WATER QUALITY OF THE NORTH PLATTE RIVER, EAST-CENTRAL WYOMING

By L. R. Larson

U.S. GEOLOGICAL SURVEY
Water-Resources Investigations Report 84-4172

U.S. DEPARTMENT OF THE INTERIOR
March 3, 1849

Cheyenne, Wyoming

1985

UNITED STATES DEPARTMENT OF THE INTERIOR

DONALD PAUL HODEL, Secretary

GEOLOGICAL SURVEY

Dallas L. Peck, Director

For additional information
write to:

District Chief
U.S. Geological Survey
2120 Capitol Avenue
P.O. Box 1125
Cheyenne, Wyoming 82003

Copies of this report can
be purchased from:

Open-File Services Section
Western Distribution Branch
U.S. Geological Survey
Box 25425, Federal Center
Denver, Colorado 80225
Telephone: (303) 236-7476

CONTENTS

ILLUSTRATIONS

ILLUSTRATIONS--Continued

Page

Figures

TABLES

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
acre-foot (acre-ft)	1,233	cubic meter
cubic foot per second (ft^3/s)	28.32	liter per second
mile (mi)	1.609	kilometer
pounds per square inch (lb/in^2)	6.895	kilopascal
square mile (mi^2)	2.590	square kilometer

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

$$°F = 9/5\ (°C) + 32$$

$$°C = 5/9\ (°F - 32)$$

WATER QUALITY OF THE NORTH PLATTE RIVER,

EAST-CENTRAL WYOMING

By L. R. Larson

ABSTRACT

This report is a statistical summary of 40 different constituents or characteristics that describe the water quality of the North Platte River between Alcova Dam and Orin, upstream from Glendo Reservoir in east-central Wyoming. Data from seven stations are summarized for 1970-79.

The streamflow in the study reach is controlled primarily by the release from Alcova Reservoir. During the 10 years, the annual mean discharge at Alcova Dam ranged from 860 ft^3/s (cubic feet per second) in 1970 to 2,144 ft^3/s in 1973. The mean discharge for 1970-79 was 1,442 ft^3/s at Alcova Dam and 2,029 ft^3/s at Orin.

Tributary inflow, primarily from spring runoff, increased the annual mean discharge about 40 percent between the boundary stations at Alcova Dam and Orin. Tributary inflow downstream from the city of Casper mostly is from streams draining the Laramie Mountains. This water generally is low in dissolved solids, especially during high flow. Water entering the river upstream from Casper generally is of poorer quality (more mineralized) than water in the North Platte River or water from tributaries entering the river downstream from Casper.

The downstream change in dissolved-solids concentration shows a pattern typical of many other constituents. The mean and median value for dissolved-solids concentration at the upper sampling station is about 320 mg/L (milligrams per liter). Just downstream from Casper, the mean and median value increased to about 430 mg/L. The average dissolved-solids concentration changed very little from immediately below Casper (river mile 57) to Orin (river mile 143), the most downstream sampling station.

The mean fecal-coliform-bacteria concentration at the station below Alcova Dam was about 8 colonies per 100 milliliters and about 4,000 colonies per 100 milliliters at the station immediately downstream from Casper. The change in the concentration of fecal coliform bacteria was the most dramatic change of all the constituents.

Water from the North Platte River can be used for irrigation and as raw water for municipal supply. Concentrations of some constituents were periodically above the maximum recommended for drinking-water supplies. About 24 percent of the dissolved-solids concentrations were more than 500 mg/L. Some selenium concentrations exceeded the maximum allowable limit of 10 μg/L (micrograms per liter) mandated for public water supplies. The maximum concentration of cadmium was 6 μg/L; the maximum permissible concentration is 10 μg/L.

Occurrences of ammonia, copper, and zinc in concentrations above recommended limits indicate that these constituents might be a problem for sensitive aquatic life. The total-phosphorus concentration may cause an algal-growth problem in Glendo Reservoir, downstream from the study reach. More samples of trace metals, nutrients, and polychlorinated biphenyls are needed to determine sources and the normal ranges of concentrations.

Dissolved-solids concentrations are related to specific conductance. Concentrations of calcium, magnesium, sodium, sulfate, strontium, and uranium correlate with dissolved-solids concentrations and specific conductance. Regression equations for these constituents are presented in this report.

INTRODUCTION

The water quality of the North Platte River in east-central Wyoming is important to the semiarid region through which it flows. Agricultural, municipal, industrial, and recreational users depend on the North Platte River as a major source of water. Development of the North Platte River began with the construction of a series of dams beginning in the early 1900's. These dams created water storage for irrigation and power generation.

Another early use of the North Platte River was for waste disposal. A few decades ago, municipal, refinery, and other industrial wastes caused such extreme pollution downstream from Casper that it was doubtful this reach of stream would ever recover. Larry Peterson, District Fisheries Manager of the Wyoming Game and Fish Commission, was quoted as saying:

> What I remember most about the river in those days was the smell. In the spring of the year, when the water was released from the dams for irrigation, it picked up the human sewage and refinery waste that had accumulated over the winter and carried them downstream. That slug of stuff eliminated not only all of the fish along the way, but the bottom food as well. You could smell it for 3, 4 miles away. (Gannon, 1966, p. 37).

There was a major cleanup of industrial and municipal pollution in the 1950's and 1960's. In 1958, Congress authorized Gray Reef Dam as an afterbay of the Alcova Powerplant. The authorization provided for a minimum flow of 330 ft^3/s below Gray Reef Dam. The cleanup and provision for a minimum flow gradually resulted in a stream recovery resulting in a return of trout and other pollution-intolerant species to this once biologically stressed reach.

The cities of Casper, Glenrock, and Douglas have had population increases as a result of a rapid expansion in the development of energy-minerals industries. Future population increases in these cities may be erratic but are to be expected as the energy industries in the area expand.

Description of the Problem

An assessment of the present water quality of the North Platte is needed to properly manage this important stream. Questions that need answering are: (1) What is the general quality of the water in the North Platte? (2) How variable are constituents that affect water quality? (3) Which constituents are problems or potential problems (exceeding or approaching maximum recommended limits) for such common uses as domestic supply or irrigation? (4) What are the factors affecting the water quality of the stream? (5) Do the data need qualifying? (6) How can the water quality of the stream be monitored more effectively? To help answer these questions it is necessary to summarize the voluminous water-quality data available and to portray the data in a format that makes it possible to assess the water quality of the river.

Purpose of the Report

The primary purpose of this report is to summarize and assess the water-quality data from a period that reflects present (1979) conditions. Ideally, the present condition includes the period: (1) After the cleanup of the North Platte River, (2) after establishment of a minimum base-flow release from the Alcova Reservoir, and (3) before any hydrologic impact of a new population boom was reflected by changes in water quality.

Secondary purposes of the report are to: (1) Describe functional relationships between individual constituents; (2) indicate some of the changes in sampling, preservation, and analytical techniques that may have affected the data; (3) provide criteria for evaluating the effect of individual constituents on water quality; and (4) determine needed changes in the sampling program.

Scope of the Investigation

The study reach is the section of the North Platte River downstream from Alcova Dam and upstream from Glendo Reservoir (fig. 1). Data have been summarized from seven sampling stations located between Alcova Dam and Orin, Wyoming, upstream from Glendo Reservoir.

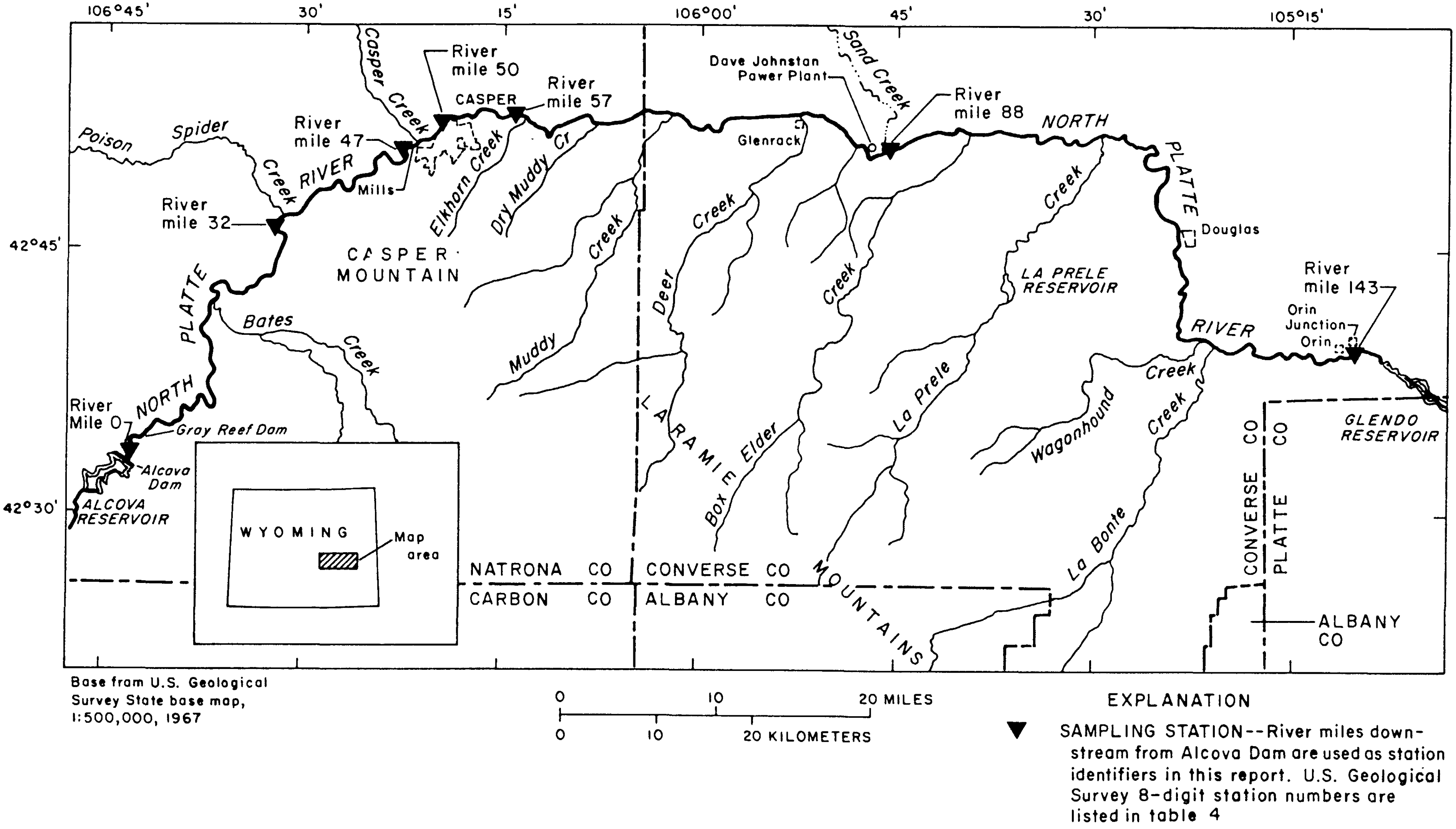
The 10 years from October 1, 1969 to September 30, 1979 are summarized. This represents water years 1970-79. A water year begins on October 1 and ends on September 30 of the next calendar year. Although the period of record for some stations begins before 1970, there are a number of reasons for not using those data: (1) Prior to this period most samples were composited from daily samples, rather than being discrete samples; (2) the variety of constituents was limited; (3) generally only unfiltered samples were analyzed; (4) preservation and analytical techniques have greatly changed for many constituents; and (5) management of this reach of the North Platte River has changed.

To describe the water quality of the North Platte River, 40 constituents and characteristics have been analyzed. Total-trace-metal analyses are not included in this report because: (1) Criteria for evaluating total-trace-metal data generally are lacking; (2) the digestion process used in a total-trace-metal analysis may only strip sorbed material from the sediment, or it may also partially or totally dissolve the sediment, depending on the nature of the sediment; (3) total-trace-metal samples were collected before sediment-sampling techniques were used; and (4) relatively insensitive analytical techniques were used for total cadmium, copper, and lead during most of the study period.

DESCRIPTION OF THE STREAMFLOW AND ITS RELATION TO WATER QUALITY

Streamflow in the study reach is controlled primarily by the release from Alcova Reservoir. A secondary source of streamflow is tributary inflow.

Water is stored in three reservoirs upstream from Alcova Dam. Alcova Reservoir has a storage capacity of 180,000 acre-feet. Pathfinder and Seminoe Reservoirs each have storage capacities of more than 1 million acre-feet.



Base from U.S. Geological Survey State base map, 1:500,000, 1967

▼ SAMPLING STATION--River miles downstream from Alcova Dam are used as station identifiers in this report. U.S. Geological Survey 8-digit station numbers are listed in table 4

Figure 1.--Study reach of the North Platte River and location of sampling stations.

Pathfinder Reservoir is about 8 river miles upstream from Alcova Dam, and Seminoe Reservoir is about 25 river miles upstream from Alcova Dam. Inflow to these reservoirs is primarily supplied by snowmelt from the mountains of southern Wyoming and northern Colorado.

The dissolved-solids concentration of the streams supplying water to the reservoirs varies indirectly with discharge. This normal stream variation in quality is decreased by the large, combined-storage capacity of the three reservoirs. The water released from Alcova Reservoir thus had little seasonal variation in quality. The mean daily discharge, for water years 1970-79, of the North Platte River at Alcova Dam (river mile 0) and at Orin, Wyoming (river mile 143), and the average seasonal pattern for the two boundary stations are shown in figure 2. In this report sampling stations are designated by distance downstream from Alcova Dam.

Mean annual discharges for the North Platte River at Alcova Dam and at Orin for water years 1970-79 and the annual increase in discharge between the two stations are shown in table 1. The lowest annual mean discharge for the period of study at Alcova Dam was 860 ft^3/s (water year 1970), and the highest was 2,144 ft^3/s (water year 1973); the average discharge for the period was 1,442 ft^3/s. The lowest annual mean discharge at Orin was 1,426 ft^3/s (water year 1978) and the highest was 2,915 ft^3/s (water year 1973); the average discharge for 1970-79 was 1,869 ft^3/s.

The principal tributaries responsible for the increase in discharge between Alcova Dam and Orin are listed in table 2. These tributaries, except for Bates Creek, drain the Laramie Mountains. Except for Deer Creek, the major tributary, streamflow data that coincide with the 1970-79 study period are not available. Therefore, data for periods of record are presented. Tributary inflow varies seasonally and from year to year. The seasonal pattern of discharge by the main tributaries is shown in the hydrograph (1975 water year) for Deer Creek (fig. 3).

Seasonal and annual variation for the 10-year study period is shown for Deer Creek in table 3. More than 80 percent of the annual runoff occurred during April, May, and June. The average May discharge was more than 50 percent of the average annual discharge (water years 1970-79). The highest annual mean discharge, 165 ft^3/s, was in water year 1973; the lowest, 28 ft^3/s, was in water year 1979. These figures show nearly a sixfold variation in annual discharge during the 10-year study period.

The total tributary inflow for the study period can be estimated from table 1 using the annual increase in discharge between Alcova Dam and Orin. The increase in annual flow between the two stations ranged from a maximum of 771 ft^3/s during water year 1973 to a minimum of 148 ft^3/s during water year 1979. The mean annual increase between the two stations for the period was 427 ft^3/s or 30 percent. Thus it is evident that although tributary inflow is secondary to the release at Alcova Dam, it is significant.

The dissolved-solids concentration of tributary inflow is inversely related to discharge. The relation of specific conductance to discharge for Deer Creek is shown in figure 3. From the middle of April until the middle of

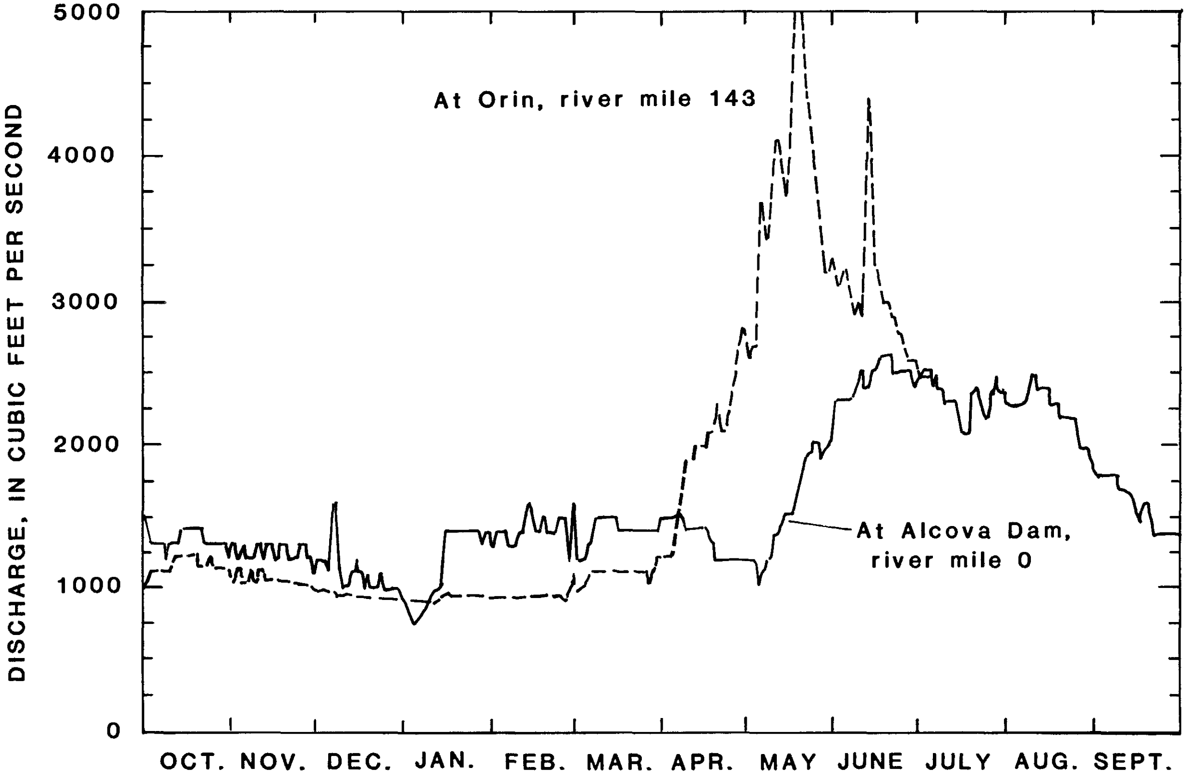


Figure 2.--Mean daily discharges for the North Platte River at Alcova Dam and Orin, water years 1970-79.

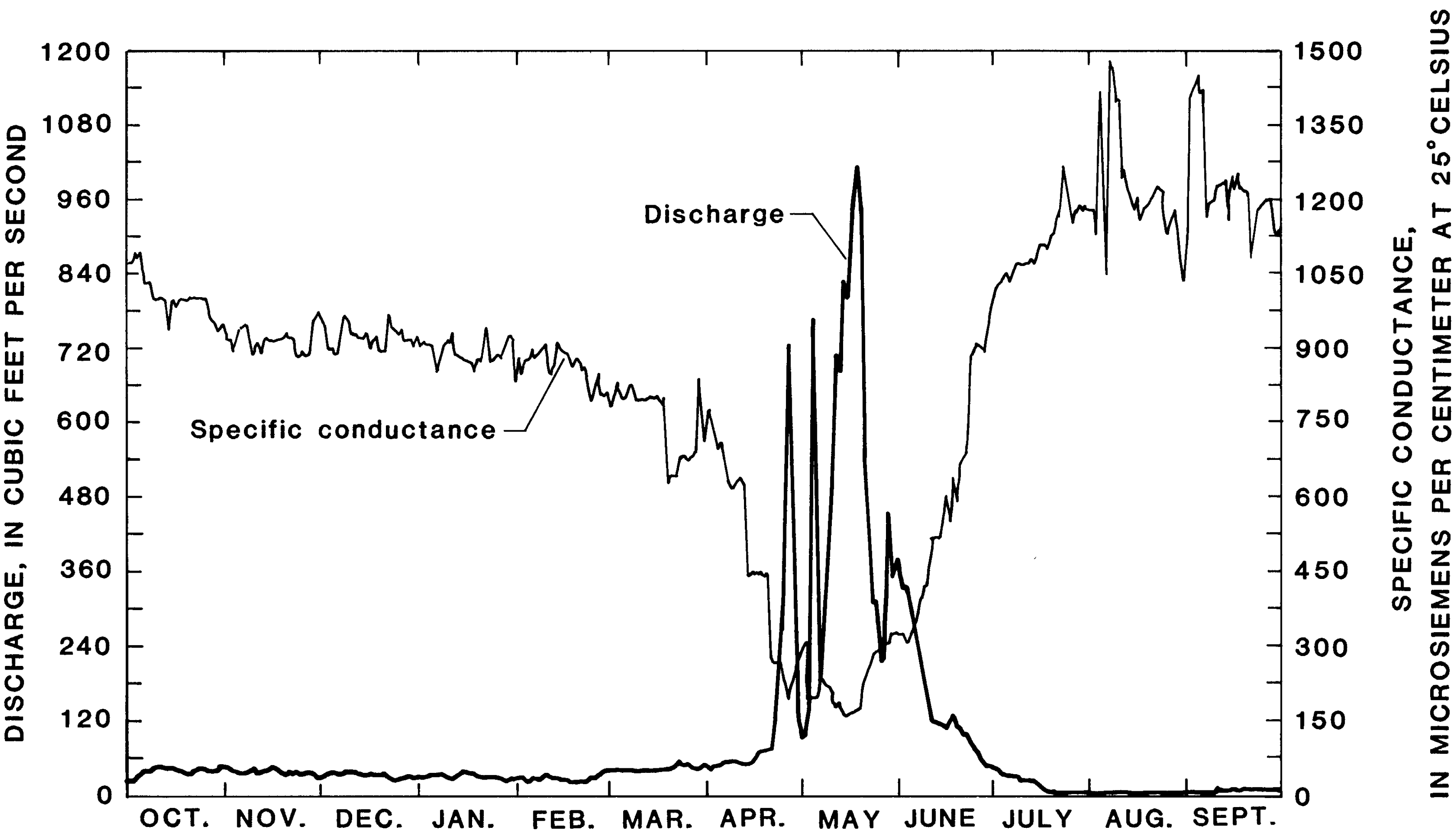


Figure 3.--Mean daily discharge and specific conductance for Deer Creek at Glenrock, water year 1975.

Table 1.--Discharge for the North Platte River at Alcova Dam (river mile 0) and at Orin (river mile 143), water years 1970-79

Water year	Discharge at Alcova Dam (cubic feet per second)	Discharge at Orin (cubic feet per second)	Increase between stations (cubic feet per second)	Percent increase between stations
1970	860	1,556	696	81
1971	1,520	2,226	706	46
1972	1,283	1,739	456	36
1973	2,144	2,915	771	36
1974	2,077	2,451	374	18
1975	1,475	1,702	227	15
1976	1,367	1,616	249	18
1977	1,308	1,580	272	21
1978	1,060	1,426	366	34
1979	1,330	1,478	148	11
Average discharge, water years 1970-79	1,442	1,869	427	30

Table 2.--Discharge of principal tributaries to the North Platte River between Alcova Dam and Orin

				Discharge (cubic feet per second)	
Tributary	Station number	Drainage area (square miles)	Period of record (water years)	Average	Minimum Maximum
Bates Creek near Alcova	06643000	393	1916-24; 1935-61	13	0 4,000
Deer Creek below Millar Wasteway at Glenrock	06646600	211	1962-79	74	0 14,200
Box Elder Creek near Careyhurst	06648000	202	1911; 1915-24; 1928-33; 1935-69	45	0 8,250
La Prele Creek near Orpha	06649500	177	1916; 1918; 1923-24; 1928-33; 1935-70	13	0 6,000
Wagonhound Creek near La Bonte	06650500	112	1916-24; 1929-32; 1937-69	10	0 3,500
La Bonte Creek near La Bonte	06651500	287	1916-24; 1928-33; 1935-69	54	0 8,770

Table 3.--Annual and monthly mean discharge for Deer Creek below Millar Wasteway near Glenrock, water years 1970-79

Water year	Annual mean discharge (cubic feet per second)	Monthly mean discharge (cubic feet per second)											
		Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1970	142	5.2	20	22	21	20	24	66	973	529	12	1.8	3.2
1971	120	16	23	23	27	26	45	237	808	207	1.8	.5	15
1972	68	30	34	33	24	28	120	154	320	57	5.7	4.2	5.0
1973	165	18	28	24	27	28	30	74	1,375	290	21	15	30
1974	94	34	36	37	35	35	80	362	448	39	2.0	2.0	8.6
1975	68	28	28	23	20	18	32	102	408	129	12	1.0	4.1
1976	58	11	20	22	20	22	27	150	348	57	6.9	1.4	9.2
1977	49	19	20	19	19	16	20	297	175	4.3	.4	.9	1.2
1978	64	10	20	21	25	24	33	90	486	44	1.2	1.4	3.5
1979	28	17	20	20	21	22	24	83	104	14	.8	2.2	3.0
Mean discharge, water years 1970-79	86	19	25	24	24	24	44	162	545	137	6.4	3.0	8.3
Percent of total	--	1.9	2.4	2.4	2.4	2.2	4.4	15.5	54.0	13.1	.6	.3	.8

June, the period of most of the spring runoff, the specific conductance averaged less than 300 µS (microsiemens per centimeter at 25° Celsius). This specific conductance indicates a dissolved-solids concentration of less than 200 mg/L.

Deer Creek and other streams draining the Laramie Mountains are the principal tributaries entering the North Platte River downstream from Casper from the south. These tributaries have fresh and unpolluted water; dissolved-solids concentrations are low during the spring runoff--when most of the total annual runoff is measured. During low flow, dissolved-solids concentrations increase; but they have little effect on the North Platte River.

Tributaries entering the North Platte River between Alcova Dam and Casper drain basins that are much lower in elevation than the Laramie Mountains. The natural runoff and the irrigation return flow from these basins generally are much more mineralized than water in streams draining the Laramie Mountains or in the North Platte River. The more mineralized water of the tributaries is indicated by high dissolved-solids, nitrate, and selenium concentrations. For example, Poison Spider Creek, flowing at 20 ft^3/s on June 26, 1979, had the following concentrations: Dissolved solids, 1,730 mg/L; nitrate, 6.5 mg/L as nitrogen; and selenium, 74 µg/L.

The quantity of ground-water inflow to the study reach generally is not known except for an estimate from a model for the Bates Creek alluvium. Glover (1983) measured a streamflow gain of 9.5 to 10.7 ft^3/s to the North Platte River from this alluvium during February and March 1978. Water from wells completed in this alluvium has a dissolved-solids concentration of about 1,500 mg/L.

CONCENTRATIONS OR VALUES AND CRITERIA FOR SELECTED WATER-QUALITY CONSTITUENTS OR CHARACTERISTICS

Forty water-quality constituents and characteristics were selected to define the water quality of the North Platte River for the 143-mile study reach between Alcova Dam and Glendo Reservoir. The constituents and characteristics are presented alphabetically, from alkalinity to zinc.

For each constituent or characteristic an illustration is used to graphically summarize the data. A bar graph, showing the maximum, minimum, mean, and median concentrations or values and indicating the number of samples, is plotted against distance downstream from Alcova Dam. The names of the sampling stations and the downstream-order station numbers are given in table 4. Regression equations are given for constituents or characteristic having good correlation with the dissolved-solids concentration or specific conductance: Calcium, magnesium, sodium, sodium-adsorption ratio, specific conductance, strontium, and uranium. Both the coefficient of determination (r^2) and the coefficient of correlation (r) between specific conductance and selected constituents along with the sodium-adsorption ratio, are listed in table 5. The appropriate regression equation also is given in the section for each constituent or characteristic listed in table 5.

The correlation between the concentration of an individual constituent and dissolved-solids concentration is usually better than the correlation

Table 4.--Name, station number, and distance downstream from Alcova Dam of sampling stations along the North Platte River

Name	Station number	Distance downstream from Alcova Dam (river miles)
North Platte River at Alcova Dam	06642000	0
North Platte River above Poison Spider Creek	06643510	32
North Platte River at Mills	06644085	47
North Platte River at Casper	06644500	50
North Platte River below Casper	06645000	57
North Platte River near Glenrock	06646800	88
North Platte River at Orin	06652000	143

Table 5.--Constituents and characteristic showing good correlation with specific conductance

Constituent or characteristic	Number of samples	Coefficient of determination (r^2)	Coefficient of correlation (r)
Dissolved solids	400	0.845	0.919
Calcium	411	.628	.792
Magnesium	412	.686	.828
Hardness	410	.800	.894
Sodium	406	.804	.896
Sodium-adsorption ratio	406	.729	.854
Sulfate	413	.835	.914
Strontium	10	.838	.915

between the constituent and specific conductance. However, the correlation with specific conductance generally is good and may be more useful because of the ease with which specific conductance is measured.

Regression equations may be used to check the accuracy of an analysis or to predict a value of an unanalyzed constituent. Also, changes in the equation's slope or intercept may indicate a change in the hydrologic system.

The criteria for evaluating individual constituents and characteristics are briefly discussed. The discussion is limited mostly to the use of water as a public water supply, as an aquatic habitat, or less commonly, for irrigation. Industrial requirements generally are too varied to discuss in this report.

The National Interim Primary Drinking Water Regulations (U.S. Environmental Protection Agency, 1977) mandate the maximum contaminant level allowed in public water supplies in order to protect the health of the consumer. The National Secondary Drinking Water Regulations (U.S. Environmental Protection Agency, 1979) are not mandatory. However, in order to provide water that will be esthetically pleasing to the consumer, the National Secondary Drinking Water Regulations list maximum contaminant levels that should not be exceeded.

The criteria presented for evaluating individual constituents and characteristics are either from a report by the National Academy of Sciences and National Academy of Engineering (1973) or from a report by the U.S. Environmental Protection Agency (1976). Both reports are excellent sources for more detailed information on water quality. Mean values for stations in the National Stream Quality Accounting Network (NASQAN), operated by the U.S. Geological Survey, are given for comparing the North Platte River with other rivers in the Nation. The NASQAN data are from Briggs and Ficke (1977).

Alkalinity

Alkalinity is a measure of the ability of water to neutralize acid. This buffering capacity allows water to receive and neutralize a limited quantity of acid while maintaining a relatively constant pH. Alkalinity values were obtained by titrating an aliquot of sample with dilute sulfuric acid to a pH of 4.5. Alkalinity is expressed as an equivalent concentration of calcium carbonate. Bicarbonate and carbonate ions are the primary contributors to alkalinity. Phosphate ions also contribute to alkalinity, but to a much lesser extent because phosphate concentrations generally are relatively low. Hydroxide ions, when present, also contribute to alkalinity; but this occurrence is relatively rare and is not the case for the water in this reach of the North Platte River.

