per liter) (fig. 5.3.1-1). The median dissolved-solids concentration (632 mg/L) was less than the statewide median (725 mg/L), and the average (1,100 mg/L) was less than the statewide average (1,430 mg/L). Concentrations in 47 percent of the samples were less than the secondary drinking-water standard of 500 mg/L (U.S. Environmental Protection Agency, 1979). Concentrations in 50 percent of the samples ranged from 218 to 1,347 mg/L, and concentrations in three samples exceeded 5,000 mg/L.

Water is used from many aquifers, and 51 ground-water samples have been collected from 21 identified aquifers (fig. 5.3.1-2). The dissolved-solids concentrations of water samples from unidentified aquifers at 47 sites ranged from 55 to 6,450 mg/L (not graphed in fig. 5.3.1-2). The water in the Holocene alluvium was sampled more than any other aquifer (10 sites) and had a large range in dissolved-solids concentration, 168 to 5,840 mg/L. Water from a 206-foot well completed in the Cretaceous Frontier Formation had the highest dissolved-solids concentration, 9,730 mg/L. Depths of wells from which samples were collected range from 8 to 1,900 feet. The median depth is 119 feet; the average depth is 301 feet.

Although Precambrian rock crops out in much of the mountainous area of the county and is used as an aquifer, no samples from wells completed in or from springs issuing from the Precambrian rock in this county have been collected by the Survey. Water in the Precambrian aquifer in other areas of Wyoming generally is of excellent quality, suitable for drinking and other uses.

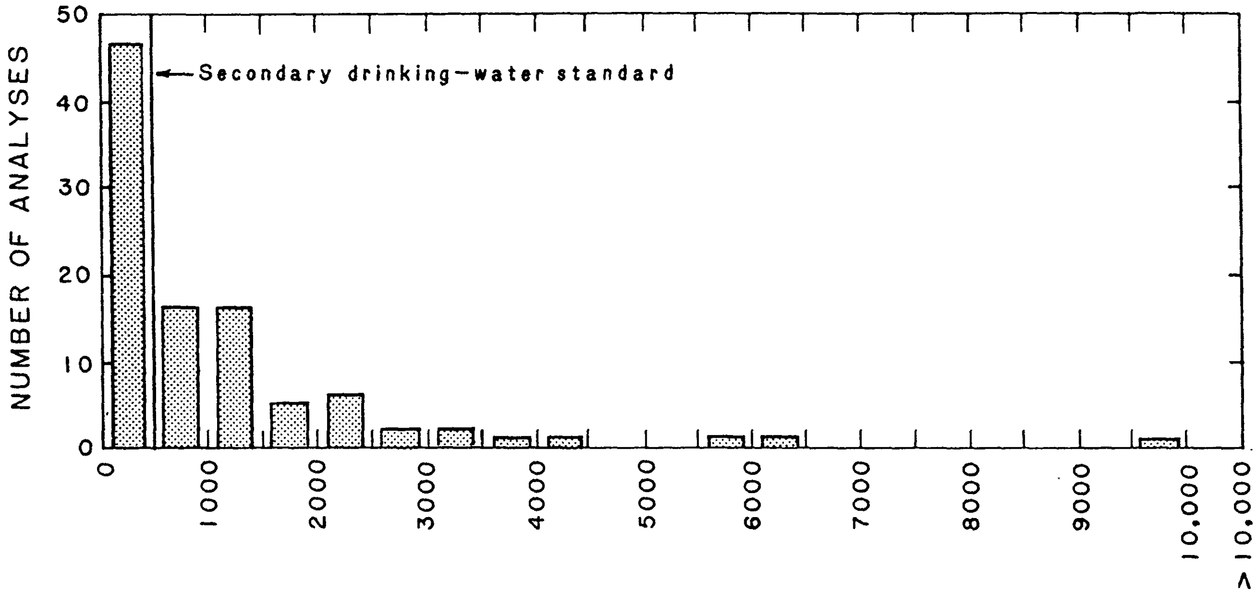


Figure 5.3.1-1--Histogram of dissolved-solids concentrations.

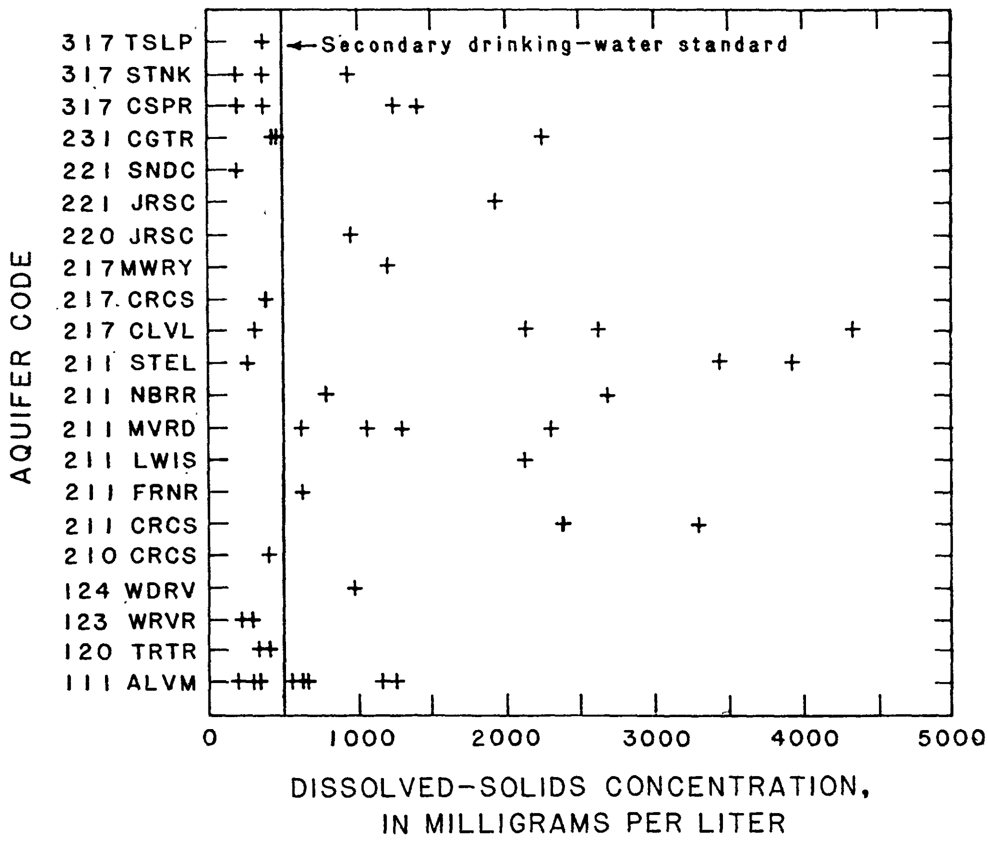


Figure 5.3.1-2--Dissolved-solids concentrations in water samples, by aquifer.
(For explanation of aquifer code see section 4.0.)

5.3.2 Big Horn County

MEDIAN DISSOLVED-SOLIDS CONCENTRATION - 927 MILLIGRAMS PER LITER

The Madison Limestone, Tensleep Sandstone, and Flathead Sandstone generally yield excellent quality water in Big Horn County. However, a sample from a spring in the Mowry Shale had a dissolved-solids concentration of 18,000 milligrams per liter.

The dissolved-solids concentrations in ground-water samples from 107 wells and springs in Big Horn County ranged from 142 to 18,000 mg/L (milligrams per liter) (fig. 5.3.2-1). Dissolved-solids concentrations in 34 percent of the 107 samples were less than the 500-mg/L secondary drinking-water standard (U.S. Environmental Protection Agency, 1979). The median dissolved-solids concentration was 927 mg/L, greater than the statewide median of 725 mg/L; the average was 1,560 mg/L, also greater than the statewide average of 1,430 mg/L. Concentrations in 50 percent of the samples ranged between 312 and 1,840 mg/L. Concentrations in 6 samples exceeded 5,000 mg/L.

The samples with some of the lowest dissolved-solids concentrations in Big Horn County were collected from wells completed in the Madison Limestone, the Tensleep Sandstone, or the Flathead Sandstone (fig. 5.3.2-2). Eight of the 10 samples from the Madison had dissolved-solids concentrations of 383 mg/L or less. The highest concentration (979 mg/L) in water from the Madison was from a 4,500-foot-deep well, but the lowest dissolved-solids concentrations were from wells in the Madison greater than 2,000 feet deep. Samples from the Tensleep Sandstone and the Flathead Sandstone also were generally of excellent quality. Two exceptions were samples from deep wells completed in the Tensleep. The lowest dissolved-solids concentration in Big Horn County (142 mg/L) was in a sample obtained from a well completed in the Flathead Sandstone. The highest concentration (18,000 mg/L) was in a spring, the only ground-water sample from the Mowry Shale.

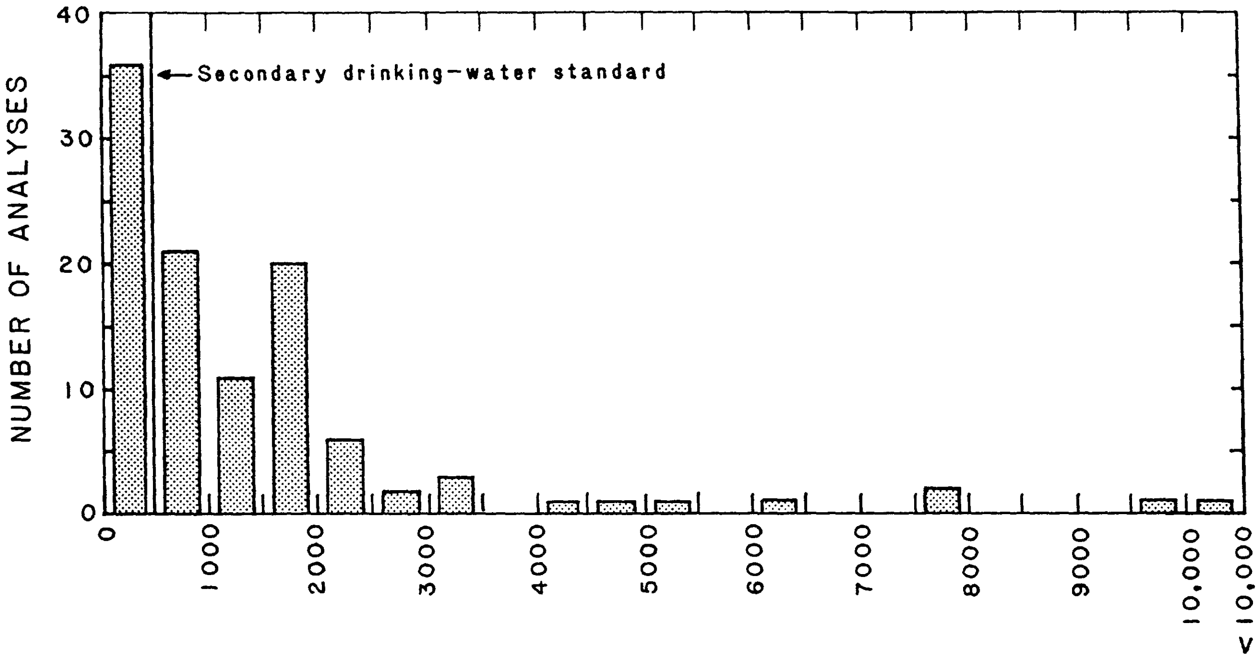


Figure 5.3.2-1--Histogram of dissolved-solids concentrations.

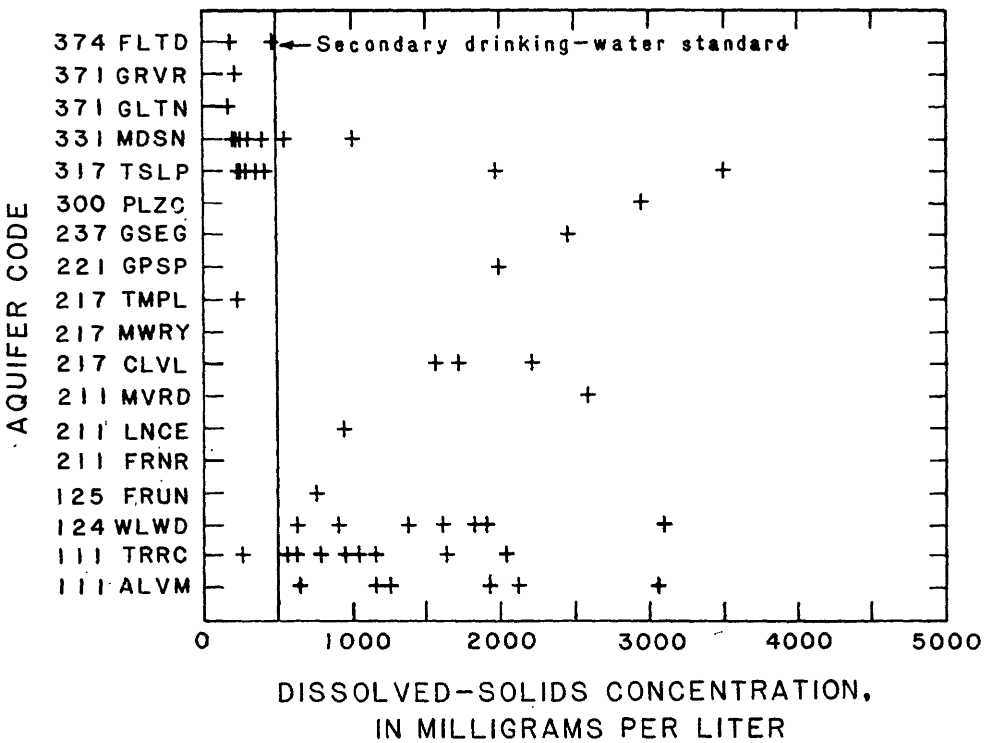


Figure 5.3.2-2—Dissolved-solids concentrations in water samples, by aquifer. (For explanation of aquifer code see section 4.0.)

5.3.3 Campbell County

MEDIAN DISSOLVED-SOLIDS CONCENTRATION - 1,220 MILLIGRAMS PER LITER

Only 11 percent of the ground-water samples had dissolved-solids concentrations less than the secondary drinking-water standard.

Although richly endowed with energy minerals such as coal, oil, and gas, Campbell County generally lacks ground water of suitable quality for drinking. Only 11 percent of the ground-water samples were less than the 500-mg/L (milligrams per liter) secondary drinking-water standard (U.S. Environmental Protection Agency, 1979). This is the lowest percentage for any county in the State except for Hot Springs and Natrona Counties. However, Hot Springs and Natrona Counties have good quality surface water available to meet much of their water needs, Campbell County does not. The median dissolved-solids concentration in Campbell County ground-water samples was 1,220 mg/L (fig. 5.3.3-1), the second highest of all the counties in the State. Sixty-seven percent of the dissolved-solids concentrations exceeded 1,000 mg/L.

Campbell County is located in a structural basin between the Bighorn Mountains to the west and the Black Hills to the east. Nearly all of Campbell County is overlain by thick layers of the Fort Union and Wasatch Formations. Most of the wells from which samples were collected are completed in one of these two aquifers (fig. 5.3.3-2). The water samples from the Fort Union had a median concentration of 1,230 mg/L and an average concentration of 1,480 mg/L. The median concentration in samples from the Wasatch was 1,220 mg/L and the average concentration 1,430 mg/L.

Ground water in the Fox Hills Formation has been sampled in 11 wells. Most of these wells are over 2,000 feet deep with the deepest 6,810 feet. Although none of the samples from the Fox Hills Formation had dissolved-solids concentrations below 500 mg/L, nearly all had concentrations less than about 1,000 mg/L, except the sample from the 6,810-foot-deep well, which had a concentration of 3,200 mg/L.

In order to obtain a sufficient amount of water suitable for drinking, the city of Gillette (the major city of the county) drilled wells in the Madison Limestone east of Campbell County, towards the Black Hills recharge area. Although the Madison also underlies Campbell County, the aquifer there is too deep and too saline for a good municipal supply. By drilling to the east closer to the Black Hills recharge area, water of suitable quality was obtained.

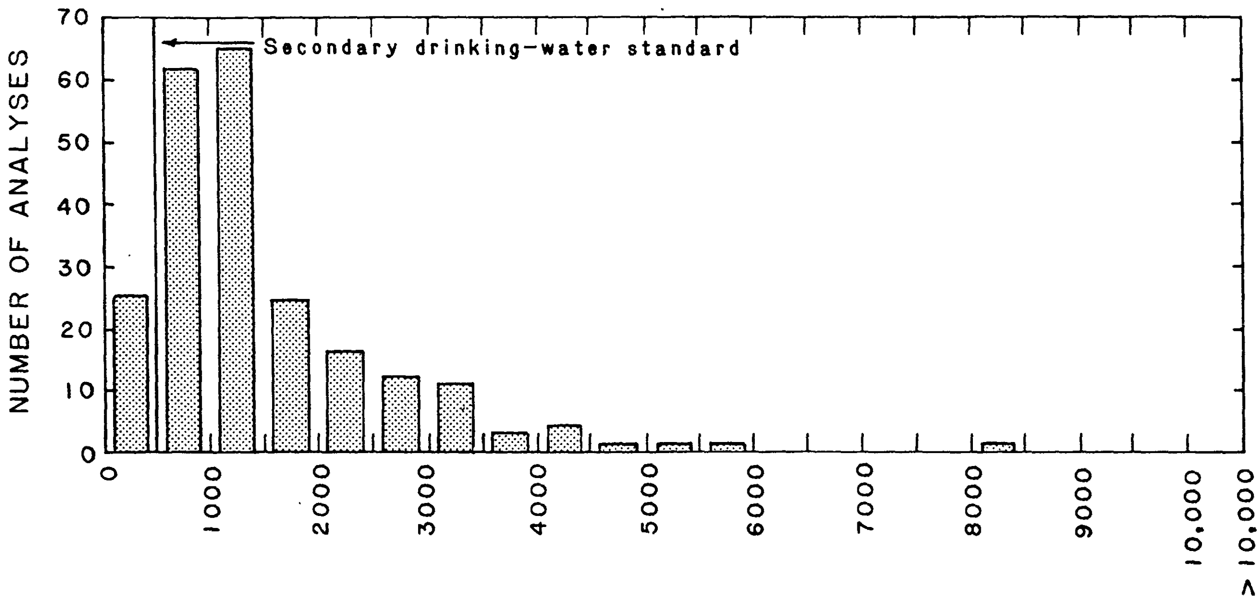


Figure 5.3.3-1--Histogram of dissolved-solids concentrations.

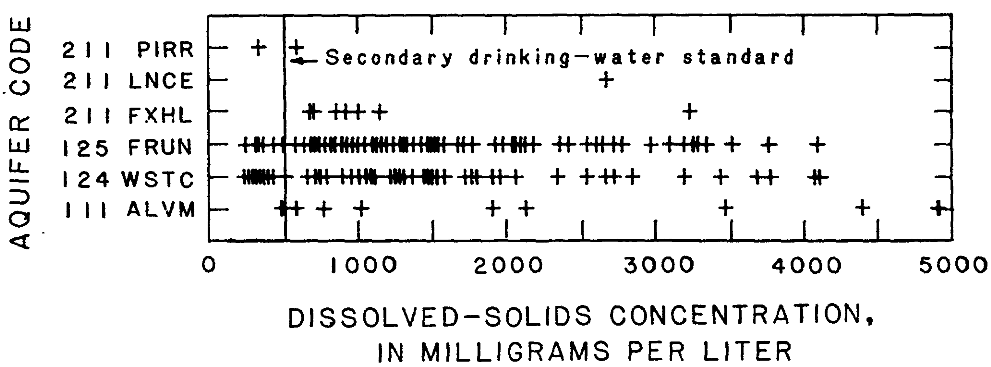


Figure 5.3.3-2--Dissolved-solids concentrations in water samples, by aquifer. (For explanation of aquifer code see section 4.0.)

MEDIAN DISSOLVED-SOLIDS CONCENTRATION - 662 MILLIGRAMS PER LITER

Concentrations in 43 percent of the ground-water samples were less than the secondary drinking-water standard for dissolved solids. The White River, North Park, and Wind River Formations yield water of good quality.

The dissolved-solids concentrations of Carbon County ground-water samples ranged from 375 to 57,700 mg/L (milligrams per liter) (fig. 5.3.4-1). The median concentration was 662 mg/L, less than the statewide median concentration of 725 mg/L. Concentrations in 43 percent of the ground-water samples were less than the 500-mg/L secondary drinking-water standard (U.S. Environmental Protection Agency, 1979).

Ground-water samples have been collected from 29 different aquifers in Carbon County as shown in figure 5.3.4-2. Of the aquifers from which 10 or more samples were collected, the White River, North Park, and Wind River Formations had the lowest median dissolved-solids concentrations. Water samples from the Holocene alluvium were also of good quality. The median and average dissolved-solids concentrations for the alluvium were both less than 500 mg/L. Good quality water in the alluvium of the North Platte River and its mountain tributaries is not unexpected, because of the good quality water in these streams. The highest median dissolved-solids concentrations were in samples from the Hanna (1,550 mg/L) and Ferris Formations (2,840 mg/L).

