TEXAS WATER DEVELOPMENT BOARD

REPORT 86

RECONNAISSANCE OF THE CHEMICAL QUALITY OF SURFACE WATERS OF THE CANADIAN RIVER BASIN, TEXAS

By

H. L. Kunze and J. N. Lee
United States Geological Survey

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ABSTRACT

The quality of water in streams of the Canadian River basin, Texas, is controlled by the geology, streamflow pattern and characteristics, and in some areas by man's activities. Most of the streams drain rocks of the Ogallala Formation of Tertiary age and Dockum Group of Triassic age and generally contain water of good quality, with dissolved-solids concentrations less than 250 ppm (parts per million). However, the 12,700 square miles of the basin in the semiarid Texas Panhandle receives an average of only 19 inches of rainfall per year, of which less than 1 inch leaves the State as runoff. The surface-water supply of the basin is very limited, with most of the streams dry many days during the year.

The water in the Canadian River, as it enters Texas from New Mexico, contains more than 500 ppm dissolved solids; as the river flows across the Texas Panhandle, the dissolved-solids content progressively increases. The meager flows of streams with water of good quality from Ogallala and Dockum rocks are not sufficient to dilute natural saline inflows from Permian rocks and inflows of oil-field brines and municipal wastes. Most surface waters in the basin range from hard to very hard. Calcium, sodium, magnesium, and bicarbonate are the principal dissolved constituents in most streams.

Lake Meredith, completed in 1965, is the only major surface-water supply in the basin except for Lake Rita Blanca which is used solely for recreation. Water from Lake Meredith will be used to supplement ground water for municipal and industrial purposes. Water impounded in this lake, although usable for public supply, is very hard and does not meet U.S. Public Health Service standards for dissolved-solids concentrations. During extended dry periods, the dissolved solids may approach 1,000 ppm. There are no plans to use Lake Meredith water or any other surface supply in the basin for irrigation. Any surface-water source to supplement the ground water presently used for irrigation would probably have to be imported to the basin.

RECONNAISSANCE OF THE CHEMICAL QUALITY OF SURFACE WATERS OF THE CANADIAN RIVER BASIN, TEXAS

INTRODUCTION

The investigation of the chemical quality of the surface waters of the Canadian River basin in Texas is part of a statewide reconnaissance. This report is one in a series presenting the results of the study and a summary of available chemical-quality data. Reports on the Sabine, Neches, Trinity, San Jacinto, Brazos, and Colorado River basins have been published (Figure 1). Future reports are planned for each major river basin in Texas.

Knowledge of the quality of water that will be available is essential in planning any water-use project, because the chemical character of the water determines its suitability for domestic supply, irrigation, or industrial use. In addition to determining the suitability of water for specific uses, chemical-quality data are needed for: (1) the inventory of water resources, (2) determination of the type or extent of treatment needed to make the water suitable for a specific use, (3) detection and control of pollution, (4) planning for reuse of water, and (5) demineralization of water.

A network of daily chemical-quality stations on principal streams in Texas is operated by the U.S. Geological Survey in cooperation with the Texas Water Development Board and with federal and local agencies. However, this network has not been adequate to describe completely the chemical quality of the surface waters of the State. To supplement the information being obtained by the network, a cooperative statewide reconnaissance by the U.S. Geological Survey and the Texas Water Development Board was begun in September 1961. In this study, samples for chemical analyses have been collected periodically at numerous sites throughout Texas so that some quality-of-water information would be available at locations where water-development projects are likely to be built. These data aid in the delineation of areas having water-quality problems and in the identification of probable sources of pollution, thus indicating areas in which more detailed investigations are needed.

During the period September 1961 to June 1966, water-quality data were collected from the principal streams and tributaries and from two major reservoirs in the Canadian River basin. Some water-quality data from the basin in New Mexico and Oklahoma are included in this study.

Other agencies that have cooperated in the collection of chemical-quality and streamflow data include the Canadian River Municipal Water Authority, the city of Amarillo, the U.S. Bureau of Reclamation, the Texas State Department of Health, the Oklahoma Water Resources Board, and the New Mexico Interstate Stream Commission.

CANADIAN RIVER DRAINAGE BASIN

General Description

The Canadian River basin in Texas is in the northern half of the Texas Panhandle (Figure 1). The area, which includes part of the North Canadian River subbasin, is bounded on the west by the New Mexico-Texas state line, on the north and east by the Texas-Oklahoma state line, and on the south by the Red River basin. The drainage basin, which includes all or part of sixteen counties, has a total area of 12,700 square miles in Texas, of which about 4,500 square miles is probably noncontributing.