Criteria

No guidelines are recommended in present drinking-water regulations or water-quality criteria. Variations in alkalinity are undesirable for treatment control of raw water for public supplies (National Academy of Sciences and National Academy of Engineering, 1973, p. 54).

Observations

The mean, median, and range of values increased in a downstream direction (fig. 4). The mean value reported for NASQAN stations during 1975 (Briggs and Ficke, 1977, p. 30) was 113 mg/L, as calcium carbonate. The mean alkalinity for the study reach is about 140 mg/L.

Arsenic

Arsenic is a toxic metalloid widely distributed in nature. However, adverse health effects from arsenic in drinking water have not been reported in the United States (National Academy of Sciences and National Academy of Engineering, 1973, p. 56).

Criteria

Maximum arsenic concentration allowed in public drinking-water supplies is 50 µg/L (U.S. Environmental Protection Agency, 1977). To protect livestock, a maximum limit of 200 µg/L arsenic in their drinking water is recommended (National Academy of Sciences and National Academy of Engineering, 1973, p. 310).

Observations

The dissolved-arsenic concentrations are below the present drinking-water standard. The limited data available from four stations indicate that a tributary may possibly be bringing in arsenic, upstream from river mile 47, that is mostly sorbed by sediment or precipitated from solution before reaching river mile 143 (fig. 5).

The mean concentration for dissolved arsenic reported for the 1975 NASQAN stations was 2.4 µg/L. This approximates the concentrations at the stations at river miles 0 and 143 but is lower than that at the other two stations.

Barium

Soluble barium salts are very toxic, acting as muscle stimulants, especially on the heart. A fatal dose for humans is 0.8 to 0.9 gram. Sulfate and carbonate ions act as a control in natural waters by precipitating the barium as nontoxic compounds (U.S. Environmental Protection Agency, 1976, p. 37).

Criteria

The U.S. Environmental Protection Agency (1977) limits barium in public water supplies to 1,000 µg/L.

Observations

Only the station at river mile 57 has been extensively sampled for dissolved barium. All concentrations were below the drinking-water standard (fig. 6).

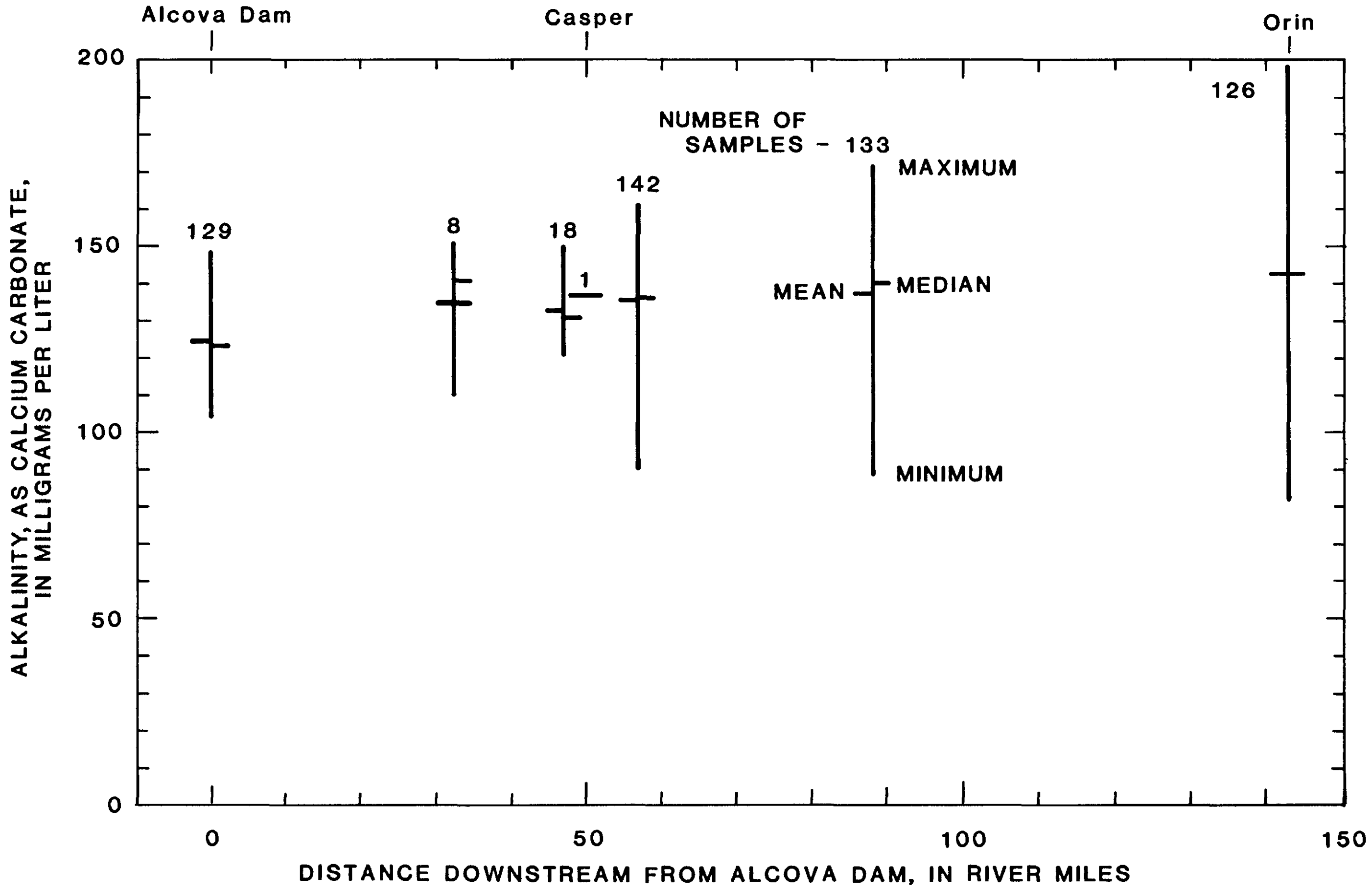


Figure 4.--Maximum, minimum, mean, and median alkalinity concentrations at all sampling stations along the North Platte River between Alcova Dam and Orin, water years 1970-79.

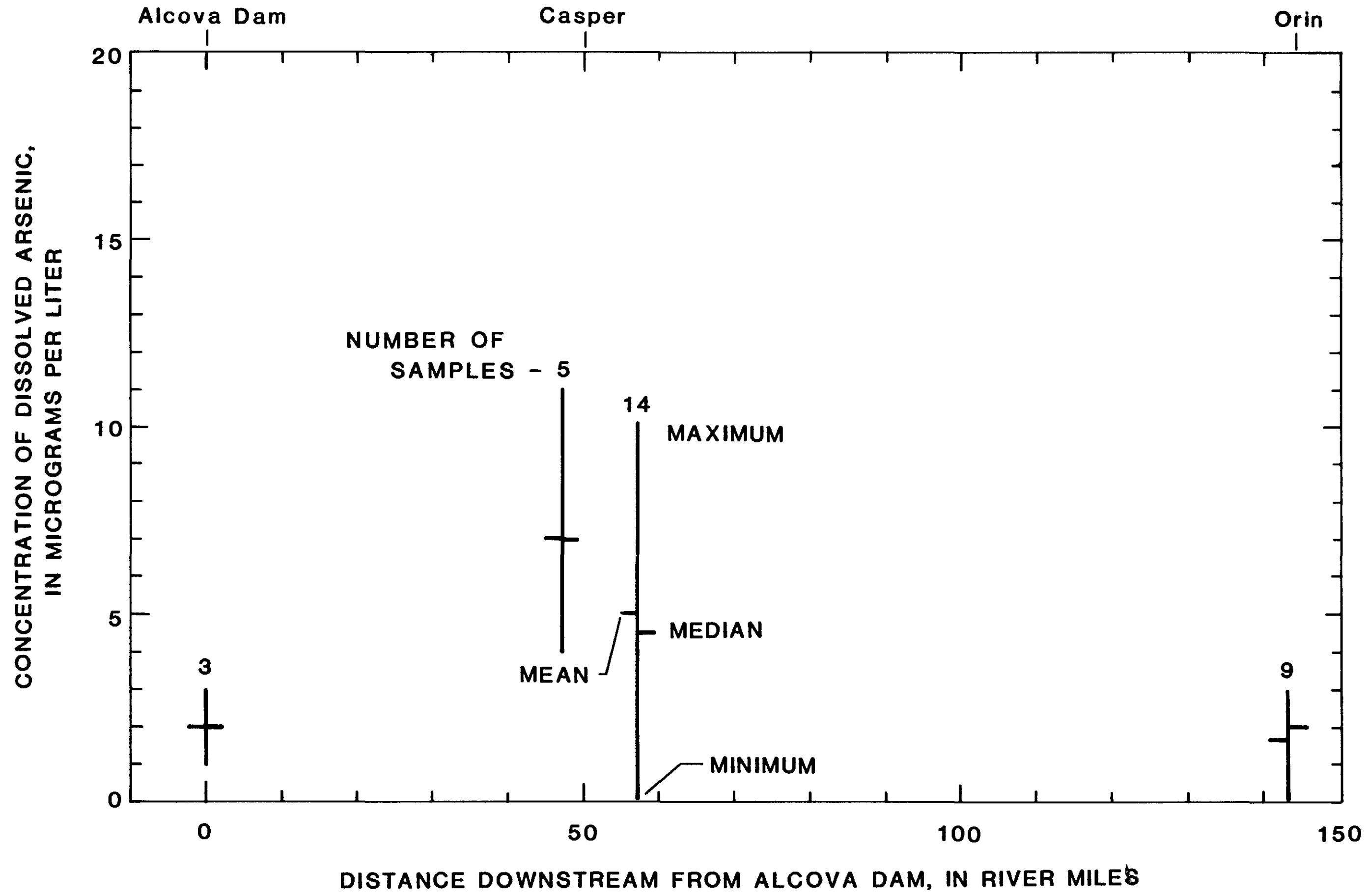


Figure 5.--Maximum, minimum, mean, and median dissolved-arsenic concentrations at four sampling stations along the North Platte River between Alcova Dam and Orin, water years 1970-79.

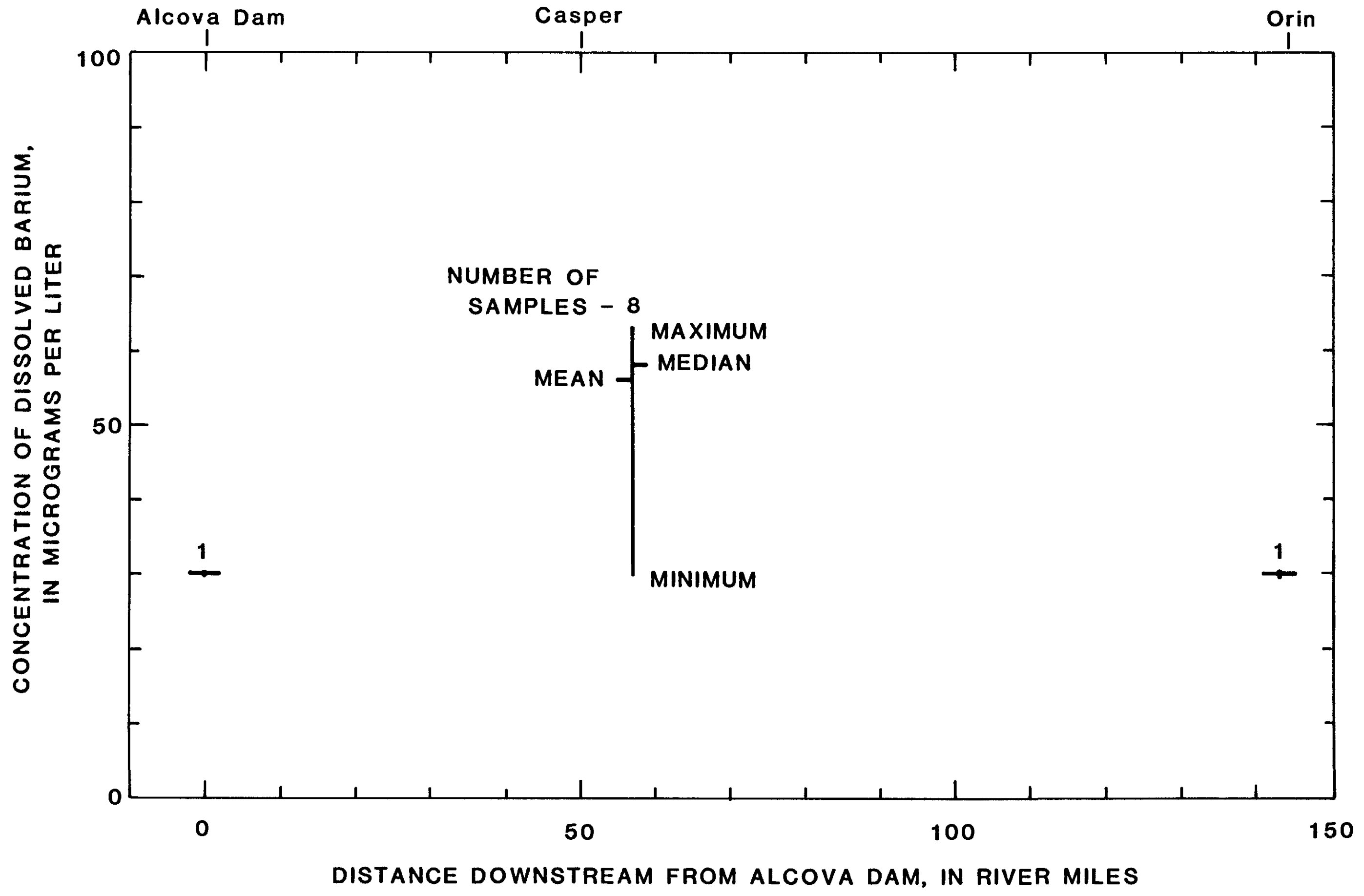


Figure 6.--Maximum, minimum, mean, and median dissolved-barium concentrations at three sampling stations along the North Platte River between Alcova Dam and Orin, water years 1970-79.

Bicarbonate

Bicarbonate and carbonate ions are the primary ions contributing to the alkalinity of water. Ideally, these constituents should be determined at the sampling site. The concentrations in this report, however, have been measured in a laboratory.

Criteria

No limits are recommended in drinking-water regulations.

Observations

Little downstream change can be noted in the mean and median values (fig. 7). The range in values increases in a downstream direction.

Boron

Boron is an essential trace element for plant growth. High concentrations, however, can injure boron-sensitive plants.

Criteria

Standards have not been established for public water supplies. A maximum contaminant level of 750 µg/L is recommended as a long-term limit for irrigation water on boron-sensitive crops (U.S. Environmental Protection Agency, 1976, p. 47).

Observations

The mean and median concentrations indicate a slight increase of dissolved boron in the study reach (fig. 8). Concentrations of 97 percent of the samples were less than 160 µg/L.

Cadmium

Cadmium is a highly toxic metal with no known biologically beneficial use. Cadmium ingested by humans is retained largely in the kidney and liver; excretion is extremely slow (U.S. Environmental Protection Agency, 1976, p. 50).

Criteria

An upper contamination limit of 10 µg/L is mandated by the U.S. Environmental Protection Agency (1977). Even lower limits are recommended for sensitive aquatic life--0.4 µg/L in soft water and 1.2 µg/L in hard water (U.S. Environmental Protection Agency, 1976).

Observations

Sampling for cadmium has been limited. Some concentrations are high enough (although below the drinking-water standard) to indicate a need for more frequent monitoring of this very toxic element (fig. 9). The maximum

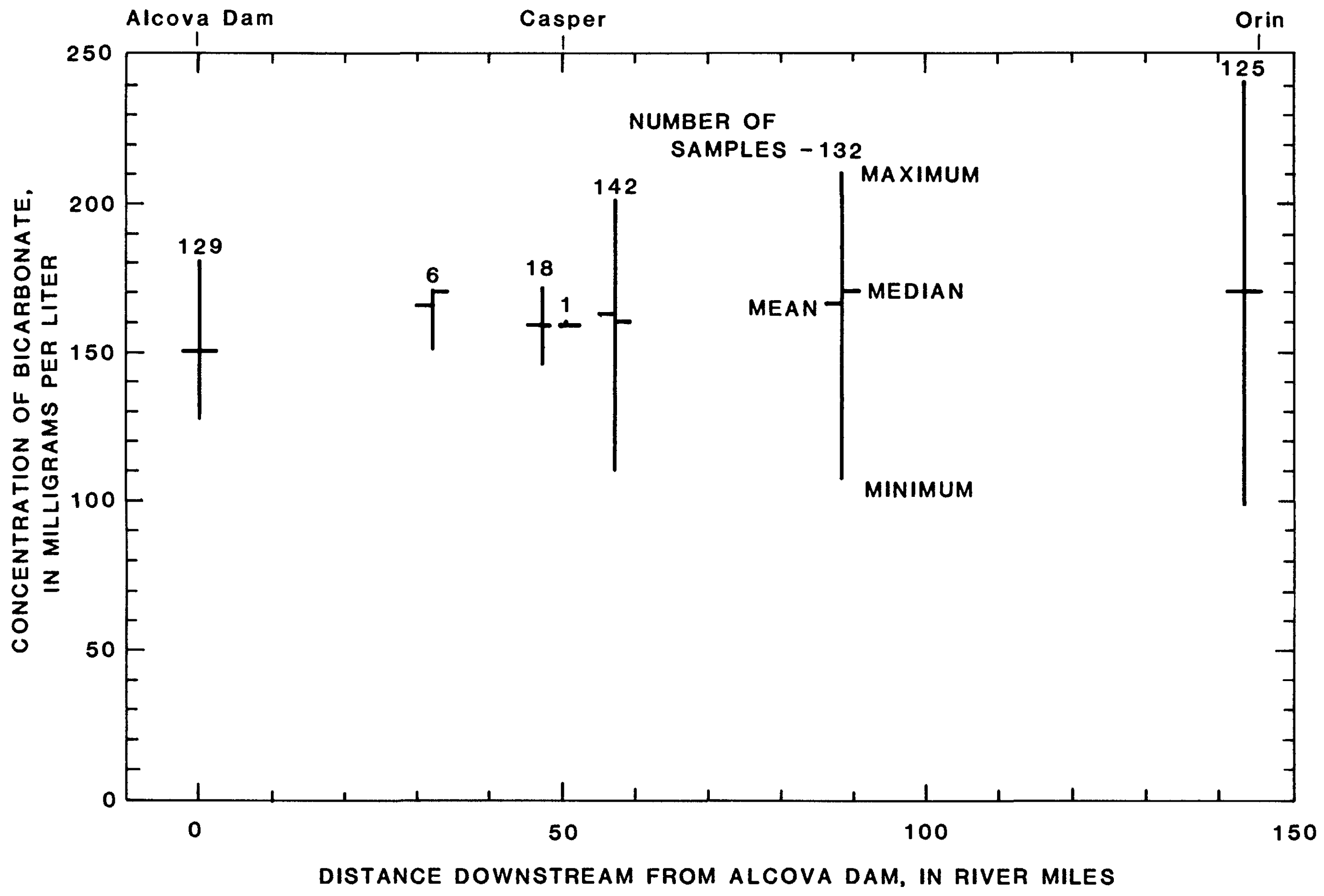


Figure 7.--Maximum, minimum, mean, and median bicarbonate concentrations at all sampling stations along the North Platte River between Alcova Dam and Orin, water years 1970-79.

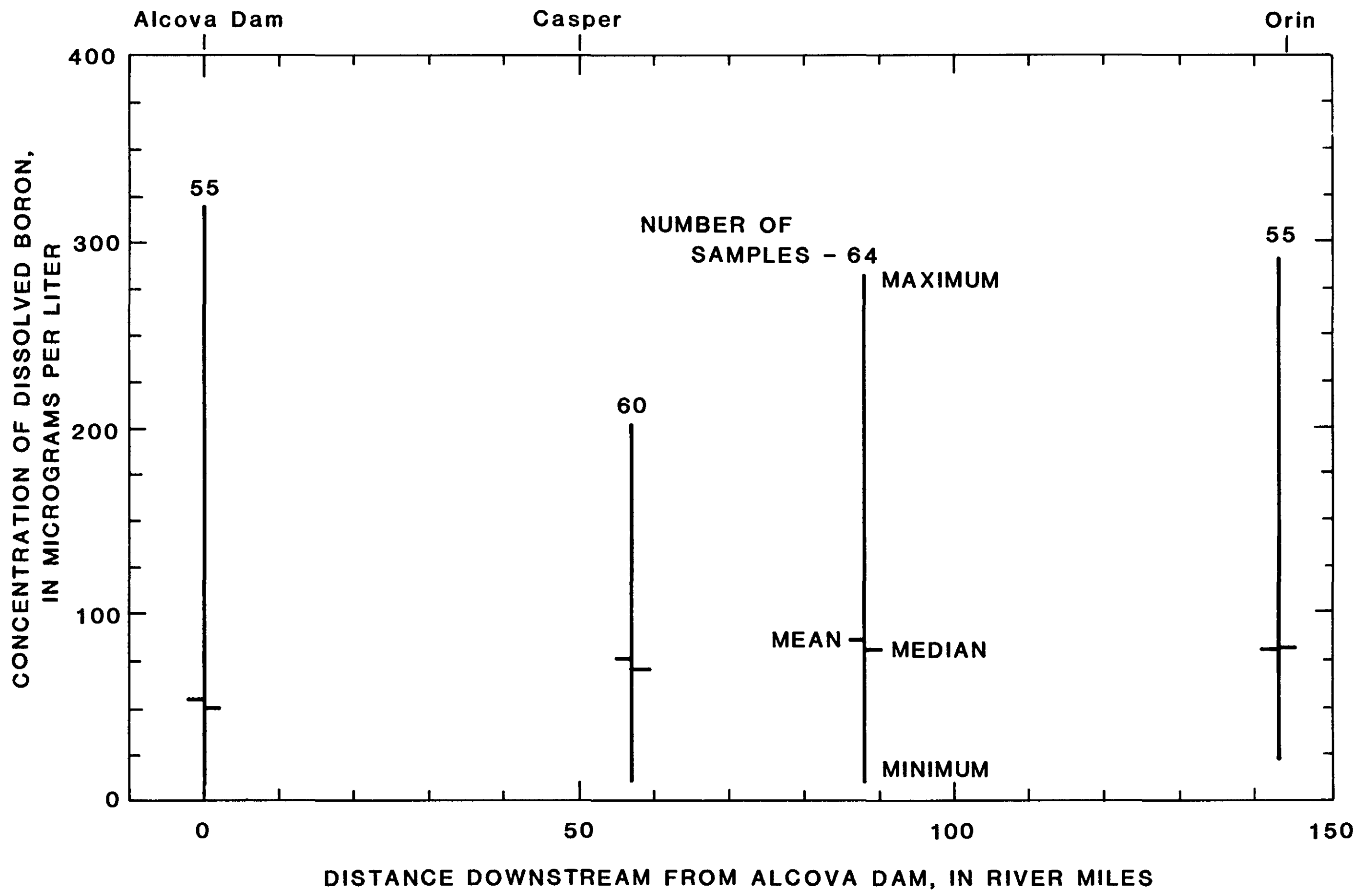


Figure 8.--Maximum, minimum, mean, and median dissolved-boron concentrations at four sampling stations along the North Platte River between Alcova Dam and Orin, water years 1970-79.

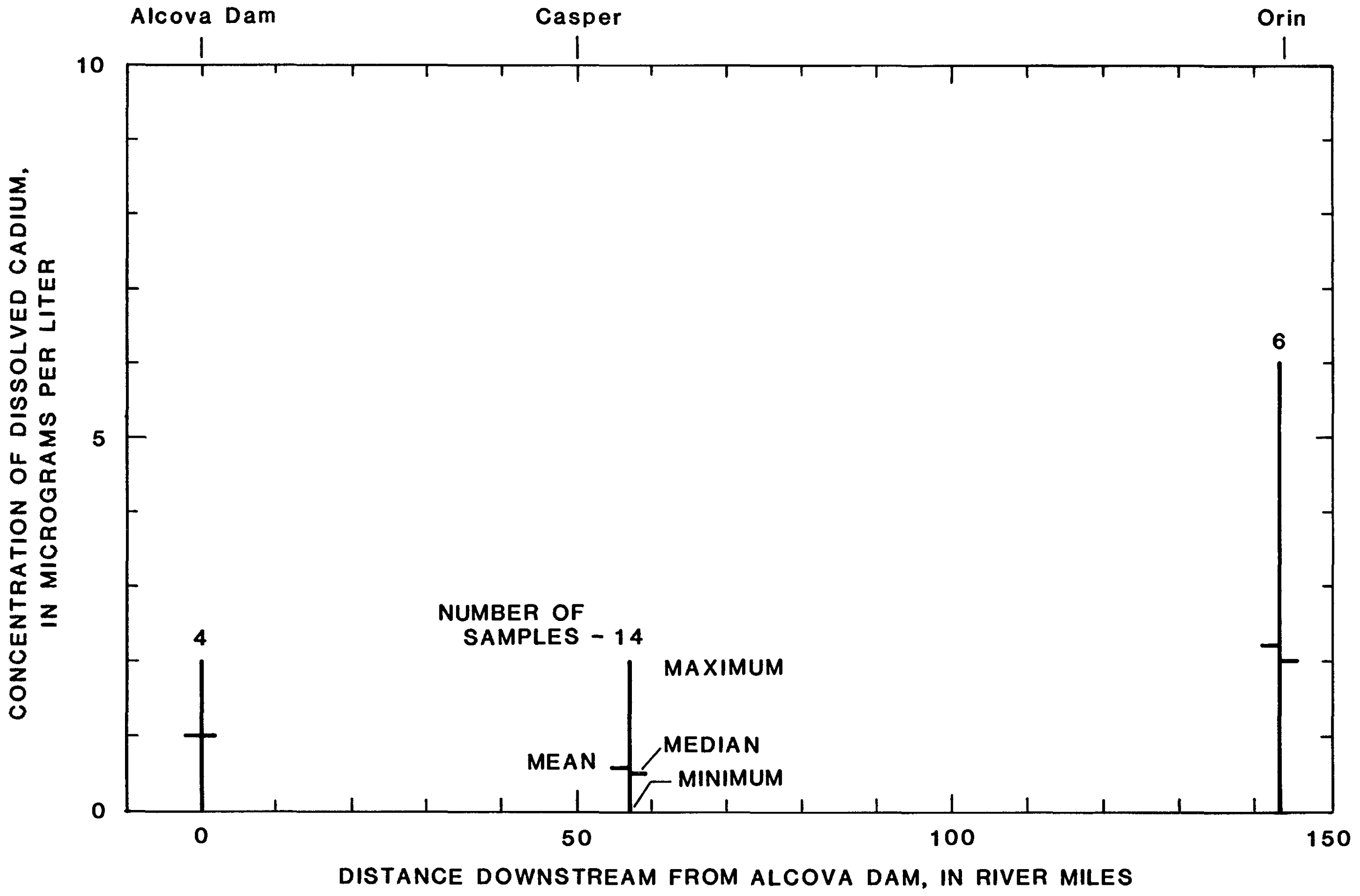


Figure 9.--Maximum, minimum, mean, and median dissolved-cadmium concentrations at three sampling stations along the North Platte River between Alcova Dam and Orin, water years 1970-79.

concentration at river mile 143 could be the result of contamination from paint. This may have occurred to a varying degree for a period of time in the past. Nitric acid is used to preserve trace-metal samples. Until the problem was identified, the ampuls used to store the acid were color coded. The paint used for color coding contained both lead and cadmium. In transferring the acid from the ampuls to the sample bottles, a potential for contamination existed.

Calcium

Calcium is an element necessary for biological growth. Early calcium data used in this report were obtained using a colorimetric-titration procedure. This method is less precise and accurate than the atomic-absorption method currently used.

Criteria

Standards have not been established for public-water supplies. However, the calcium concentration in water has a very definite effect on hardness, scaling, and corrosion properties when the water is used for domestic supply. The suitability of water for irrigation also is dependent on calcium and magnesium concentrations relevant to the sodium concentration. Criteria for evaluating its effects, however, commonly are given in terms of hardness, scaling or corrosion indices, and sodium-adsorption ratio. Calcium is just one of the factors used in calculating these properties.

Observations

The mean and median concentrations increased about 20 percent between river mile 0 and river mile 143 (fig. 10). Some of the variance in values in the data may be due to a less-precise, analytical technique used before the the atomic-absorption method was adopted.

The dissolved-calcium concentration for the study reach can be predicted from the dissolved-solids concentration or specific conductance:

Calcium (mg/L) = 0.0816 X dissolved solids concentration (mg/L) + 25; and
calcium (mg/L) = 0.0499 X specific conductance (µS) + 27.

Carbonate

Carbonate, like bicarbonate, is a principal contributor to alkalinity. Ideally, carbonate should be measured at the sampling site. (The concentrations for carbonate in this report were not determined at the sampling site.) A pH measured at the sampling site that is greater than 8.3 indicates the presence of carbonate; however, subsequent laboratory analysis may show no carbonate present. This indicates a change in pH and, therefore, carbonate change from the time of sample collection to the time of laboratory analysis. It should be noted that the earlier pH values measured during the study were measured in the laboratory rather than at the sampling site.