Generally, deep wells yield water high in dissolved-solids concentrations. The deepest well sampled (5,417 feet) had a dissolved-solids concentration of 9,850 mg/L. However, another well (3,202 feet deep) had a dissolved-solids concentration of only 178 mg/L. The median depth of the wells sampled is 120 feet and the average depth is 176 feet. The depths range from 0 feet (springs) to 5,417 feet.

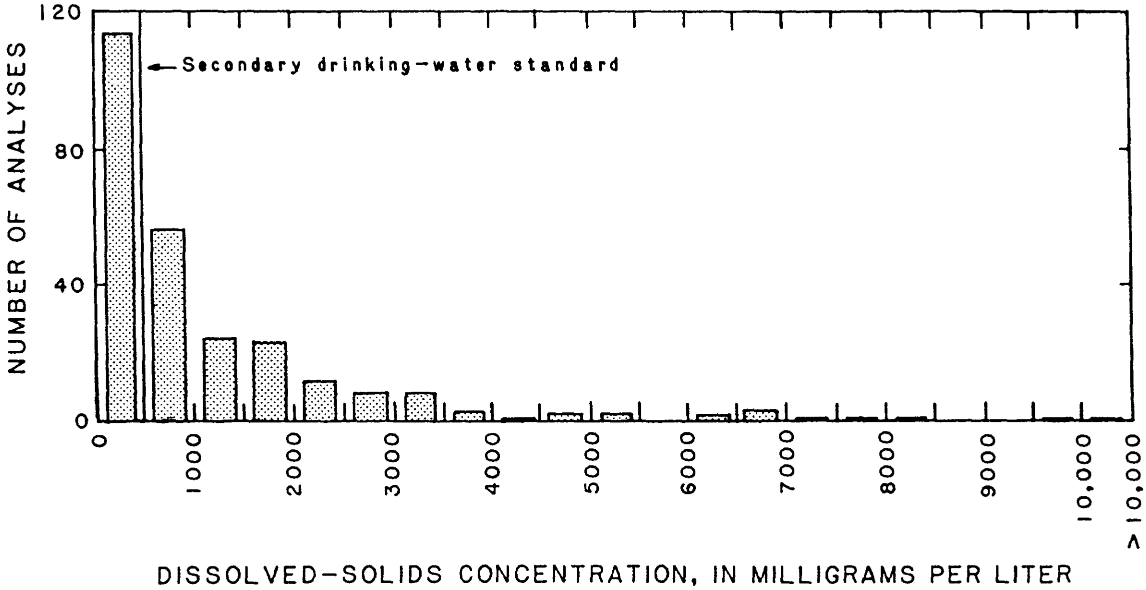


Figure 5.3.4-1--Histogram of dissolved-solids concentrations.

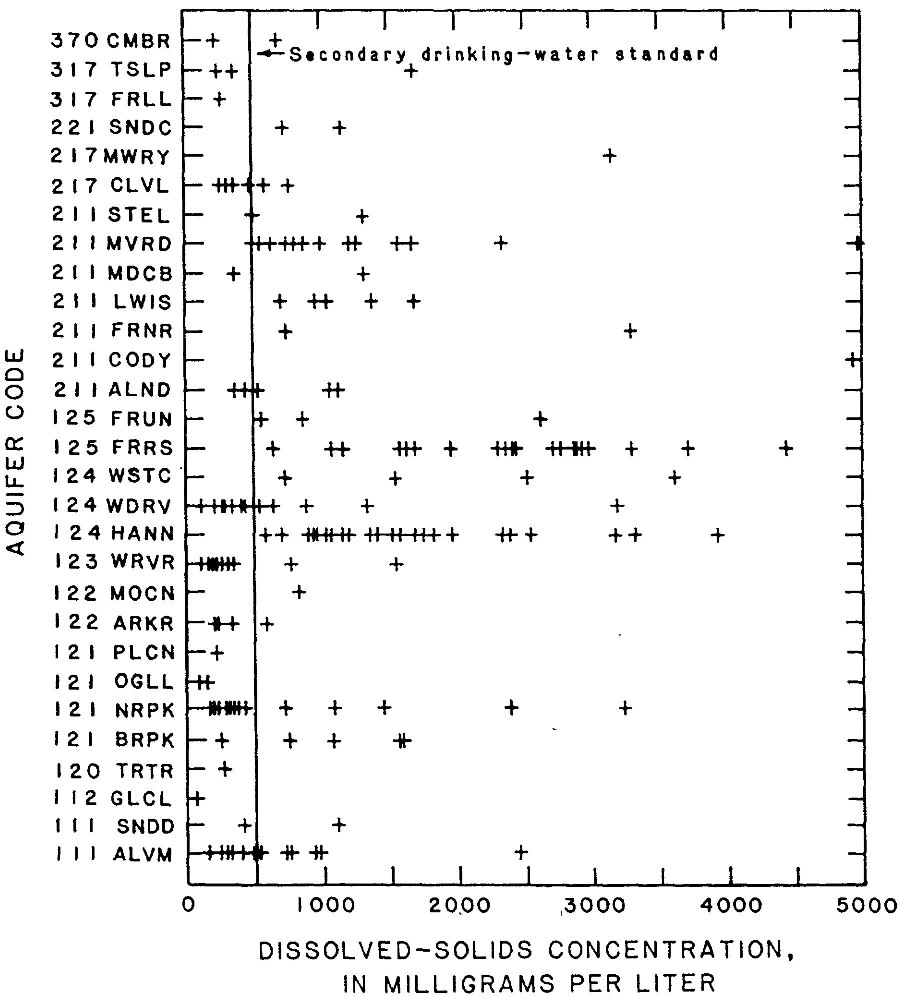


Figure 5.3.4-2--Dissolved-solids concentrations in water samples, by aquifer. (For explanation of aquifer code see section 4.0.)

5.3.5 Converse County

MEDIAN DISSOLVED-SOLIDS CONCENTRATION - 475 MILLIGRAMS PER LITER

Concentrations in 51 percent of the ground-water samples were less than the secondary drinking-water standard for dissolved solids. The Wasatch and Fort Union Formations are principal aquifers in the county.

The median dissolved-solids concentration of 75 Converse County ground-water samples was 475 mg/L (milligrams per liter) and the average concentration was 926 mg/L. The concentrations ranged from 53 to 4,540 mg/L (fig. 5.3.5-1). Concentrations in 51 percent of the samples were less than the 500-mg/L secondary drinking-water standard (U.S. Environmental Protection Agency, 1979).

The Wasatch and Fort Union Formations are the source of most of the water samples in Converse County, as shown in figure 5.3.5-2. The median concentration of 25 water samples from the Wasatch was 420 mg/L. The median concentration of 22 water samples from the Fort Union was 390 mg/L. Both of these values are much lower than the concentrations in the same aquifers to the north in Campbell County, where the median concentration of water from the Wasatch was 1,220 mg/L and the median concentration of the water from the Fort Union was 1,230 mg/L.

The two samples with the lowest dissolved-solids concentrations in Converse County (53 mg/L and 204 mg/L) came from mountain springs in Precambrian rock and the Tensleep Sandstone. The samples with the highest dissolved-solids concentrations (all about 4,500 mg/L) were in water from three shallow wells in the White River Formation. The dissolved-solids concentrations of samples collected from six wells deeper than 6,000 feet in the Madison Limestone ranged from 440 to 3,350 mg/L.

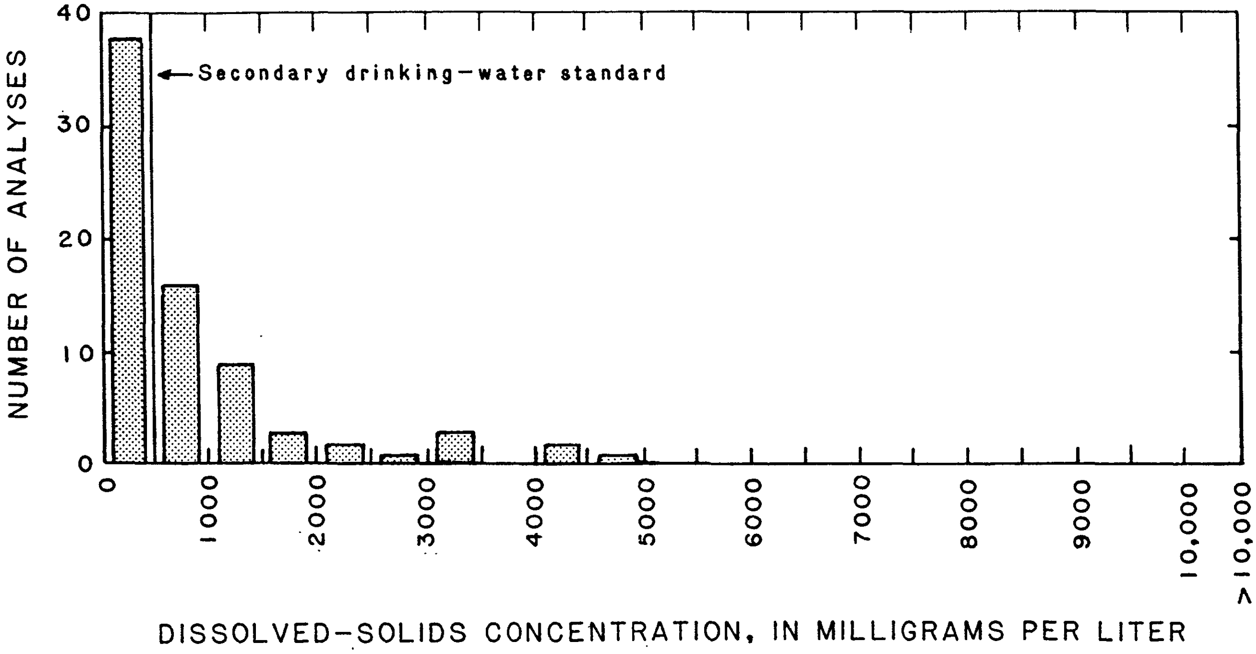


Figure 5.3.5-1--Histogram of dissolved-solids concentrations.

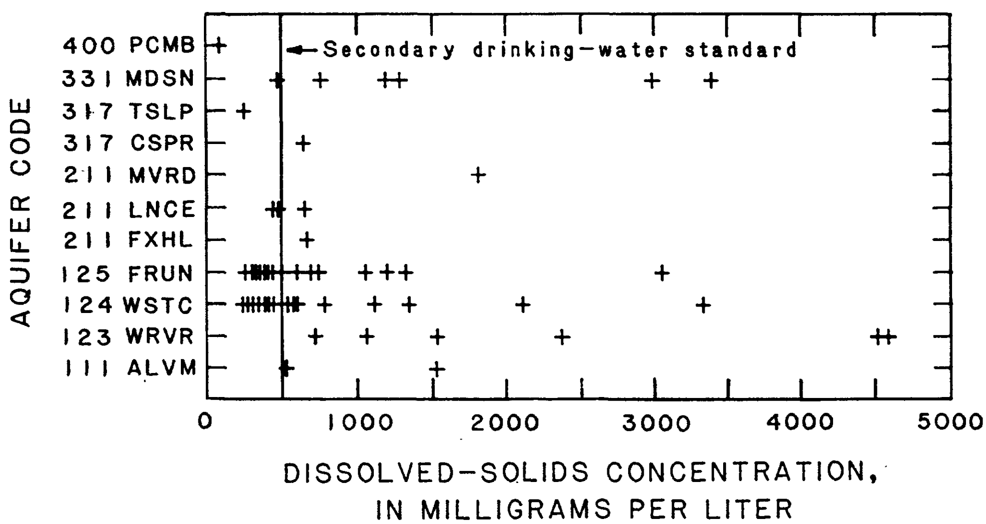


Figure 5.3.5-2--Dissolved-solids concentrations in water samples, by aquifer. (For explanation of aquifer code see section 4.0.)

5.3.6 Crook County

MEDIAN DISSOLVED-SOLIDS CONCENTRATION - 608 MILLIGRAMS PER LITER

Thirty percent of the dissolved-solids concentrations of the ground-water samples were less than the secondary drinking-water standard. One-third of the ground-water samples were collected from a deep experimental well.

The median dissolved-solids concentration of 64 ground-water samples collected in Crook County and graphed in figure 5.3.6-1 was 608 mg/L (milligrams per liter). The average concentration was 877 mg/L. Only 30 percent of the samples had dissolved-solids concentrations less than the 500-mg/L secondary drinking-water standard (U.S. Environmental Protection Agency, 1979). However, 84 percent of the samples had dissolved-solids concentrations less than 1,000 mg/L.

About one-third of the 64 Crook County ground-water samples were collected at various depths from a deep experimental well in the northern part of the county. The Upper Mississippian Madison Limestone yielded samples with dissolved-solids concentrations of about 900 mg/L (fig. 5.3.6-2). All but one of the samples collected from the deeper aquifers, the Lower Mississippian Madison Limestone and the Upper Ordovician Red River Formation of the Bighorn Group had a dissolved-solids concentration of less than 500 mg/L. The intervals sampled for these two aquifers range from 2,800 to 3,480 feet.

The median dissolved-solids concentration of the 26 water samples collected from the Minnelusa Formation was 520 mg/L and the average concentration was 773 mg/L. Concentrations ranged from 230 to 2,450 mg/L. Depths of the wells from which samples were collected range from 0 feet (a spring) to 1,450 feet. The median depth is 620 feet.

The sample with the lowest dissolved-solids concentration (80 mg/L) was collected at a spring in the Tertiary intrusive rock in the Black Hills. The sample with the highest concentration (3,200 mg/L) was collected from a shallow well in alluvium.

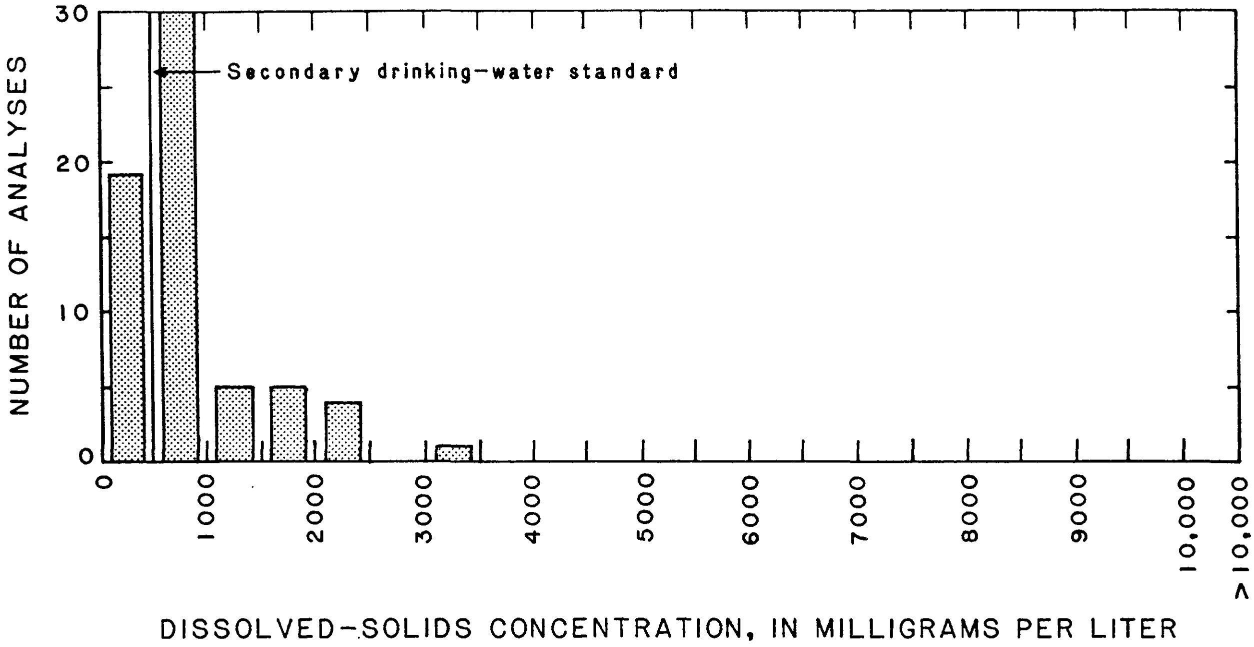


Figure 5.3.6-1--Histogram of dissolved-solids concentrations.

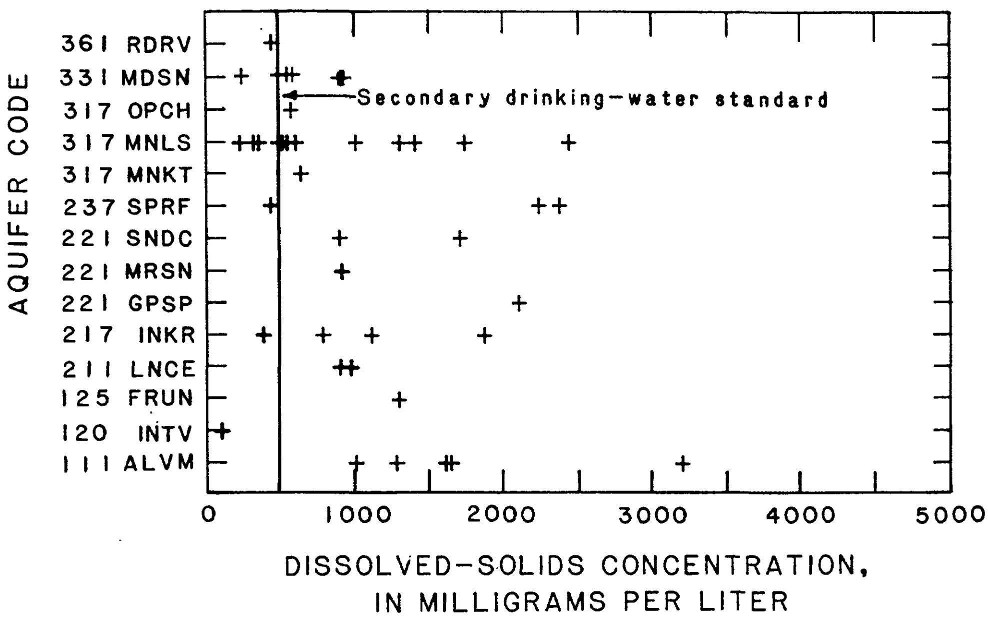


Figure 5.3.6-2--Dissolved-solids concentrations in water samples, by aquifer. (For explanation of aquifer code see section 4.0.)

MEDIAN DISSOLVED-SOLIDS CONCENTRATION - 798 MILLIGRAMS PER LITER

One-third of the ground-water samples have dissolved-solids concentrations less than the secondary drinking-water standard.

The median dissolved-solids concentration of the 90 Fremont County ground-water samples shown in figure 5.3.7-1 was 798 mg/L (milligrams per liter) and the average concentration was 1,149 mg/L. The concentrations ranged from 149 to 5,420 mg/L. Thirty-three percent of the samples had dissolved-solids concentrations less than the 500-mg/L secondary drinking-water standard (U.S. Environmental Protection Agency, 1979).

The water quality of the Wind River Formation from which 18 samples were collected, and of the Holocene alluvium from which 12 samples were collected, is variable as shown in figure 5.3.7-2. The dissolved-solids concentrations in water from the Wind River Formation ranged from 203 to 3,790 mg/L. The median concentration was 784 mg/L. The highest and lowest concentrations were in samples collected from shallow wells less than 120 feet deep. However, all of the wells sampled were less than 500 feet deep. Concentrations of samples collected from wells in alluvium ranged from 329 to 4,090 mg/L. The median concentration for alluvium water samples was 1,360 mg/L.

The sample with the lowest dissolved-solids concentration in Fremont County (149 mg/L) was collected from a well in the Wasatch Formation near the Wind River Range. The sample with the highest concentration (5,420 mg/L) was collected from 312-foot-deep well tapping an unidentified aquifer in the arid, eastern section of the county.

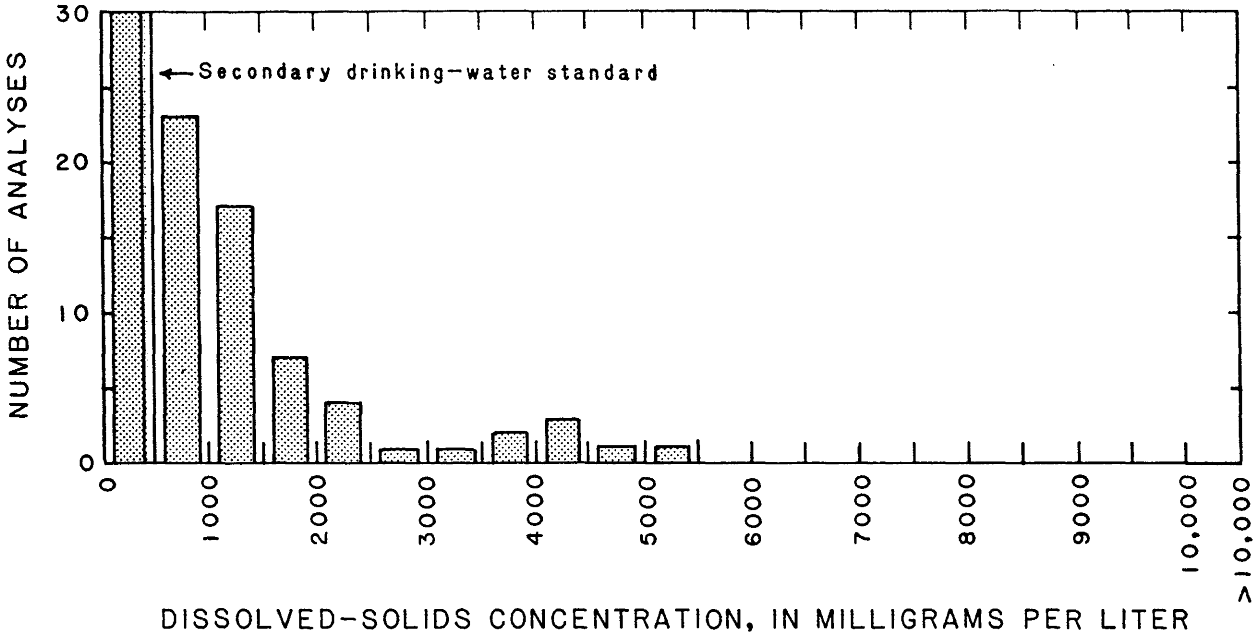


Figure 5.3.7-1--Histogram of dissolved-solids concentrations.