The Canadian River rises in New Mexico and flows easterly across the Texas Panhandle into Oklahoma (Figure 2). The principal tributaries in Texas are Punta de Agua and Red Deer Creeks. The northern part of the study area is drained by tributaries of the North Canadian River, which flows into the Canadian River in Oklahoma. The principal tributaries that have extensive drainage areas in Texas are Coldwater, Palo Duro, Kiowa, and Wolf Creeks.

The altitude of the basin ranges from 4,735 feet above mean sea level in northwestern Dallam County, Texas, to about 2,167 feet in the valley of the Canadian River (Hemphill County) where it enters Oklahoma.

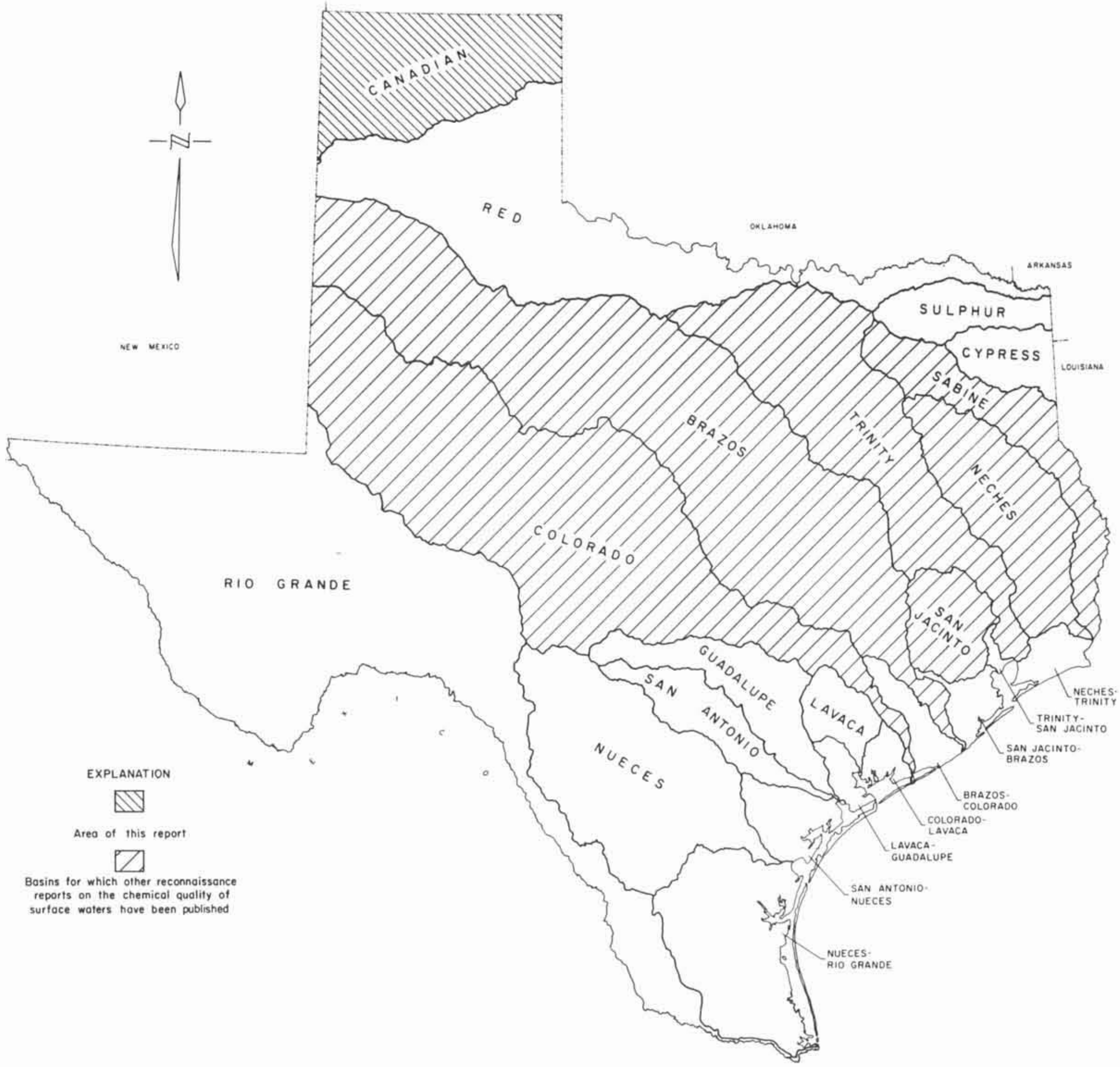

Figure 1.--River Basins and Coastal Areas

Sharply contrasting flat plains and rolling to rugged erosional "breaks" mark the topography of the basin. The plains, which make up a little over half the area, slope eastward about 10 feet per mile. Drainage is poorly developed, and surface runoff is limited to catchment in hundreds of depression ponds or playas dotting the plains. Very little vegetation other than native grasses and cultivated farm crops grows on the plains.