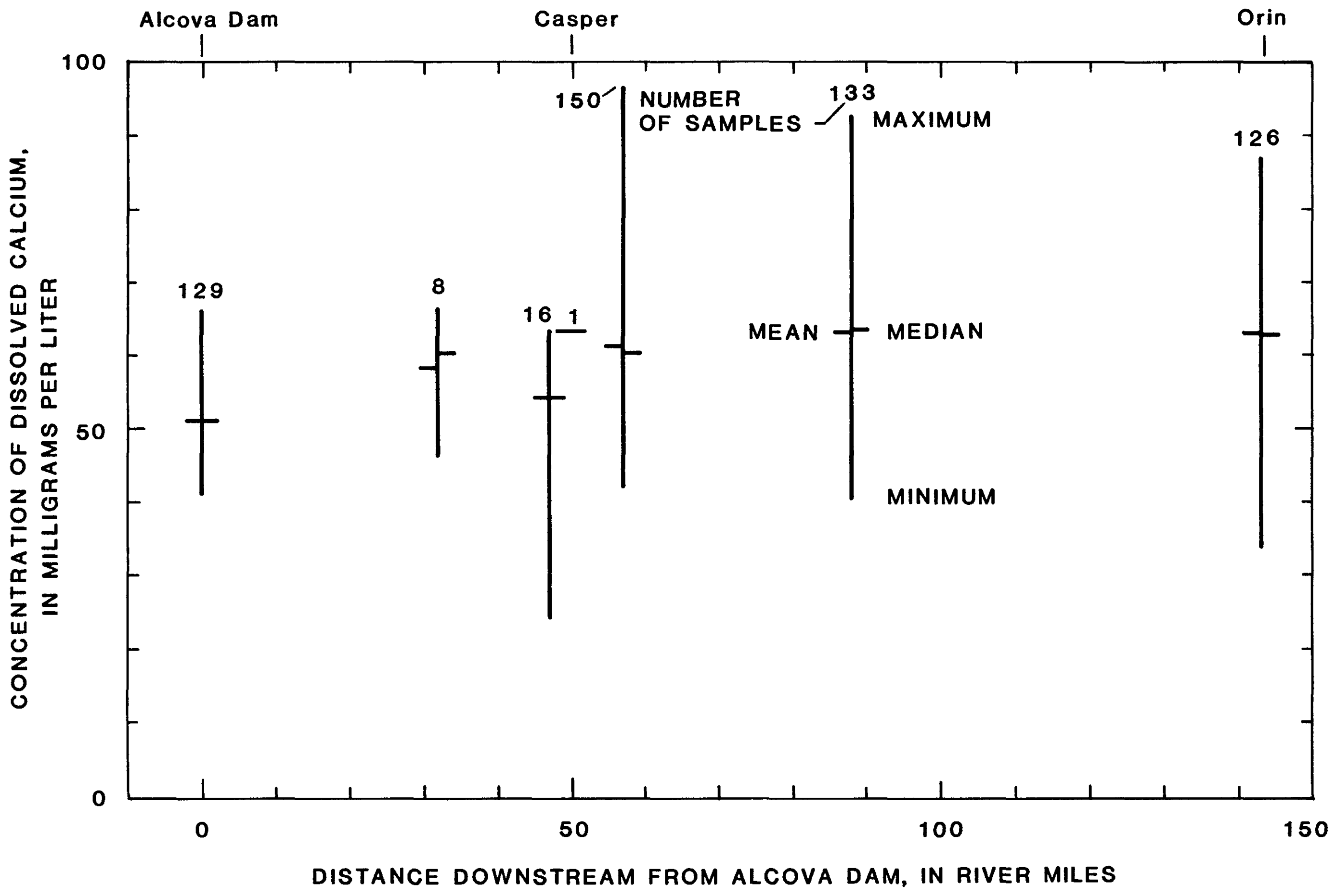


Figure 10.--Maximum, minimum, mean, and median dissolved-calcium concentrations at all sampling stations along the North Platte River between Alcova Dan and Orin, water years 1970-79.

Criteria

Current drinking-water standards or water-quality criteria do not deal directly with the carbonate ion.

Observations

The median concentration at most stations is 0 (fig. 11). The mean concentrations are less than 5 mg/L. Accuracy of these concentrations in representing the stream condition is questionable because the concentrations were measured in the laboratory rather than at the sampling site.

Total Organic Carbon

Total organic carbon represents the organic carbon, dissolved and suspended, present in the water. Sampling and subsampling techniques are critical. Early analysis lacked proper laboratory subsampling technique. It should be noted that the low total-organic-carbon concentrations do not necessarily indicate the absence of individual organic compounds that may be harmful at relatively low concentrations.

Criteria

Drinking-water standards or water-quality criteria have not been established for total organic carbon.

Observations

The three stations at which total-organic-carbon data were collected have maximum concentrations (fig. 12) that are below most regional ranges shown in the 1975 NASQAN data (Briggs and Ficke, 1977). These lower concentrations may partially be due to the trapping of suspended organic matter by upstream reservoirs.

Chemical Oxygen Demand

Chemical oxygen demand (COD) is a measure of the quantity of oxygen required to oxidize both organic and inorganic material in a sample, under specific laboratory conditions. The sample is oxidized by refluxing it with an acid-dichromate solution. A total (unfiltered) sample is used. Sampling and subsampling techniques are critical in order to obtain a representative sample.

Criteria

Criteria have not been established in present drinking-water standards. High COD values may make water unsuitable for aquatic life, irrigation, and certain industries.

Observations

Mean and median values for the three stations sampled are about 25 mg/L (fig. 13).

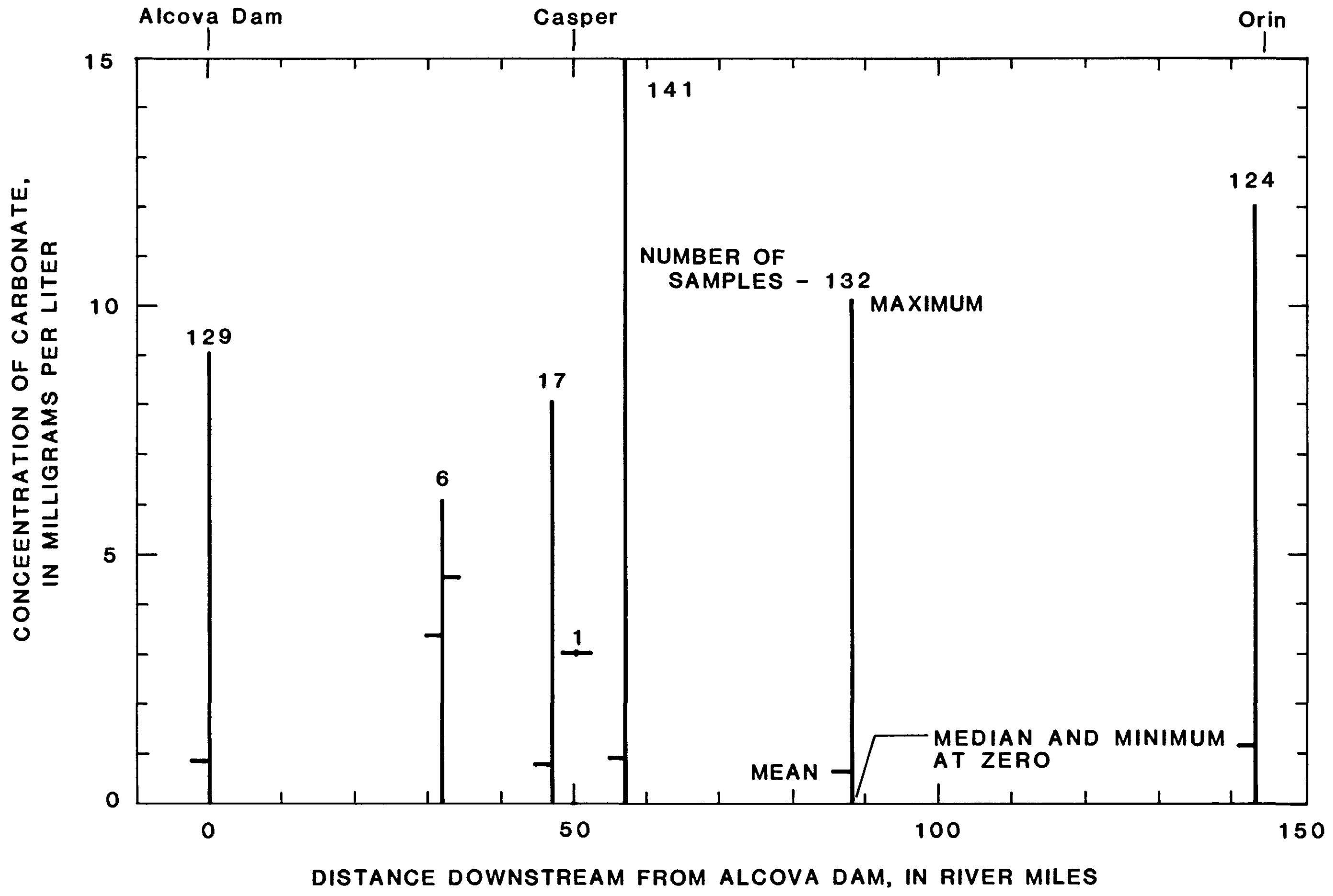


Figure 11.--Maximum, minimum, mean, and median carbonate concentrations at all sampling stations along the North Platte River between Alcova Dam and Orin, water years 1970-79.

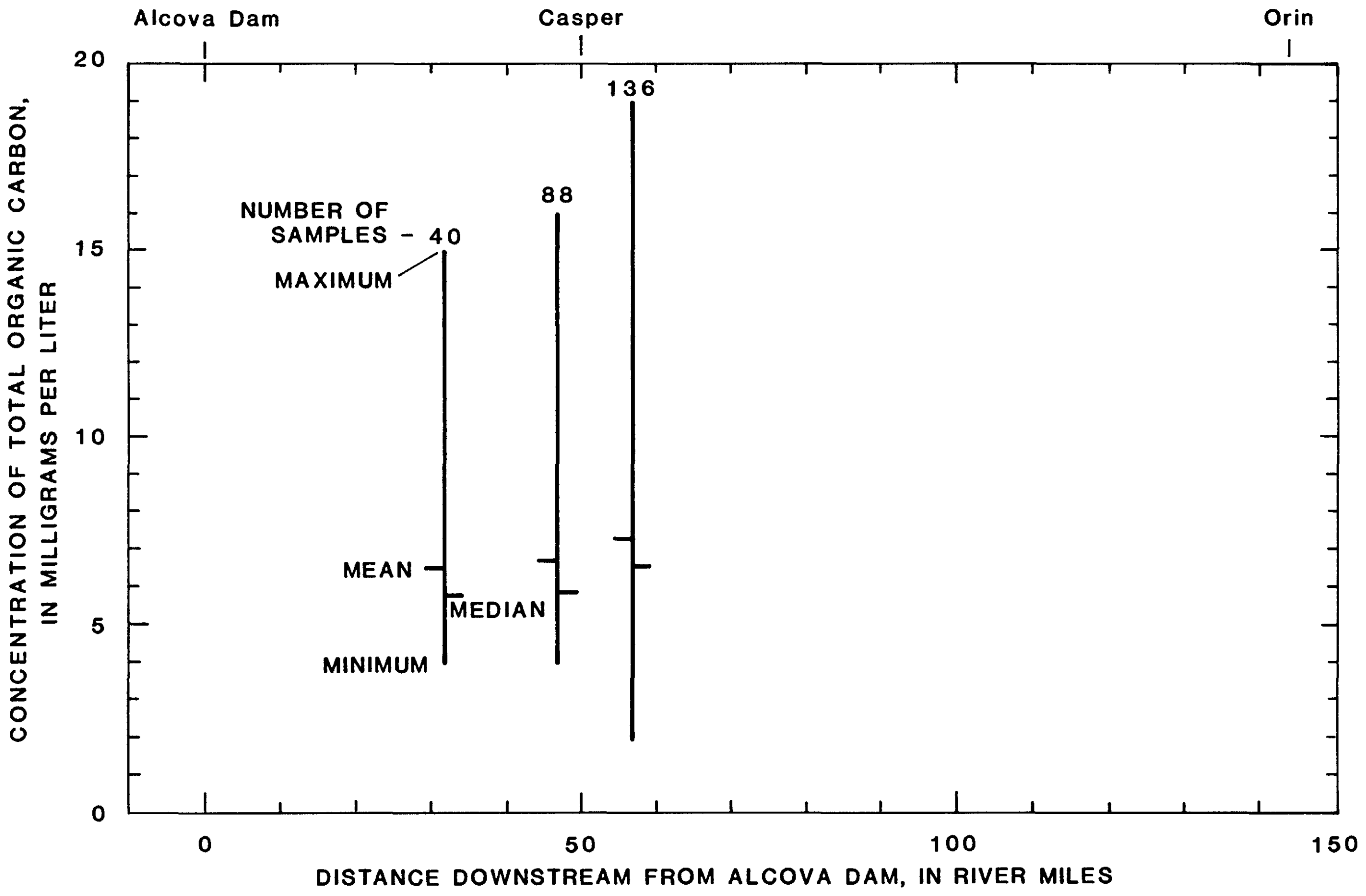


Figure 12.--Maximum, minimum, mean, and median total-organic-carbon concentrations at three sampling stations along the North Platte River beween Alcova Dam and Orin, water years 1970-79.

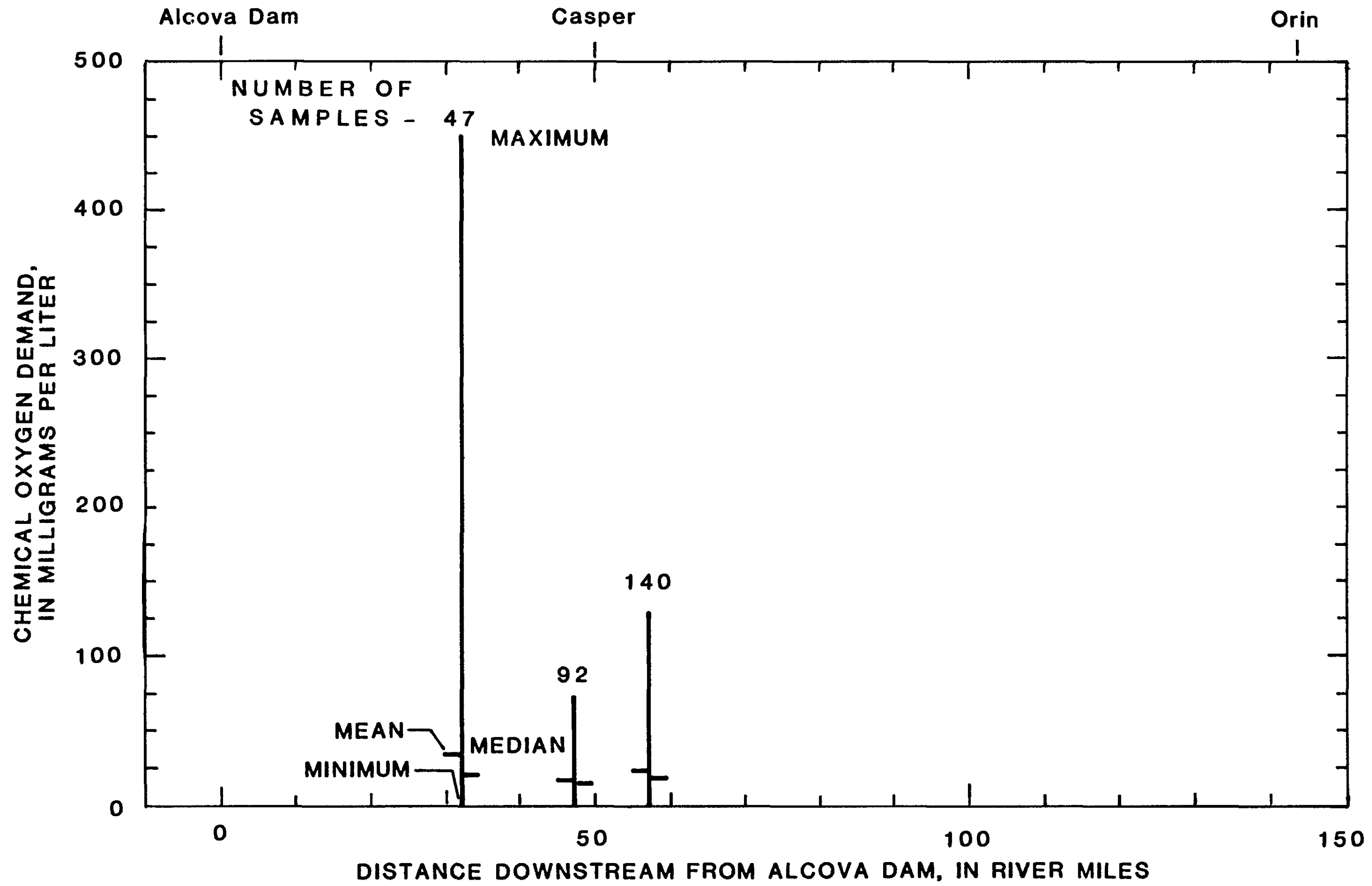


Figure 13.--Maximum, minimum, mean, and median chemical-oxygen-demand concentrations at three sampling stations along the North Platte River between Alcova Dam and Orin, water years 1970-79.

Chloride

Chloride is a highly soluble ion that is present in all natural waters. Normally, chloride concentrations in surface waters are less than bicarbonate or sulfate concentrations. Human activities such as road deicing (using chloride salts), and the disposal of oil-production brines and municipal and industrial waste usually result in increased chloride in surface water. Natural sources of chloride include springs with large chloride loads, volcanic gases, and airborne spray from the ocean. The latter source accounts for the high chloride concentrations in rainfall near the oceans.

Criteria

In public water supplies chloride concentrations should not exceed 250 mg/L (U.S. Environmental Protection Agency, 1979) because of the undesirable taste that high concentrations of chloride impart to water. Foliar adsorption of chlorides may adversely affect crops irrigated by sprinkler systems. Acceptable chloride levels in irrigation water depend upon type of crop, environment, and management practices (National Academy of Sciences and National Academy of Engineering, 1973, p. 329).

Observations

Mean and median dissolved-chloride concentrations increase from about 10 mg/L at river mile 0 to about 14 mg/L at river mile 57 but do not change from river mile 57 to river mile 143 (fig. 14). There is a considerable range in chloride concentrations at most sampling stations; however, the concentrations of more than 90 percent of the samples were 25 mg/L or less.

Chromium

Chromium, although toxic in high concentrations, is considered to be an essential trace element for human nutrition. Inhalation of, and skin contact with hexavalent chromium have been considered harmful almost entirely as occupational health effects (U.S. Environmental Protection Agency, 1976, p. 71). Dissolved-chromium concentrations in natural waters are normally below the maximum-limit drinking-water standard. The 1975 NASQAN data summary showed only one sample with concentration above 50 µg/L (Briggs and Ficke, 1977, p. 55). The sample was collected downstream from a chemical spill, and the high concentration persisted for only a short time.

Criteria

The U.S. Environmental Protection Agency (1977) limits maximum chromium concentration to 50 µg/L for public water supplies.

Observations

The 29 samples have concentrations below the drinking-water standard (fig. 15). No downstream trend is evident.

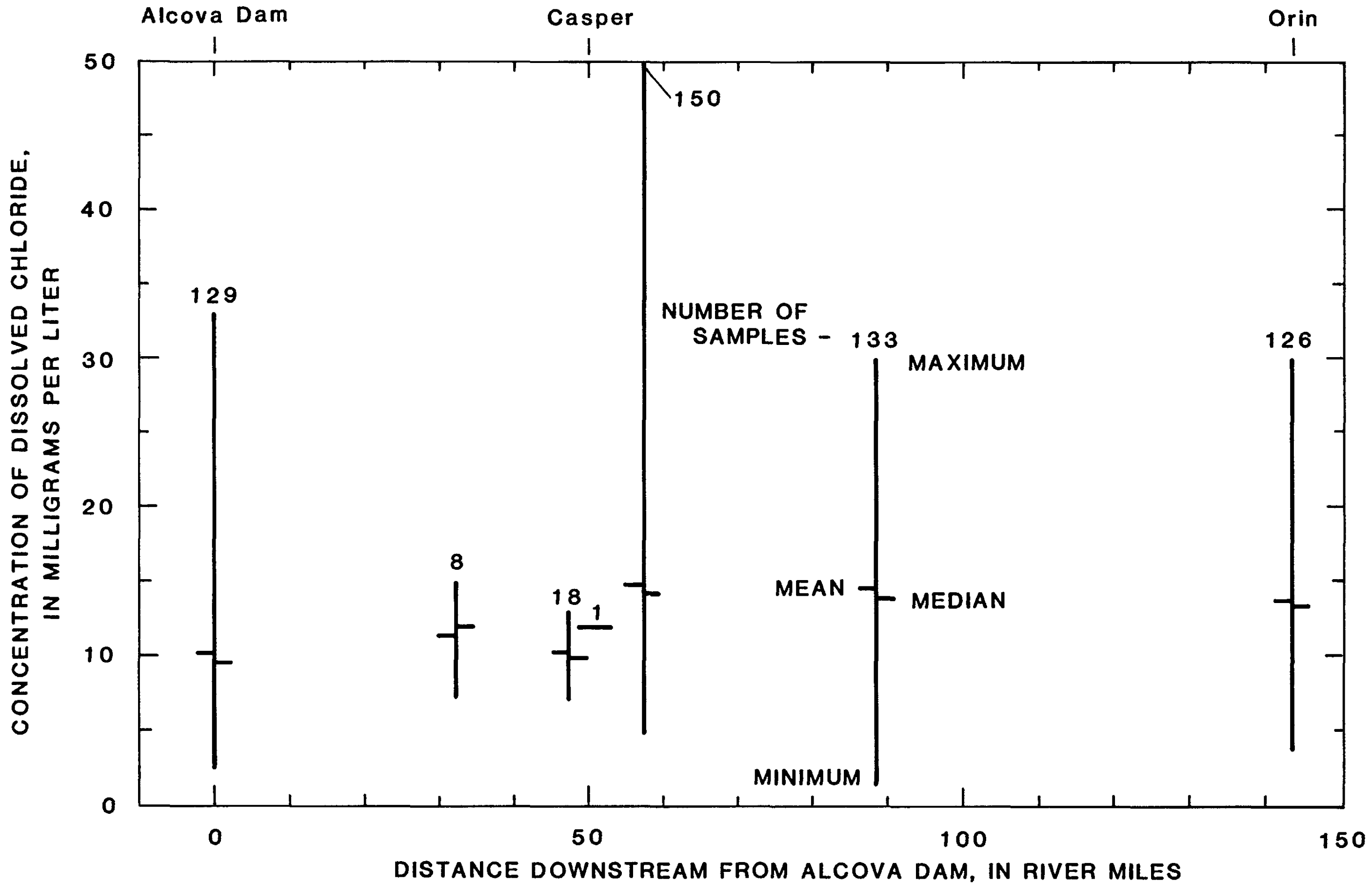


Figure 14.--Maximum, minimum, mean, and median dissolved-chloride concentrations at all sampling stations along the North Platte River between Alcova Dam and Orin, water years 1970-79.

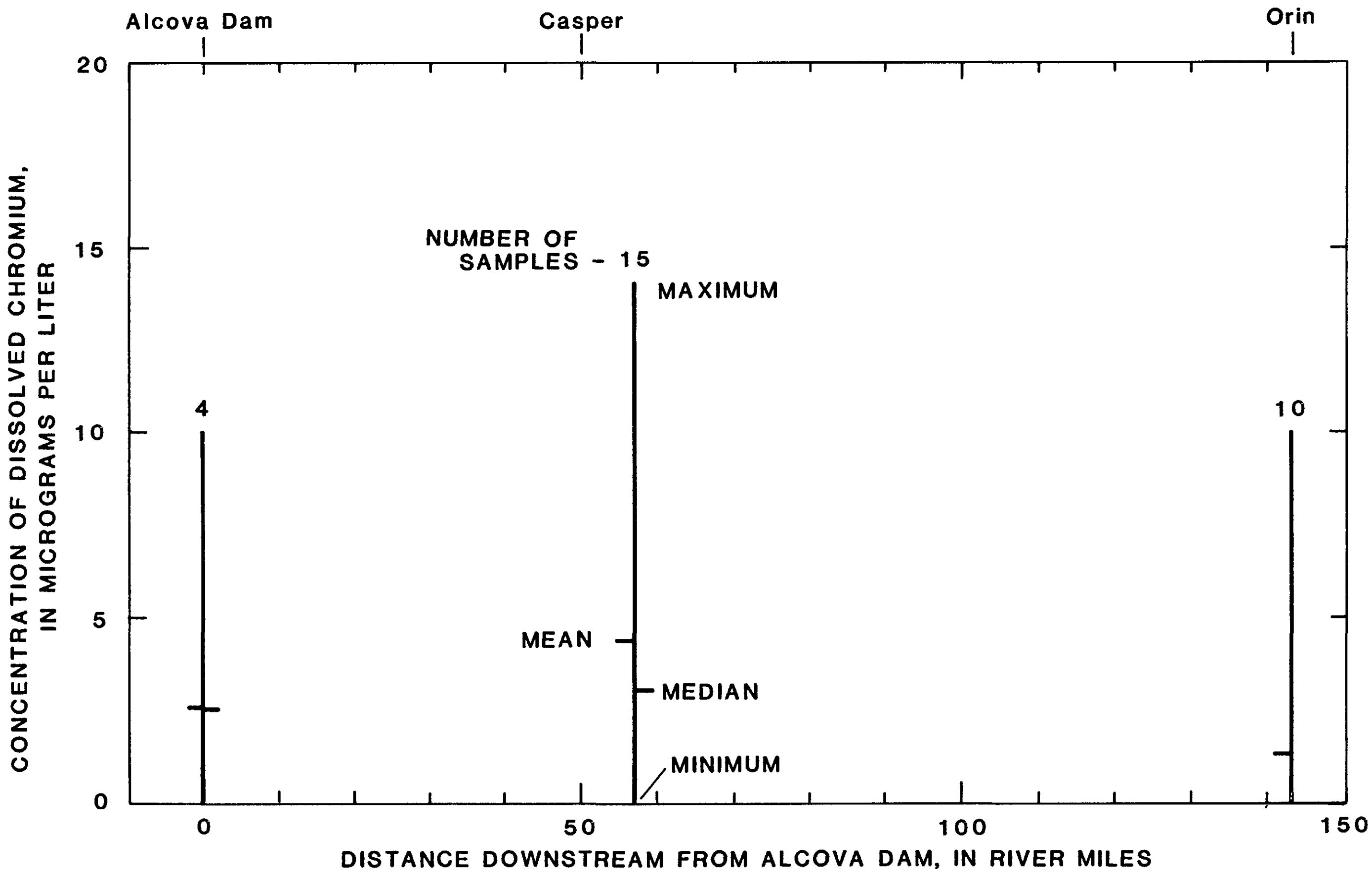


Figure 15.--Maximum, minimum, mean, and median dissolved-chromium concentrations at three sampling stations along the North Platte River between Alcova Dam and Orin, water years 1970-79.

Fecal Coliform Bacteria

Instead of analyzing directly for disease-causing bacteria, viruses, protozoa, worms, and fungi, fecal-coliform-bacteria concentrations are used as an indicator of sanitary water quality. Direct analysis of individual pathogens is impractical. Increased concentrations of fecal coliform bacteria are assumed to indicate an increased risk of pathogen presence.

The fecal coliform bacteria in the samples produced blue colonies on M-FC medium when incubated for 24 hours at 44.5°C . The bacteria were first removed from the water by filtration through 0.7 micron filters.

Criteria

The National Primary Drinking Water Regulations (U.S. Environmental Protection Agency, 1977) limit monthly fecal-coliform-bacteria averages to no more than 1 colony per 100 ml of sample with no more than 5 percent of the monthly samples exceeding 4 colonies per 100 ml. These limits apply to treated water. Raw water used for intake supplies should have a geometric mean no greater than 2,000 colonies per 100 ml (National Academy of Sciences and National Academy of Engineering, 1973, p. 58). For swimming, a maximum geometric mean of 200 colonies per 100 ml calculated from at least 5 samples collected within a 30-day period is recommended (U.S. Environmental Protection Agency, 1976, p. 90).

Observations

The water released from Alcova Reservoir is of high sanitary quality. Sanitary degradation is evident at river mile 57 (fig. 16). Samples were not taken between river mile 57 and river mile 143. With the exception of samples collected at river mile 57, samples had mean values below recommended limits for swimming and for raw-water intakes. The mean value for the entire reach is below the 1975 NASQAN mean of 15,000 colonies per 100 ml (Briggs and Ficke, 1977, p. 44).

Copper

Copper is an essential trace metal to both plant and animal life. Concentrations of copper found in natural waters are not toxic to man; however, water with concentrations greater than 1,000 µg/L has an unpleasant taste. Aquatic life is much more sensitive to copper than are humans.

Criteria

Because of the possibility of unpleasant taste, the National Secondary Drinking Water Regulations (U.S. Environmental Protection Agency, 1979) suggest the limit of concentration of copper in public water supplies to not more than 1,000 µg/L. The toxicity of copper to aquatic life depends on biological specie and its age. Rainbow trout are among the more sensitive species; the young are more intolerant to copper than adults. High alkalinity and hardness values mitigate the toxicity of copper to fish.

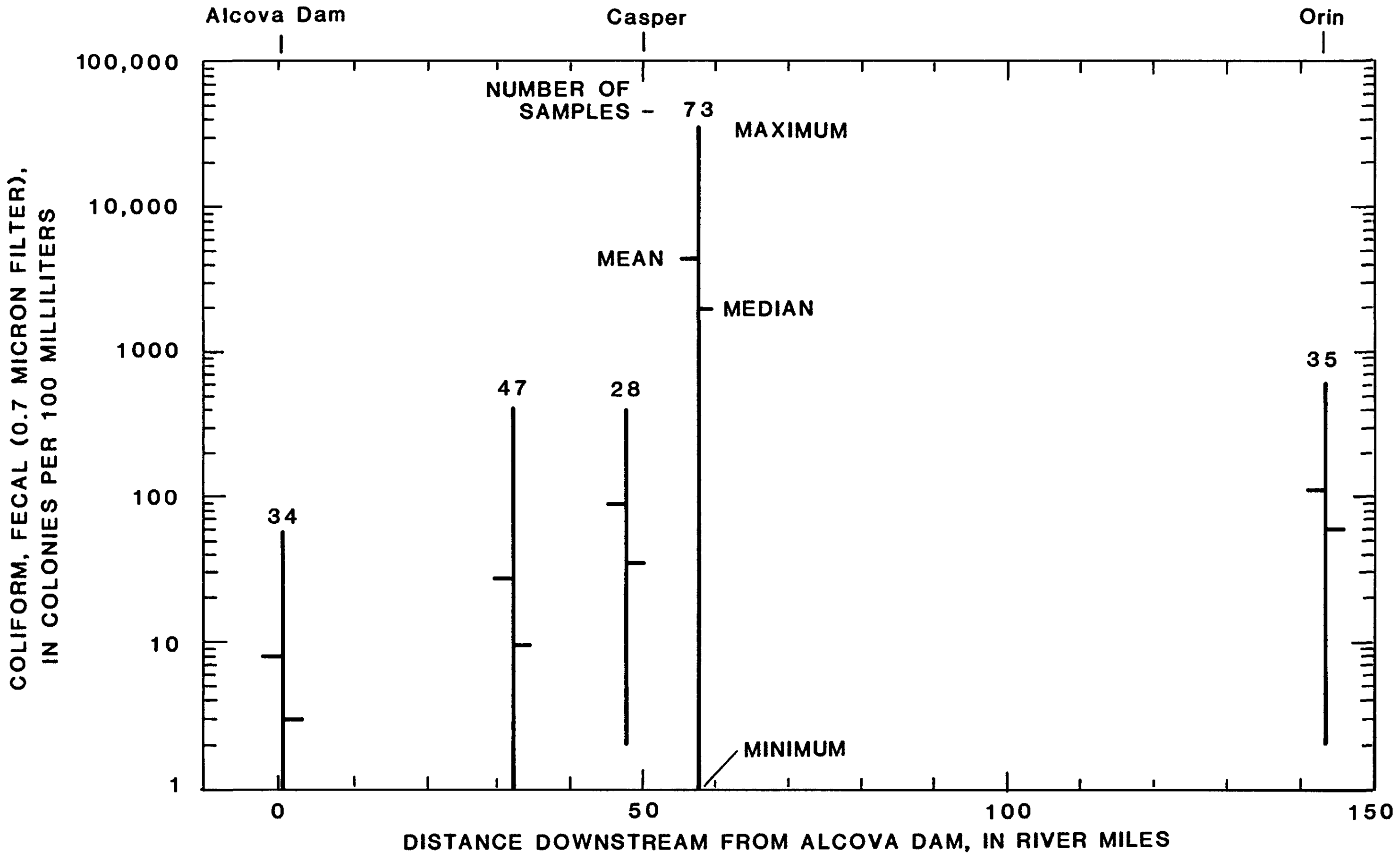


Figure 16.--Maximum, minimum, mean, and median fecal-coliform-bacteria concentrations at five sampling stations along the North Platte River between Alcova Dam and Orin, water years 1970-79.