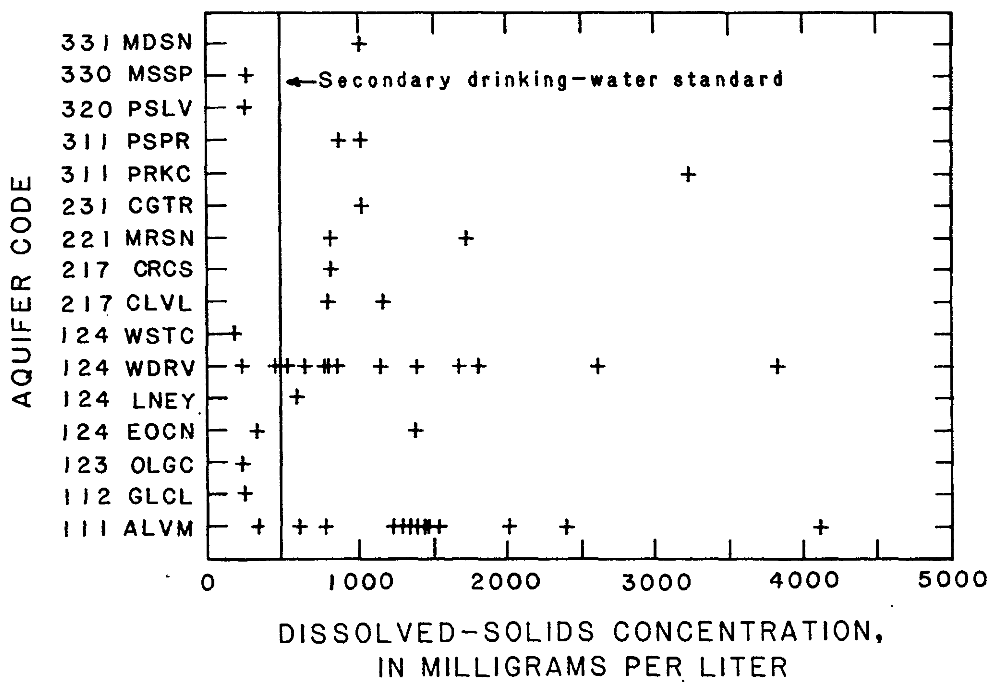


Figure 5.3.7-2--Dissolved-solids concentrations in water samples, by aquifer.
(For explanation of aquifer code see section 4.0.)

5.3.8 Goshen County

MEDIAN DISSOLVED-SOLIDS CONCENTRATION - 513 MILLIGRAMS PER LITER

Forty-eight percent of the dissolved-solids concentrations of Goshen County ground-water samples were less than the secondary drinking-water standard. Ninety-eight percent of the water samples had dissolved-solids concentrations less than 1,000 milligrams per liter.

The median dissolved-solids concentration for ground-water samples collected in Goshen County was 513 mg/L (milligrams per liter) and the average concentration was 521 mg/L (fig. 5.3.8-1). The range of concentrations (233 to 1,250 mg/L) was relatively narrow compared with most other counties in Wyoming. Only 2 of 95 samples had dissolved-solids concentrations greater than 1,000 mg/L. Forty-eight percent of the dissolved-solids concentrations of the ground-water samples were less than the 500-mg/L secondary drinking-water standard (U.S. Environmental Protection Agency, 1979).

The aquifers from which samples were collected are relatively young rocks and contain water with low dissolved-solids concentrations (fig. 5.3.8-2). The median dissolved-solids concentrations in samples from the Arikaree Formation (278 mg/L) and the Brule Formation (360 mg/L) were the lowest of the aquifers sampled in Goshen County. Dissolved-solids concentrations in samples from the alluvium were more variable than the other aquifers, ranging from 336 to 1,030 mg/L. The lowest concentration in the county was in a sample from the Arikaree Formation (278 mg/L) and the highest (1,250 mg/L) was in a sample from the Lance Formation.

Most of the wells from which samples were collected are shallow. The median well depth is 90 feet and the average is 119 feet. Ninety percent of the wells are less than 200 feet deep.

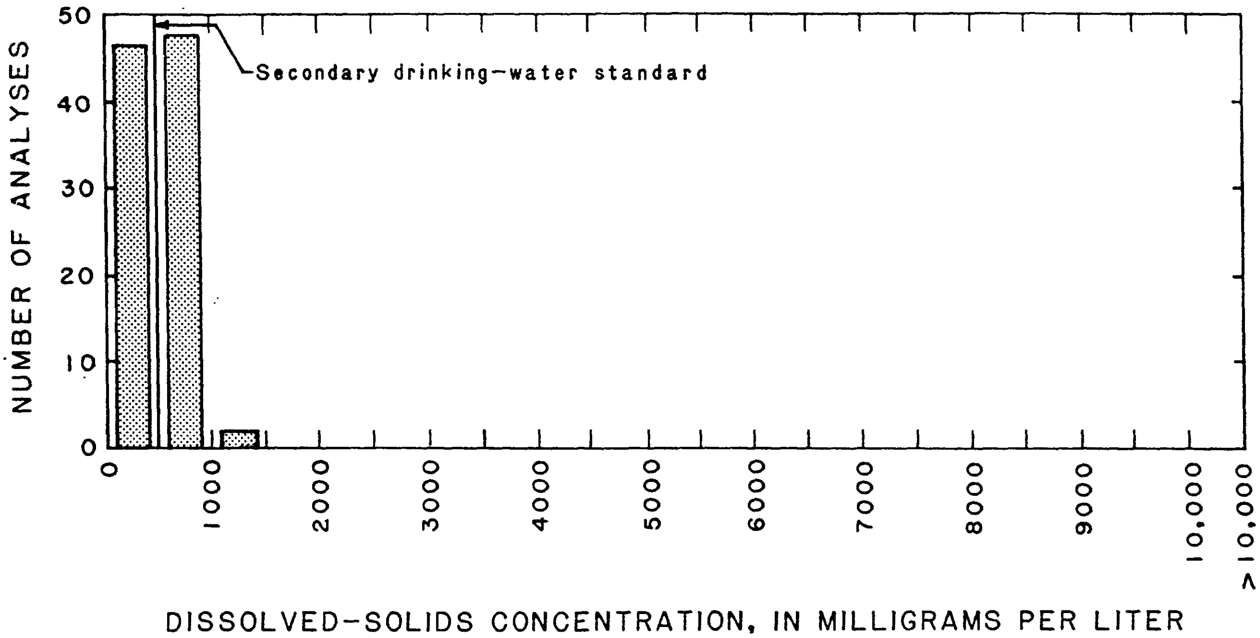


Figure 5.3.8-1--Histogram of dissolved-solids concentrations.

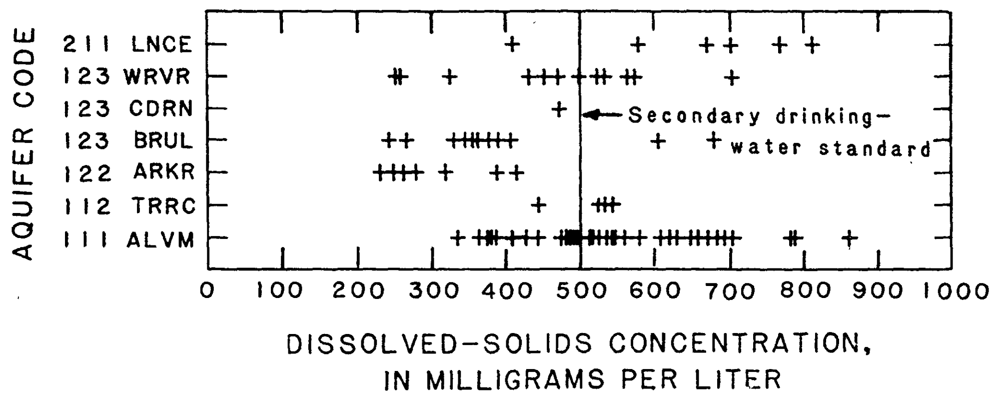


Figure 5.3.8-2--Dissolved-solids concentrations in water samples, by aquifer. (For explanation of aquifer code see section 4.0.)

MEDIAN DISSOLVED-SOLIDS CONCENTRATION - 1,850 MILLIGRAMS PER LITER

The median dissolved-solids concentration of ground-water samples collected in Hot Springs County was the highest of all the counties in the State. Concentrations in only 2 of 54 samples were less than the secondary drinking-water standard for dissolved solids.

The median dissolved-solids concentration of the 54 ground-water samples collected in Hot Springs County (fig. 5.3.9-1) was 1,850 mg/L (milligrams per liter), the highest of all the counties in the State. The median dissolved-solids concentration of Hot Springs County was 10 times greater than that of Teton County, which had the lowest median concentration in the State. Although the 54 samples may not adequately represent the entire population of wells in the county, a water-quality problem evidently exists. The dissolved-solids concentration of a sample collected from a well used by the town of Kirby for municipal supply was 2,400 mg/L (Lowry and others, 1976). This is nearly five times the maximum recommended concentration for drinking water. Only 3.7 percent of the samples (2 of 54) had dissolved-solids concentrations less than the 500-mg/L secondary drinking-water standard (U.S. Environmental Protection Agency, 1979). Although most ground-water samples had dissolved-solids concentrations suitable for the watering of livestock, the quality of the ground water generally is undesirable for domestic use by the farmers, ranchers, and other rural dwellers who use water from the same aquifers.

Samples were collected from 15 aquifers. However, none of the aquifers have been sampled at more than five sites (fig. 5.3.9-2). The two lowest concentrations (420 mg/L and 479 mg/L) were in water from wells completed in the Tensleep Sandstone. The two highest (5,710 mg/L and 11,100 mg/L) were in water collected from wells completed in alluvium.

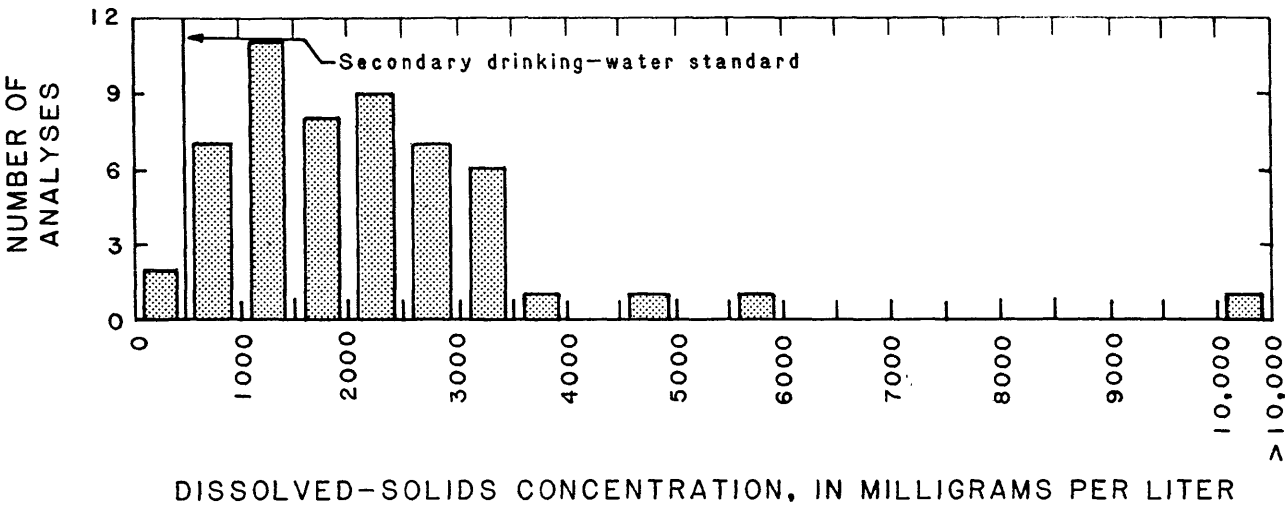


Figure 5.3.9-1--Histogram of dissolved-solids concentrations.

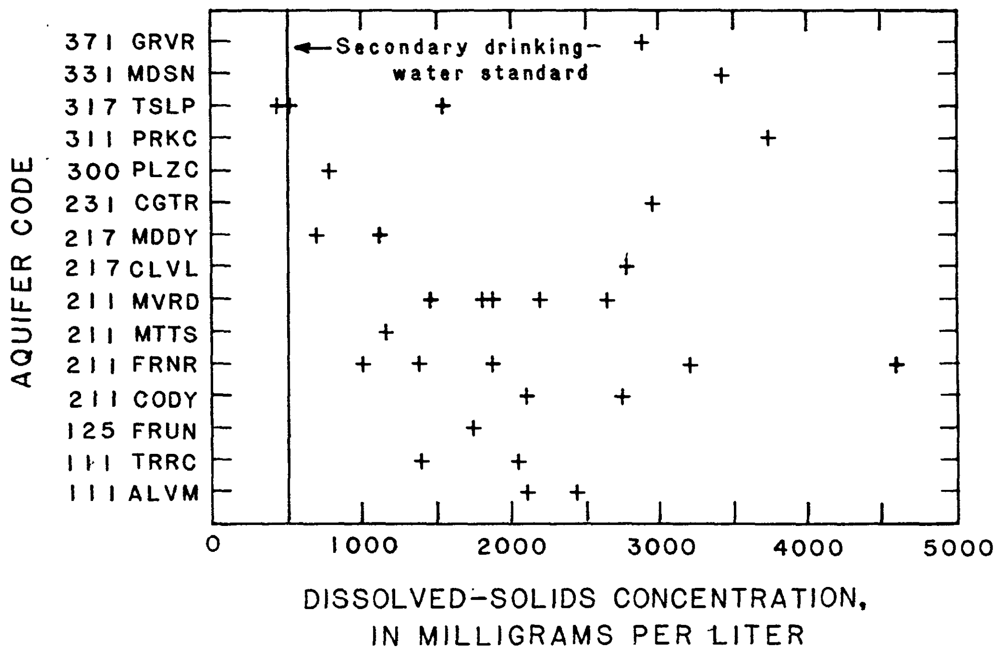


Figure 5.3.9-2--Dissolved-solids concentrations in water samples, by aquifer.
(For explanation of aquifer code see section 4.0.)

5.3.10 Johnson County

MEDIAN DISSOLVED-SOLIDS CONCENTRATION - 1,005 MILLIGRAMS PER LITER

Only 29 percent of the ground-water samples had dissolved-solids concentrations less than the secondary drinking-water standard. The median concentration of the Wasatch Formation was 781 milligrams per liter. However, concentrations in samples from this aquifer ranged from 320 to 4,620 milligrams per liter.

The dissolved-solids concentrations of Johnson County ground-water samples were extremely variable, ranging from 63 to 12,580 mg/L (milligrams per liter) (fig. 5.3.10-1). The median dissolved-solids concentration of 1,005 mg/L was considerably higher than the statewide median of 725 mg/L. Only 29 percent of the ground-water samples had dissolved-solids concentrations less than the 500-mg/L secondary drinking-water standard (U.S. Environmental Protection Agency, 1979). However, the western one-third of the county, in or near the Bighorn Mountains, has some excellent quality ground water. Ground water in this generally unpopulated, mountainous area has not been extensively developed.

The Wasatch Formation, which overlies most of the county, is the principal aquifer used in the county. Of the 98 ground-water samples collected in the county, 25 were from the Wasatch (fig. 5.3.10-2). The median dissolved-solids concentration of samples from the Wasatch was 781 mg/L; concentrations ranged from 320 to 4,620 mg/L. The median depth of wells from which samples were collected in the Wasatch is 246 feet. Depths range from 60 to 760 feet.

Precambrian rocks that crop out in the Bighorn Mountains yield water of excellent quality. The dissolved-solids concentration of the only site sampled (a spring) in this aquifer was 63 mg/L. In and near the mountainous outcrop area, both the Madison Limestone and Tensleep Sandstone yield excellent quality water but the quality deteriorates as the water moves downgradient toward the center of the basin. The lowest concentration in the Madison (65 mg/L) was in a sample collected from a mountain spring. The two highest Madison concentrations (2,640 mg/L and 2,740 mg/L) were in samples collected from wells about 10,000 feet deep. The median depth of wells in the Madison from which samples were collected is 4,246 feet. Dissolved-solids concentrations in samples collected from wells completed in alluvium ranged from 72 mg/L (alluvium of a perennial mountain stream) to 4,320 mg/L (alluvium of an ephemeral plains stream).

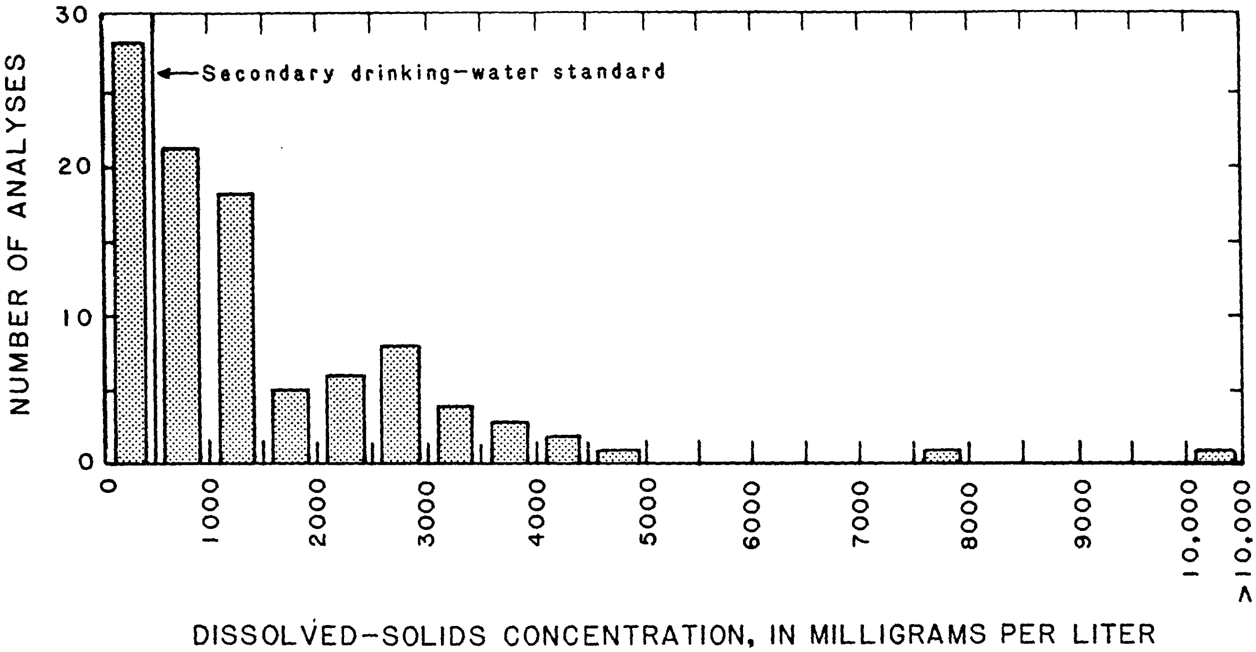


Figure 5.3.10-1--Histogram of dissolved-solids concentrations.

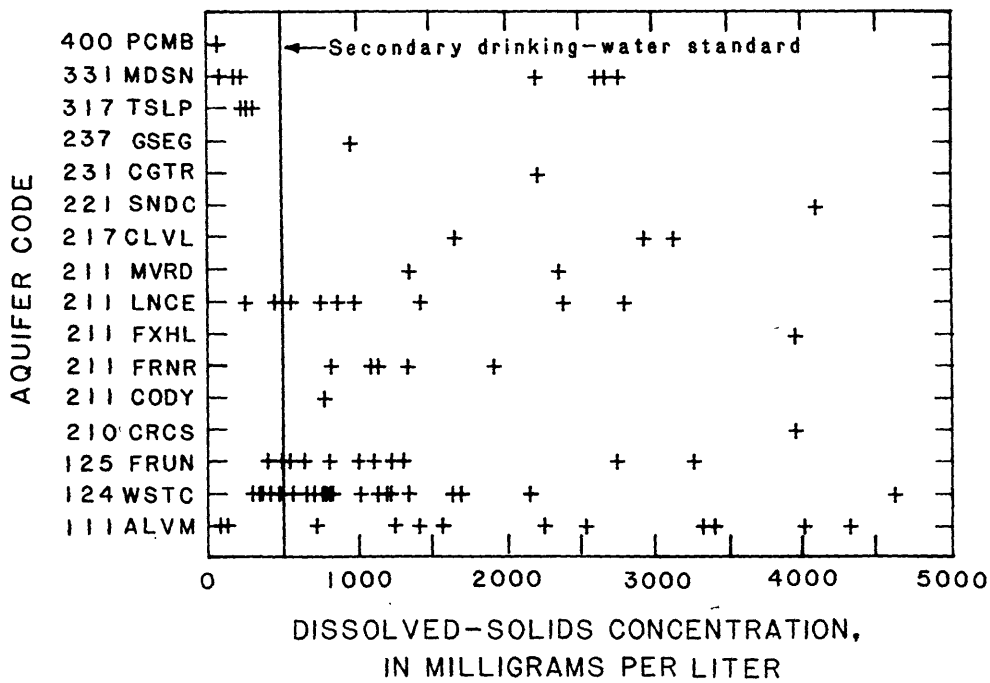


Figure 5.3.10-2--Dissolved-solids concentrations in water samples, by aquifer. (For explanation of aquifer code see section 4.0.)

5.3.11 Laramie County

MEDIAN DISSOLVED-SOLIDS CONCENTRATION - 241 MILLIGRAMS PER LITER

Concentrations in all but one of the ground-water samples were less than the secondary drinking-water standard for dissolved solids. The Quaternary and Tertiary aquifers supply good quality water.

The median dissolved-solids concentration of 241 mg/L (milligrams per liter) was the lowest median concentration of any county in the State except for Teton County. The dissolved-solids concentration in only 1 of 48 ground-water samples exceeded the 500-mg/L secondary drinking-water standard (U.S. Environmental Protection Agency, 1979). The range of concentrations (65 to 625 mg/L) (fig. 5.3.11-1) was the narrowest of all the counties in the State.

The principal water-supply aquifers in the county are the Tertiary Ogallala, Arikaree, and White River Formations. The median dissolved-solids concentrations of these three aquifers are among the lowest of the aquifers in the State: 217 mg/L in the 17 samples from the Ogallala, 225 mg/L in the 6 samples from the Arikaree, and 257 mg/L in the 11 samples from the White River (fig. 5.3.11-2). In most of the county, these aquifers generally yield good quality water at relatively shallow depths. The median depth of the wells from which samples were collected in these aquifers is about 250 feet; the greatest depth is 500 feet.

Dissolved-solids concentrations in samples collected from Quaternary alluvium ranged from 245 to 500 mg/L. The median concentration was 368 mg/L.

The two samples collected from wells in the Lance Formation were from wells with depths of 713 feet and 1,070 feet. The dissolved-solids concentrations were 625 mg/L in the shallower well and 252 mg/L in the deeper well.

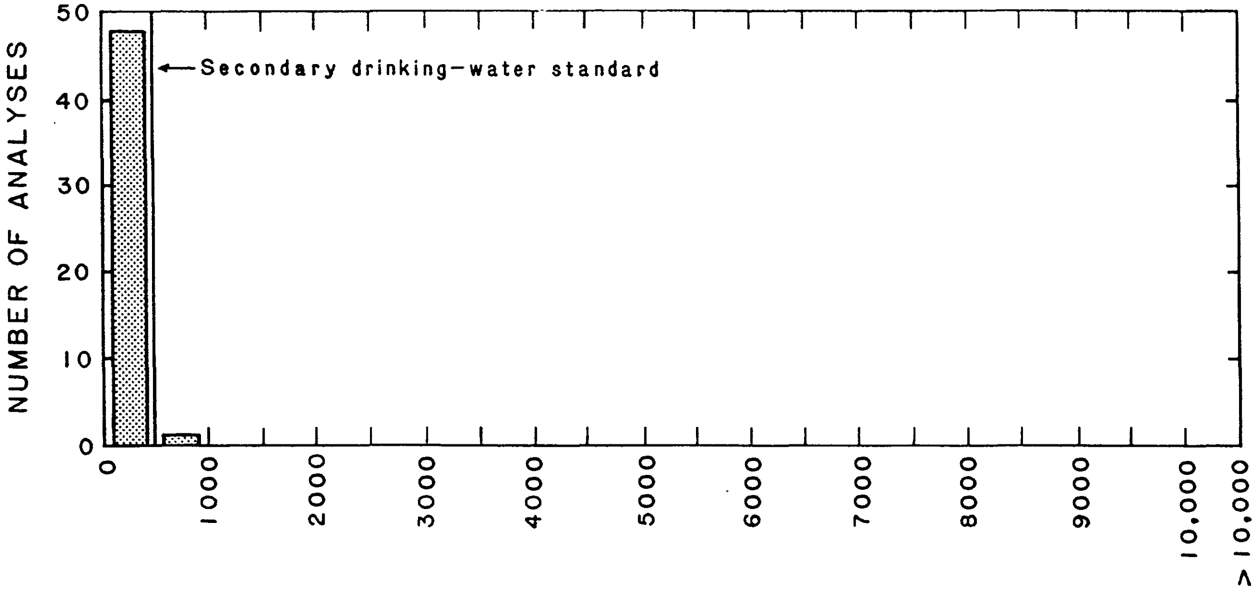


Figure 5.3.11-1--Histogram of dissolved-solids concentrations.

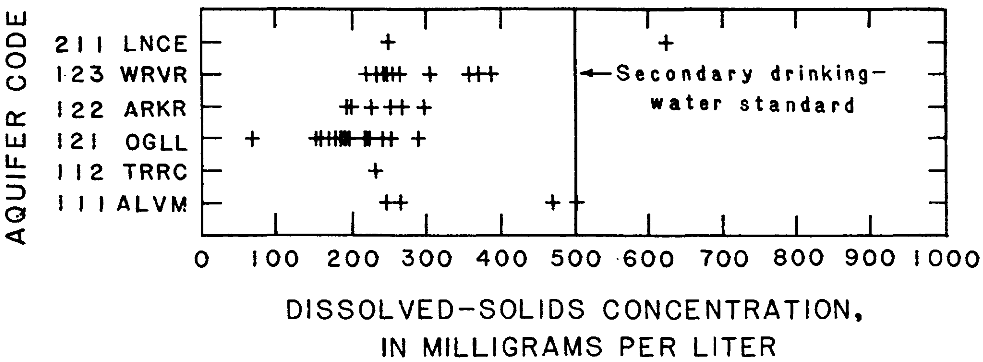


Figure 5.3.11-2--Dissolved-solids concentrations in water samples, by aquifer.
(For explanation of aquifer code see section 4.0.)

5.3.12 Lincoln County

MEDIAN DISSOLVED-SOLIDS CONCENTRATION - 334 MILLIGRAMS PER LITER

Seventy-one percent of the ground-water samples had dissolved-solids concentrations less than the secondary drinking-water standard. Complex geology results in the use of many different aquifers, most of which yield some good quality water.

The median dissolved-solids concentration of the 89 ground-water samples collected in Lincoln County was 334 mg/L (milligrams per liter), the third lowest of all Wyoming counties. Seventy-one percent of the samples had median dissolved-solids concentrations less than the 500-mg/L secondary drinking-water standard (U.S. Environmental Protection Agency, 1979). Concentrations of the samples ranged from 107 to 5,690 mg/L (fig. 5.3.12-1). Fifty percent of the samples had dissolved-solids concentrations between 227 and 660 mg/L.

At least one ground-water sample from all aquifers listed in figure 5.3.12-2, except the Wasatch Formation and the Evanston Formation, had a dissolved-solids concentration less than 500 mg/L, including even the Laney Member of the Green River Formation and the Frontier Formation, which generally yield poor quality water. Such low concentrations frequently reflect the proximity of the sample site to a recharge area.

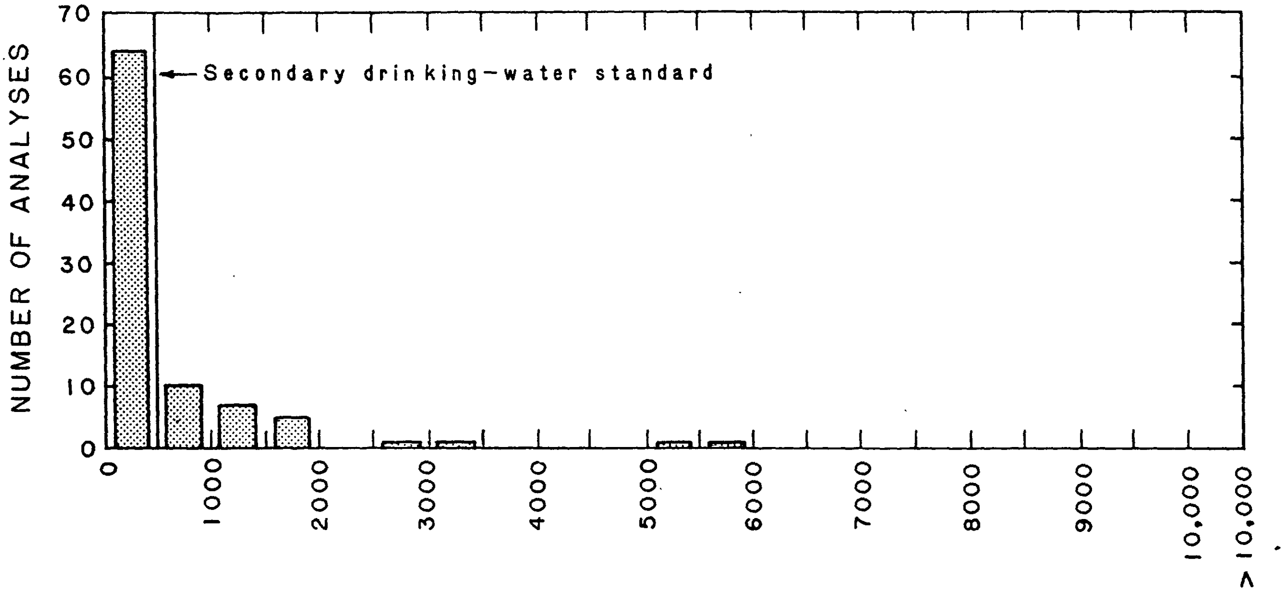


Figure 5.3.12-1--Histogram of dissolved-solids concentrations.

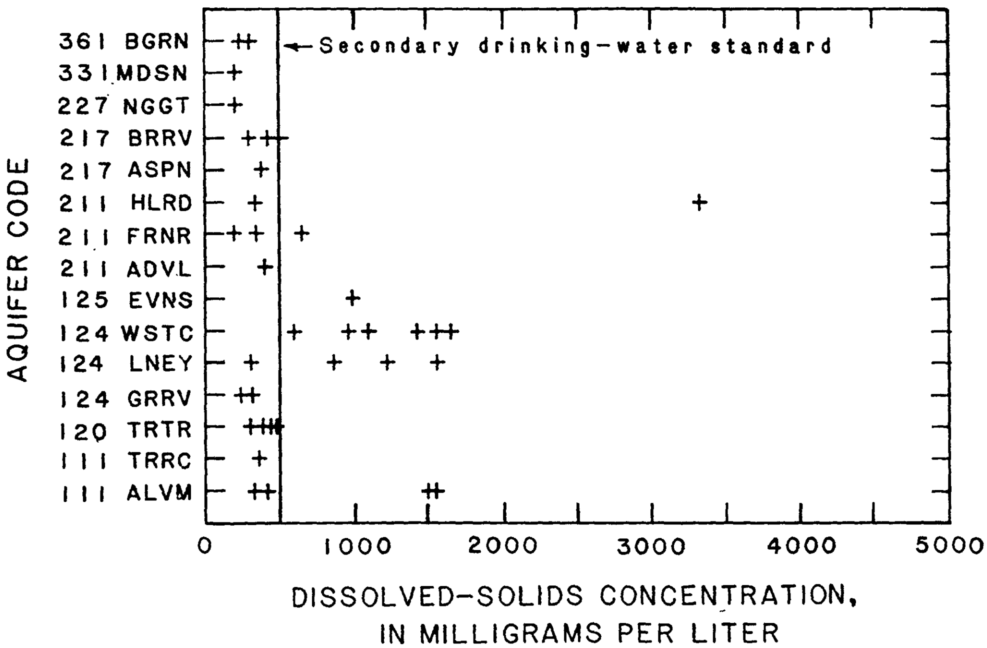


Figure 5.3.12-2--Dissolved-solids concentrations in water samples, by aquifer. (For explanation of aquifer code see section 4.0.)

MEDIAN DISSOLVED-SOLIDS CONCENTRATION - 1,390 MILLIGRAMS PER LITER

Only 29 percent of the ground-water samples for Natrona County had dissolved-solids concentrations less than the secondary drinking-water standard. Samples have been collected from wells completed in 19 different aquifers.

The median dissolved-solids concentration of ground-water samples collected in Natrona County was 1,390 mg/L (milligrams per liter), the second highest of the 23 counties in Wyoming. Only 29 percent of the ground-water samples in the county had dissolved-solids concentrations less than the 500-mg/L secondary drinking-water standard (U.S. Environmental Protection Agency, 1979). Concentrations ranged from 191 to 12,700 mg/L (fig. 5.3.13-1); 4 of the 72 samples exceeded 5,000 mg/L.

Twenty-eight geologic formations known to yield water to wells and springs crop out in Natrona County (Crist and Lowry, 1972, p. 31). Some of these aquifers have low yields but nonetheless are important locally. The dissolved-solids concentrations in 12 samples from wells completed in the alluvium ranged from 200 to 8,950 mg/L and had a median concentration of 1,390 mg/L (fig. 5.3.13-2). Concentrations in 10 samples from wells completed in the Frontier Formation ranged from 962 to 2,460 mg/L and had a median concentration of 1,905 mg/L. The concentrations in six samples from wells completed in the Tensleep Sandstone ranged from 204 to 2,930 mg/L and had a median concentration of 445 mg/L. The concentrations in eight samples from wells completed in the Madison Limestone ranged from 2,310 to 7,900 mg/L and had a median concentration of 2,785 mg/L. The depths of the Madison wells from which samples were collected range from 5,049 to 7,615 feet.

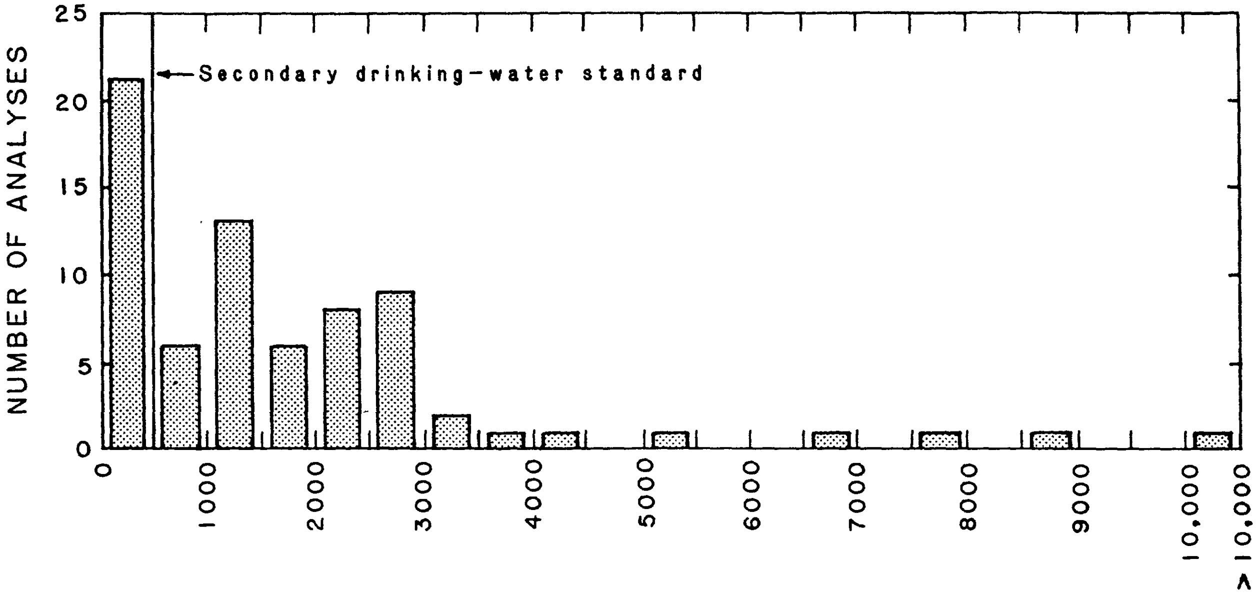


Figure 5.3.13-1--Histogram of dissolved-solids concentrations.

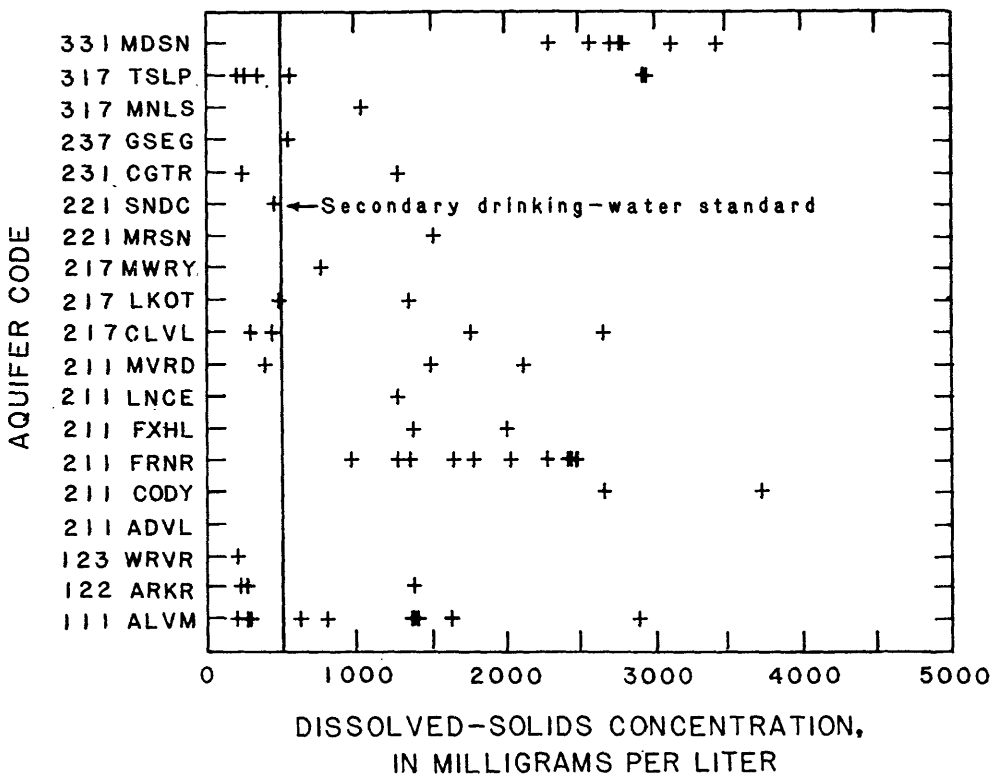


Figure 5.3.13-2--Dissolved-solids concentrations in water samples, by aquifer.
(For explanation of aquifer code see section 4.0.)

5.3.14 Niobrara County

MEDIAN DISSOLVED-SOLIDS CONCENTRATION - 973 MILLIGRAMS PER LITER

About 36 percent of the 45 ground-water samples in Niobrara County had dissolved-solids concentrations less than the secondary drinking-water standard. Many of the samples with dissolved-solids concentrations less than 500 milligrams per liter were collected from wells completed in the Arikaree and White River Formations.

The median dissolved-solids concentration of the 45 ground-water samples from Niobrara County was 973 mg/L (milligrams per liter), which is higher than the statewide median of 725 mg/L. However, the county average of 1,068 mg/L was lower than the statewide average of 1,430 mg/L. About 36 percent of the samples had dissolved-solids concentrations less than the 500-mg/L secondary drinking-water standard (U.S. Environmental Protection Agency, 1979). Dissolved-solids concentrations ranged from 218 to 3,250 mg/L (fig. 5.3.14-1), a lower range than for most counties.

Fourteen of the 16 ground-water samples with dissolved-solids concentrations less than 500 mg/L came from wells completed in either the Arikaree or the White River Formations (fig. 5.3.14-2). The median concentration of the 12 samples from the Arikaree was 321 mg/L. The median concentration of the five samples from the White River was 423 mg/L. In both of these formations, the wells from which samples were collected are relatively shallow. The eight water samples from the Lance Formation had dissolved-solids concentrations ranging from 973 to 2,850 mg/L and a median concentration of 1,350 mg/L. A sample collected from a well completed in the Inyan Kara Group had the lowest dissolved-solids concentration (219 mg/L) of any other ground-water sample in the county.