Observations

The dissolved-copper concentrations in the study reach are below the drinking-water regulation (1,000 μg/L). Samples from the station at river mile 47 had significantly higher values than samples collected at the other three stations, but the 18 concentrations from samples collected at river mile 57 are less than 10 μg/L copper (fig. 17).

Dissolved Solids

Waters with high dissolved-solids concentrations often have problems with hardness, corrosion, scaling, or taste when used for domestic supply. Drinking water with high concentrations of dissolved solids may have a temporary laxative effect.

Criteria

The National Secondary Drinking Water Regulations (U.S. Environmental Protection Agency, 1979) recommend that the dissolved-solids concentration should not exceed 500 mg/L.

Observations

Mean and median values increase from about 320 mg/L at river mile 0 to about 430 mg/L at river mile 57 (fig. 18). Significant change in mean and median dissolved-solids concentration is not evident between river mile 57 and river mile 143.

A wide range in values is evident from samples taken frequently at all stations except the station at river mile 0 which shows little variation, due to the influence of Alcova and the two other upstream reservoirs. The wide range in dissolved-solids concentrations in samples frequently collected at the other stations is due to the influence of the tributaries. Tributaries upstream from river mile 57 have a large concentration of salt during periods of high flow, resulting in an increased dissolved-solids concentration in the North Platte. High flow in tributaries downstream from river mile 57 may dilute the dissolved solids in the North Platte to concentrations less than the minimum values at river mile 0. About 80 percent of all dissolved-solids concentrations are less than the drinking-water standard of 500 mg/L. More than 93 percent of all samples are 560 mg/L or less. The 1975 NASQAN mean for the Nation was 600 mg/L (Briggs and Ficke, 1977, p. 23).

The dissolved-solids concentration generally shows excellent correlation with specific conductance. However, some of the specific conductance values are very likely in error. The regression equation using selected data is:

Dissolved solids (mg/L) = 0.704 X specific conductance (μS) - 38.

Fluoride

Fluoride, in concentrations lower than the maximum recommended concentration, is considered desirable in drinking water. The only documented harmful

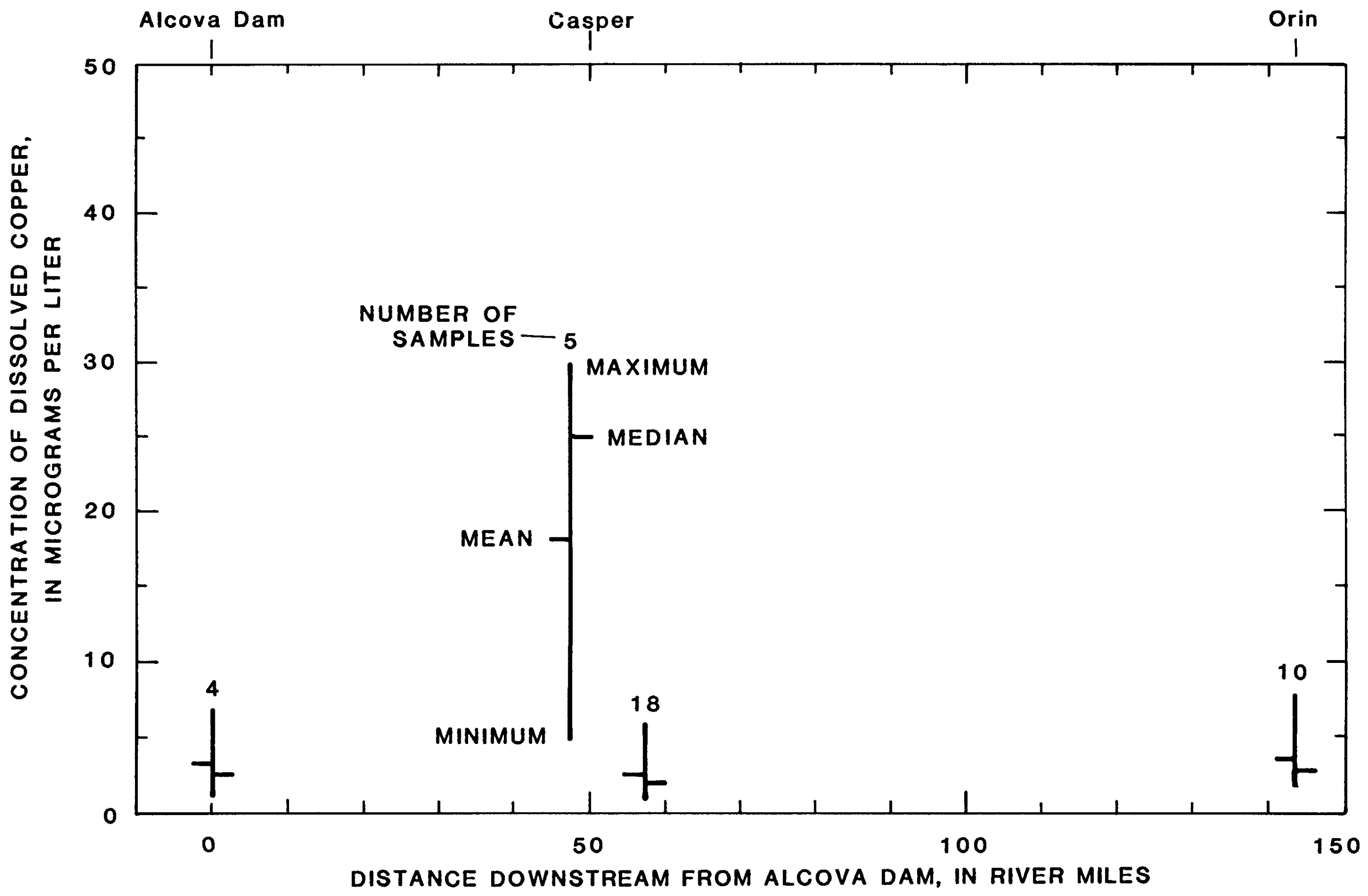


Figure 17.--Maximum, minimum, mean, and median dissolved-copper concentrations at four sampling stations along the North Platte River between Alcova Dam and Orin, water years 1970-79.

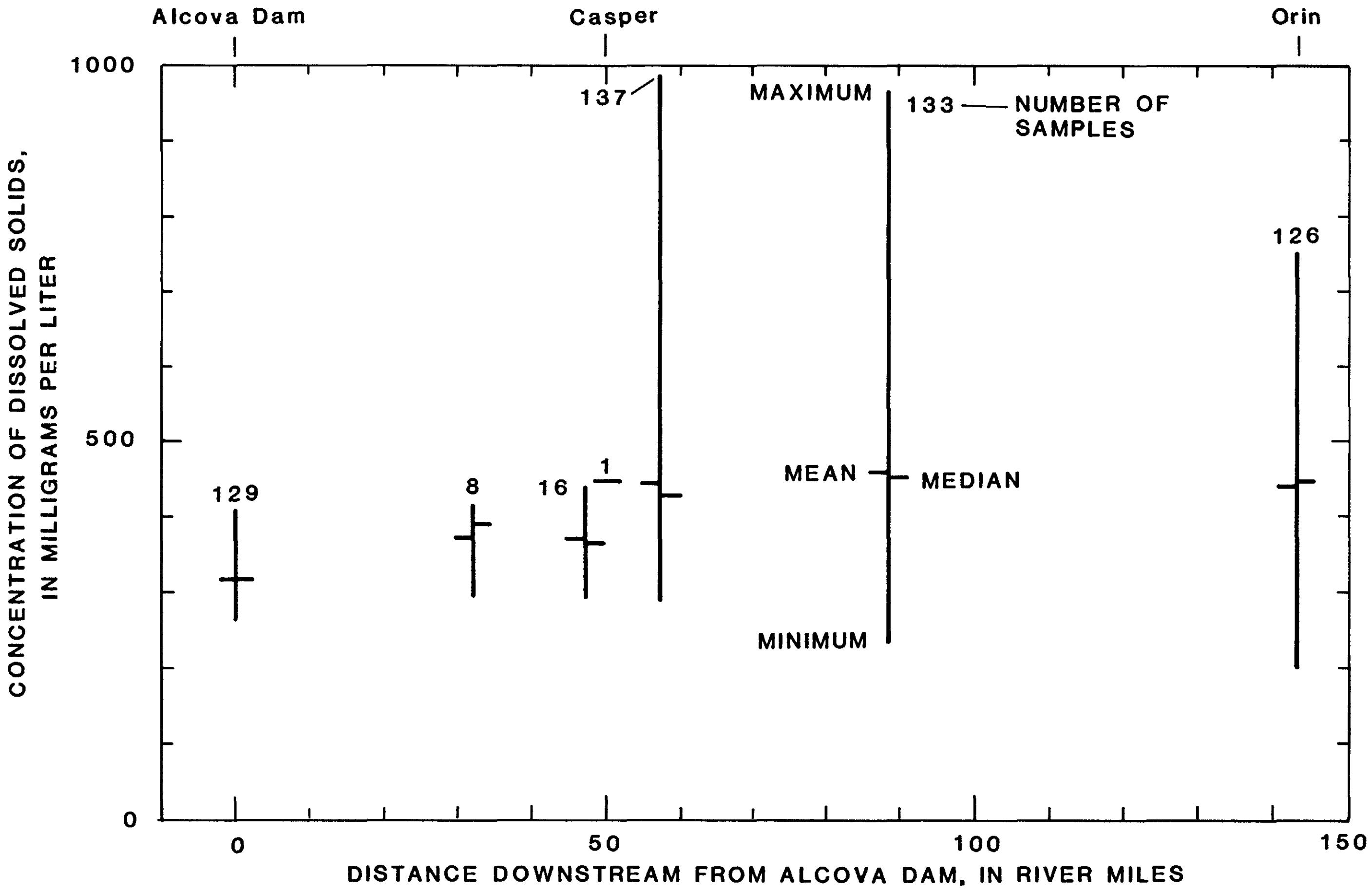


Figure 18.--Maximum, minimum, mean, and median dissolved-solids concentrations at all sampling stations along the North Platte River between Alcova Dam and Orin, water years 1970-79.

effect of high fluoride concentrations in drinking water in the United States has been mottling of dental enamel (National Academy of Science and National Academy of Engineering, 1973, p. 66).

Criteria

The maximum intake level for inorganic contaminants, except fluoride, is based on an assumed human intake of 2 liters of water per day. The maximum and optimum fluoride levels for a given community depend on climatic conditions because the amount of water (and consequently the amount of fluoride) ingested by children is primarily influenced by air temperature (U.S. Environmental Protection Agency, 1977, p. 66). Therefore, maximum recommended fluoride concentrations are based on the annual average of maximum daily air temperature.

The maximum concentration of fluoride established by the National Primary Interim Drinking Water Regulations (U.S. Environmental Protection Agency, 1977) is 2.0 mg/L for Casper, which has an annual average daily-maximum air temperature between 58.4°F and 63.8°F. The optimum fluoride concentration for Casper is 1.0 mg/L. This is the desired concentration to prevent dental caries (cavities) in the teeth of children.

Observations

The mean and median dissolved-fluoride concentrations for all seven sampling stations are between 0.4 and 0.5 mg/L (fig. 19). The range of concentrations at river mile 57 is greater than at all other stations. However, the maximum dissolved-fluoride concentration (1.1 mg/L) at that station is below the maximum recommended 2.0 mg/L. The concentrations of about 94 percent of all samples are between 0.3 and 0.7 mg/L.

The mean fluoride concentration for all NASQAN stations (1975) was 0.33 mg/L (Briggs and Ficke, 1977, p. 31). This is slightly lower than the mean concentration for the seven North Platte stations.

Hardness

For practical purposes, hardness may be defined as the soap- or detergent-consuming property of water. Most hardness values used in this report have been calculated by summing the equivalent concentrations of calcium and magnesium and then expressing the sum as an equivalent concentration of calcium carbonate. Early analyses, however, determined hardness directly by the complexometric method by which all alkaline earth ions are measured.

Criteria

The level of hardness acceptable to the public varies. There are no adverse health effects which are known to be caused by hardness. Hardness may readily be removed by water softeners or in treatment plants. Recommendations to govern public water supplies have not been made. Hard water is considered desirable for irrigation.

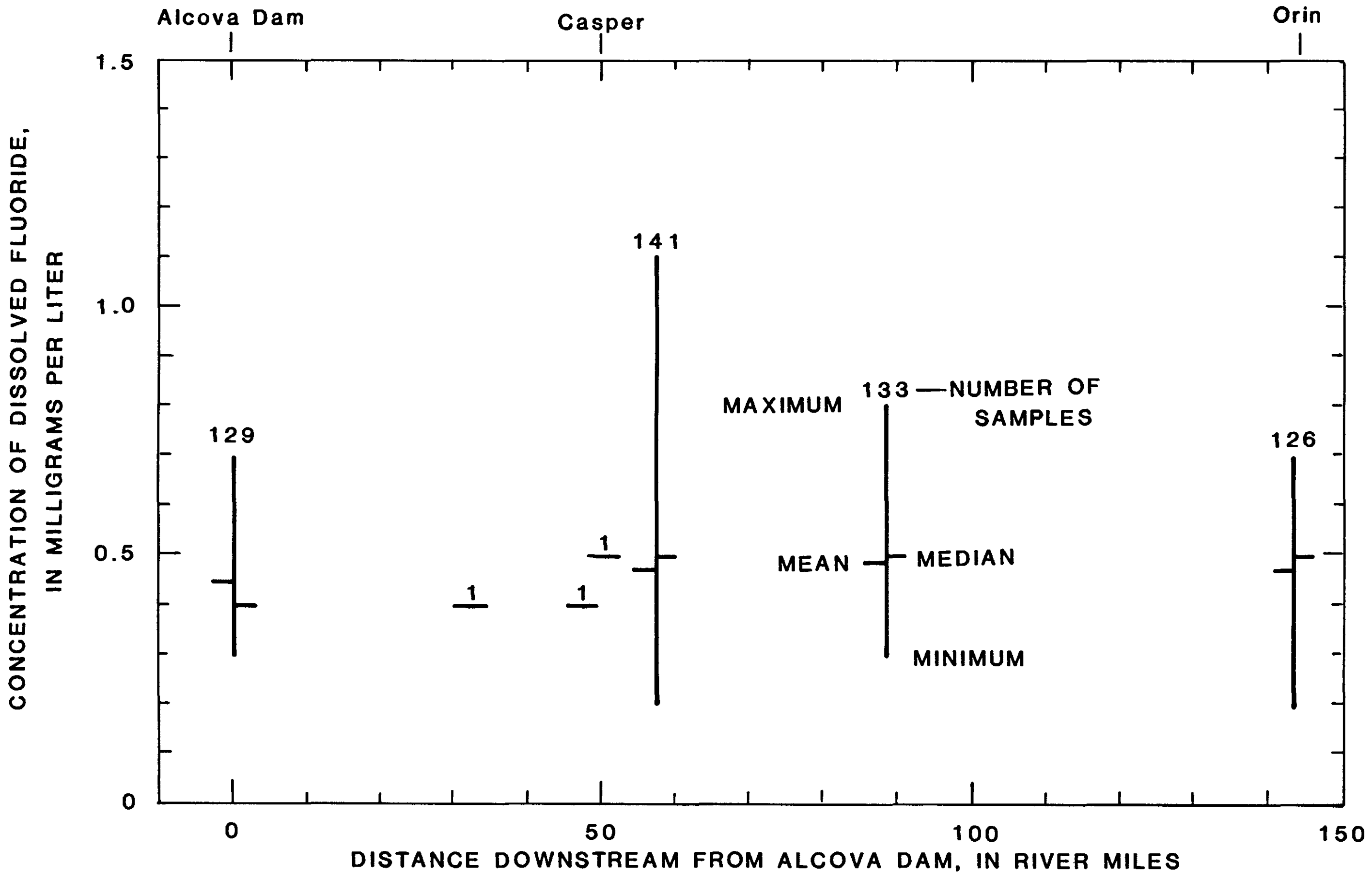


Figure 19.--Maximum, minimum, mean, and median dissolved-fluoride concentrations at all sampling stations along the North Platte River between Alcova Dam and Orin, water years 1970-79.

Observations

About a 25-percent increase in the mean value is evident between river mile 0 and river mile 143 (fig. 20). Most values would be classified as hard to very hard. The 1975 NASQAN mean hardness value was 217 mg/L, as $CaCO_3$ (Briggs and Ficke, 1977, p. 25)--or slightly lower than the mean of about 230 mg/L for the North Platte. Hardness is correlated with the dissolved-solids concentration and specific conductance. Prediction equations for hardness are:

> Hardness (mg/L as $CaCO_3$) = 0.403 X dissolved solids concentration (mg/L) + 64; and hardness (mg/L as $CaCO_3$) = 0.254 X specific conductance (µS) + 64.

Hydrogen-ion Activity

The concentration of hydrogen ions in natural water is normally very low and highly variable. The effective hydrogen-ion concentration or hydrogen-ion activity is important since it greatly influences the chemistry of water. To conveniently express the hydrogen-ion activity, the term, pH, is used. The pH is the negative logarithm of the hydrogen-ion activity expressed in moles per liter. A pH of 7.0 is neutral, less than 7.0 is acidic, and more than 7.0 is alkaline.

Early pH values for the 1970-79 data were determined in the laboratory, whereas later values were determined at the sampling site at the time of collection. A diurnal pH cycle is normal due to plant photosynthesis and respiration, especially in biologically-active water. Plant uptake of carbon dioxide results in a decreased hydrogen-ion concentration (increasing pH) during daylight. Plant production of carbon dioxide at night increases the hydrogen-ion concentration (decreases pH). The data were collected during daylight, resulting in higher mean pH values than would be obtained with random sampling.

Criteria

The National Secondary Drinking Water Regulations (U.S. Environmental Protection Agency, 1979) recommend a pH range from 6.5 to 8.5 for public water supplies. To protect freshwater aquatic life, a pH range from 6.5 to 9.0 has been suggested (U.S. Environmental Protection Agency, 1976, p. 337).

Observations

Nearly all data meet the criteria for public water supplies and for protection of aquatic life. Most exceptions occur at river mile 57, where there is an appreciably greater pH range than at the other six stations (fig. 21).

Iron

Iron is an essential trace element for both plants and animals. Although abundant in the earth's crust, the low solubility of the ferric ion limits its concentration in well-aerated surface water. Iron is undesirable in public water supplies because of taste and staining problems wtih laundary and plumbing fixtures.

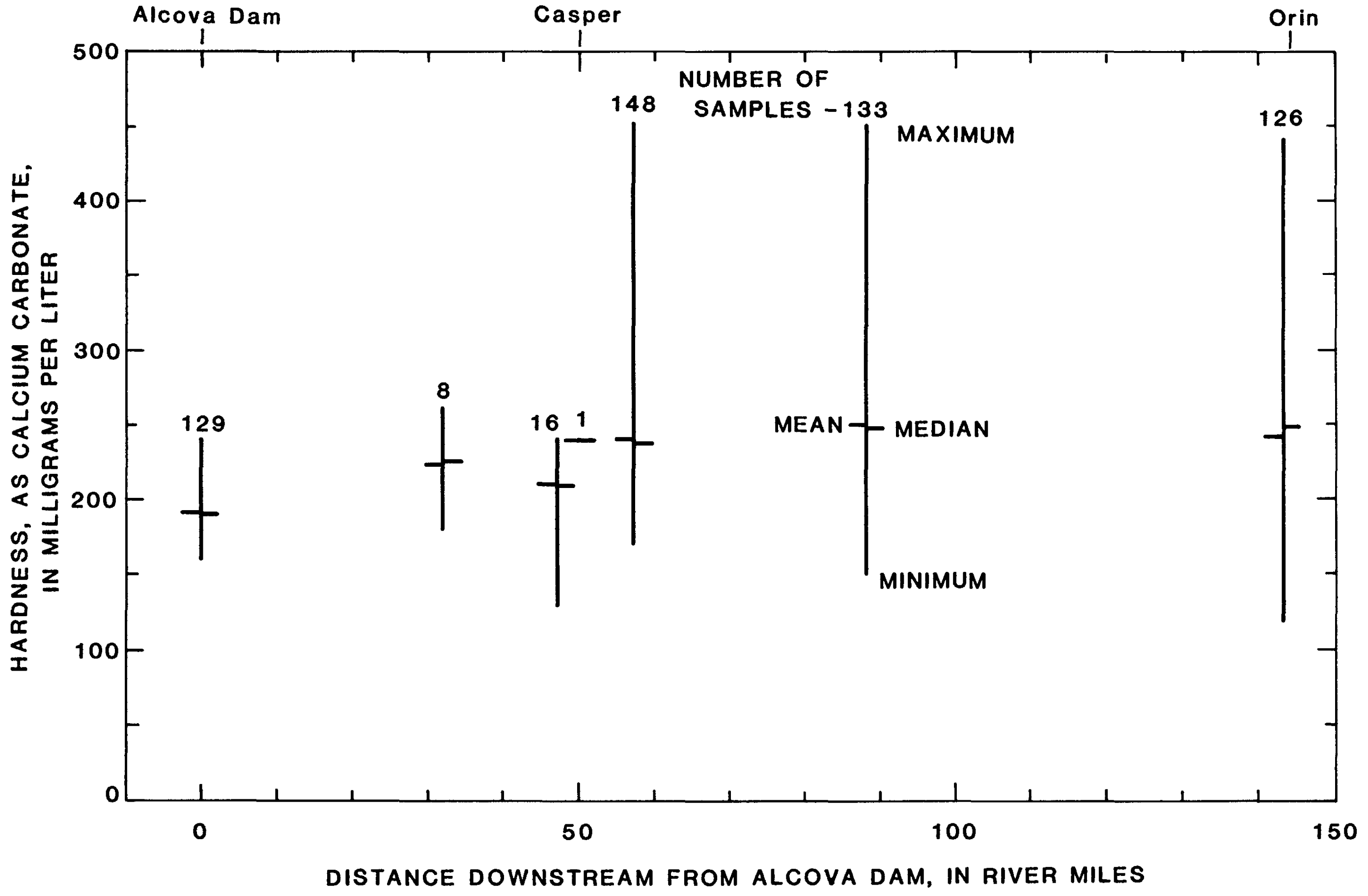


Figure 20.--Maximum, minimum, mean, and median values of hardness at all sampling stations along the North Platte River between Alcova Dam and Orin, water years 1970-79.

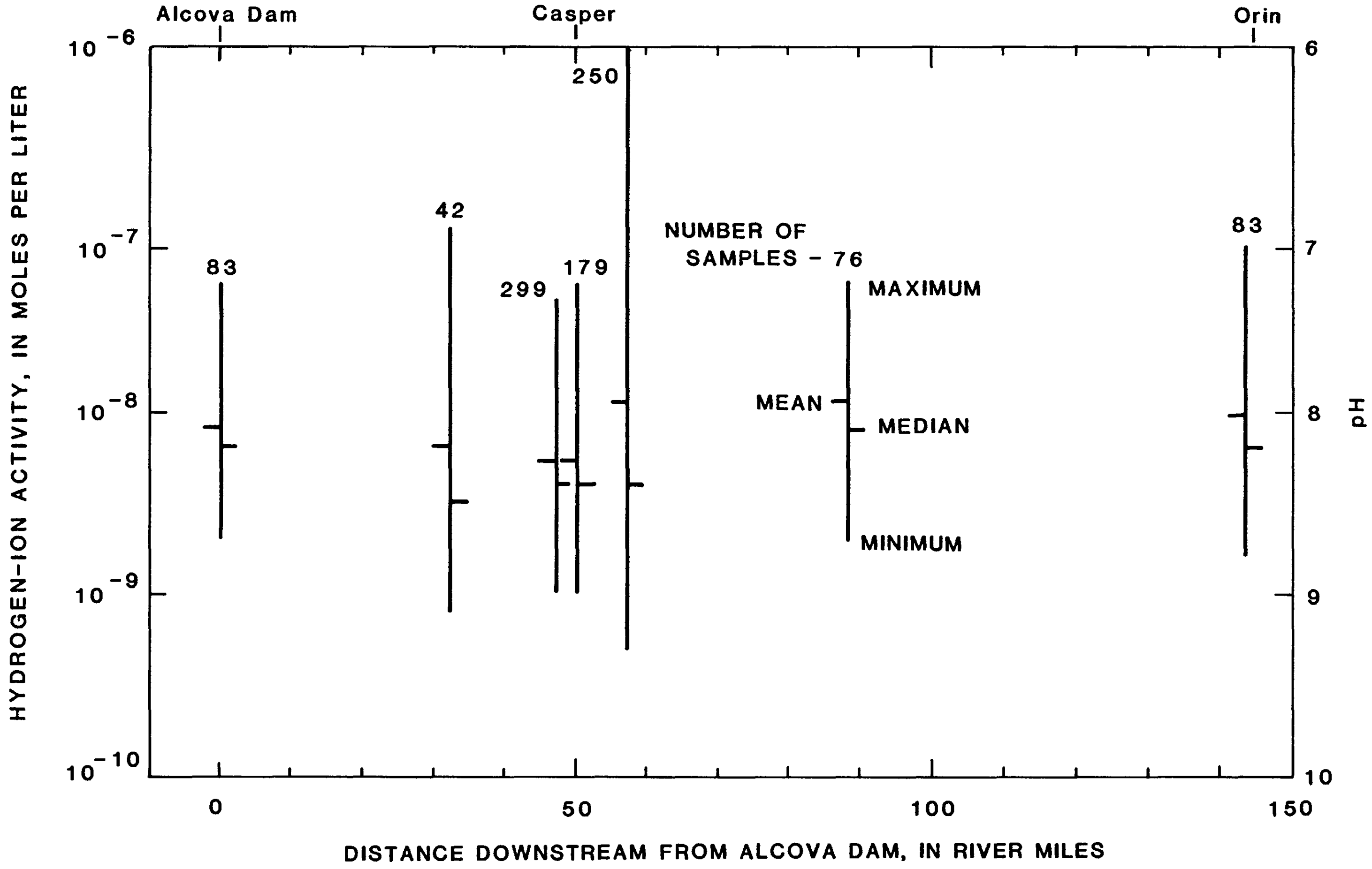


Figure 21.--Maximum, minimum, mean, and median hydrogen-ion activity and pH at all sampling stations along the North Platte River between Alcova Dam and Orin, water years 1970-79.

Criteria

The National Secondary Drinking Water Regulations (U.S. Environmental Protection Agency, 1979) recommend a maximum dissolved-iron concentration of 300 µg/L in water used for public supply. A maximum limit of 1,000 µg/L is recommended in order to protect freshwater aquatic life (U.S. Environmental Protection Agency, 1976, p. 152).

Observations

Nearly all dissolved-iron concentrations are within the recommended criteria (fig. 22).

Lead

Lead is an undesirable trace metal in water. Humans have no known nutritional need for lead, and its toxic effects are well documented. Due to their higher absorption and retention rates, children are more susceptible to lead poisoning than adults. Lead may enter drinking water through corrosion of lead plumbing in areas with soft water.

Criteria

The National Primary Drinking Water Regulations (U.S. Environmental Protection Agency, 1977) specify a maximum contamination level of 50 µg/L for lead. Standards set to protect aquatic life require consideration of the specie and the pH, alkalinity, and hardness of the water.

Observations

Only a limited number of dissolved-lead analyses are available for the study reach. Two relatively high concentrations at river mile 143 suggest a need for more sampling (fig. 23). However, it is possible that some lead and cadmium samples were contaminated by paint. It is not known if the high lead concentrations at river mile 143 were due to contamination, but the potential for contamination is discussed previously in the observations for cadmium.

Magnesium

Although the geochemical properties of magnesium and calcium differ, they are often discussed together. Both magnesium and calcium have a similar effect (hardness) on domestic water and on irrigation water. Magnesium salts generally are more soluble but less abundant than calcium salts.

Magnesium values determined before April 1975 in this data set were calculated by subtracting the equivalents of calcium from the equivalents of hardness. The hardness determination was usually more accurate and precise than the calcium determination. A positive error in calcium resulted in a negative error in magnesium. After April 1975, magnesium and calcium values were determined individually by atomic absorption which resulted in improved precision and accuracy.