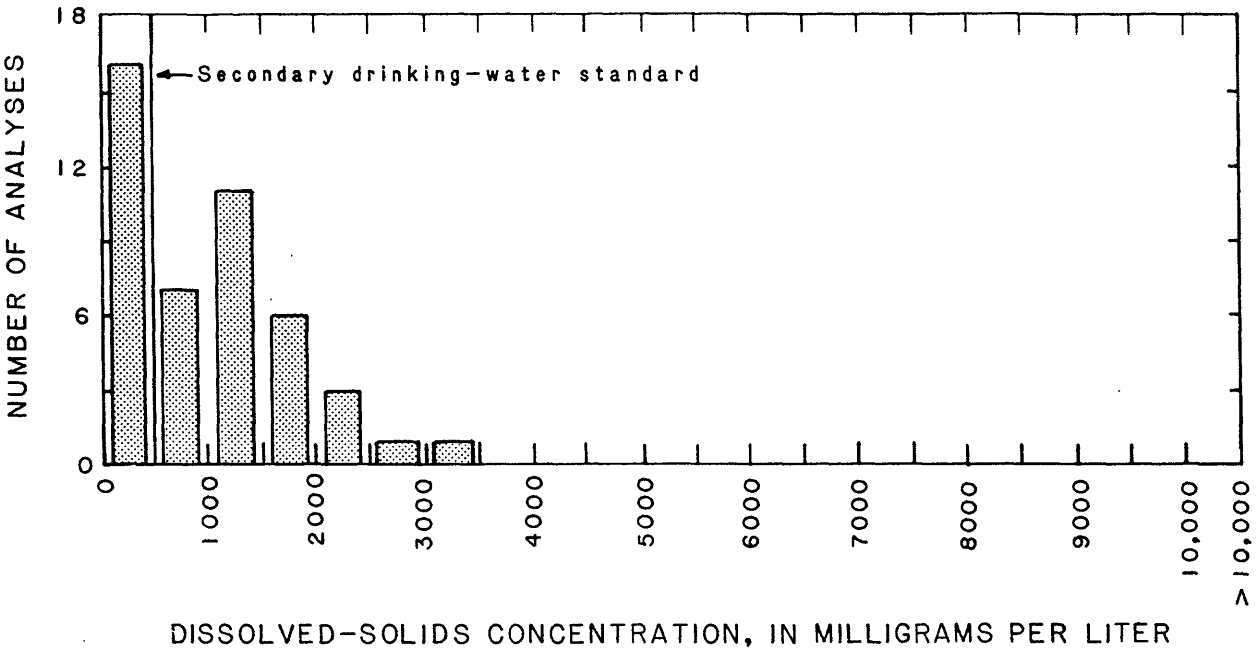


Figure 5.3.14-1--Histogram of dissolved-solids concentrations.

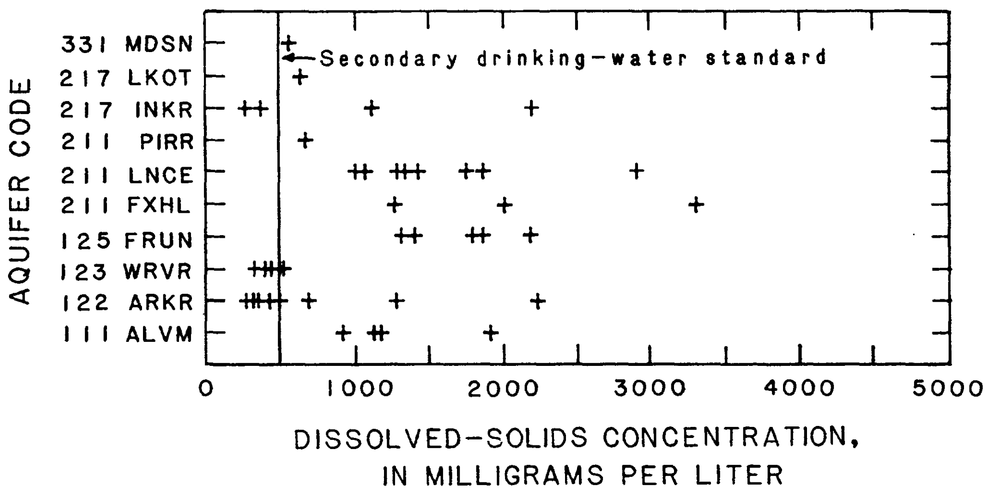


Figure 5.3.14-2--Dissolved-solids concentrations in water samples, by aquifer. (For explanation of aquifer code see section 4.0.)

MEDIAN DISSOLVED-SOLIDS CONCENTRATION - 752 MILLIGRAMS PER LITER

Thirty-four percent of the 70 ground-water samples in Park County had dissolved-solids concentrations less than the secondary drinking-water standard. Most samples with dissolved-solids concentrations less than 500 milligrams per liter were collected in or near the mountainous area.

The median dissolved-solids concentration of 70 ground-water samples collected in Park County was 752 mg/L (milligrams per liter), which is nearly equal to the statewide median of 725 mg/L. Thirty-four percent of the samples had dissolved-solids concentrations less than the 500-mg/L secondary drinking-water standard (U.S. Environmental Protection Agency, 1979), compared to 38 percent statewide (fig. 5.3.15-1). The dissolved-solids concentrations of the 70 ground-water samples ranged from 65 to 6,080 mg/L. The western two-thirds of the county is mountainous and lies in Yellowstone National Park and national forest. In this less arid portion of the county, ground water of good quality is relatively abundant. In the more arid eastern one-third of the county, good quality ground water generally is less available.

The 10 ground-water samples from lacustrine deposits had a very low median concentration, 99 mg/L (fig. 5.3.15-2). However, lacustrine deposits are only of local importance in Yellowstone National Park. Despite this, the low dissolved-solids concentrations of these samples probably indicate the generally excellent quality of ground water available in the mountainous, western two-thirds of the county where these deposits are found. The dissolved-solids concentrations in 11 ground-water samples from the Willwood Formation ranged from 232 to 2,950 mg/L and had a median concentration of 953 mg/L. The concentrations in eight ground-water samples from alluvium ranged from 79 to 974 mg/L and had a median concentration of 492 mg/L. The single ground-water sample from the Madison Limestone was collected from a well 8,319 feet deep.

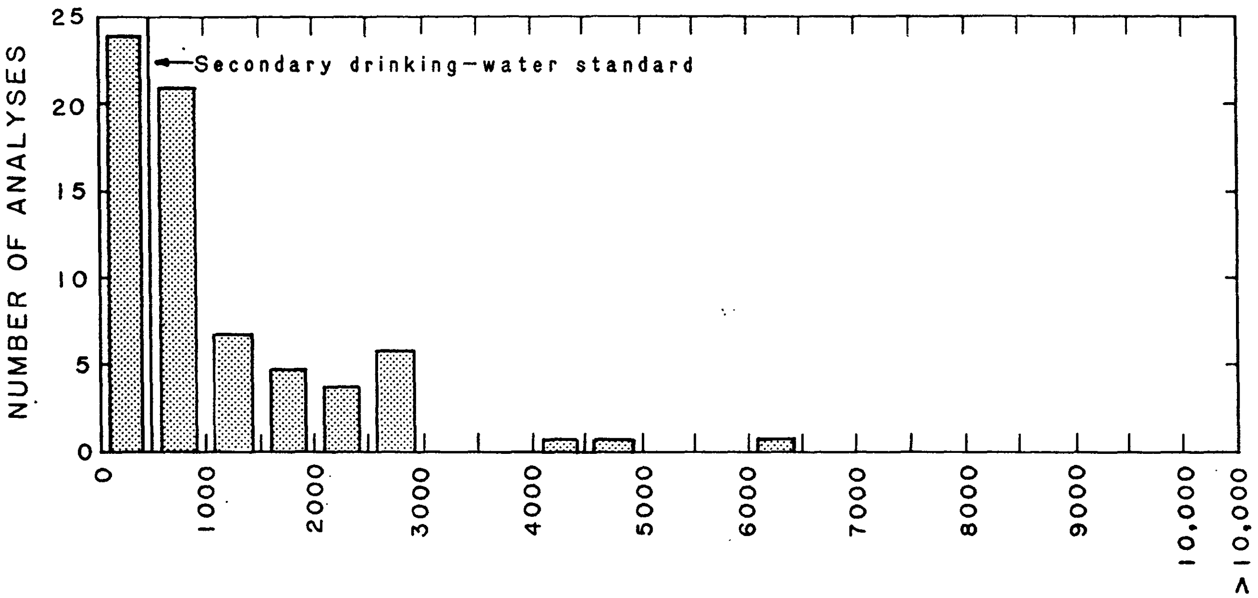


Figure 5.3.15-1--Histogram of dissolved-solids concentrations.

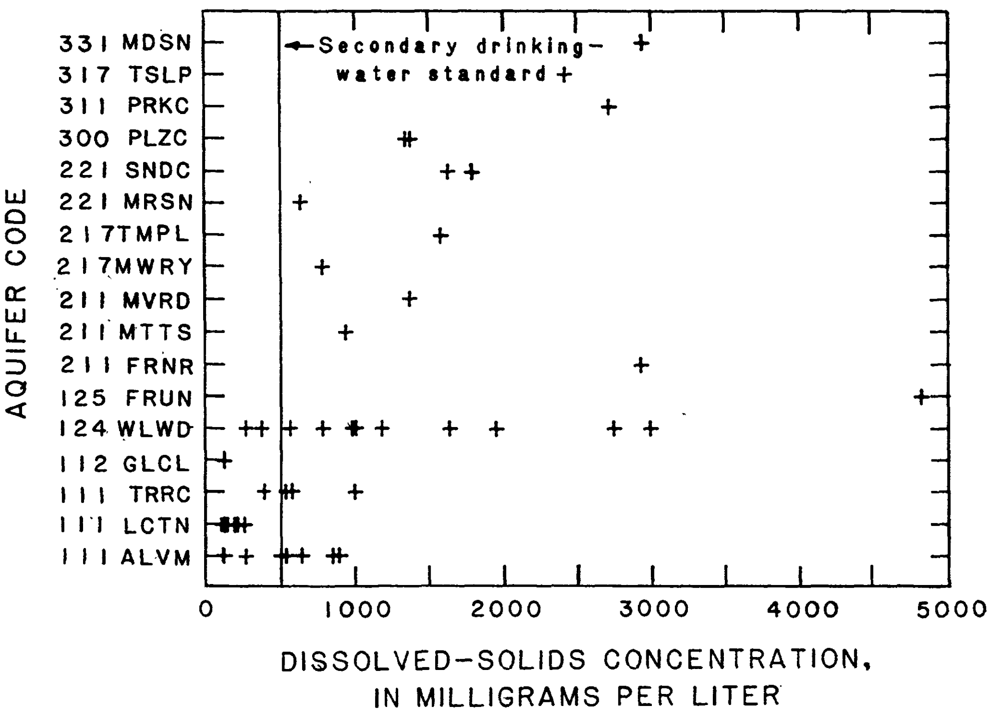


Figure 5.3.15-2--Dissolved-solids concentrations in water samples, by aquifer. (For explanation of aquifer code see section 4.0.)

5.3.16 Platte County

MEDIAN DISSOLVED-SOLIDS CONCENTRATION - 373 MILLIGRAMS PER LITER

Sixty-three percent of the 35 ground-water samples had dissolved-solids concentrations less than the secondary drinking-water standard. Most of the ground-water samples from the Holocene alluvium, and the Arikaree and Hartville Formations had dissolved-solids concentrations less than 500 milligrams per liter.

The median dissolved-solids concentration of the 35 ground-water samples from Platte County was 373 mg/L (milligrams per liter), considerably less than the statewide median of 725 mg/L. Concentrations of the ground-water samples in the county ranged from 226 to 1,460 mg/L (fig. 5.3.16-1). This is a relatively narrow range due to the unusually low maximum concentration. Sixty-three percent of the 35 ground-water samples had dissolved-solids concentrations less than the 500-mg/L secondary drinking-water standard (U.S. Environmental Protection Agency, 1979).

Most of the ground-water samples with dissolved-solids concentrations less than 500 mg/L were collected from wells in alluvium, and the Arikaree and Hartville Formations (fig. 5.3.16-2). Dissolved-solids concentrations in the alluvium ranged from 284 to 1,460 mg/L, which was the largest range of all aquifers in the county. The median concentration from alluvium was 329 mg/L. Ground-water samples collected from the Arikaree ranged from 264 to 604 mg/L and had a median concentration of 420 mg/L. Concentrations in ground-water samples from the Hartville Formation ranged from 226 to 440 mg/L and had a median concentration of 261 mg/L.

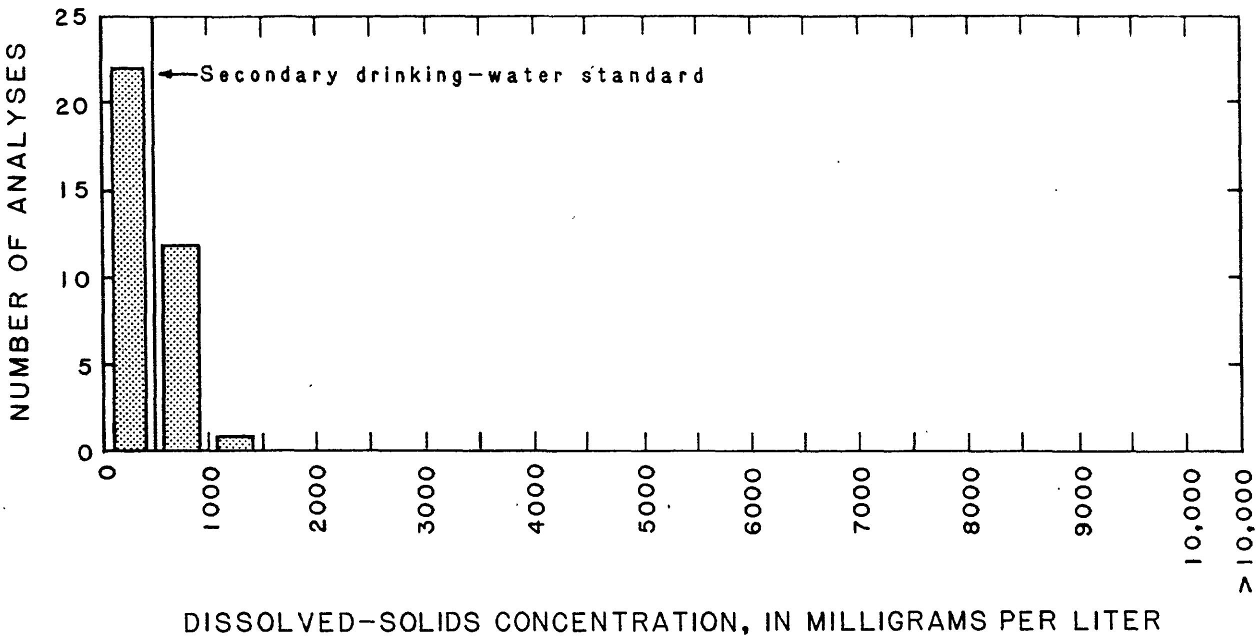


Figure 5.3.16-1--Histogram of dissolved-solids concentrations.

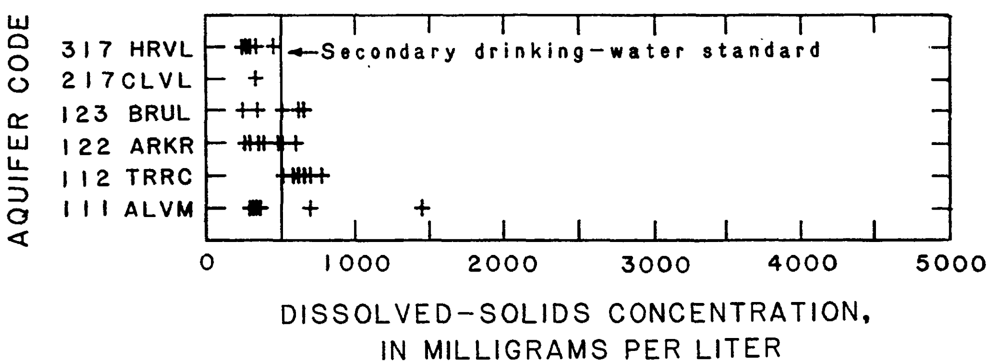


Figure 5.3.16-2--Dissolved-solids concentrations in water samples, by aquifer. (For explanation of aquifer code see section 4.0.)

5.3.17 Sheridan County

MEDIAN DISSOLVED-SOLIDS CONCENTRATION - 892 MILLIGRAMS PER LITER

Only 22 percent of the 64 ground-water samples in Sheridan County had dissolved-solids concentrations less than the secondary drinking-water standard. However, all five ground-water samples from the Madison Limestone had dissolved-solids concentrations less than the drinking-water standard.

The median dissolved-solids concentration of 64 ground-water samples collected in Sheridan County was 892 mg/L (milligrams per liter). Dissolved-solids concentrations ranged from 112 to 6,620 mg/L (fig. 5.3.17-1). Only 22 percent of the samples had dissolved-solids concentrations less than the 500-mg/L secondary drinking-water standard (U.S. Environmental Protection Agency, 1979).

All of five samples from wells completed in the Madison Limestone had low dissolved-solids concentrations, ranging from 191 to 320 mg/L (fig. 5.3.17-2). The median concentration was 214 mg/L. The wells from which these samples were collected were relatively shallow, less than 2,000 feet. Unfortunately, the Madison is too deep in most of Sheridan County to be an affordable source of water for most farmers, ranchers and other rural dwellers, except in or near the mountains.

The ground-water samples from the aquifers most commonly used for water supply, the Wasatch and Fort Union Formations, are of widely varying quality. The dissolved-solids concentrations of 21 ground-water samples from wells completed in the Wasatch ranged from 141 to 6,620 mg/L and had a median concentration of 860 mg/L. The concentrations of 19 ground-water samples from wells completed in the Fort Union ranged from 484 to 4,630 mg/L and had a median concentration of 1,160 mg/L.

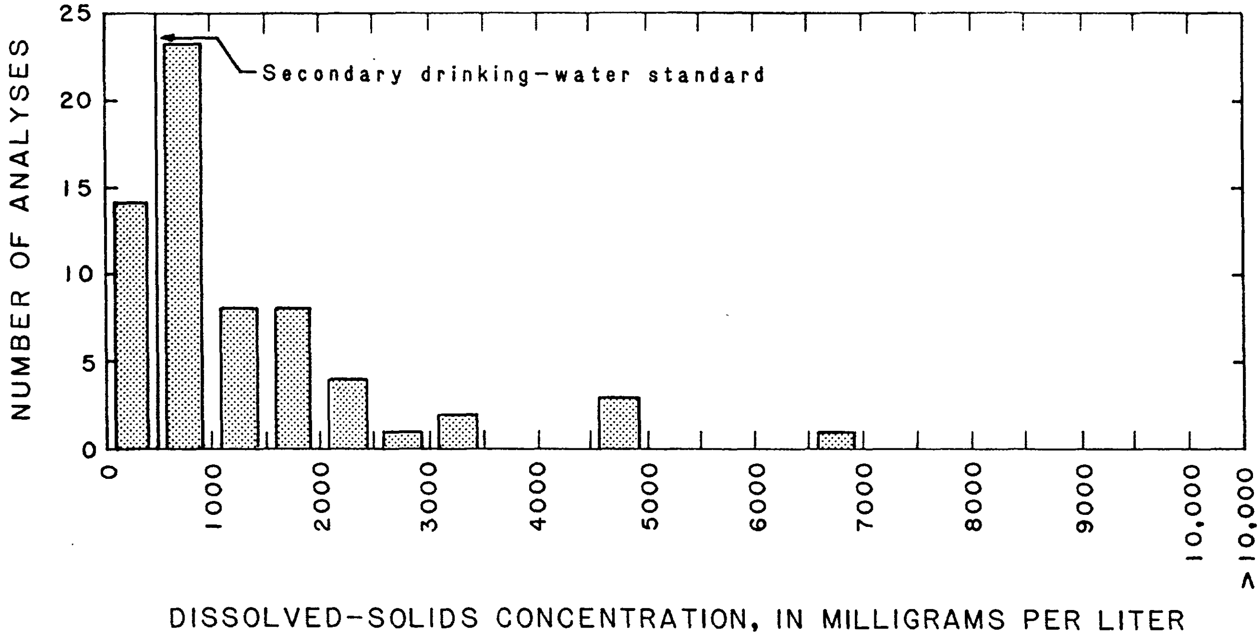


Figure 5.3.17-1--Histogram of dissolved-solids concentrations.

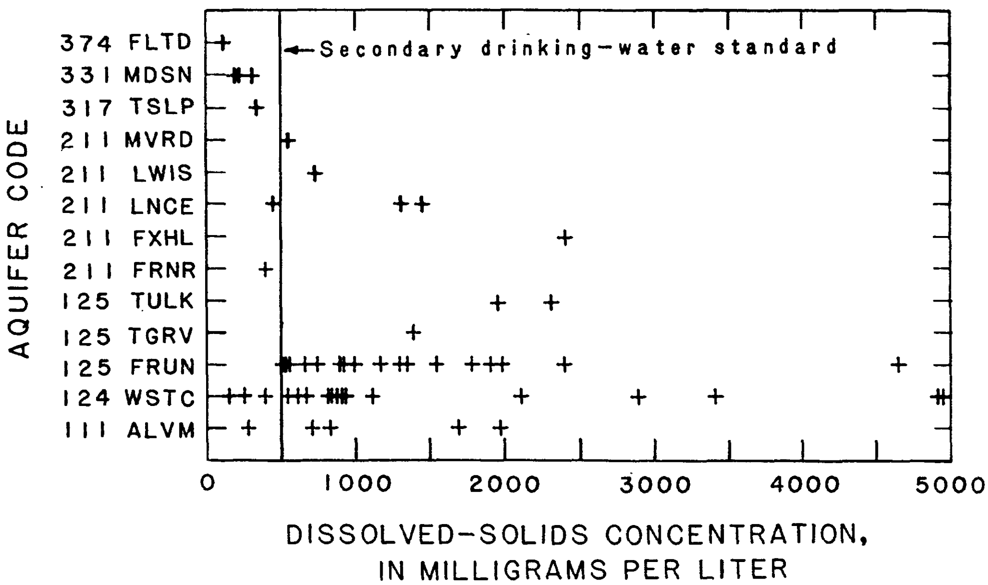


Figure 5.3.17-2--Dissolved-solids concentrations in water samples, by aquifer. (For explanation of aquifer code see section 4.0.)

5.3.18 Sublette County

MEDIAN DISSOLVED-SOLIDS CONCENTRATION - 526 MILLIGRAMS PER LITER

Forty-seven percent of the 68 ground-water samples had dissolved-solids concentrations less than the secondary drinking-water standard. Dissolved-solids concentrations in ground-water samples from the Wasatch Formation ranged from 186 to 1,780 milligrams per liter.

Sublette County, surrounded by mountains on three sides, has some excellent quality ground water. The median dissolved-solids concentration in the 68 ground-water samples was 526 mg/L (milligrams per liter), much less than the statewide median (725 mg/L). However, concentrations ranged from 118 mg/L to as much as 7,020 mg/L (fig. 5.3.18-1).

Ground-water samples were collected from wells completed in the alluvium at 14 sites and from the Wasatch Formation at 29 sites (fig. 5.3.18-2). Dissolved-solids concentrations of ground-water samples from alluvium ranged from 148 to 1,010 mg/L, with a median concentration of 338 mg/L. The low median concentration for the alluvial ground-water samples reflects the good water quality of the streams draining the surrounding mountains. The dissolved-solids concentrations of ground-water samples from the Wasatch ranged from 196 to 1,780 mg/L, and had a median concentration of 622 mg/L. Forty-one percent of the 29 samples collected from wells completed in the Wasatch had dissolved-solids concentrations less than the 500-mg/L secondary drinking-water standard (U.S. Environmental Protection Agency, 1979).

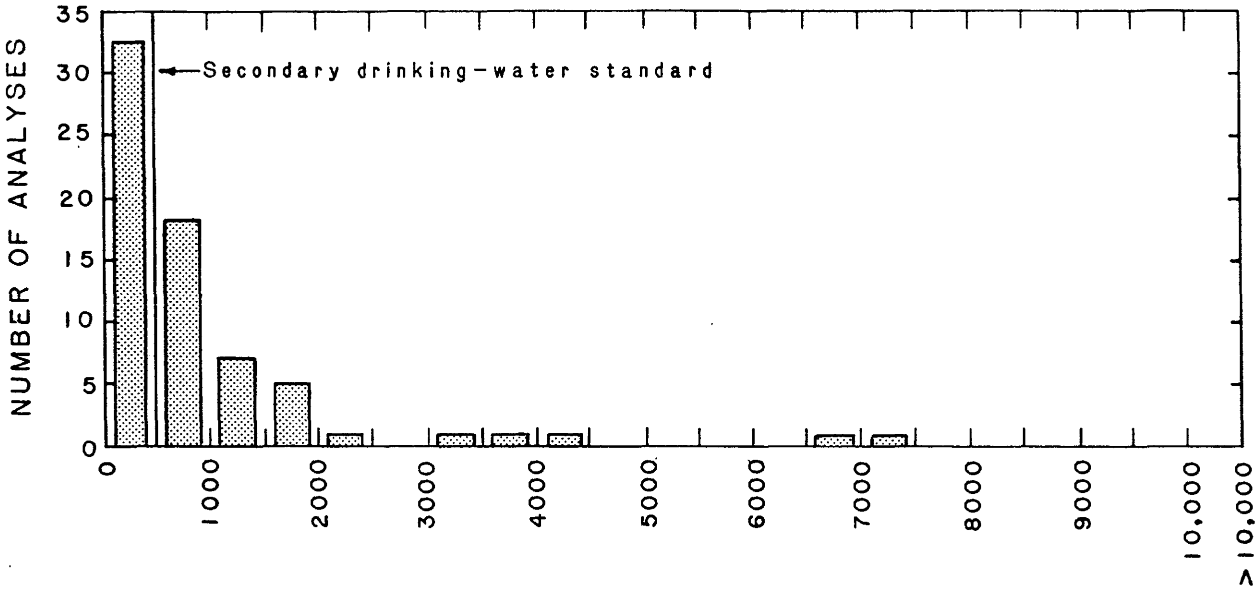


Figure 5.3.18-1--Histogram of dissolved-solids concentrations.

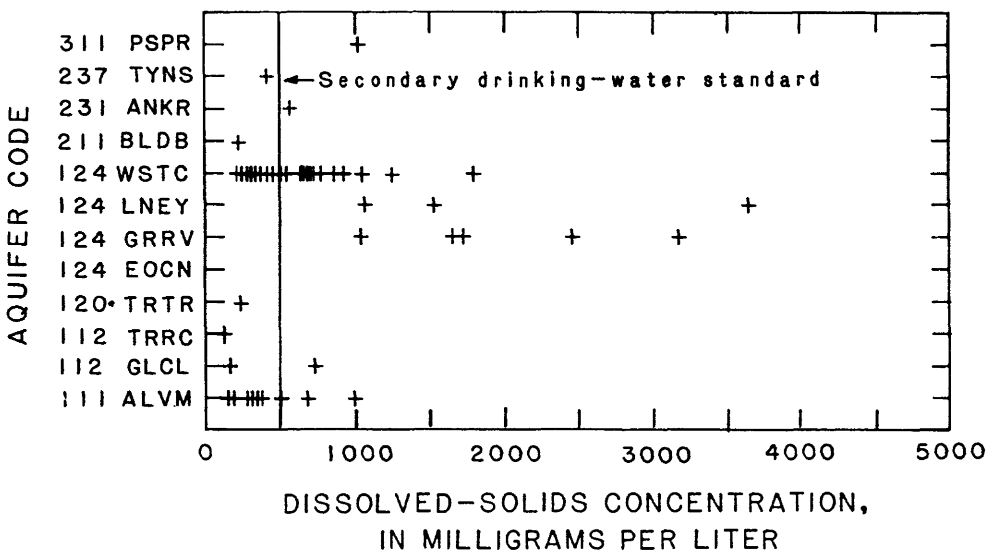


Figure 5.3.18-2--Dissolved-solids concentrations in water samples, by aquifer. (For explanation of aquifer code see section 4.0.)

MEDIAN DISSOLVED-SOLIDS CONCENTRATION - 896 MILLIGRAMS PER LITER

About 24 percent of 274 ground-water samples in Sweetwater County had dissolved-solids concentrations less than the secondary drinking-water standard. Concentrations ranged from 70 to 99,400 milligrams per liter.

Sweetwater County has a wide range in ground-water quality (fig. 5.3.19-1). The dissolved-solids concentrations of 274 ground-water samples ranged from 70 to 99,400 mg/L (milligrams per liter). The median dissolved-solids concentration was 896 mg/L, higher than the statewide median (725 mg/L). About 8 percent of the samples exceeded 10,000 mg/L. However, about 24 percent of the samples had dissolved-solids concentrations less than the 500-mg/L secondary drinking-water standard (U.S. Environmental Protection Agency, 1979).

Ground-water samples were most commonly collected from the Laney Member and the Tipton Shale Member of the Green River Formation and from the Wasatch Formation (fig. 5.3.19-2). Ground-water samples from the Laney ranged from 490 to 53,700 mg/L and had a median concentration of 1,700 mg/L. Ground-water samples from the Tipton Shale Member ranged from 246 to 48,000 mg/L and had a median concentration of 1,575 mg/L. About 25 wells completed in the Tipton have been used to monitor the effects on ground water of an experimental in situ oil-shale retort near Rock Springs. Most of the samples from these wells were not plotted on figure 5.3.19-2 because their dissolved-solids concentrations were greater than 10,000 mg/L and exceeded the limits of the graph. Concentrations in ground-water samples from the Wasatch Formation ranged from 306 to 6,590 mg/L and had a median concentration of 1,053 mg/L.

The very high dissolved-solids concentration--99,400 mg/L--is from a sample of an abandoned but flowing oil-exploration well. The well depth and the aquifer are not listed in the U.S. Geological Survey file.

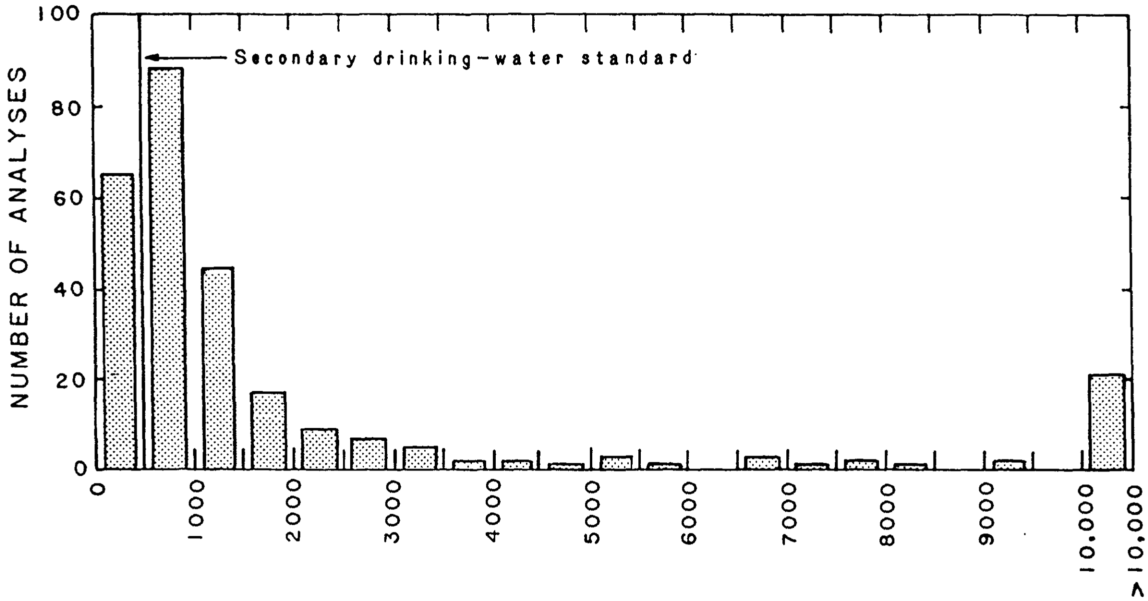


Figure 5.3.19-1--Histogram of dissolved-solids concentrations.

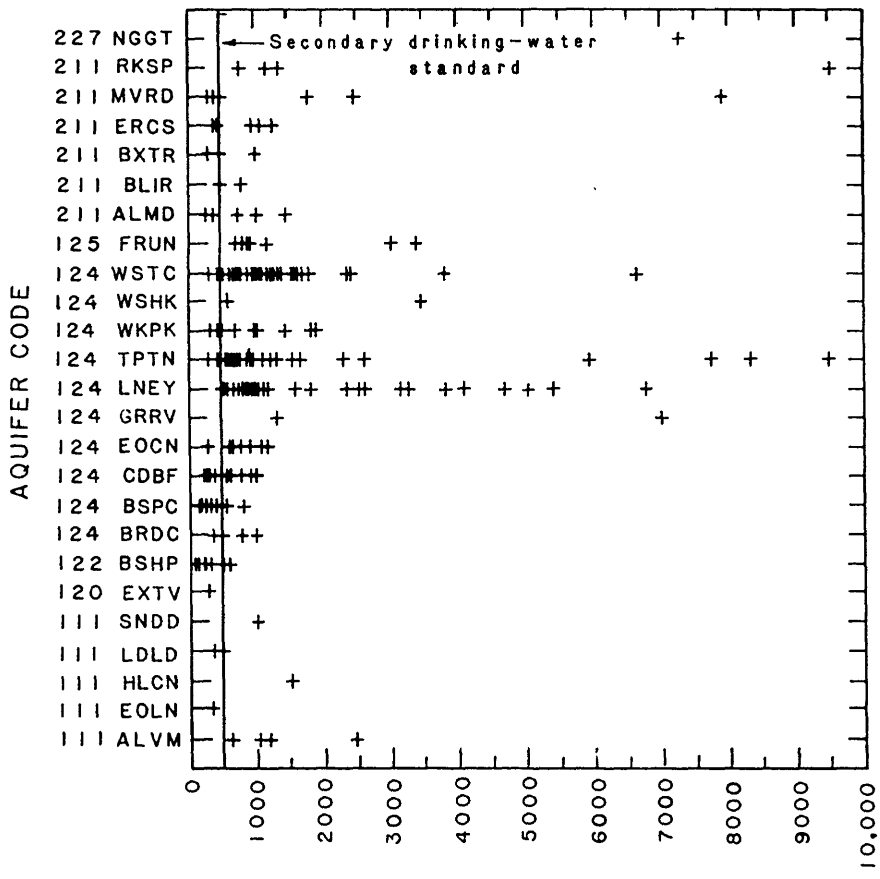


Figure 5.3.19-2--Dissolved-solids concentrations in water samples, by aquifer. (For explanation of aquifer code see section 4.0.)

5.3.20 Teton County

MEDIAN DISSOLVED-SOLIDS CONCENTRATION - 176 MILLIGRAMS PER LITER

Dissolved-solids concentrations of 70 ground-water samples from Teton County are the lowest of all the counties in Wyoming. Concentrations in about 91 percent of the samples were less than the secondary drinking-water standard.

Teton County has the best ground-water quality of any county in the State, based upon the median dissolved-solids concentration of 70 ground-water samples, 176 mg/L (milligrams per liter). The statewide median was 725 mg/L. About 91 percent of the samples had dissolved-solids concentrations less than the 500-mg/L secondary drinking-water standard (U.S. Environmental Protection Agency, 1979). Concentrations ranged from 45 to 1,280 mg/L (fig. 5.3.20-1).

Aquifers that crop out in this mountainous county are exposed to relatively abundant precipitation and streamflow. The low dissolved-solids concentrations of the ground-water samples collected from shallow aquifers reflect the effects of these conditions (fig. 5.3.20-2). Six samples from unknown aquifers had dissolved-solids concentrations of about 1,200 mg/L. Other than these six samples, all dissolved-solids concentrations were less than the secondary drinking-water standard.

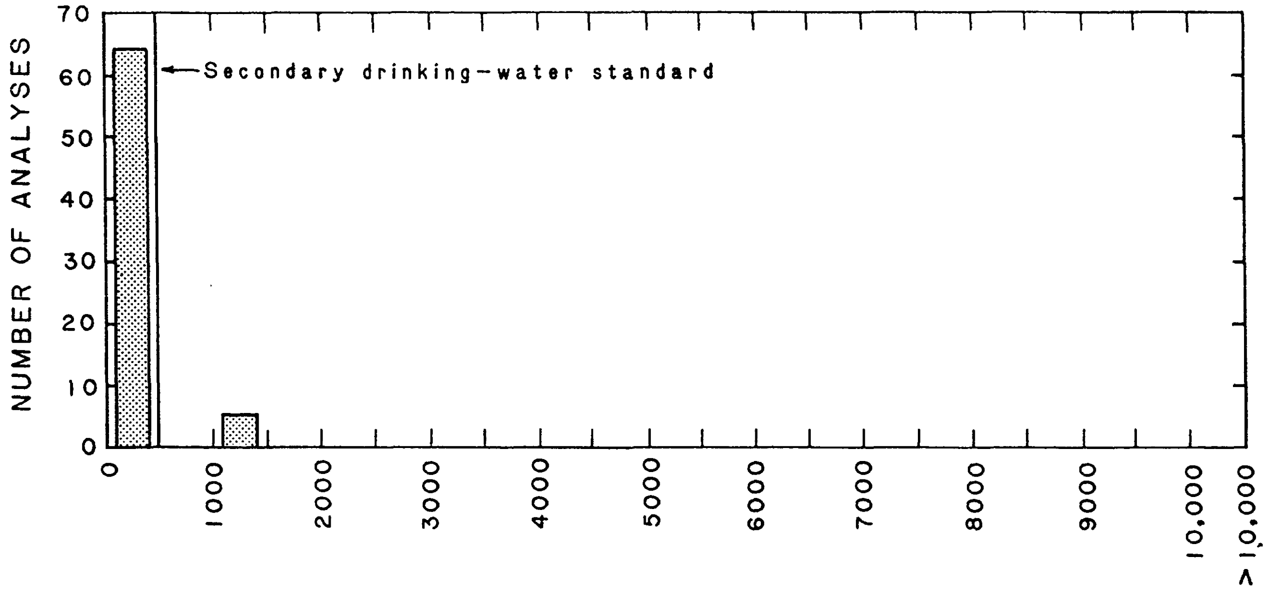


Figure 5.3.20-1--Histogram of dissolved-solids concentrations.

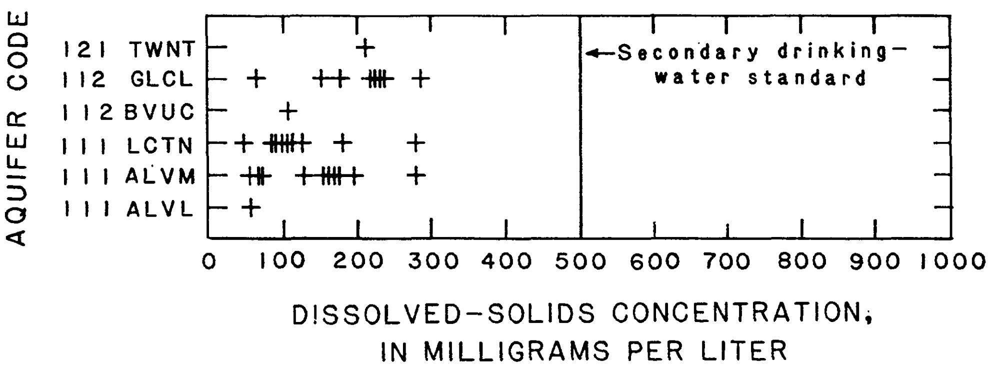


Figure 5.3.20-2--Dissolved-solids concentrations in water samples, by aquifer. (For explanation of aquifer code see section 4.0.)

MEDIAN DISSOLVED-SOLIDS CONCENTRATION - 399 MILLIGRAMS PER LITER

Sixty percent of the 91 ground-water samples had dissolved-solids concentrations less than the secondary drinking-water standard. The Bridger and Wasatch Formations and the alluvium along streams draining the Uinta Mountains are major sources of good quality ground water.

The median dissolved-solids concentration of the 91 ground-water samples from Uinta County was 399 mg/L (milligrams per liter). The statewide median concentration was 725 mg/L. Concentrations of the ground-water samples in the county ranged from 209 to 9,710 mg/L (fig. 5.3.21-1). Sixty percent of all samples had dissolved-solids concentrations less than the 500-mg/L secondary drinking-water standard (U.S. Environmental Protection Agency, 1979).

The alluvium and the Bridger and Fort Union Formations are the principal aquifers in the county and samples have been collected from each at 15 or more sites (fig. 5.3.21-2). The Wasatch and the alluvium along the Bear River, draining the Uinta Mountains are commonly used aquifers in the western part of the county; the Bridger is commonly used in the eastern part of the county where it crops out. The median concentration of 17 ground-water samples from the alluvium was 399 mg/L, with concentrations ranging from 209 to 3,400 mg/L. The median concentration of 15 ground-water samples from the Bridger was 379 mg/L, with concentrations ranging from 210 to 4,290 mg/L. The median concentration of 15 ground-water samples from the Wasatch was 527 mg/L, with concentrations ranging from 297 to 9,710 mg/L.