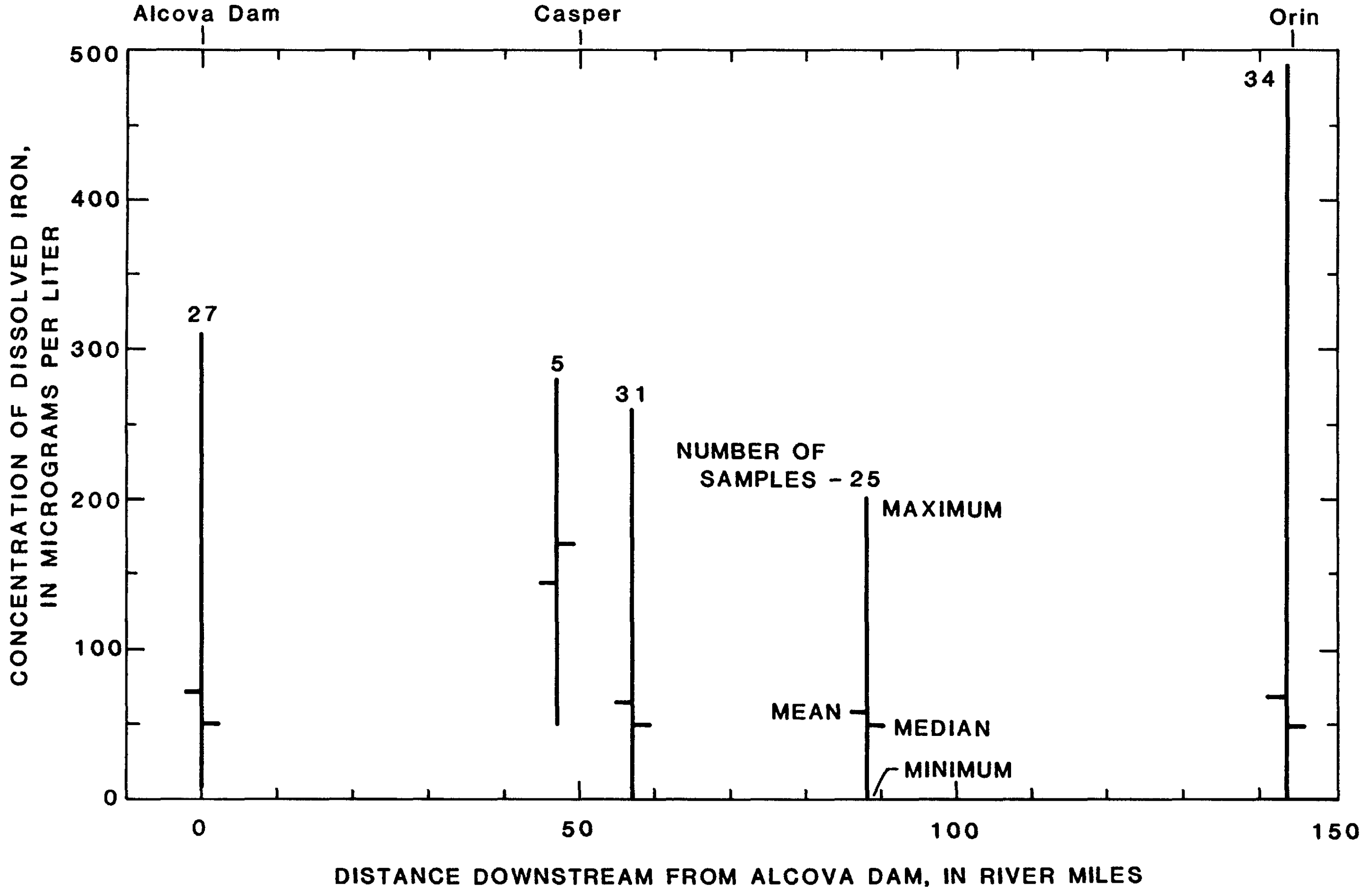


Figure 22.--Maximum, minimum, mean, and median dissolved-iron concentrations at five sampling stations along the North Platte River between Alcova Dam and Orin, water years 1970-79.

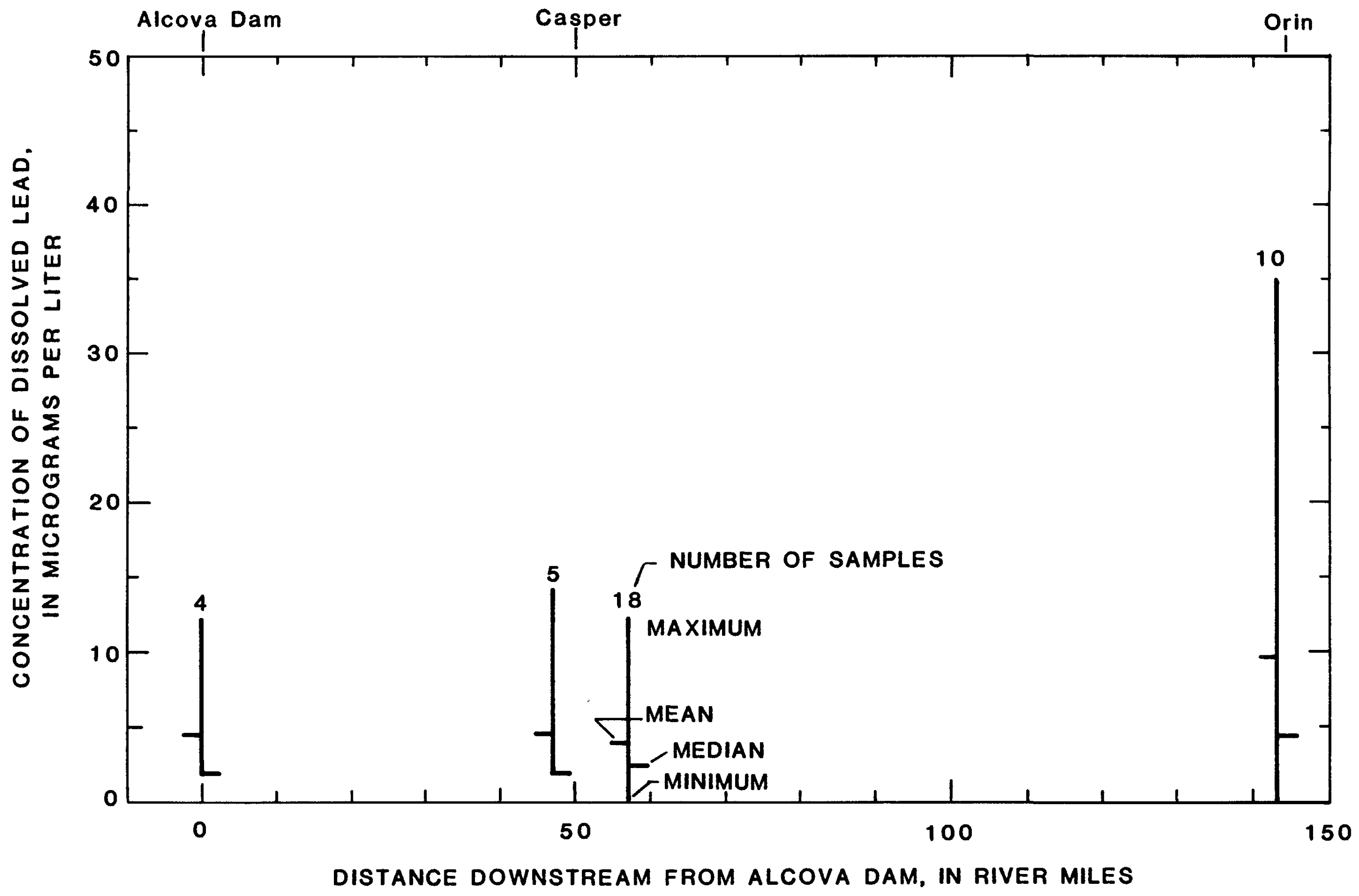


Figure 23.--Maximum, minimum, mean, and median dissolved-lead concentrations at four sampling stations along the North Platte River between Alcova Dam and Orin, water years 1970-1979.

Criteria

Magnesium is not included in either the National primary or secondary drinking-water regulations.

Observations

Mean and median dissolved-magnesium concentrations between river mile 0 and river mile 57 increase slightly (fig. 24). Average values from river mile 57 to river mile 143 show little variation. Some of the range in values is probably due to the change in analytical techniques during 1975. For example, magnesium values during the water year 1977-78 ranged from 18 to 28 mg/L at river mile 57; before 1975 they ranged from 5 to 56 mg/L.

Dissolved-magnesium concentrations may be predicted in the study reach by the regression equation:

Magnesium (mg/L) = 0.0466 X dissolved-solids concentration (mg/L) + 1.

Manganese

Manganese, like iron, is an essential micronutrient for both plants and animals. As is iron, manganese generally is also a greater problem for domestic supplies from ground-water sources than from surface-water sources. Objections to manganese in public water supplies are its undesirable effect on taste and the stains it causes to both laundry and plumbing fixtures.

Criteria

The National Secondary Drinking Water Regulations (U.S. Environmental Protection Agency, 1979) recommends a maximum manganese contaminant level of 50 mg/L.

Observations

Sampling for dissolved manganese has not been extensive. With the exception of one sample, manganese values are below the recommended maximum standard for public water supplies (fig. 25).

Mercury

Mercury is highly toxic and is a nonessential element in human nutrition. Widespread industrial and agricultural use of mercury and mercury compounds have added to the problem caused to the environment. The burning of fossil fuels is a source of mercury pollution (National Academy of Sciences and National Academy of Engineering, 1973, p. 72). Thousandfold mercury concentrations in fish have been reported (U.S. Environmental Protection Agency, 1976, p. 179). To protect human consumers of fish, mercury concentration standards are more stringent than standards advocated for drinking water (U.S. Environmental Protection Agency, 1976, p. 183).

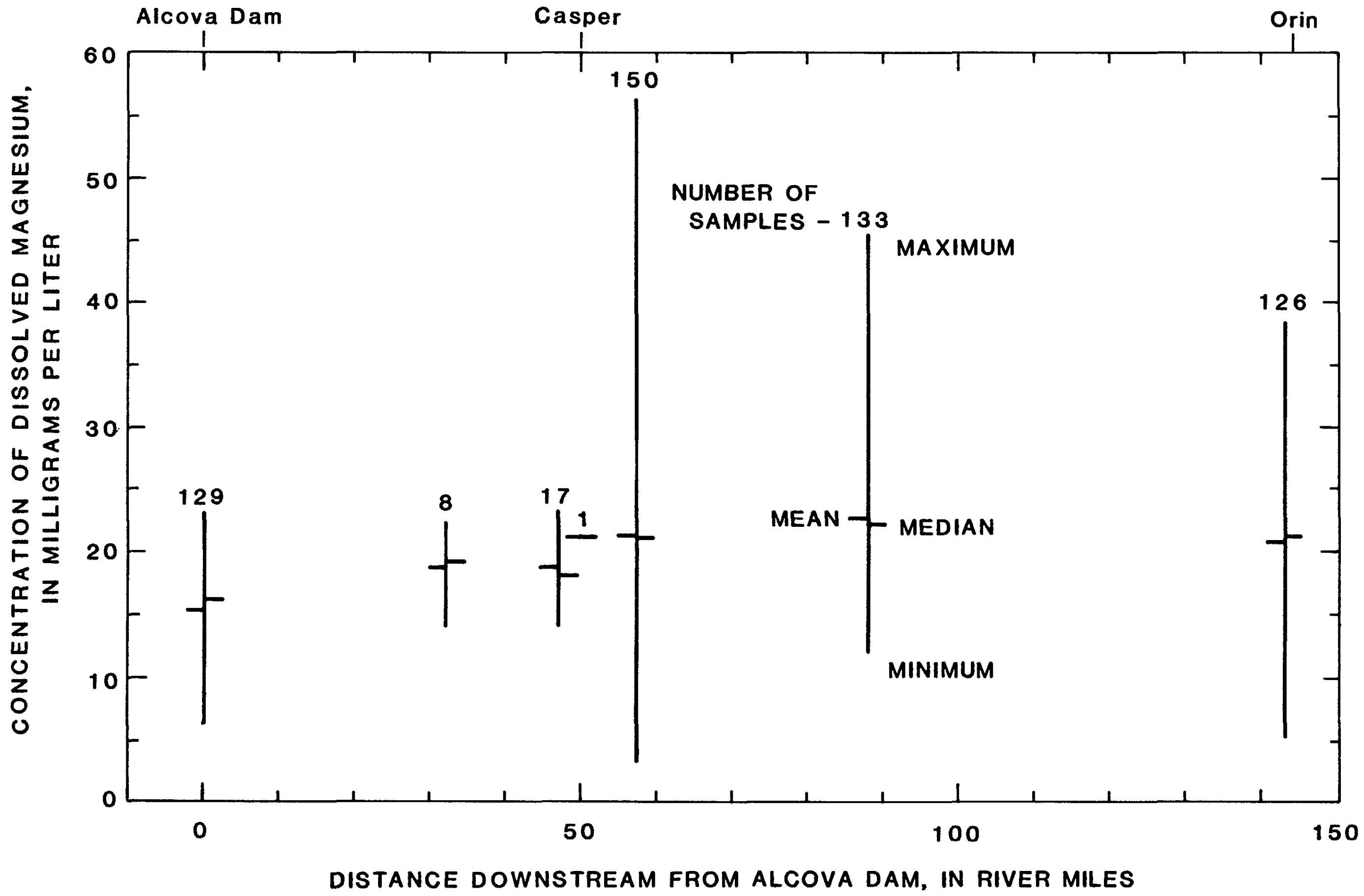


Figure 24.--Maximum, minimum, mean, and median dissolved-magnesium concentrations at all sampling stations along the North Platte River between Alcova Dam and Orin, water years 1970-79.

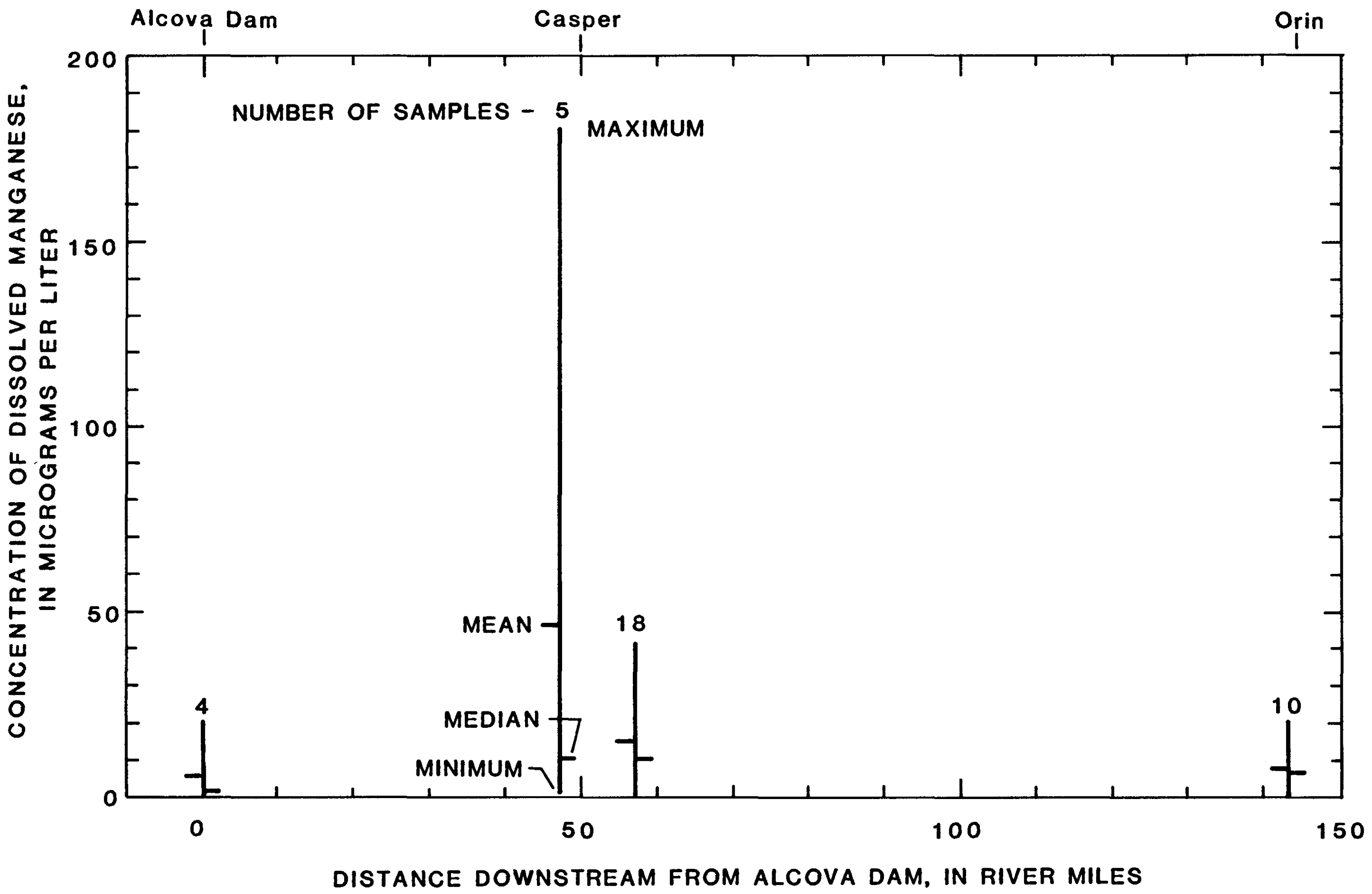


Figure 25.--Maximum, minimum, mean, and median dissolved-manganese concentrations at four sampling stations along the North Platte River between Alcova Dam and Orin, water years 1970-79.

Criteria

A maximum mercury concentration limit of 2 µg/L is mandated for public water supplies by the National primary drinking-water standard (U.S. Environmental Protection Agency, 1977, p. 179. To protect both freshwater aquatic life and the human consumer, a limit of 0.05 µg/L is recommended (U.S. Environmental Protection Agency, 1976, p. 101).

Observations

The 23 samples analyzed for dissolved mercury were all below the detection limit (fig. 26). The detection limit, however, is slightly less than the 0.05 µg/L criterion recommended to protect both fish and human consumers of fish. Because of the potential hazard of mercury contamination, this element needs to be monitored more frequently.

Ammonia Nitrogen

Concentrations of ammonia as nitrogen are normally 0.1 mg/L or less in surface water. Higher values often indicate sewage or industrial pollution (National Academy of Sciences and National Academy of Engineering, 1973, p. 55). Ammonia is undesirable in public water supplies because it combines with chlorine causing it to be a less effective disinfectant. Ammonia in sewage effluent increases the oxygen demand of the sewage load on the receiving stream.

Criteria

The recommended limit for ammonia nitrogen in public water supplies is 0.5 mg/L due to its effect on chlorination and the fact that high values may indicate pollution (National Academy of Sciences and National Academy of Engineering, 1973, p. 55).

To protect freshwater aquatic life, a limit of 0.02 mg/L has been established for un-ionized ammonia (toxic to fish) rather than for the ammonium ion. The concentration of un-ionized ammonia in freshwater depends on the total ammonia concentration, pH, and temperature of the water. (Total ammonia in this instance means all ammonia species, ionized or un-ionized, rather than meaning a whole-water sample.)

Table 6 shows total-ammonia concentrations that have an un-ionized ammonia concentration of 0.02 mg/L, according to the pH and temperature. The table indicates, for example, that the critical total-ammonia ($NH_3 + NH_4^+$) concentration is 0.52 mg/L at a temperature of 20°C and a pH of 8.0.

Observations

Total-ammonia concentrations increase at river mile 57 (fig. 27). In this case, total refers to a whole-water (unfiltered) sample. The mean, median, and maximum values for total ammonia-nitrogen at river mile 57 are considerably less than the corresponding statistic for dissolved ammonia-nitrogen. Concentrations of dissolved ammonia-nitrogen have a mean of 0.30, a median of 0.19, and a maximum of 2.4 mg/L. Total ammonia-nitrogen concentrations have a mean

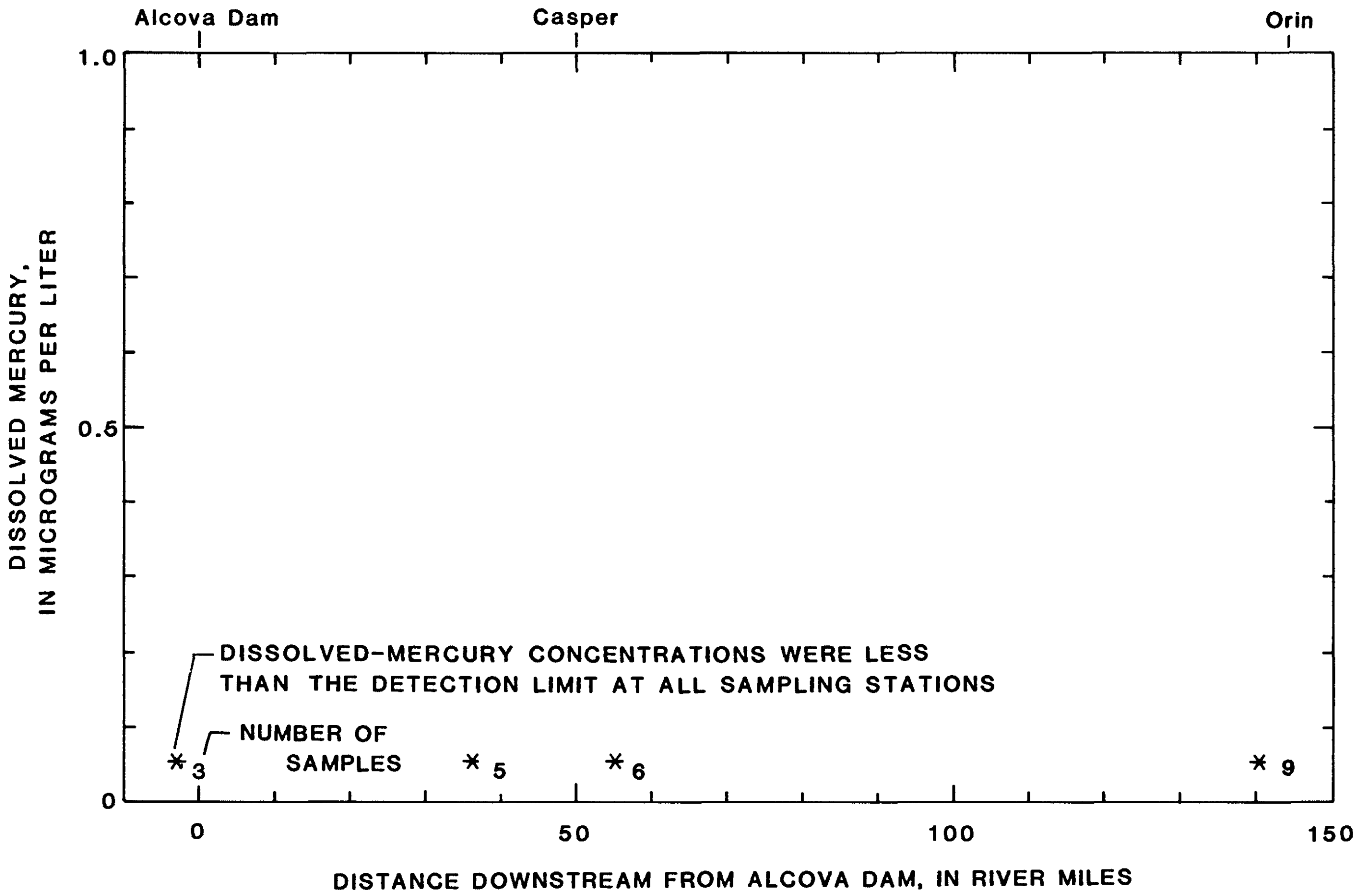


Figure 26.--Maximum, minimum, mean, and median dissolved-mercury concentrations at four sampling stations along the North Platte River between Alcova Dam and Orin, water years 1970-79.

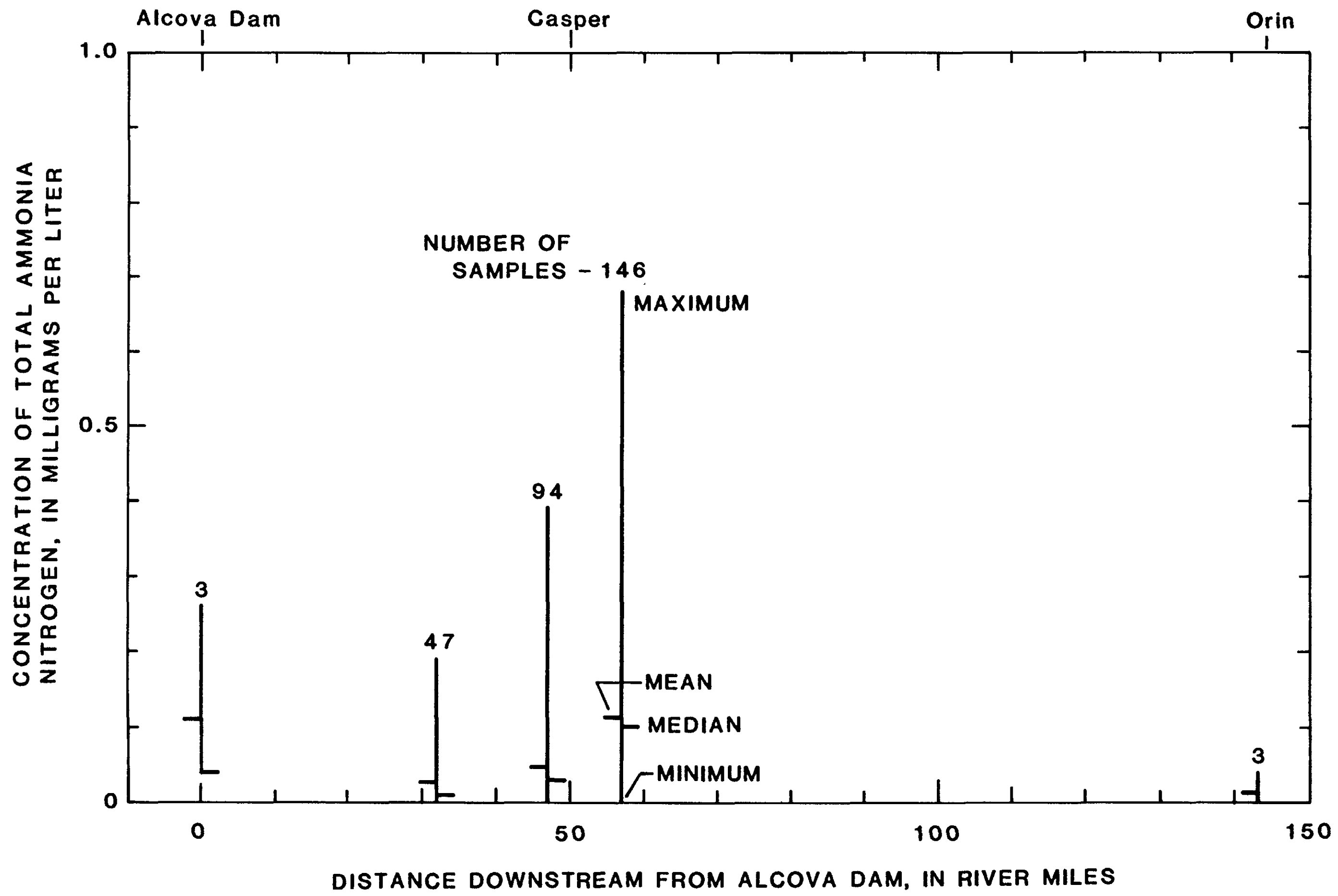


Figure 27.--Maximum, minimum, mean, and median total-ammonia-nitrogen concentrations at five sampling stations along the North Platte River between Alcova Dam and Orin, water years 1970-79.

Table 6.--Concentrations of total ammonia ($NH_3 + NH_4^+$), in milligrams per liter, containing an un-ionized ammonia concentration of 0.02 milligram per liter NH_3

[From Quality criteria for water, U.S. Environmental Protection Agency, 1976, p. 10]

Temperature (degrees Celsius)	pH								
	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0
5	160.0	51.0	16.0	5.1	1.6	0.53	0.18	0.071	0.036
10	110.0	34.0	11.0	3.4	1.1	.36	.13	.054	.031
15	73.0	23.0	7.3	2.3	.75	.25	.093	.043	.027
20	50.0	16.0	5.1	1.6	.52	.18	.070	.036	.025
25	35.0	11.0	3.5	1.1	.37	.13	.055	.031	.024
30	25.0	7.9	2.5	.81	.27	.099	.045	.028	.022

of 0.11, a median of 0.10, and a maximum of 0.68 mg/L. Filtration of the dissolved sample may account for better preservation of the ammonia present at the time of sampling.

A few ammonia samples taken at river mile 57 have exceeded the 0.5 mg/L maximum limit suggested for drinking-water supplies. However, mean and median concentrations are well below this limit.

Nitrate Nitrogen

Since 1945 about 2,000 cases of infant methemoglobinemia have been reported in Europe and North America. About 8 percent of the affected infants died (National Academy of Sciences and National Academy of Engineering, 1973, p. 73). Methemoglobinemia is a blood disorder which normally occurs only in infants. Infants (less than 3 months old) have the necessary gastrointestinal conditions needed to convert the relatively harmless nitrate ions to nitrite ions. The nitrite ions combine with the hemoglobin in the blood, impairing the transport of oxygen which results in oxygen deprivation.

The source of high nitrates frequently is shallow wells which have been contaminated from septic tanks or barnyard drainage. Surface-water concentrations of nitrate-nitrogen are generally low. The mean for the NASQAN stations in 1975 was 0.61 mg/L (Briggs and Ficke, 1977, p. 35).

Criteria

The maximum contaminant level established by the National Interim Primary Drinking Water Regulations (U.S. Environmental Protection Agency, 1977) is 10 mg/L nitrate as nitrogen.

Observations

Data for both dissolved- and total-nitrate concentrations are presented in figures 28 and 29. The nitrate concentrations presented are actually sums of both nitrate and nitrite ions reported as nitrogen. Nitrite is unstable in oxygenated water and, if present, is normally converted to the nitrate form. For convenience, nitrite plus nitrate values are referred to simply as nitrate values in this report.

Constituents designated "total" nitrates are misleading. Total nitrates have been analyzed on clear, settled samples. The U.S. Environmental Protection Agency (1979, p. 353.2-1) suggests that sediment, if present, be removed by laboratory filtration of samples for total-nitrate analysis. The assumption is made that all the nitrate is in solution.

Both dissolved and total nitrate were analyzed in 78 samples. Statistical analysis showed that total nitrate was poorly correlated with dissolved nitrate. The r^2 (residual squared) was 0.12. The "total" nitrate evidently is a poor indicator of the dissolved nitrate. The mean value for total nitrate was 0.38, the median was 0.35, and the maximum was 1.9 mg/L, all of which were values less than the corresponding statistics for the dissolved samples. For dissolved nitrate the mean value was 0.52, the median 0.43, and the maximum 3.2 mg/L.

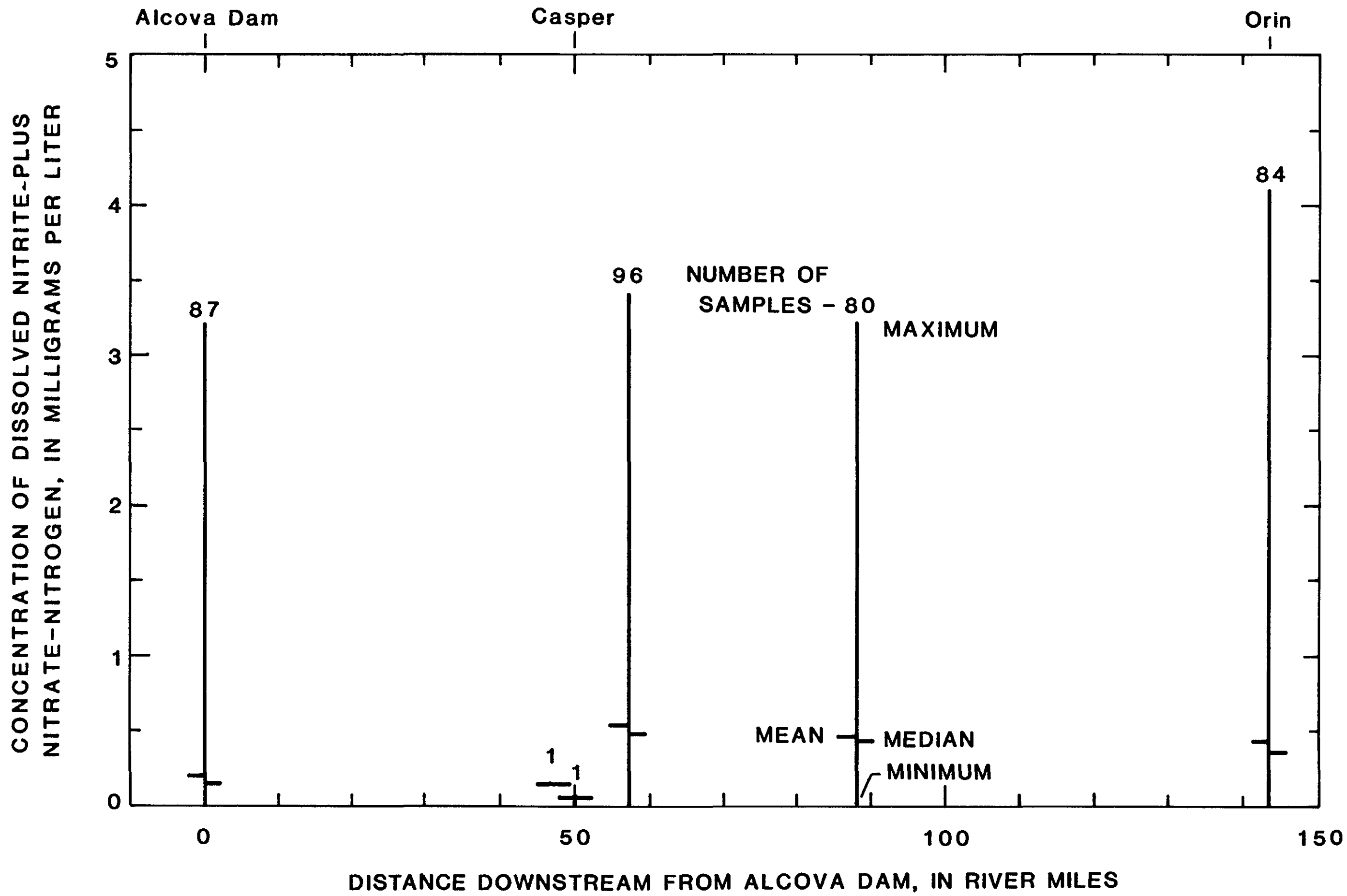


Figure 28.--Maximum, minimum, mean, and median dissolved nitrite-plus nitrate-nitrogen concentrations at six sampling stations along the North Platte River between Alcova Dam and Orin, water years 1970-79.

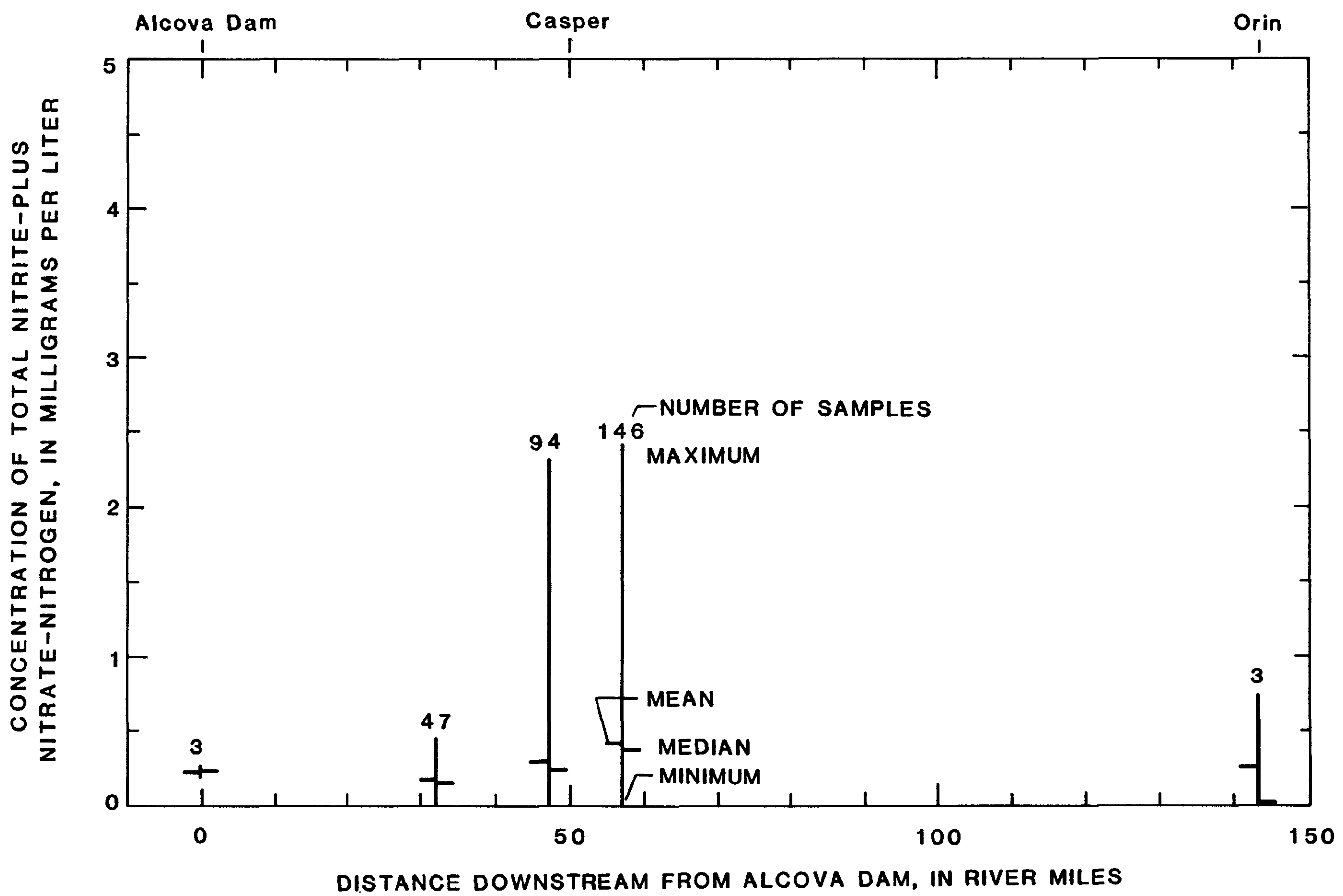


Figure 29.--Maximum, minimum, mean, and median total nitrite-plus nitrate-nitrogen concentrations at five sampling stations along the North Platte River between Alcova Dam and Orin, water

Future sampling of nitrate should be limited to dissolved nitrate unless it can be shown that: (1) Nitrates are associated with the sediment, (2) a representative sample of the water-sediment mixture is used for analysis, and (3) an effective means for preservation of the total sample can be found. Past total-nitrate determinations are of questionable value.

Total Kjeldahl Nitrogen

Total kjeldahl nitrogen analysis measures both the ammonia and organic nitrogen. It includes all nitrogen except nitrate and nitrite. In many nutrient-rich hydrologic systems, much of the nitrogen is taken up by aquatic plants and animals. The 1975 NASQAN data showed a mean total kjeldahl nitrogen value of 0.85 mg/L (Briggs and Ficke, 1977, p. 36).

Criteria

None.

Observations

Nearly nine-tenths of all the values were 1.0 mg/L or less. The mean and median values at river mile 57 were slightly higher than those at the other stations (fig. 30).

Oxygen

The solubility of dissolved oxygen in fresh waters is determined primarily by water temperature and atmospheric pressure. Saturation values for dissolved oxygen at the altitude of this reach of stream range from about 19 mg/L at 0°C to about 6 mg/L at 30°C. Oversaturation may result temporarily from algal production of oxygen during daylight.

Criteria

Dissolved oxygen is not required for drinking water, but it can improve the taste of water having high dissolved-iron or manganese concentrations by precipitating these ions. Dissolved-oxygen requirements to protect aquatic life are variable; a minimum value of 5 mg/L has been recommended by a number of researchers (U.S. Environmental Protection Agency, 1976, p. 226).

Observations

The dissolved-oxygen concentrations for all stations, except the station at river mile 57, have been higher than the minimum acceptable value of 5 mg/L (fig. 31). Ninety-nine percent of all values have been more than 6.4 mg/L. The decrease in mean and median values between river mile 0 and river mile 50 is likely due to increasing stream temperature.

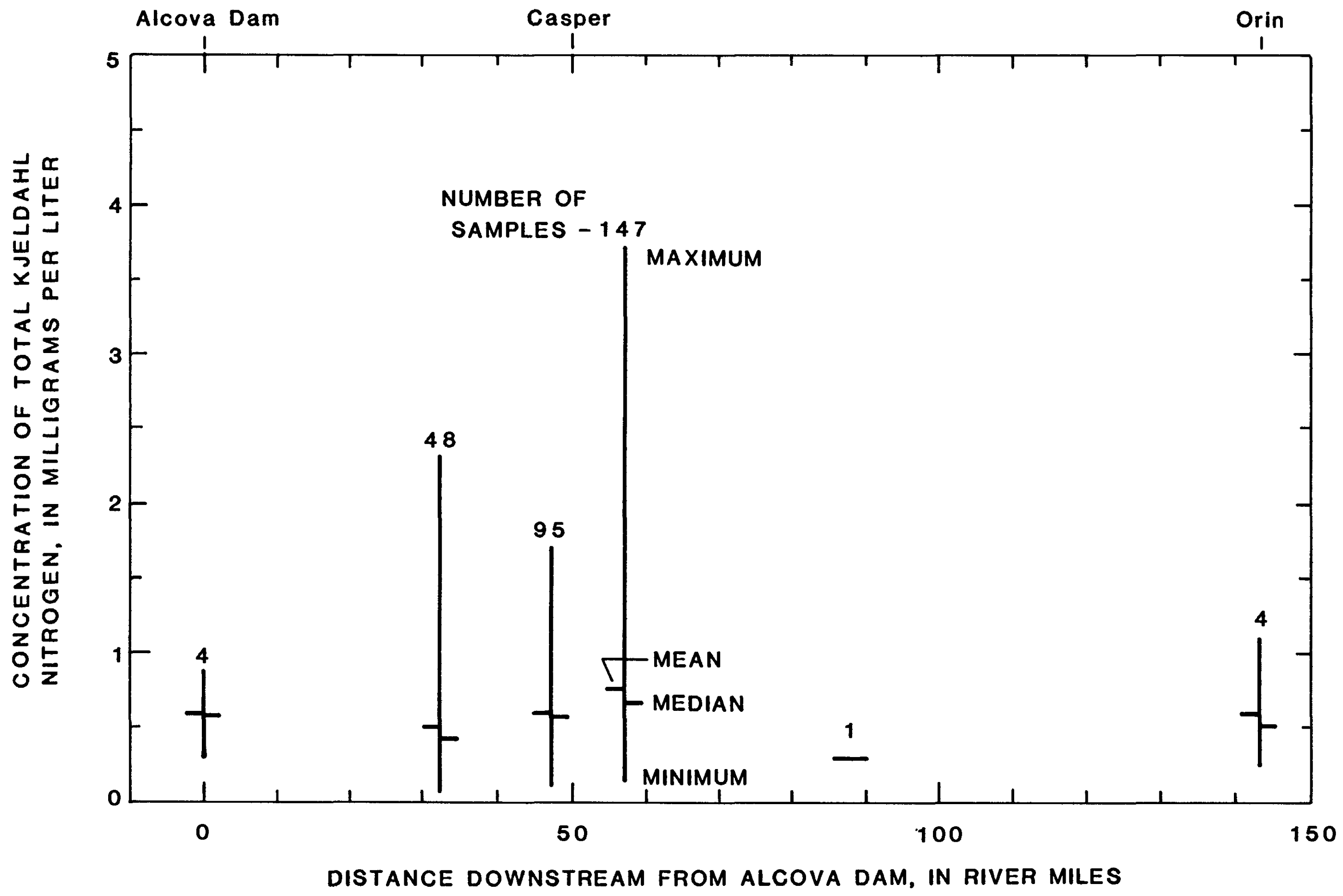


Figure 30.--Maximum, minimum, mean, and median total kjeldahl-nitrogen concentrations at six sampling stations along the North Platte River between Alcova Dam and Orin, water years 1970-79.

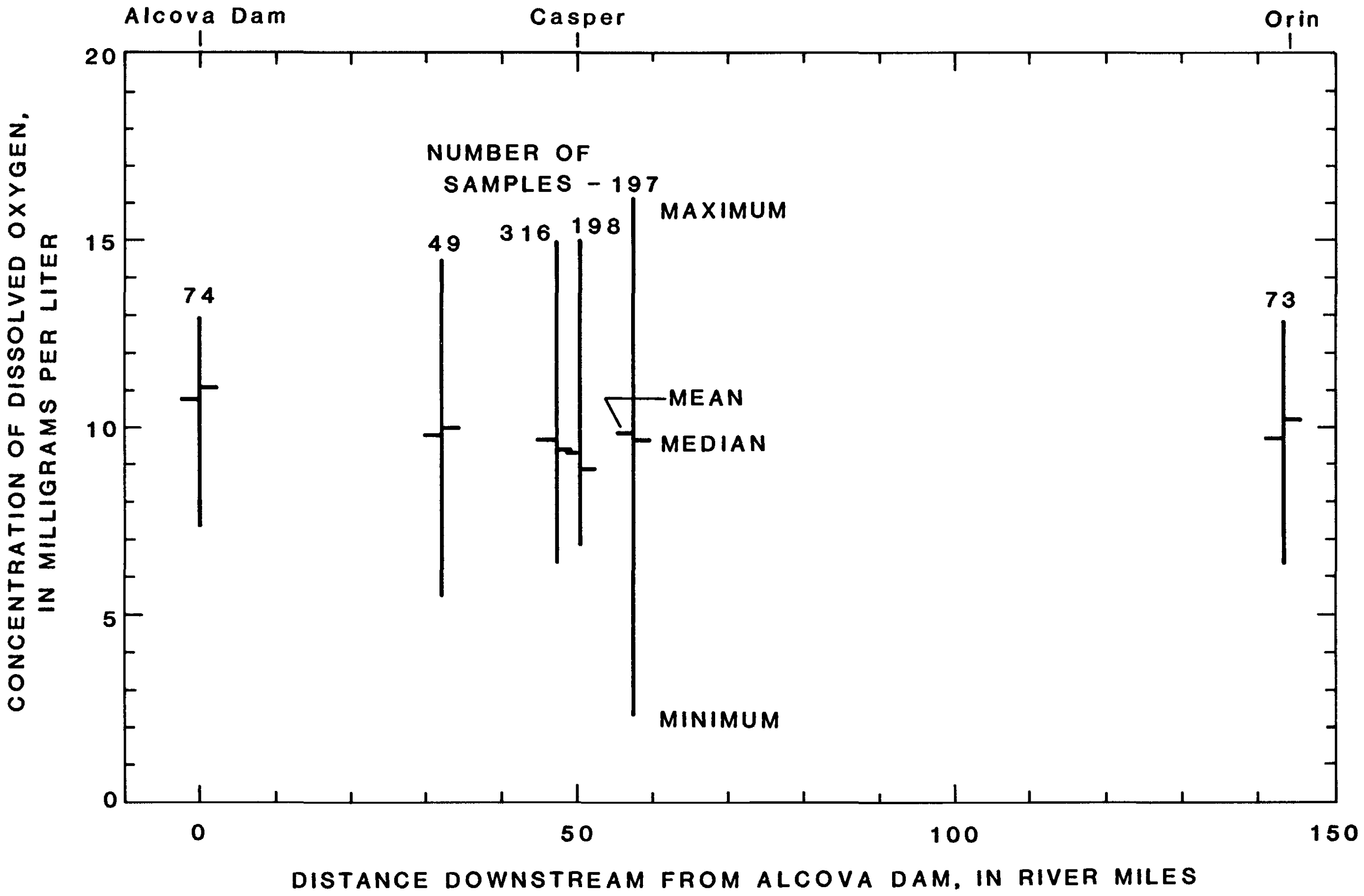


Figure 31.--Maximum, minimum, mean, and median dissolved-oxygen concentrations at six sampling stations along the North Platte River between Alcova Dam and Orin, water years 1970-79.

Total Phosphorus

Phosphorus is an essential element for all life forms. Phosphorus is often assumed to be the nutrient that limits algal growth in natural waters. Unusually high phosphate levels are able to support unusually high concentrations of algae. The resultant algal growth can cause unwanted odor and filtration problems for both domestic consumers of water and for water-treatment plants. Critical phosphorus levels are generally lower in lakes and reservoirs than in streams where turbidity tends to limit algal growth by inhibiting light penetration (National Academy of Sciences and National Academy of Engineering, 1973, p. 81). Total phosphorus includes both dissolved and suspended phosphorus. Most of the phosphorus is associated with the sediment.

Criteria

Current National drinking-water regulations do not set standards for phosphate or phosphorus. However, criteria to prevent nuisance growths in streams and lakes or reservoirs have been suggested. In order to protect lakes or reservoirs, the total phosphorus should not exceed 0.05 mg/L at the point where the stream enters the lake or reservoir. To prevent nuisance growths in streams, the maximum concentration of phosphorus should not exceed 0.1 mg/L total phosphorus (U.S. Environmental Protection Agency, 1976, p. 356).

Observations

Total-phosphorus concentrations for the study reach have a wide range; the maximum values are above criteria suggested to protect streams and reservoirs against nuisance aquatic growth. Mean values, except at river mile 57, are below the criteria suggested to protect the stream from nuisance growth (fig. 32). The mean total-phosphorus value at river mile 143 is above the maximum concentration suggested to protect Glendo Reservoir from nuisance algal growth.

Most of the values were obtained from samples collected without using sediment-sampling techniques. Sediment samples need to be included in future quality of water data-collection programs. Combined sampling for suspended sediment and total phosphorus will allow the correlation of the two constituents.

Polychlorinated Biphenyls

PCB's (polychlorinated biphenyls) are biphenylic compounds having varying degrees of chlorination. PCB's are only slightly soluble in water but are highly soluble in fats and oils. They are relatively nonflammable and have useful heat-exchange and dielectric properties. For these reasons PCB's have been widely used in electrical capacitors and transformers.

PCB's are poisonous to man and aquatic life and are highly resistant to degradation. Medical treatment after contamination does little to remove PCB's (National Academy of Sciences and National Academy of Engineering, 1973, p. 83).

Criteria

To protect aquatic life and thereby the human consumer of fish and other aquatic life, a maximum concentration of PCB's in water of 0.001 µg/L is

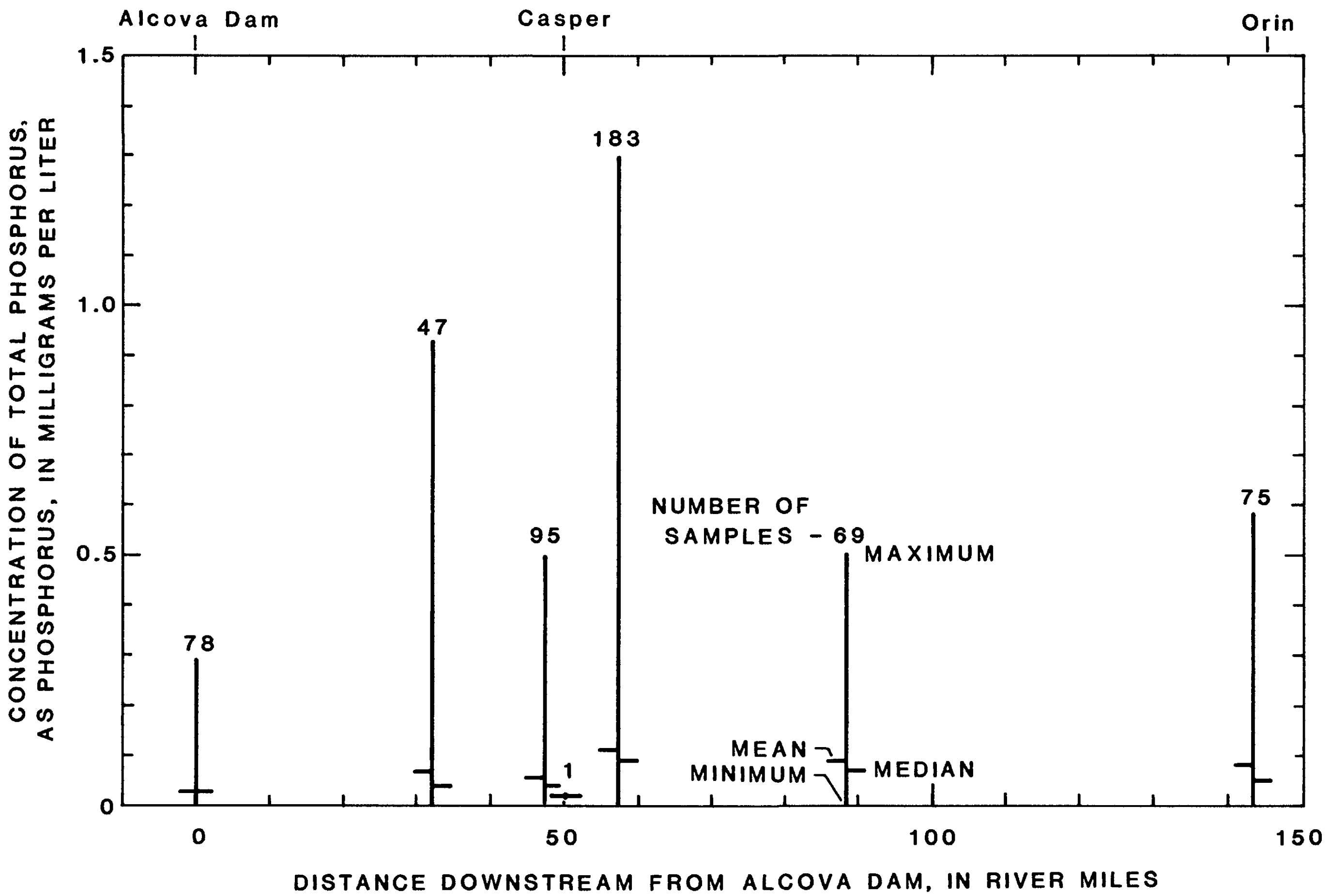


Figure 32.--Maximum, minimum, mean, and median total-phosphorus concentrations at all sampling stations along the North Platte River between Alcova Dam and Orin, water years 1970-79.

suggested. Human exposure should be kept to a minimum (U.S. Environmental Protection Agency, 1976, p. 364).

Observations

Only six samples for total PCB's in bottom material were collected--all at river mile 143. Concentrations were below the detection limit and ranged from 0 to 4 µg/kg (micrograms per kilogram); the median was 1.5 µg/kg.

Potassium

Potassium is an essential plant and animal nutrient that is relatively abundant in the earth's crust. Potassium is found in concentrations of less than 10 mg/L in natural waters. Clays strongly attract potassium, tending to keep concentrations in water low.

Criteria

None.

Observations

Mean and median dissolved-potassium concentrations show little downstream variation (fig. 33). More than 90 percent of the values are between 2.4 mg/L and 4.6 mg/L. The value of 11 mg/L at river mile 0 is abnormally high for this station and may be in error.

Suspended Sediment

Suspended sediment is the solid material in a water-sediment mixture. Sediment includes both inorganic and organic particles. Suspended-sediment concentrations affect not only the esthetics of streams but also the quality of water for many different uses, including municipal supplies, industrial use, aquatic life, and reservoir life.

Many substances, including trace metals, phosphorus, and organic compounds, tend to sorb onto sediment particles. The particles serve as sources, sinks, and transport mechanisms for the sorbed substances. Since good correlations can often be established between the "total" measurement of these substances and the sediment concentration, it is desirable to obtain a sediment-concentration analysis along with the total-phosphorus analysis. Unfortunately, the total-trace-metals and total-phosphorus concentrations analyses do not have corresponding sediment-concentrations analyses in this group of data.

Criteria

Criteria for suspended sediment vary widely. The criterion for drinking water is given in terms of turbidity rather than suspended-sediment concentration.

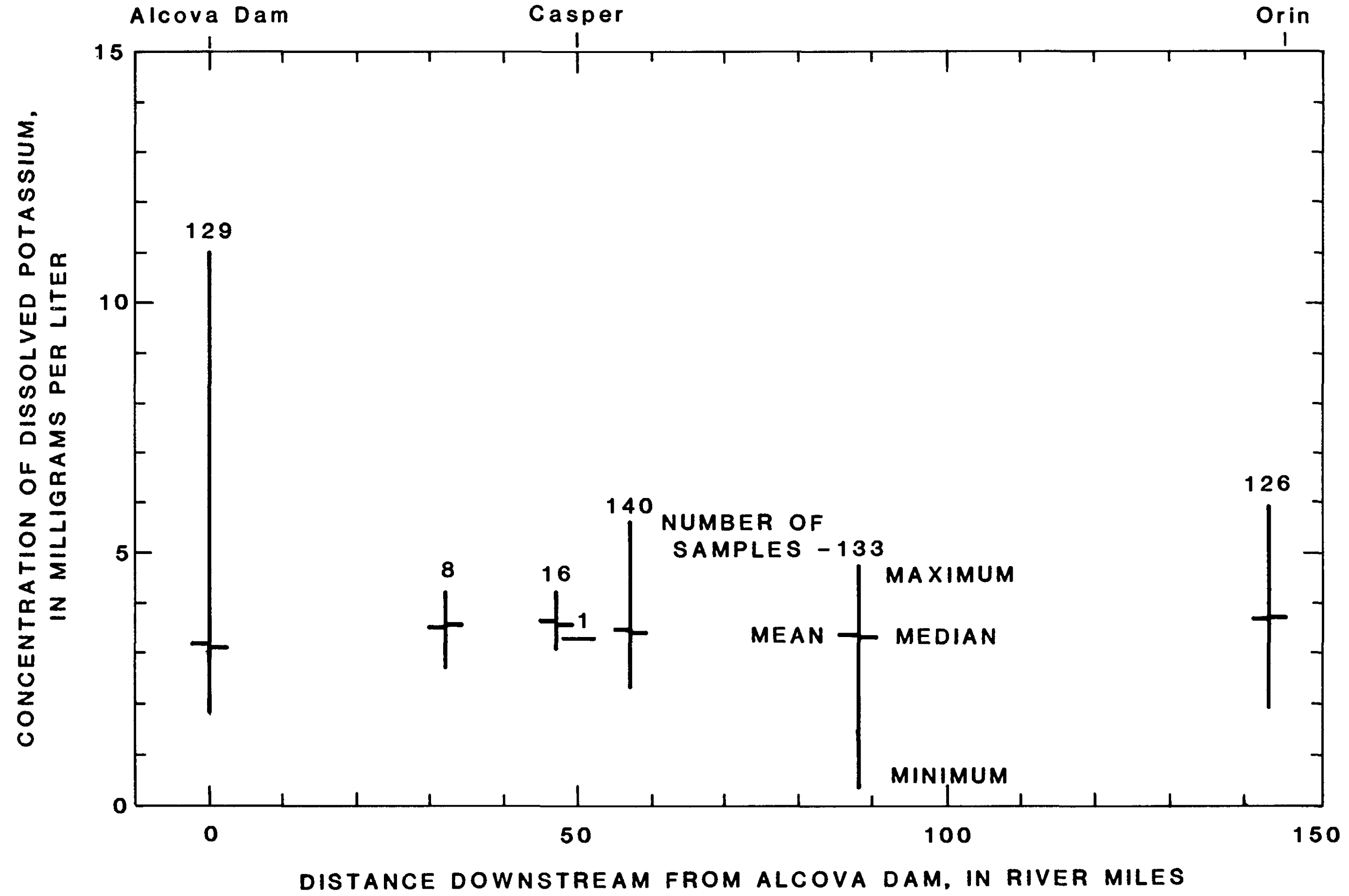


Figure 33.--Maximum, minimum, mean, and median dissolved-potassium concentrations at all sampling stations along the North Platte River between Alcova Dam and Orin, water years 1970-79.

Observations

Only the station at river mile 143 has a significant amount of suspended-sediment data available for the study reach. The 89 suspended-sediment samples collected at this station show a 10,000-fold variation in range (fig. 34). The minimum concentration was 6 mg/L and the maximum was 62,500 mg/L. The median concentration was 105 mg/L and the mean, 441 mg/L. The mean suspended-sediment concentration for the 1975 NASQAN stations was 833 mg/L (Briggs and Ficke, 1977, p. 41). The tributaries are the principal sources of sediment downstream from Alcova Reservoir which traps nearly all suspended sediment entering it.

Future sampling programs should include the collection of suspended-sediment samples in conjunction with the collection of total-trace-metal and total-phosphorus samples. Correlation could be established between suspended-sediment concentrations and the total-trace-metal and total-phosphorus concentrations to better define the hydrologic system.

Selenium

The toxicity of selenium is similar to that of arsenic. Recent studies, however, indicate that small amounts of selenium are essential in animal diets (U.S. Environmental Protection Agency, 1976, p. 385). Usually concentrations in surface and ground waters are below 50 µg/L. Researchers suggest that these natural, low-selenium levels result from the precipitation of the selenite ion with ferric hydroxide. Another study indicates that both selenite and selenate are removed from water by microbial activity (National Academy of Sciences and National Academy of Engineering, 1973, p. 316).

During the 1960's a study on selenium in waters in and adjacent to the Kendrick irrigation project indicated that four streams were the principal tributaries contributing selenium to the North Platte River (Crist, 1974, p. 2). The tributaries and the selenium concentrations in samples collected in June 1979 are as follows: Poison Spring Creek, 200 µg/L; Poison Spider Creek, 74 µg/L; Oregon Trail Drain, 54 µg/L; and Casper Creek, 45 µg/L. The selenium load from these tributaries was 7.6 kg/d (kilograms per day).

Criteria

The National Interim Primary Drinking Water Regulations (U.S. Environmental Protection Agency, 1977) establish a maximum concentration of 10 µg/L for selenium. A maximum selenium concentration of 50 µg/L is recommended for livestock water (National Academy of Sciences and National Academy of Engineering, 1973, p. 316).

Observations

Dissolved-selenium concentrations ranged from more than the maximum allowable for drinking water, 10 µg/L to less than 1 µg/L (fig. 35). Selenium sampling has been too infrequent to adequately define the temporal and spatial variation of this element. More frequent selenium sampling is needed on both the North Platte and its tributaries.