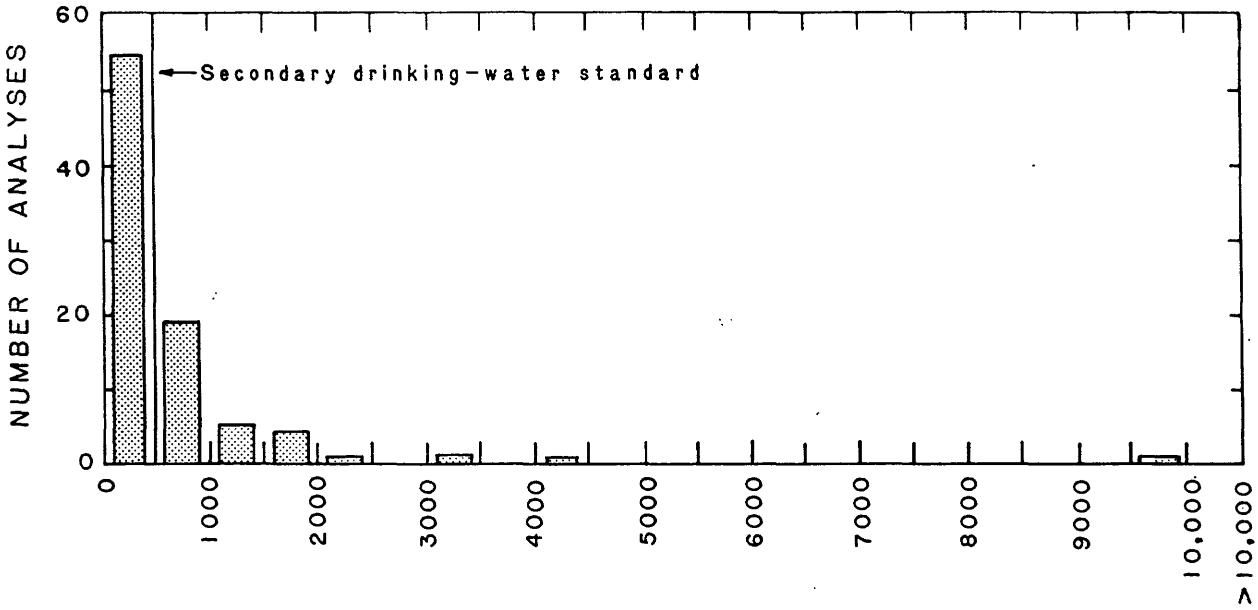


Figure 5.3.21-1--Histogram of dissolved-solids concentrations.

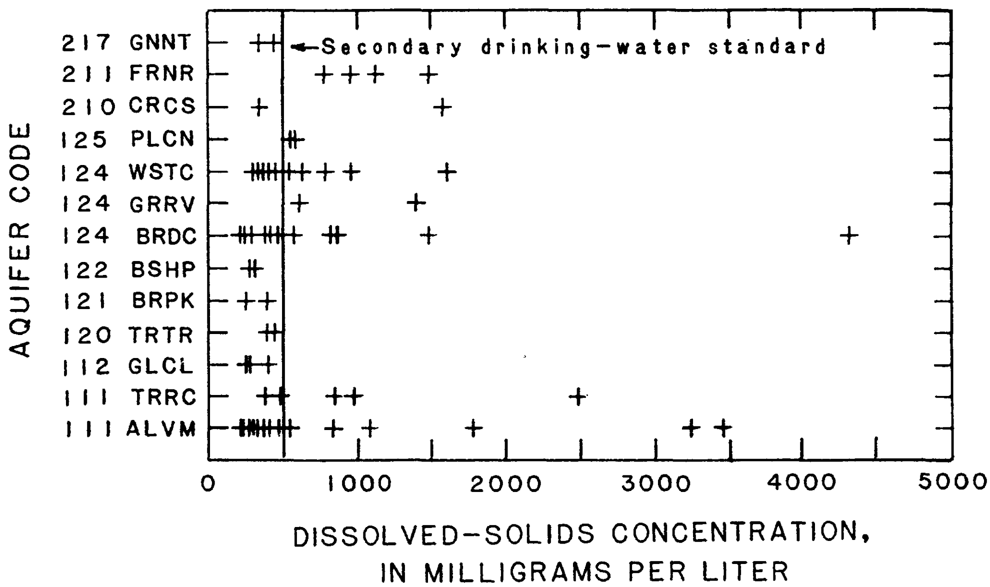


Figure 5.3.21-2--Dissolved-solids concentrations in water samples, by aquifer.
(For explanation of aquifer code see section 4.0.)

5.3.22 Washakie County

MEDIAN DISSOLVED-SOLIDS CONCENTRATION - 607 MILLIGRAMS PER LITER

Concentrations in about 49 percent of 125 ground-water samples in Washakie County were less than the secondary drinking-water standard. The Madison Limestone and Tensleep Sandstone are sources of excellent quality ground water.

The median dissolved-solids concentration of the 125 ground-water samples collected in Washakie County was 607 mg/L (milligrams per liter). About 49 percent of the samples had dissolved-solids concentrations less than the 500-mg/L secondary drinking-water standard (U.S. Environmental Protection Agency, 1979). Concentrations of the samples ranged from 156 to 6,040 mg/L (fig. 5.3.22-1).

Washakie County, like many other Wyoming counties, has some ground water of excellent quality. However, as with most other counties, the best quality ground water frequently is in or near the thinly populated mountainous-recharge area. The towns and cities as well as farms and ranches in the plains areas generally do not have direct access to the best quality ground water in the county.

The aquifers with the lowest median dissolved-solids concentrations were the Madison Limestone, which had a median concentration of 222 mg/L, and the overlying Tensleep Sandstone, which had a median concentration of 243 mg/L (fig. 5.3.22-2). These formations crop out in the Bighorn Mountains and underlie most of the county. However, both formations are steeply dipping and can be reached only by deep wells except at or near the outcrop area.

The city of Worland currently (1984) is using water piped about 20 miles to Worland under artesian pressure from deep wells in the Madison close to the mountains. However, construction costs of deep wells required to reach the Madison usually are too expensive for most rural dwellers.

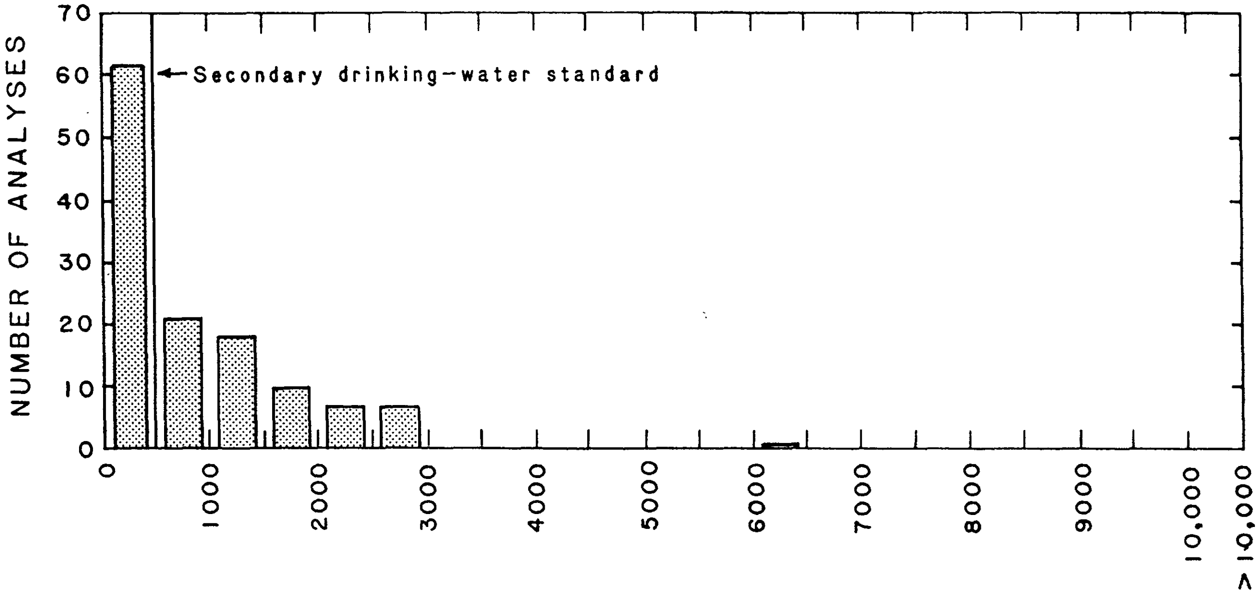


Figure 5.3.22-1--Histogram of dissolved-solids concentrations.

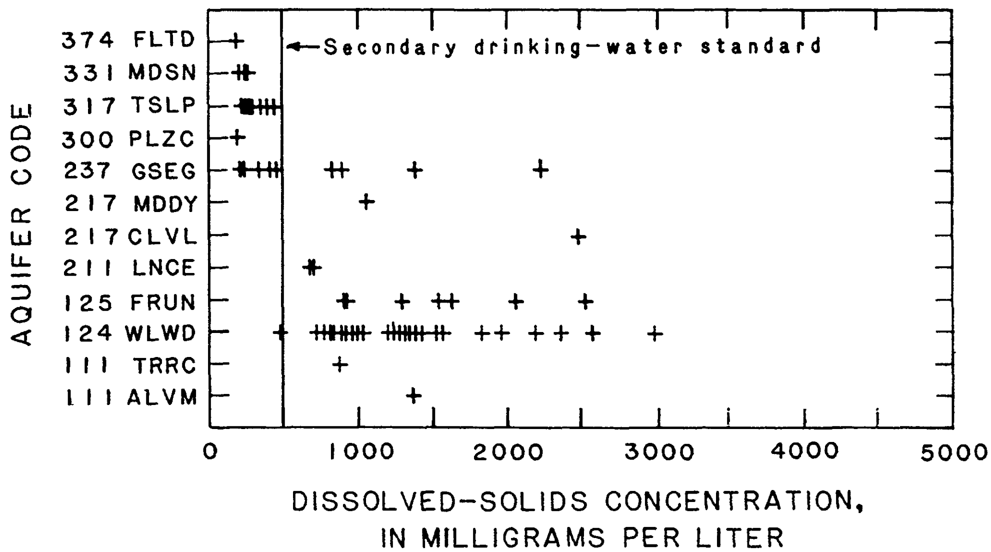


Figure 5.3.22-2--Dissolved-solids concentrations in water samples, by aquifer.
(For explanation of aquifer code see section 4.0.)

MEDIAN DISSOLVED-SOLIDS CONCENTRATION - 900 MILLIGRAMS PER LITER

Dissolved-solids concentrations in only 29 percent of the 119 ground-water samples in Weston County were less than the secondary drinking-water standard. Concentrations of ground-water samples from 14 aquifers ranged from 180 to 30,100 milligrams per liter.

The median dissolved-solids concentration of the 119 Weston County ground-water samples was 900 mg/L (milligrams per liter). The statewide median concentration was 725 mg/L. Concentrations in ground-water samples from 14 aquifers ranged from 180 to 30,100 mg/L (fig. 5.3.23-1). Only 29 percent of the ground-water samples in the county had concentrations less than the 500-mg/L secondary drinking-water standard (U.S. Environmental Protection Agency, 1979).

The samples from the Madison Limestone had the lowest median dissolved-solids concentration, about 350 mg/L (fig. 5.3.23-2). To tap this aquifer, wells commonly have been drilled to considerable depths. The wells in the Madison from which samples were collected range from 380 to 8,870 feet deep and have a median depth of 3,072 feet.

The sample with the highest dissolved-solids concentration (30,100 mg/L) was from a spring in the Spearfish Formation. Water from this spring has been used as a source of salt.

Ground-water samples have been collected from the Inyan Kara Group and from the Lakota Formation at 17 sites each and both had a median dissolved-solids concentration of 1,190 mg/L. However, dissolved-solids concentrations in samples from the Lakota ranged from 180 to 3,200 mg/L; concentrations in samples from the Inyan Kara ranged from 541 to 2,510 mg/L.

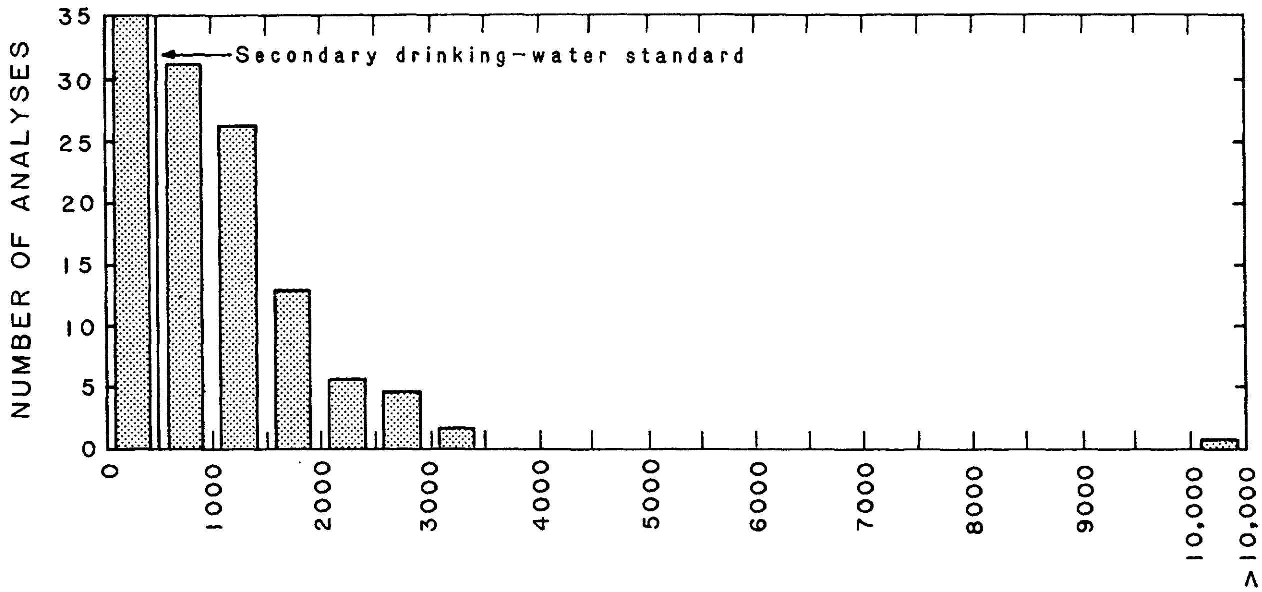


Figure 5.3.23-1--Histogram of dissolved-solids concentrations.

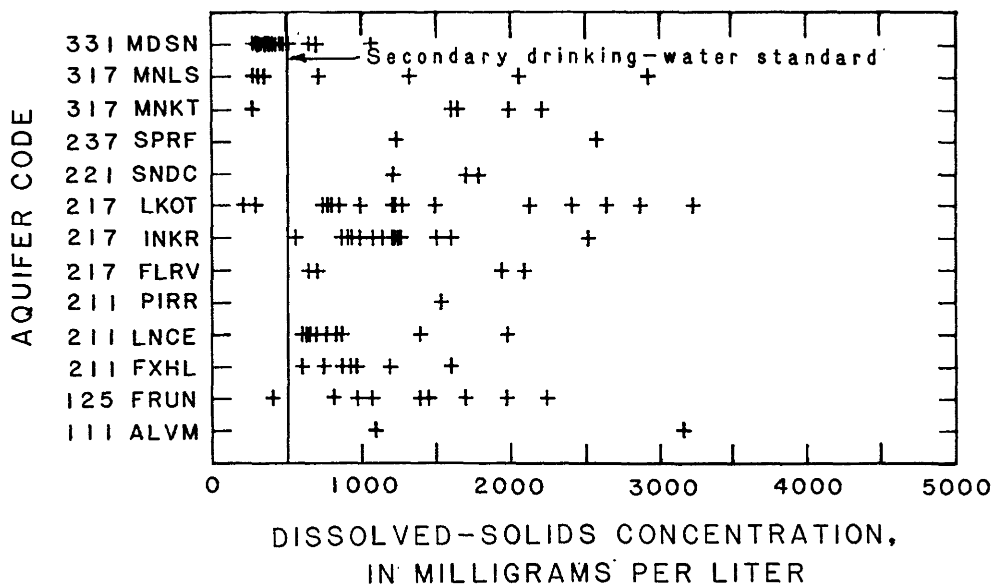


Figure 5.3.23-2--Dissolved-solids concentrations in water samples, by aquifer. (For explanation of aquifer code see section 4.0.)

6.0 NITRATE

HIGH NITRATE CONCENTRATIONS - A POTENTIALLY DEADLY PROBLEM

Concentrations in about 3 percent of ground-water samples throughout the State exceeded the primary drinking-water standard for nitrate.

About 3 percent of the 1,544 ground-water samples collected from wells and springs in Wyoming exceeded the primary drinking-water standard for nitrate (fig. 6.0-1). The maximum allowable nitrate concentration, expressed as nitrogen, in public drinking-water supplies is 10 mg/L (milligrams per liter) (U.S. Environmental Protection Agency, 1975, p. 59570). The maximum nitrate (as nitrogen) concentration in the ground-water samples was 207 mg/L. Five other ground-water samples had nitrate concentrations that exceeded 100 mg/L.

The National Academy of Sciences and National Academy of Engineering (1973, p. 73) reported that since 1945, about 2,000 infants in North America and Europe using private water supplies were diagnosed as having a blood disorder called methemoglobinemia ("blue-baby disease"). About 8 percent of these infants died. The cause of methemoglobinemia is nitrate concentrations in drinking water in excess of 10 mg/L (nitrate, as nitrogen). Because of the toxicity of nitrates to infants, even the relatively small number of samples in which nitrate concentrations exceeded the drinking-water standard is a cause for concern.

Methemoglobinemia primarily is restricted to infants less than 3 months of age. These very young infants generally have more alkaline fluids in their stomach than older children and adults. These higher pH levels are conducive to the growth of nitrate-reducing bacteria. Also, gastrointestinal illnesses of very young infants may tend to reduce nitrates to nitrites in the upper intestinal tract causing more nitrite to be absorbed (National Academy of Sciences and National Academy of Engineering, 1973, p. 73). Very young infants, therefore, are more likely to convert relatively harmless nitrate ions to potentially dangerous nitrite ions. Nitrite ions absorbed into the blood stream combine with the hemoglobin and prevent it from transporting oxygen. When this condition becomes severe, suffocation results. The term "blue baby" describes one visual effect of the suffocation of the infant.

Large nitrate concentrations are most common in water from shallow aquifers throughout the State due to surface or near-surface activities which are potential sources of nitrates. One-fourth of the 48 nitrate concentrations exceeding the drinking-water standard were in samples collected from wells completed in alluvium. All except 6 of the 48 were collected from shallow Quaternary or Tertiary aquifers. Common sources of high nitrate concentrations in ground water include infiltration from septic tanks, feedlots, barnyards, and possibly nitrate fertilizers (National Academy of Sciences and National Academy of Engineering, 1973, p. 73).

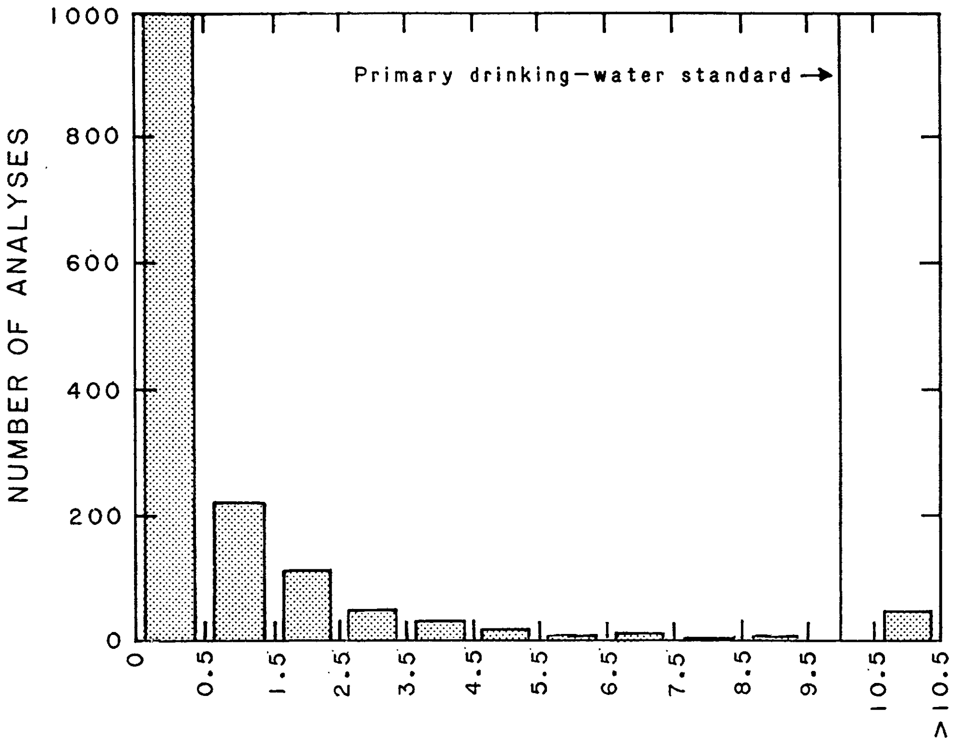


Figure 6.0-1--Histogram of nitrate concentrations (statewide) in ground-water samples.

6.0 NITRATE

7.0 FLUORIDE

HIGH FLUORIDE CONCENTRATIONS - A COMMON PROBLEM

Concentrations in about 14 percent of the Wyoming ground-water samples were greater than the primary drinking-water standard for fluoride. The highest fluoride concentration was 90 milligrams per liter.

Fluoride concentrations of ground-water samples throughout Wyoming ranged from undetectable to 90 mg/L (milligrams per liter) (fig. 7.0-1). The maximum concentration of fluoride acceptable in a public water supply is based upon the annual average maximum daily air temperature. Assuming an annual average maximum daily air temperature of 54° to 58° Fahrenheit, the maximum acceptable fluoride concentration in a public supply is 2.2 mg/L (U.S. Environmental Protection Agency, 1975). About 14 percent of the ground-water samples throughout the State exceeded this concentration.