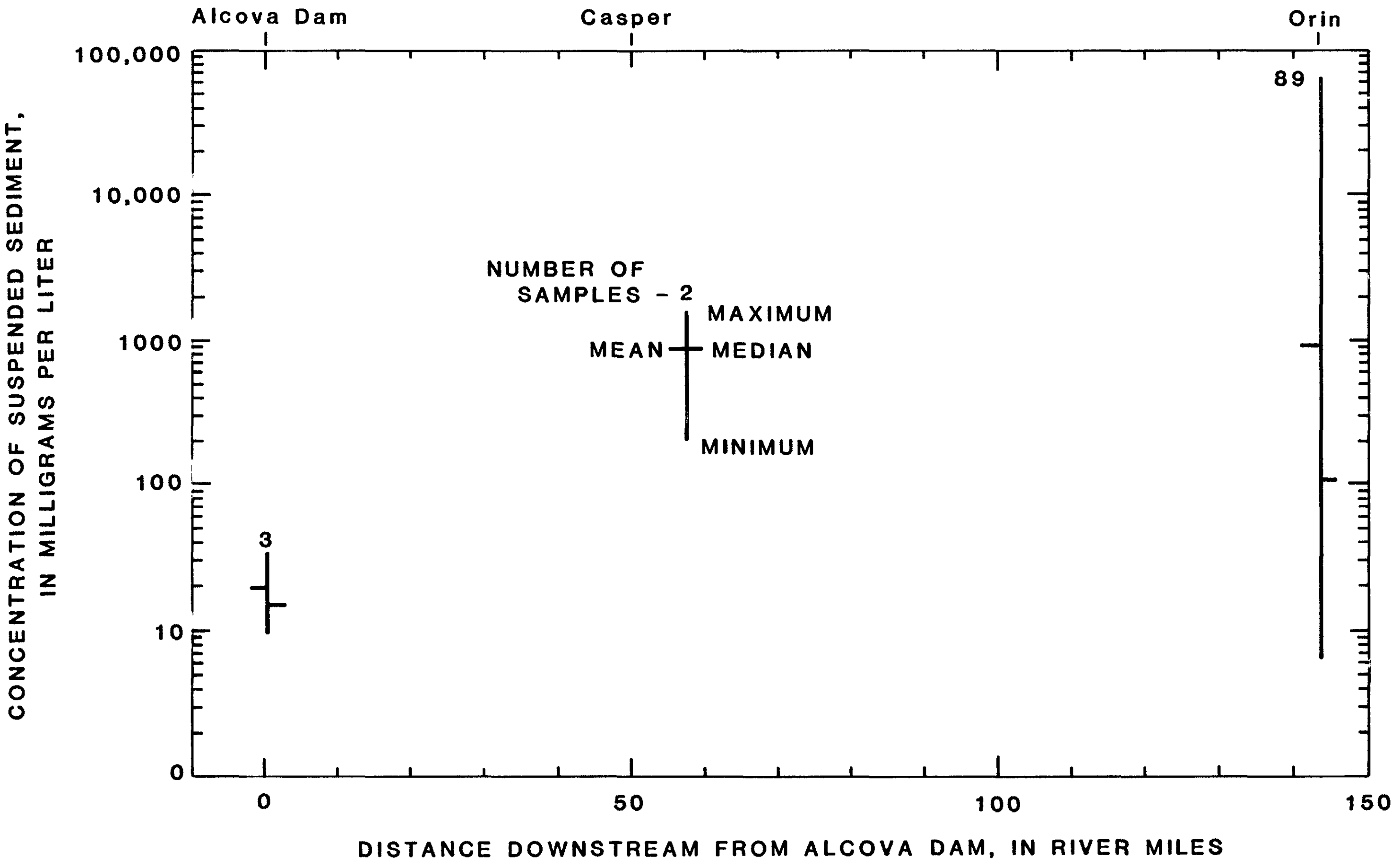


Figure 34.--Maximum, minimum, mean, and median suspended-sediment concentrations at three sampling stations along the North Platte River between Alcova Dam and Orin, water years 1970-79.

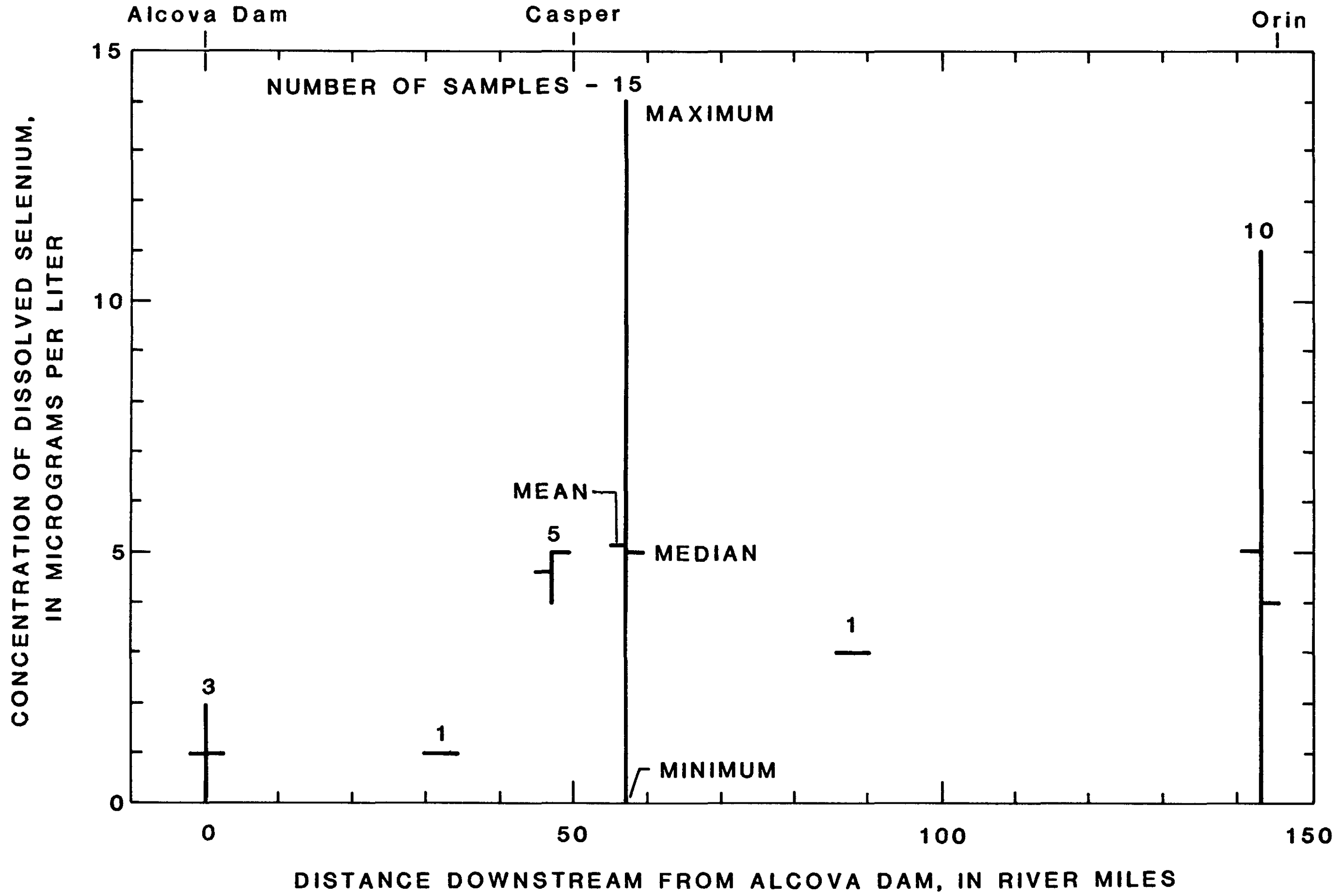


Figure 35.--Maximum, minimum, mean, and median dissolved-selenium concentrations at six sampling stations along the North Platte River between Alcova Dam and Orin, water years 1970-79.

Tributary inflow between river miles 0 and 57 provides the principal source of selenium for the study reach. The variability of the selenium concentrations in the study reach is due to the variability of the selenium load from the tributaries and the variability of the discharge of the North Platte water receiving the load. The dilution effect of discharge on selenium concentrations is shown in figure 36 for assumed selenium loads of 10 and 20 kg/d. These loads are arbitrary but are within the maximum-load range known to have occurred. A sample collected on April 24, 1972 had a selenium concentration of 14 µg/L. The stream discharge, which was 1,020 ft^3/s, carried a selenium load of 35 kg/d.

Silica

Silicon is the second most abundant element in the earth's crust. The element is commonly reported in terms of the oxide, silica. Limited solubility, and uptake and release by diatoms are known controls on silica concentrations in water.

Criteria

Silica concentrations are primarily a concern in industrial uses of water. Boiler-feed water has stringent silica requirements. High-pressure boilers (700 to 1,500 lb/in^2) require silica concentrations of less than 0.7 mg/L (National Academy of Sciences and National Academy of Engineering, 1973, p. 377). Electrical utilities using high-pressure boilers may require concentrations as low as 0.01 mg/L. Such stringent requirements necessitate treatment to remove silica.

Observations

No downstream trend in mean and median values is detectable (fig. 37). About 84 percent of all values are between 8 and 16 mg/L.

Sodium

Sodium, the highly soluble alkali metal, is a major ion in nearly all waters. Sources of sodium in the hydrologic system are caused by sewage and industrial effluents, salts used in deicing roads, and water softeners. Normally, human intake of sodium may average 6 grams per day without creating adverse effects on health (National Academy of Sciences and National Academy of Engineering, 1973, p. 88). More restrictive limits than are the normal intake are often prescribed by physicians for individuals afflicted with such health problems as high blood pressure and edema.

Criteria

The national drinking-water regulations do not include sodium. The regulations (U.S. Environmental Protection Agency, 1977) suggest, however, that the States monitor the sodium concentrations of public water supplies and advise the public and physicians of high levels so individuals who require low-sodium diets might use an alternative low-sodium source of drinking water, if necessary.

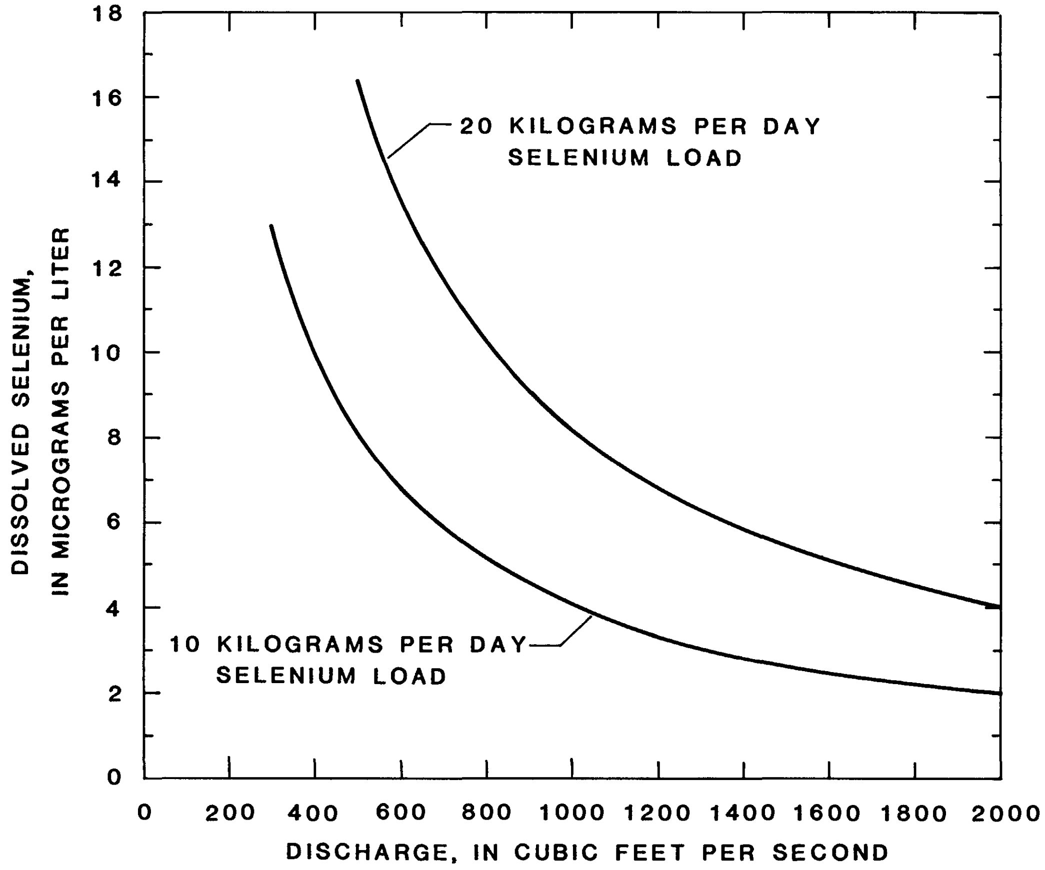


Figure 36.--Selenium-concentration model for the North Platte River at Casper.

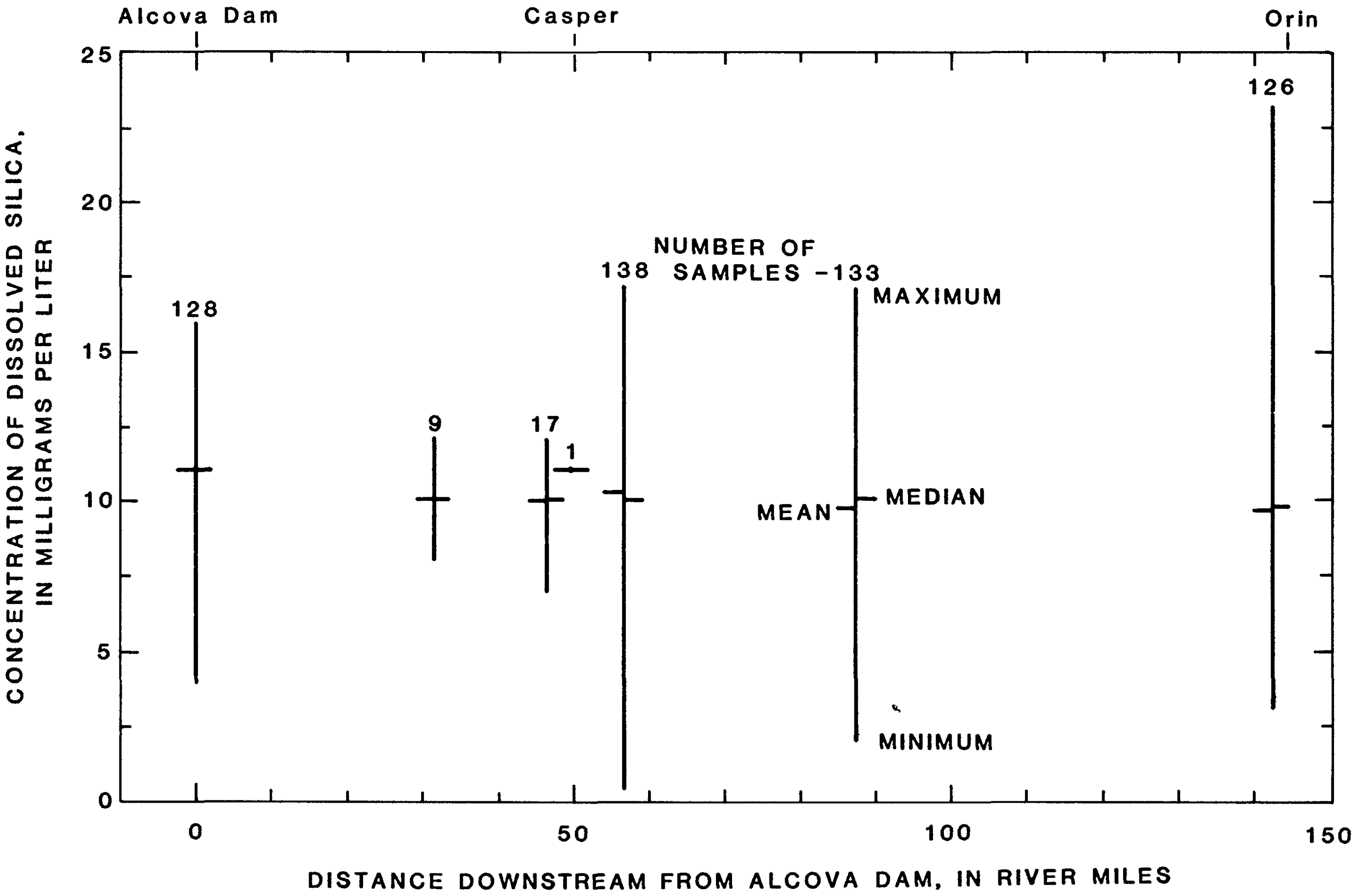


Figure 37.--Maximum, minimum, mean, and median dissolved-silica concentrations at all sampling stations along the North Platte River between Alcova Dam and Orin, water years 1970-79.

Observations

Mean and median dissolved-sodium concentrations increase from about 30 to about 50 mg/L between river mile 0 and river mile 57 (fig. 38). The range in concentrations at river mile 57 and downstream is much greater than at the upstream sampling stations. Over 95 percent of the sodium values at all stations are below 80 mg/L.

Sodium concentration is correlated with the dissolved-solids concentration and specific conductance. The following equations may be used to predict sodium concentrations for this reach of stream:

Sodium (mg/L) = 0.162 X dissolved solids concentration (mg/L) - 20; and
sodium (mg/L) = 0.099 X specific conductance (μS) - 17.

Sodium-Adsorption Ratio

The sodium-adsorption ratio (SAR) is used to estimate the degree to which sodium in irrigation water will be adsorbed by the soil and is calculated as follows:

$$\mathrm{SAR} = \frac{(\mathrm{Na}^{+})}{\sqrt{\dfrac{(\mathrm{Ca}^{++}) + (\mathrm{Mg}^{++})}{2}}}$$

Ion concentrations are expressed in milliequivalents per liter.

Exchange of sodium for calcium and magnesium on soil-exchange sites results in poor soil permeability and poor plant growth.

Criteria

Recommended limits for SAR are complicated by many factors such as type of soil and crop-irrigation practice. Handbook 60 (U.S. Salinity Laboratory Staff, 1954) is the authoritative text on this subject. A general recommendation is a maximum SAR of 4 for sensitive crops and 8 to 18 for other crops (National Academy of Sciences and National Academy of Engineering, 1973, p. 330).

Observations

Mean and median SAR values for all stations are less than 1.5 (fig. 39). The SAR values for the stations at river mile 57 and farther downstream have much greater ranges than those for the upstream stations. However, more than 93 percent of all SAR values are 1.85 or less. SAR values for the study reach of the North Platte may be predicted from the following equations:

SAR = 0.00328 X dissolved solids concentration (mg/L) - 0.20; and
SAR = 0.00198 X specific conductance (μS) + 0.04.

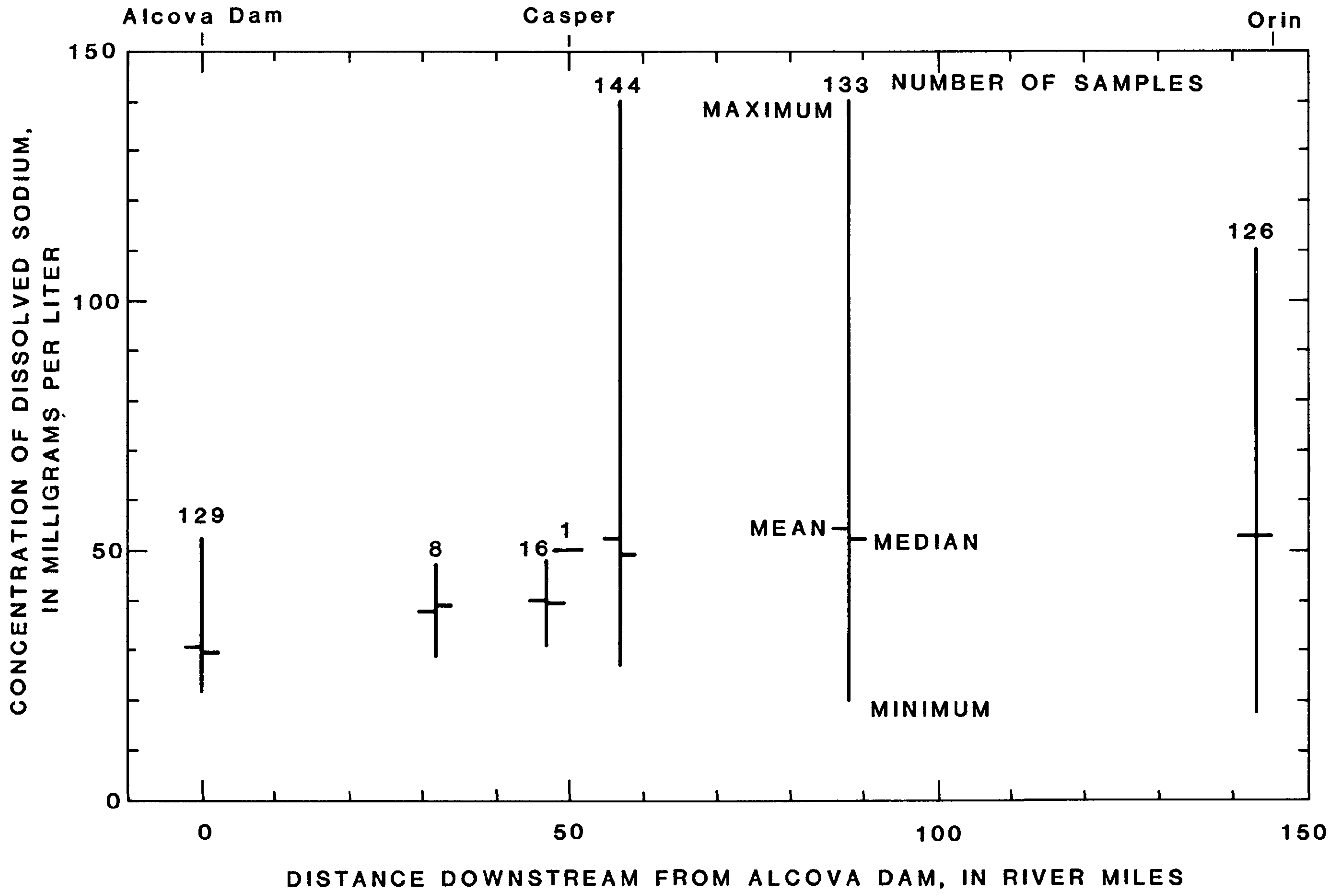


Figure 38.--Maximum, minimum, mean, and median dissolved-sodium concentrations at all sampling stations along the North Platte River between Alcova Dam and Orin, water years 1970-79.

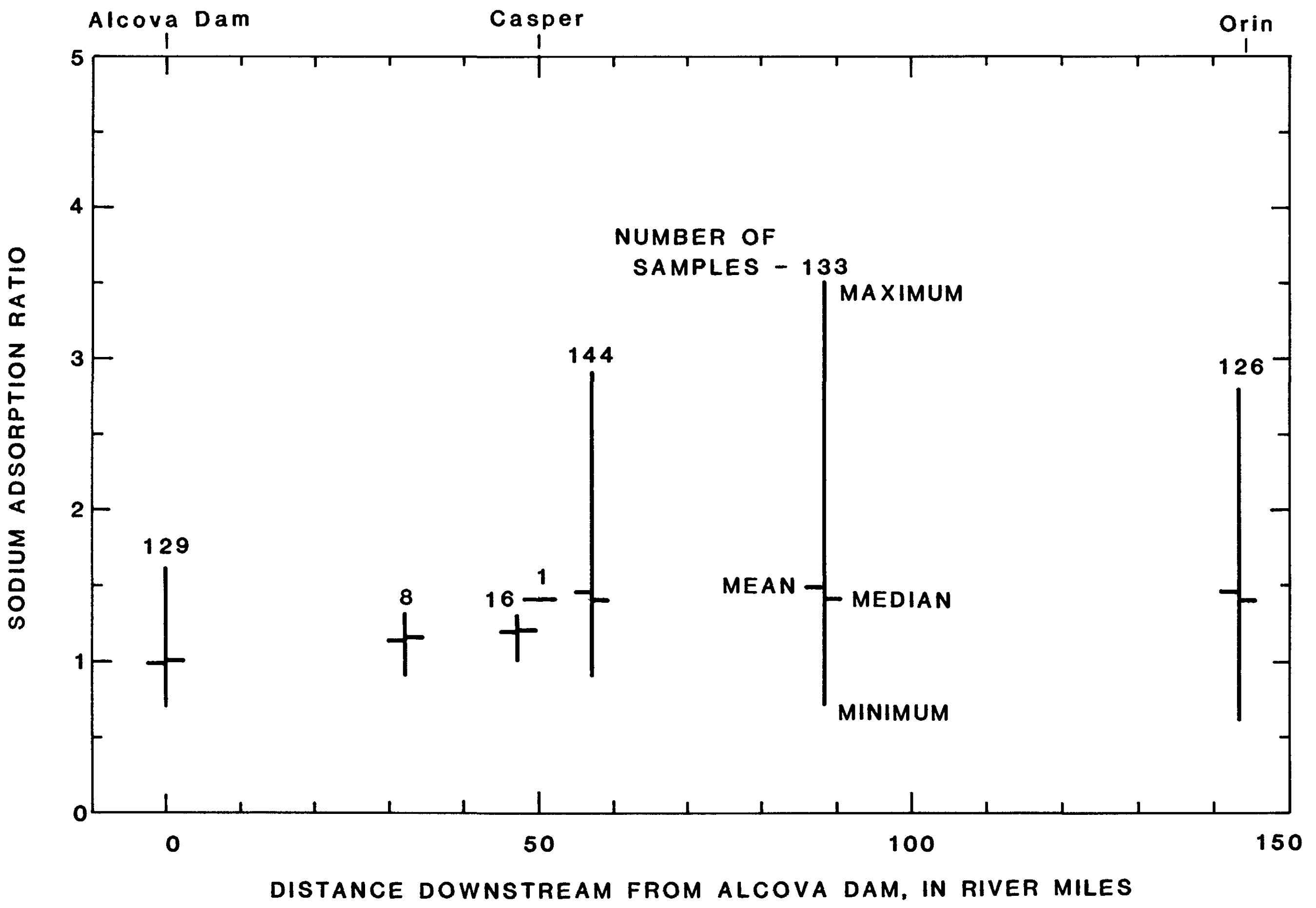


Figure 39.--Maximum, minimum, mean, and median sodium-adsorption ratio at all sampling stations along the North Platte River between Alcova Dam and Orin, water years 1970-79.

Specific Conductance

Specific conductance is the electrical conductivity of 1.0 cubic centimeter of water measured between opposite faces at a specified temperature. The traditional unit of measurement, the mho, is the reciprocal of the unit of resistance, the ohm. The name "mho" has been replaced by "siemen" in the International System of Units, which has been adopted by the American Society for Testing and Materials.

Specific conductance varies with temperature. For this reason, reported specific conductances of water have been corrected for a standard temperature of 25°C. Although the response of specific conductance differs for individual salts and concentrations, an increase in temperatuare of 1°C in a dilute solution will generally increase the specific conductance about 2 percent (Hem, 1970, p. 97).

Specific conductance provides a quick, easily-obtained field estimate of the dissolved-solids concentration. Although a general formula may be used, it is best to establish the correlation between specific conductance and dissolved-solids concentration for an individual site or specific reach of stream. Concentrations of other constituents may also correlate well with specific conductance.

In the past, specific-conductance values were determined in the laboratory. Most of the specific-conductance values for the study period were determined in the field.

Criteria

Specific-conductance values are used in evaluating the salinity hazard of irrigation water. The classification of irrigation water for use in arid or semiarid regions is shown in table 7. A more complete description is found in Handbook 60 (U.S. Salinity Laboratory Staff, 1954, p. 76-80).

Observations

Mean and median values of specific conductance increase approximately 40 percent between river mile 0 and river mile 57 (fig. 40). Little change in mean and median values is evident downstream from river mile 57. Although some high values are shown by the maximums in figure 39, 96 percent of all values are 960 µS or less.

Specific conductance correlates well with the constituents shown in table 5. (The regression equation for each of the constituents listed in table 5 is given in its respective section.) Generally, however, the correlation is not as good with the specific conductance as with the dissolved-solids concentration. This may be due to the relative precision and accuracy of the two measurements.

Strontium

Strontium, an alkaline earth, is chemically similar to calcium and barium. Strontium salts generally are intermediate in solubility--between

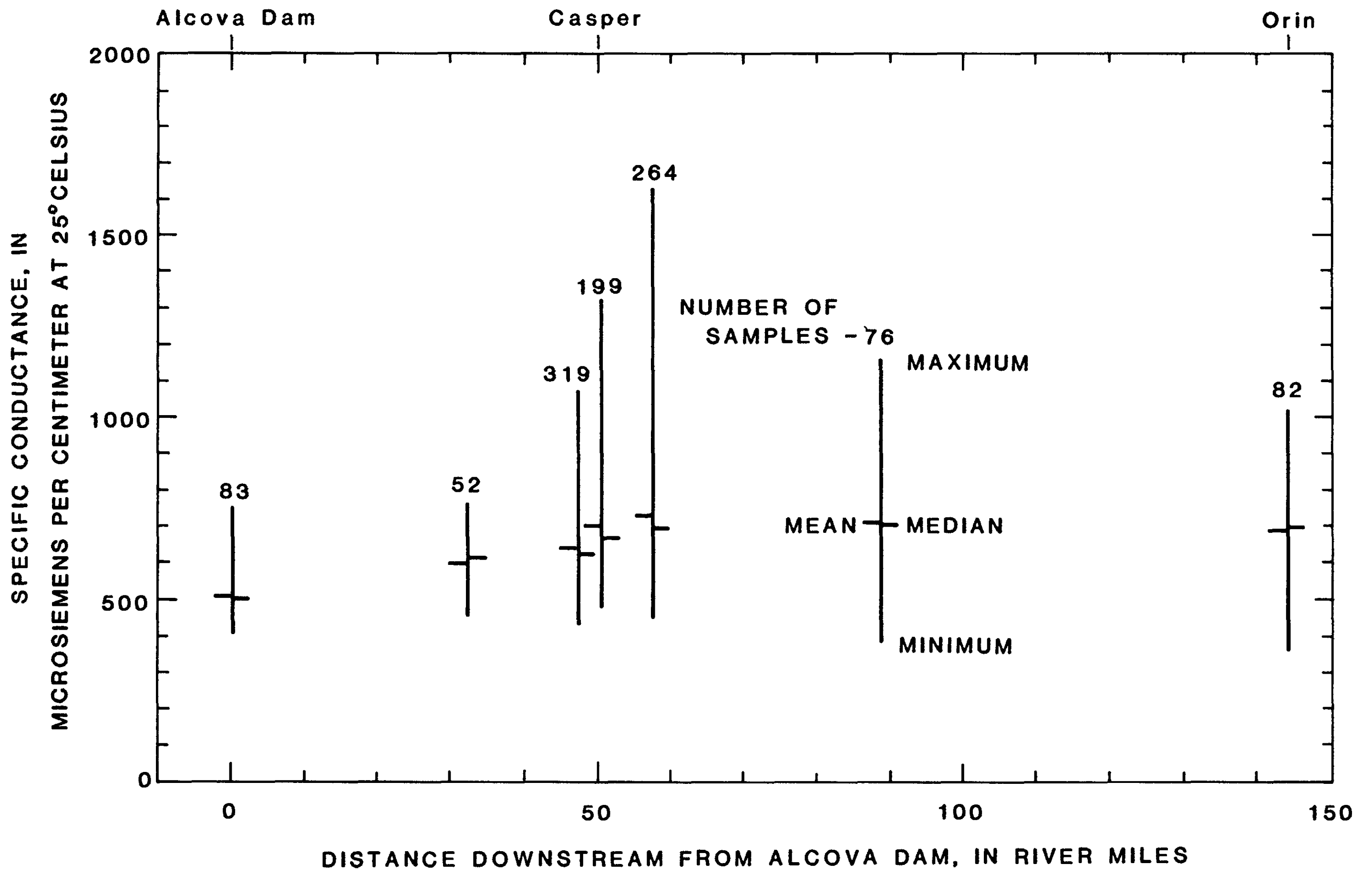


Figure 40.--Maximum, minimum, mean, and median specific conductance at all sampling stations along the North Platte River between Alcova Dam and Orin, water years 1970-79.