Fluoride concentrations greater than the drinking-water standard have been found throughout the State in water from many different aquifers. The Ogallala and Arikaree Formations are notable exceptions (fig. 7.0-2). In all counties, at least one sample had a fluoride concentration that exceeded the drinking-water standard. However, Campbell, Carbon, Natrona, Sweetwater, and Washakie Counties had 20 or more samples with fluoride concentrations greater than 2.2 mg/L. The maximum concentrations (as much as 90 mg/L) were in water samples from the Tipton Shale Member of the Green River Formation. Fluoride concentrations greater than 10 mg/L also were found in the Cathedral Bluffs Tongue of the Wasatch Formation, the Laney Member of the Green River Formation, the Wasatch Formation, the Fort Union Formation, and the Frontier Formation.

Fluoride in drinking water in concentrations less than the recommended maximum is potentially beneficial in preventing dental caries (cavities). Excessive fluoride concentrations, however, cause mottling of teeth, especially in children. This is the only documented harmful effect from fluoride in drinking water in the United States (National Academy of Sciences and National Academy of Engineering, 1973, p. 66). The same authority recommends (p. 312) a maximum fluoride concentration of 2.0 mg/L in drinking water for livestock. Some tooth mottling may occur in livestock at this concentration but other injurious effects would not occur until fluoride concentrations increased several fold (National Academy of Sciences and National Academy of Engineering, 1973, p. 312).

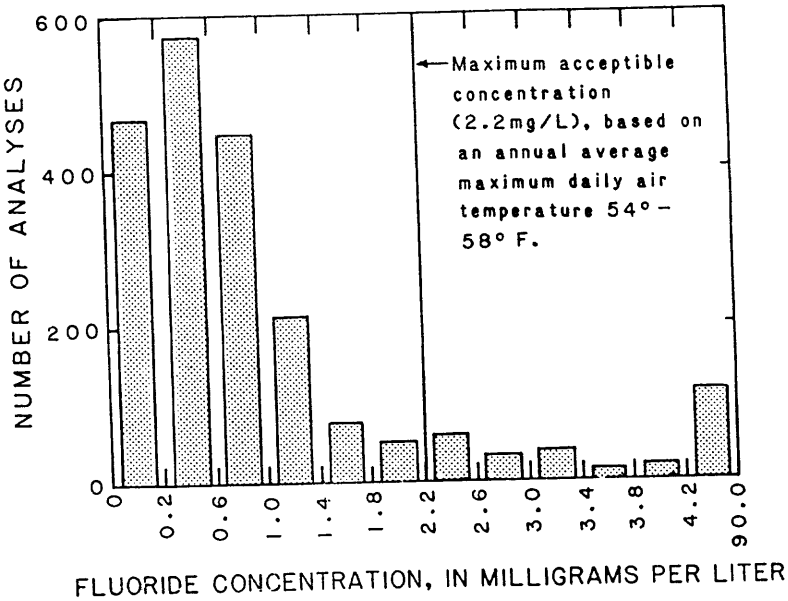


Figure 7.0-1--Statewide fluoride concentrations in ground-water samples.

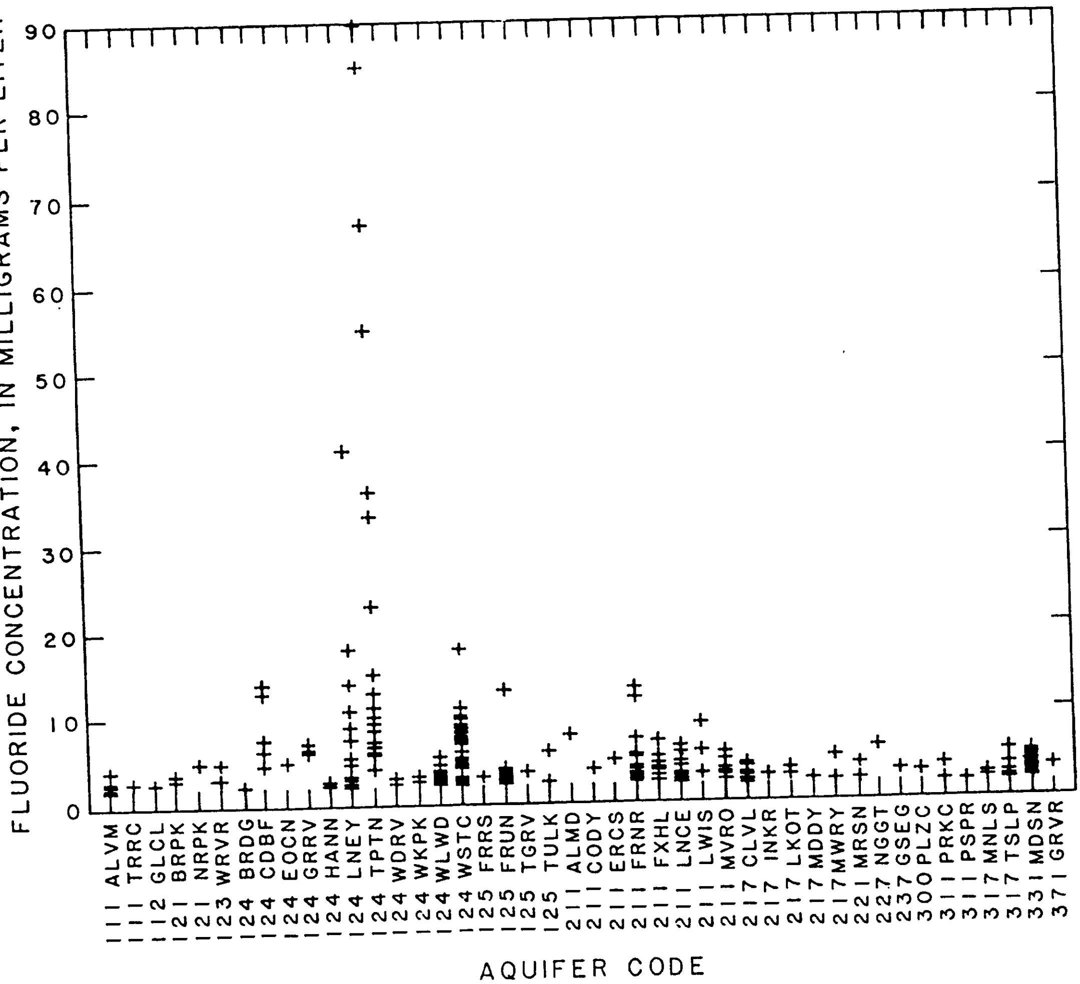


Figure 7.0-2--Fluoride concentrations (statewide) greater than 2.0 milligrams per liter.

8.0 TOXIC TRACE ELEMENTS

SELENIUM - A TOXIC TRACE ELEMENT PROBLEM

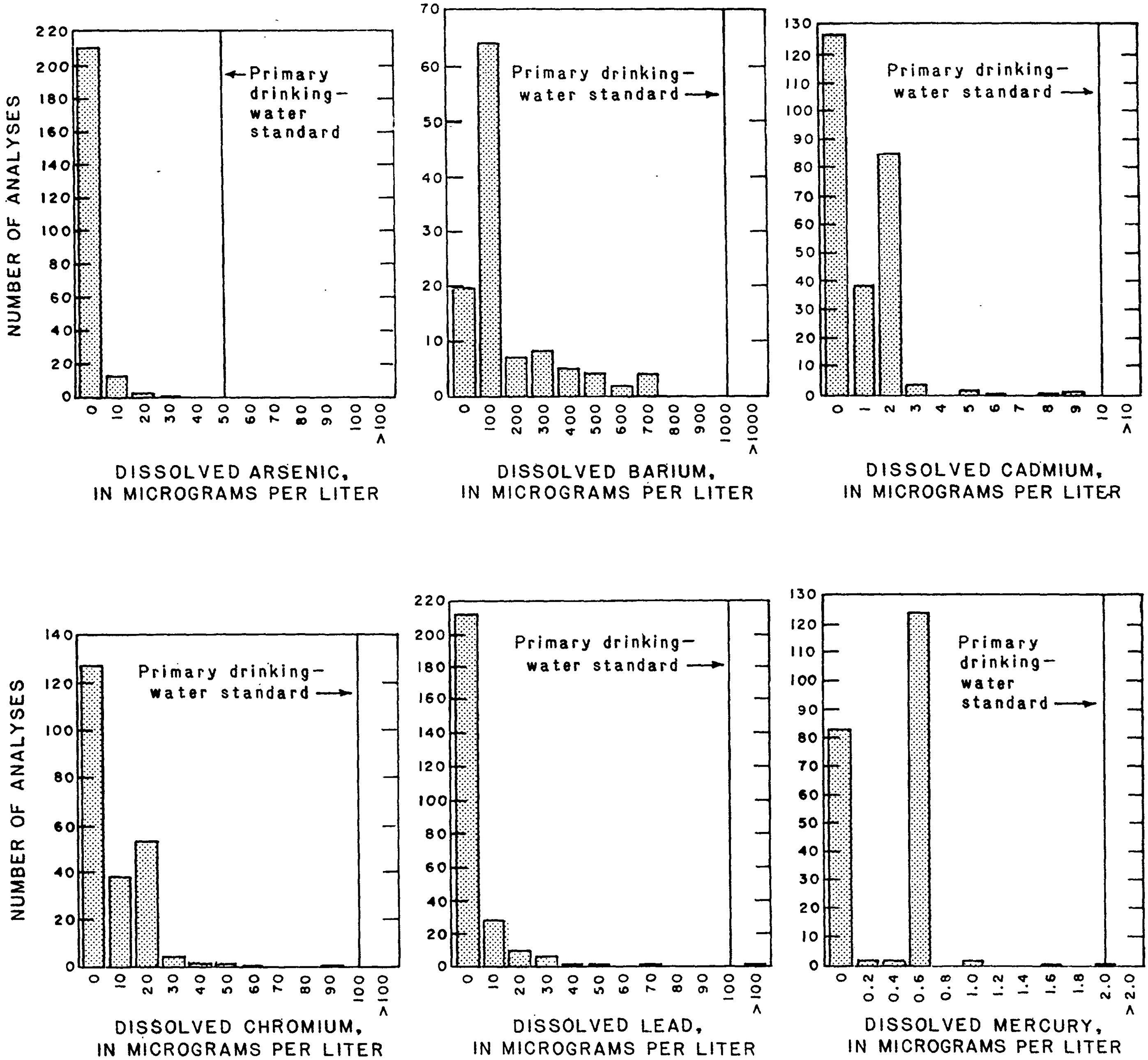
Except for selenium, ground-water samples do not indicate toxic trace elements to be a problem in Wyoming.

The toxic trace elements included in the National Interim Primary Drinking Water Regulations (U.S. Environmental Protection Agency, 1975) are arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver. Of the ground-water data analyzed, only selenium concentrations have exceeded the primary drinking-water standard more than once. Histograms of trace-element concentrations and concentration limits for drinking-water standards are presented in figure 8.0-1. Data on silver concentrations were insufficient to summarize. However, the National Academy of Sciences and National Academy of Engineering (1973, p. 87) states that silver in water is rarely detected in concentrations of more than 1 μg/L (microgram per liter). The primary drinking-water standard for silver is 50 μg/L (U.S. Environmental Protection Agency, 1975, p. 59570).

The toxicity of selenium resembles that of arsenic and, if exposure is sufficient, can cause death: One human death has been reported from selenium-contaminated well water (National Academy of Sciences and National Academy of Engineering, 1973, p. 86). The maximum allowable selenium concentration in public drinking water is 10 μg/L (U.S. Environmental Protection Agency, 1975, p. 59570). The selenium concentrations in Wyoming ground-water samples ranged from not detected to 80 μg/L.

Selenium poisoning of livestock has been a problem in certain areas of Wyoming. Poisoning of livestock occurs from the ingestion of certain plants which concentrate selenium from seleniferous soils, which occur naturally in some areas of Wyoming. To protect livestock and people who eat livestock and irrigated crops, the National Academy of Sciences and National Academy of Engineering (1973, p. 316 and 345) recommends a maximum selenium concentration of 50 μg/L in livestock water and a maximum selenium concentration of 20 μg/L in irrigation water.

A previous study has documented high selenium concentrations in ground water in part of Natrona County (Crist, 1974). These data have not been entered into the U.S. Geological Survey water-quality file and, therefore, are not summarized here.



Drinking-water standards (U.S. Environmental Protection Agency, 1975, p. 59570)

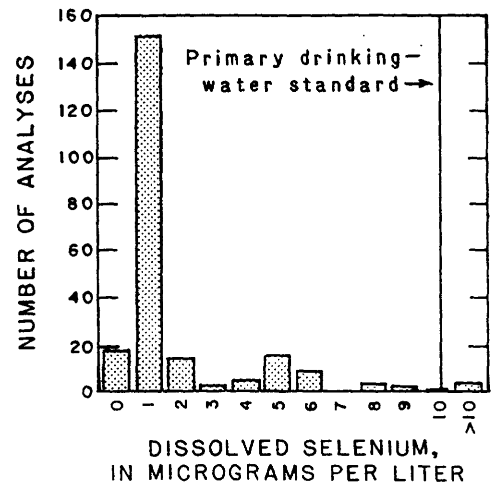


Figure 8.0-1--Histograms of toxic trace-element concentrations (statewide) in ground-water samples.

9.0 IRON AND MANGANESE

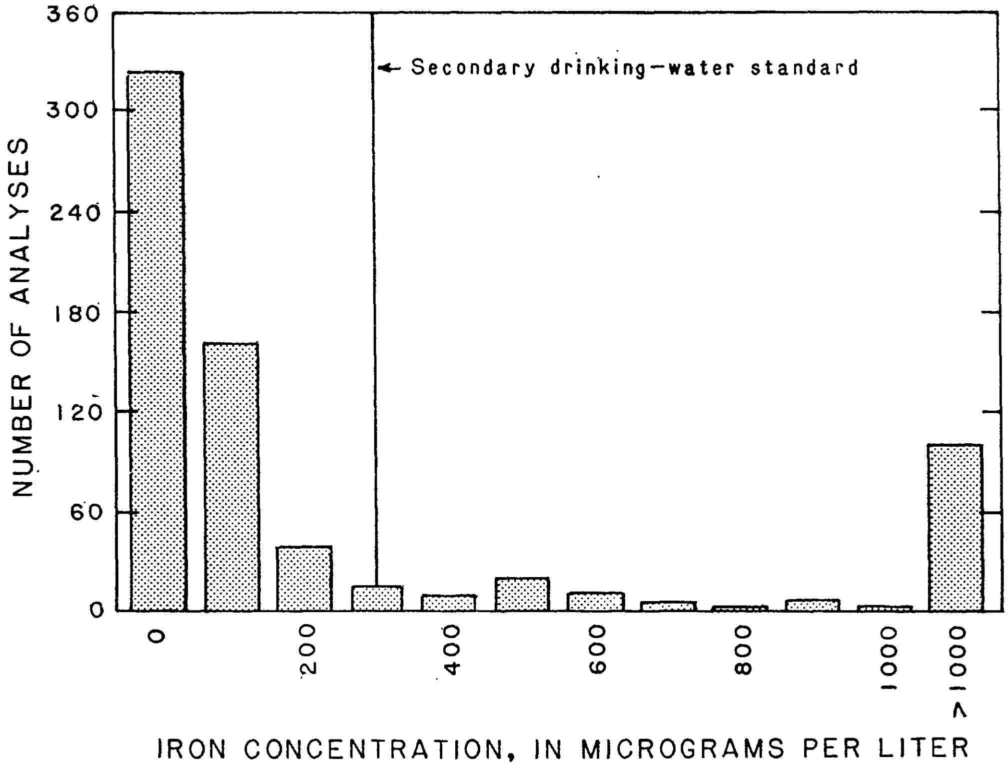
IRON AND MANGANESE - COMMON PROBLEMS IN WATER FOR DOMESTIC USE

About 19 percent of the ground-water samples analyzed for iron and 30 percent of the ground-water samples analyzed for manganese exceeded the secondary drinking-water standards. High concentrations of iron and manganese in ground water cause esthetic problems in domestic supplies.

Both iron and manganese concentrations in ground-water samples commonly exceeded the recommended drinking-water standard. The U.S. Environmental Protection Agency (1979, p. 42198) recommends a maximum concentration of 300 µg/L (micrograms per liter) for iron and 50 µg/L for manganese in public drinking-water supplies. About 19 percent of the iron analyses in ground-water samples exceeded the secondary drinking-water standard, and about 30 percent of the manganese analyses exceeded the standard. The maximum iron concentration was 120,000 µg/L, and the maximum manganese concentration was 10,000 µg/L. However, about 89 percent of the iron samples had concentrations less than 1,000 µg/L and 95 percent of the manganese samples had concentrations less than 500 µg/L.

Although iron and manganese are essential micronutrients, their presence in domestic supplies in concentrations exceeding the drinking-water standards are objectionable for esthetic and economic reasons. High concentrations impart a bitter taste to drinking water, cause staining of laundry and plumbing fixtures, and may clog pipes.

The National Academy of Sciences and National Academy of Engineering (1973, p. 312) did not consider it necessary to recommend maximum limits for iron and manganese in livestock water. High concentrations of ferrous iron normally precipitate out of solution as harmless ferric oxide with exposure to atmospheric oxygen. Manganese ions also tend to precipitate out of solution with exposure to air.



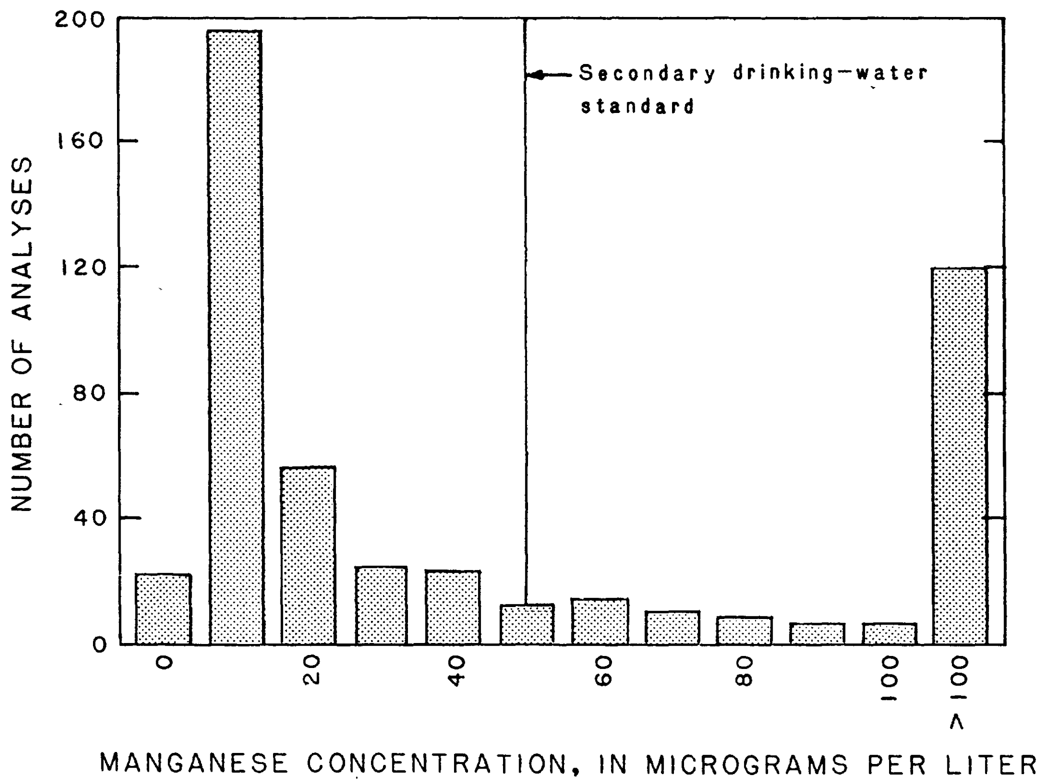


Figure 9.0-1--Histograms of iron and manganese concentrations (statewide).

10.0 FUTURE NEEDS

GROUND-WATER-QUALITY DATA MONITORING NETWORK NEEDED

In order to evaluate the effects of man on ground-water quality, a data monitoring network needs to be established. Increasing the computer-accessible water-quality data base by combining data from State and Federal agencies and private corporations would be desirable.

A ground-water data monitoring network sensitive to the effects on water quality of activities such as coal mining, uranium milling, oil refining, crop irrigation and fertilization, waste disposal, and use of septic-tank leach fields in suburban areas needs to be established. Such a network could: (1) Determine whether or not these activities are a significant source of ground-water contaminants in Wyoming, (2) determine the magnitude of the problems, if they exist, and (3) serve to provide data to calibrate and verify predictive computer models of ground-water transport of contaminants. Although in some instances industry is required to monitor the ground-water quality adjacent to their operations, the U.S. Geological Survey, industry, and the public would gain additional hydrologic knowledge with a water-quality monitoring network.

Although over 2,300 Wyoming ground-water sites with chemical-quality data are recorded in the Survey water-quality file, the natural or existing ground-water quality of the State generally is not adequately defined. Additional data are needed in order to predict the ground-water quality in an aquifer at a particular depth and location. Computer access to the large volume of additional data, possibly available from other Federal and State agencies as well as private corporations, is desirable.

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