Table 7.--Classification of irrigation water in arid or semiarid regions

[National Academy of Science and National Academy of Engineering, 1973, p. 335]

Classification	Specific conductance (microsiemens per per centimeter at 25° Celsius)
Water for which no detrimental effects are usually noticed	0 - 750
Water that can have detrimental effects on sensitive crops	750 - 1,500
Water that can have adverse effects on many crops; requires careful management practices	1,500 - 3,000
Water that can be used on tolerant plants or permeable soils with careful management practices	3,000 - 7,500

calcium and barium. The median strontium concentration found in the water supplies of the Nation's 100 largest cities was 110 μg/L (Durfor and Becker, 1964, p. 78).

Criteria

There are no National drinking-water regulations for nonradioactive strontium.

Observations

Only the station at river mile 57 has been sampled for dissolved strontium to any extent. The concentrations of the eight samples taken there vary considerably (fig. 41).

Strontium concentrations show a correlation with the dissolved-solids concentration and specific conductance. The dissolved-strontium concentration may be predicted from the specific conductance as follows:

Dissolved strontium (μg/L) = 1.13 X specific conductance (μS) - 218.

The correlation of determination (r^2) is 0.838; however, this is based upon only 10 samples.

Sulfate

Sulfate is the stable form of sulfur in an oxidizing environment. Most sulfate salts are highly soluble and readily leached from soils.

High sulfate concentrations are objectionable in drinking water because of undesirable taste and laxative effects. Taste may be a problem at a concentration of about 250 mg/L. The laxative effect varies with the individual and the type of cation associated with the sulfate. Magnesium-sulfate type waters are the most laxative. Sulfate concentrations as low as 200 mg/L may have a laxative effect on sensitive individuals unaccustomed to the water. However, the average individual can tolerate sulfate concentrations of 500 to 1,000 mg/L without ill effects (National Academy of Sciences and National Academy of Engineering, 1973, p. 89).

Criteria

The National Secondary Drinking Water Regulations (U.S. Environmental Protection Agency, 1979) recommend a maximum sulfate concentration of 250 mg/L for public water supplies.

Observations

Mean and median dissolved-sulfate concentrations increase by about 50 percent between river mile 0 and river mile 57 (fig. 42). The tributaries and irrigation drains entering the North Platte along this reach have relatively high sulfate concentrations, even during periods of high flow. The sample

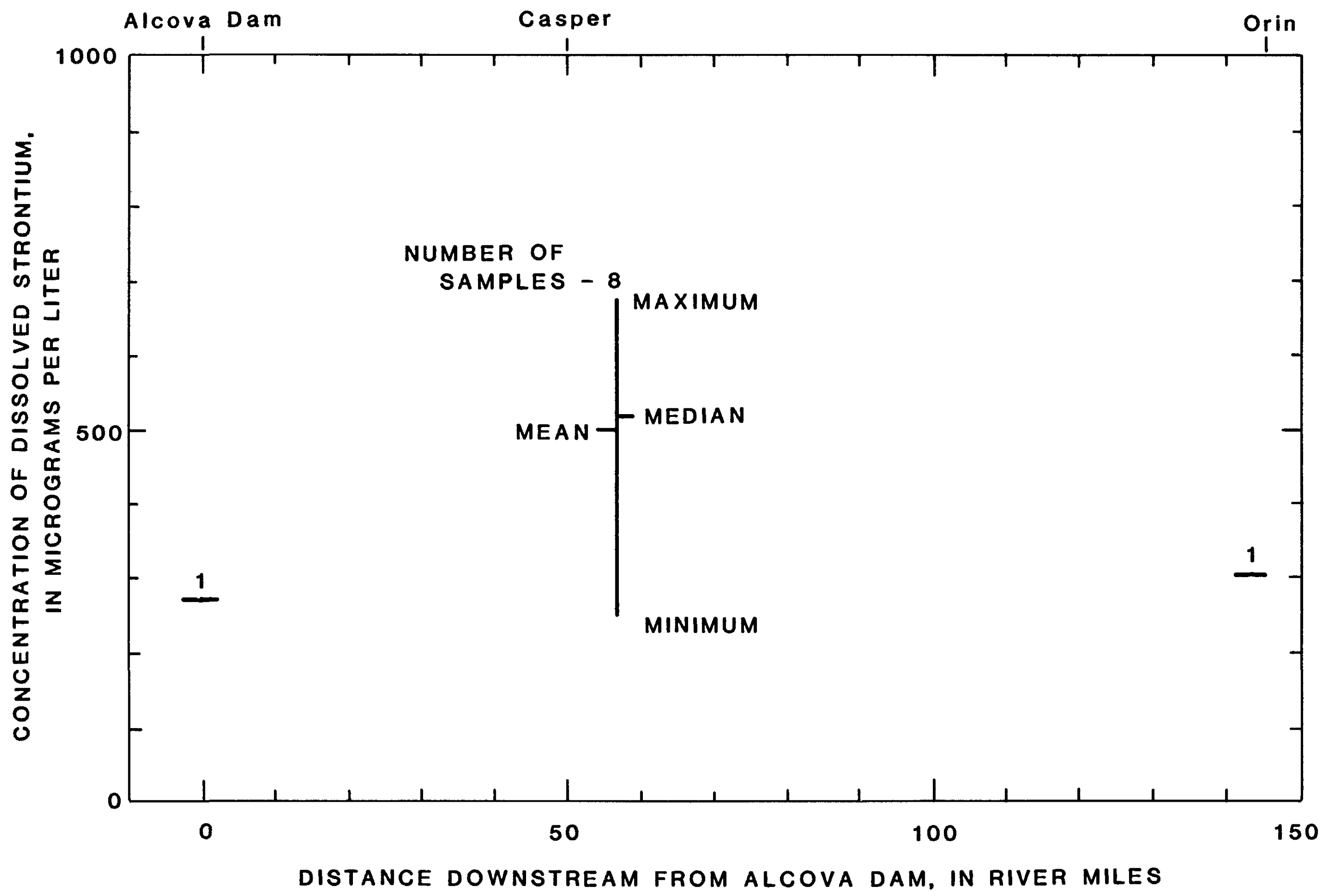


Figure 41.--Maximum, minimum, mean, and median dissolved-strontium concentrations at three sampling stations along the North Platte River between Alcova Dam and Orin, water years 1970-79.

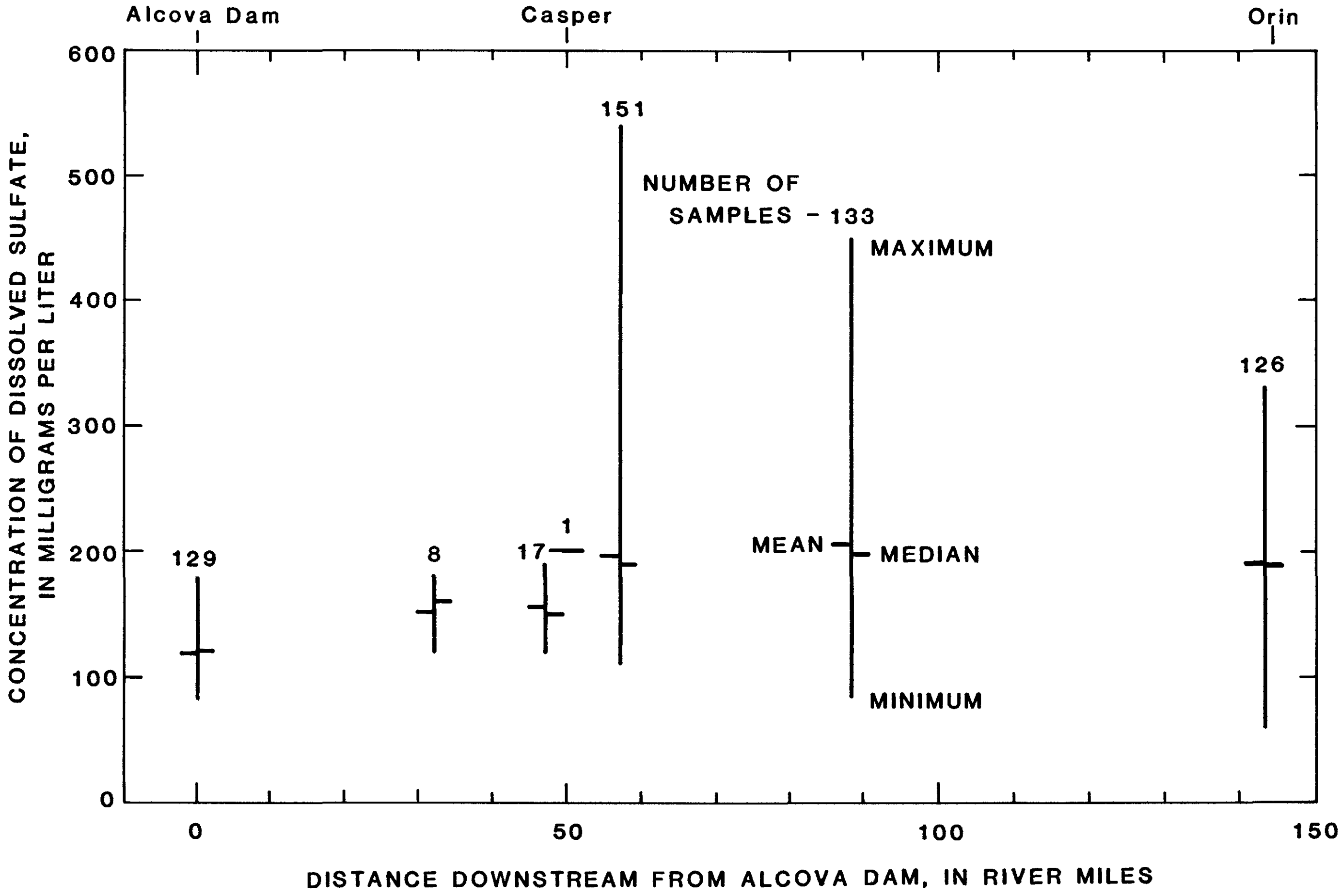


Figure 42.--Maximum, minimum, mean, and median dissolved-sulfate concentrations at all sampling stations along the North Platte River between Alcova Dam and Orin, water years 1970-79.

with maximum sulfate concentration (540 mg/L) and collected at river mile 57 is due to the large sulfate load brought into the stream from tributaries. Downstream from river mile 57 the principal tributaries, which have low sulfate concentrations during the periods of high flow, tend to dilute the sulfate concentration of the main stream.

All sulfate concentrations upstream from river mile 57 were less than 250 mg/L. The stations between river mile 0 and river mile 57, however, were not frequently sampled for sulfate. Sulfate concentrations of about 12 percent of the samples collected from river mile 57 to river mile 143 were 250 mg/L or greater. The NASQAN mean for sulfate (water year 1975) was 133 mg/L (Briggs and Ficke, 1977, p. 25).

Sulfate concentrations correlate well with both dissolved-solids concentrations and specific conductance. Sulfate concentrations may be predicted by the following equations:

Sulfate (mg/L) = 0.582 X dissolved-solids concentration (mg/L) - 63; and
sulfate (mg/L) = 0.367 X specific conductance (μS) - 60.

Turbidity

Turbidity is a measure of the optical interference of light transmission by suspended particles in water. Turbidity measurements in this report were made with a nephelometer which measures the intensity of light scattered by suspended particles. The unit of measurement is the NTU (nephelometric turbidity unit).

It should be noted that turbidities were measured in a laboratory several days after sampling. No preservation techniques for the samples were used. Ideally, turbidity values should be measured at the sampling site or shortly after sampling.

Turbidity is a factor in evaluating water quality for many uses. Turbidity affects light penetration in lakes and streams and is therefore very important to aquatic life. Esthetically, clear water is more pleasing than turbid water for drinking, boating, swimming, fishing, or just viewing. If not removed, the suspended sediment that causes the turbidity may impair the water quality for many uses.

Criteria

The National Interim Primary Drinking Water Regulations (U.S. Environmental Protection Agency, 1977) restrict turbidity in finished water at the point where it enters the distribution system as follows: The daily average values for one month should not exceed 1 NTU unit, and two consecutive days shall not average more than 5 NTU. These regulations pertain to systems using surface water as a raw-water supply.

Observations

NTU values for samples at river mile 0 just below Alcova Dam are predictably low due to the influence of the reservoir (fig. 43). The range in turbidity values at all other stations was wide. Median values for the six stations are below 20 NTU. More than 95 percent of all samples had a turbidity of 120 NTU or less.

Zinc

Zinc is an essential micronutrient for humans and animals. Zinc chlorides and sulfates are very soluble; the hydroxide and carbonate are much less soluble. The mean value for dissolved zinc for the 1975 NASQAN data was 19 μg/L (Briggs and Ficke, 1977).

Zinc is relatively nontoxic to humans. Individuals have consumed spring water with a zinc concentration of 50,000 μg/L for an extended period of time without apparent unfavorable effects (National Academy of Sciences and National Academy of Engineering, 1973, p. 93). However, zinc is very toxic to fish. High concentrations of hardness and dissolved oxygen reduce zinc toxicity to fish; high temperatures increase zinc toxicity to fish.

Criteria

The National Secondary Drinking Water Regulations (U.S. Environmental Protection Agency, 1979) recommend a maximum zinc concentration of 5,000 μg/L because of the taste problem.

The maximum zinc concentration required to protect freshwater aquatic life is one hundredth of the 96-hour LC_{50} for a sensitive, resident species (U.S. Environmental Protection Agency, 1976, p. 481). (The LC_{50} is the lethal concentration resulting in fatalities to 50 percent of the population within the time specified.) One researcher found that zinc had a 96-hour LC_{50} of 3,200 μg/L (temperature, 15°C; alkalinity, 200 mg/L; and hardness, 300 mg/L) for rainbow trout. These conditions are roughly those in the study reach. Multiplying the 3,200 μg/L by 0.01 gives a recommended limit of 32 μg/L for zinc in order to protect aquatic life.

Observations

Zinc concentrations at river mile 0 and river mile 143 were relatively low (fig. 44). The only other station sampled (river mile 57) had significantly higher concentrations; concentrations of eight samples were greater than 32 μg/L, which is the maximum contaminant limit recommended in order to protect aquatic life.

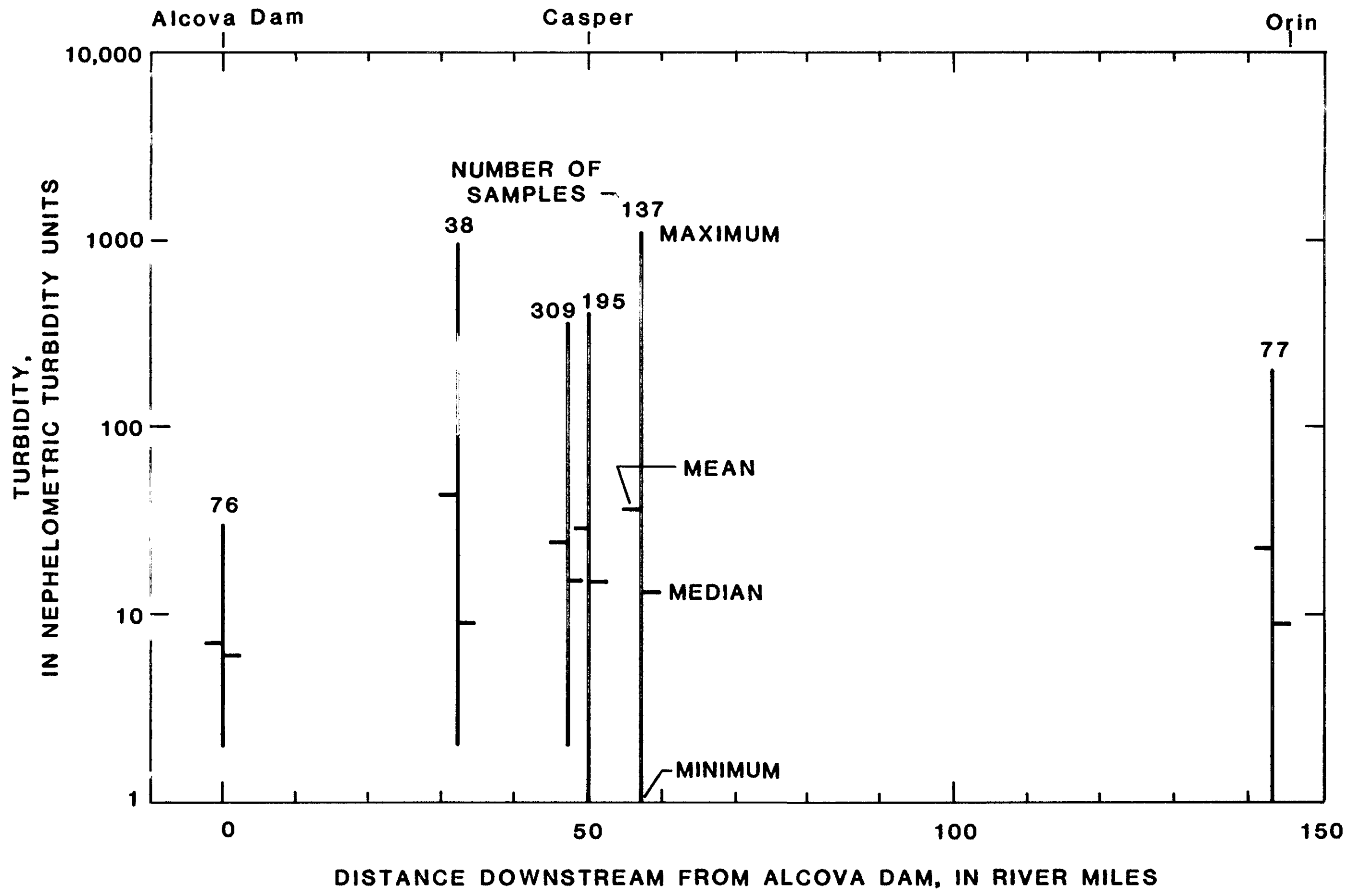


Figure 43.--Maximum, minimum, mean, and median turbidity at six sampling stations along the North Platte River between Alcova Dam and Orin, water years 1970-79

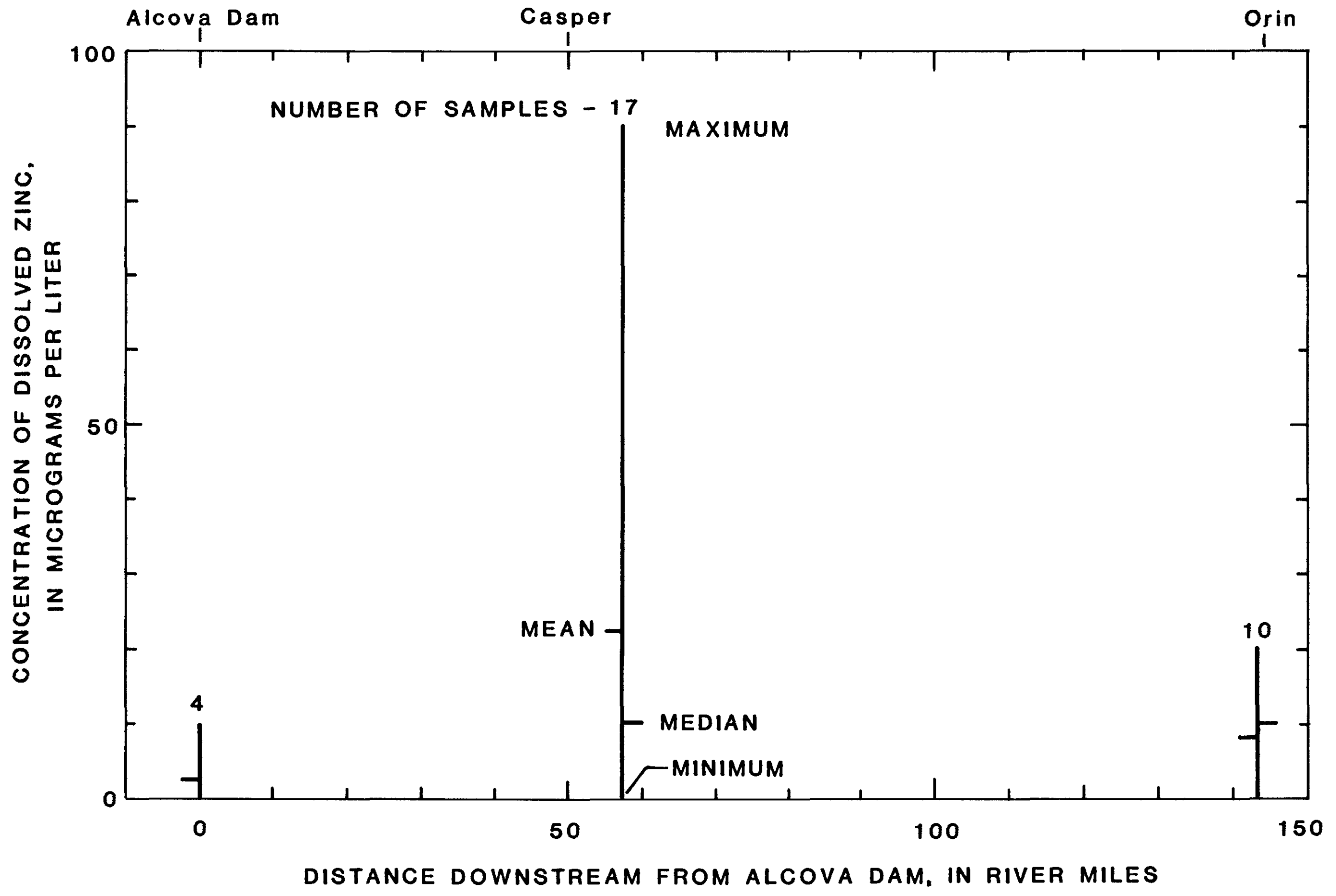


Figure 44.--Maximum, minimum, mean, and median dissolved-zinc concentrations at three sampling stations along the North Platte River between Alcova Dam and Orin, water years 1970-79.

DISCUSSION AND CONCLUSIONS

The water quality of the North Platte River for the 143-mile reach between Alvoca Dam and the station above Glendo Reservoir generally is good. This judgment is based on the current criteria used to evaluate water for both municipal supplies and irrigation.

Most constituents show a trend toward increasing concentration with downstream distance--especially between river mile 0 and river mile 57. The best quality water generally is found below Alcova Dam (river mile 0). The range in concentration of individual constituents also generally is lowest at river mile 0. Mean and median values tend to reach a maximum just downstream from Casper (river mile 57).

The increase in mean concentrations between river mile 0 and river mile 57 is probably due to: (1) The influence of tributaries and the ground-water inflow from their alluvium; and (2) municipal waste from Casper. The quality of water from the tributaries entering the North Platte between Alcova Dam and Casper generally is poor. This water contains mostly irrigation return flow and the natural flow of basins of relatively low elevations. The tributaries entering the North Platte River downstream from Casper generally have good quality water. These tributaries are fed mostly by snowmelt from the upper basins in the Laramie Mountains. During periods of high runoff the water from these streams tends to dilute the concentrations of many constituents in the North Platte. For this reason the stations downstream from river mile 57 may show lower minimum concentrations than the stations between Alcova Dam (river mile 0) and immediately below Casper (river mile 57).

The downstream trend in dissolved-solids concentration is typical of the trend for most of the major ions. The mean and median concentrations of dissolved solids are both about 320 mg/L at river mile 0 and about 430 mg/L at river miles 57, 88, and 143. Some samples had dissolved-solids concentrations above the recommended drinking-water criteria; however, none of the samples collected upstream from Casper exceed 500 mg/L, the maximum dissolved-solids concentration recommended by the National Secondary Drinking Water Regulations (U.S. Environmental Protection Agency, 1979). About 75 percent of all the samples collected in the reach had less than 500 mg/L dissolved-solids concentration.

Fecal-coliform-bacteria values showed the most dramatic downstream change of all the constituents examined. The mean, median, and maximum concentrations increased between river mile 0 and river mile 57. Fecal coliform bacteria decreased considerably between river miles 57 and 143. The station at river mile 143 was the only station downstream from river mile 57 which was sampled for fecal coliform.

Most trace-metal concentrations are within the maximums allowed by drinking-water regulations. Selenium values exceeding limits set by drinking-water regulations were found at two stations during infrequent sampling. Four tributaries upstream from Casper, sampled in June of 1979, had selenium concentrations ranging from 45 to 200 µg/L. These tributaries are probably a primary source of selenium in the study reach.

Cadmium concentrations, although within drinking-water limits (10 μg/L) were as high as 6 μg/L at river mile 143. (A possibility exists that this may be due to sample contamination.) With the limited data available, a normal range for cadmium in this reach is not predictable.

The zinc concentration at river mile 57 exceeded the recommended criteria established to protect aquatic life. However, sampling has not been extensive for this constituent.

Concentrations of calcium, magnesium, hardness, sodium, sulfate, and strontium are correlated with dissolved-solids concentrations and specific conductance. Prediction equations for these constituents are given in each discussion of individual constituents.

Based on examination of the 10 years of data, several changes in sampling design are suggested. Future emphasis should be given to constituents with concentrations which are not well defined, to critical constituents, to stations or reaches not frequently sampled, to reaches where changes in concentrations are greatest, to stations and sites that better define the sources of the salt loads, and to constituents with questionable concentrations.

Many constituents, including calcium, magnesium, sodium, potassium, alkalinity, chloride, sulfate, fluoride, dissolved solids, and silica are adequately sampled. The concentrations of most of these constituents may be estimated from specific conductance at considerable savings in cost and effort.

Specific-conductance monitors at selected stations could be valuable in ascertaining loads and short-term changes. Monitors that continually measure several constituents such as pH, dissolved oxygen, temperature, and specific conductance are available. One or two monitors might be used on an experimental basis to determine reliability and cost of operation.

More emphasis should be given to trace metals, especially to those included in drinking-water regulations, including copper because of the sensitivity of aquatic organisms to this metal. It is recommended that both dissolved and total-trace-metal samples be collected. To correlate constituents, a total sample needs to accompany a suspended-sediment sample.

Selenium and cadmium are both critical constituents because sample concentrations of these trace elements approach or exceed the maximum allowable concentration for drinking water. More radiochemical samples are needed in order to better define present conditions and to monitor effects of future mining.

Nutrients need to be given more emphasis because of the poor reliability (due to the poor preservation and sampling techniques) of the past data. Special emphasis should be given to total phosphorus because high concentrations may result in high algal concentrations in Glendo Reservoir. Analyses for dissolved nitrate and ammonia need to be given preference over the total analyses until an effective preservative is found for the total sample and until the laboratories adopt a method that determines a true, total concentration.

It is suggested that more emphasis be given to the critical reach between river miles 0 and 57. Most of the increases in mean and median values for many constituents occur between these two sites. The selenium, salt, nutrient, and trace-metal loads contributed by the tributaries, irrigation-return drains, and the city of Casper need better definition.

REFERENCES

Briggs, J. C., and Ficke, J. F., 1977, Quality of rivers of the United States, 1975 water year--Based on the National Stream Quality Accounting Network (NASQAN): U.S. Geological Survey Open-File Report 78-200, 436 p.

Crist, M. A., 1974, Selenium in waters in and adjacent to the Kendrick Project, Natrona County, Wyoming, U.S. Geological Survey Water-Supply Paper 2023, 39 p.

Durfor, C. N., and Becker, Edith, 1964, Public water supplies of the 100 largest cities in the United States, 1962: U.S. Geological Survey Water-Supply Paper 1812, 364 p.

Gannon, Robert, 1966, A sick river is returned to nature: True, April 1966, p. 35-37, 83-85.

Glover, K. C., 1983, Digital model of the Bates Creek alluvial aquifer near Casper, Wyoming: U.S. Geological Survey Water-Resources Investigations Report 82-4068, 45 p.

Hem, J. D., 1970, Study and interpretation of the chemical characteristics of natural water (2nd ed.): U.S. Geological Survey Water-Supply Paper 1473, 363 p.

National Academy of Sciences and National Academy of Engineering, 1973 [1974], Water quality criteria 1972: U.S. Government Printing Office, Ecological Research Series, EPA-R3-73-033, March 1973, 594 p.

U.S. Environmental Protection Agency, 1976, [1977], Quality criteria for water, 1976: Washington, D.C., U.S. Government Printing Office, 256 p.

________ 1977, National interim primary drinking water regulations: Office of Water Supply, EPA-570/9-76-003, 159 p.

________ 1979, National secondary drinking water regulations: Federal Register, v. 44, no. 140, July 19, p. 42195-42202.

________ 1979, Methods for chemical analysis of water and wastes: U.S. Government Printing Office, Environmental Monitoring and Support Laboratories Research and Development Series, EPA-600/4-79-020, March 1979, 460 p.

U.S. Salinity Laboratory Staff, 1954, Diagnosis and improvement of saline and alkali soils: U.S. Department of Agriculture Handbook 60, 160 p.

☆ U. S. GOVERNMENT PRINTING OFFICE: 1985—580-419/25369 REGION NO. 8