The remaining part of the basin, characterized by deep ravines and canyons, is drained by the Canadian River and its tributaries. Very little vegetation of any sort covers this area, and it is unsuitable for cultivation. In recent years, phreatophytes--plants that depend upon ground water within reach of their roots--have become established on the canyon floors and are using increasingly significant quantities of water.

The climate of the Canadian River basin is characterized by low humidity, low annual precipitation, hot summers, and frigid winters. Average precipitation in Texas ranges from about 15 inches per year in the northwest to about 22 inches in the east. For the Texas part of the basin, the annual average is about 19 inches. Mean annual precipitation in the basin, average monthly precipitation at three U.S. Weather Bureau stations, and annual precipitation for the period 1931-65 at Amarillo are shown on Figure 2.

Runoff is defined as that part of precipitation appearing in surface streams, and is the same as streamflow unaffected by artificial diversions or storage (Langbein and Iseri, 1960, p. 17). The natural runoff pattern in the Canadian River above Amarillo has been altered by the Conchas and Ute Reservoirs in New

Mexico. From Amarillo to the Oklahoma state line, the natural runoff pattern is further altered by Lake Meredith near Sanford, Texas.

The average annual runoff from Palo Duro Creek and from Canadian River near Amarillo and near Canadian during the period 1945 to 1964 was 0.6, 0.2, and 0.3 inch, respectively (Figure 2). Runoff of Wolf Creek at Lipscomb, which was plotted for the period 1962 to 1964 only, was 0.3 inch per year. Annual runoff expressed as mean discharge in cubic feet per second (cfs) and inches per year is shown on Figure 2 for the station at Canadian. These runoff figures, calculated for the contributing drainage area, would be lower for the entire basin. Springs and seeps sustain the baseflow during the winter months, but evaporation and transpiration consume most and sometimes all the base flow during the summer months. Evaporation, transpiration, and the sandy, porous soil, which allows rapid infiltration of water, contribute to the very low ratio of runoff to rainfall in the Canadian River basin.

Precipitation and runoff in the Canadian River basin are more variable than indicated by the annual and monthly averages. The yearly mean discharge of the Canadian River near Canadian has ranged from 34.5 cfs to 2,963 cfs, but instantaneous flows have varied much more. Similarly, annual rainfall at Amarillo ranged from 9.94 inches in 1956 to 37.21 inches in 1941 (Figure 2), and in 1965 the monthly totals ranged from 0.07 inch for November to 10.73 inches for June. Precipitation so unevenly distributed in time, especially in an area of low rainfall and low but rapid runoff, does not sustain streamflow. Therefore, storage is required to provide dependable quantities of surface water for municipal supply, industrial use, or irrigation.

Population and Municipalities

The population of the Canadian River basin in Texas in 1960 was just slightly under 188,000, which was about 2.6 percent of the State total (Figure 3). Only five cities with more than 5,000 population are entirely within the Canadian River basin. These cities are Pampa (24,664), Borger (20,911), Dumas (8,477), Perryton (7,903), and Dalhart (5,160). Amarillo, the largest city in the area, with a population of 137,969, lies on the divide between the Canadian and Red River basins.

Economic Development

Agriculture forms the bulk of the economic base in the Canadian River basin. Prior to 1900, most of the land was used for ranching and grazing, although some dryland farming began with the coming of the railroads in the 1880's. Modern farming equipment and the use of ground water for irrigation increased cultivation. At present, the basin is one of the State's leading areas in the production of wheat and grain sorghum.

Oil was discovered in the Canadian River basin in 1921, but production remained small until great gushers blew in at Borger in 1926. Since that time the petroleum industry has grown until the basin is now one of the leading oil and gas producing areas in the State.

The industrial development has remained largely associated with mineral production. Petroleum and natural gas are the main resources, but helium, zinc, and sulfur are produced in the southern part of the basin. Other industries include the manufacturing of commercial fertilizers, carbon black, chemicals, and farm implements.

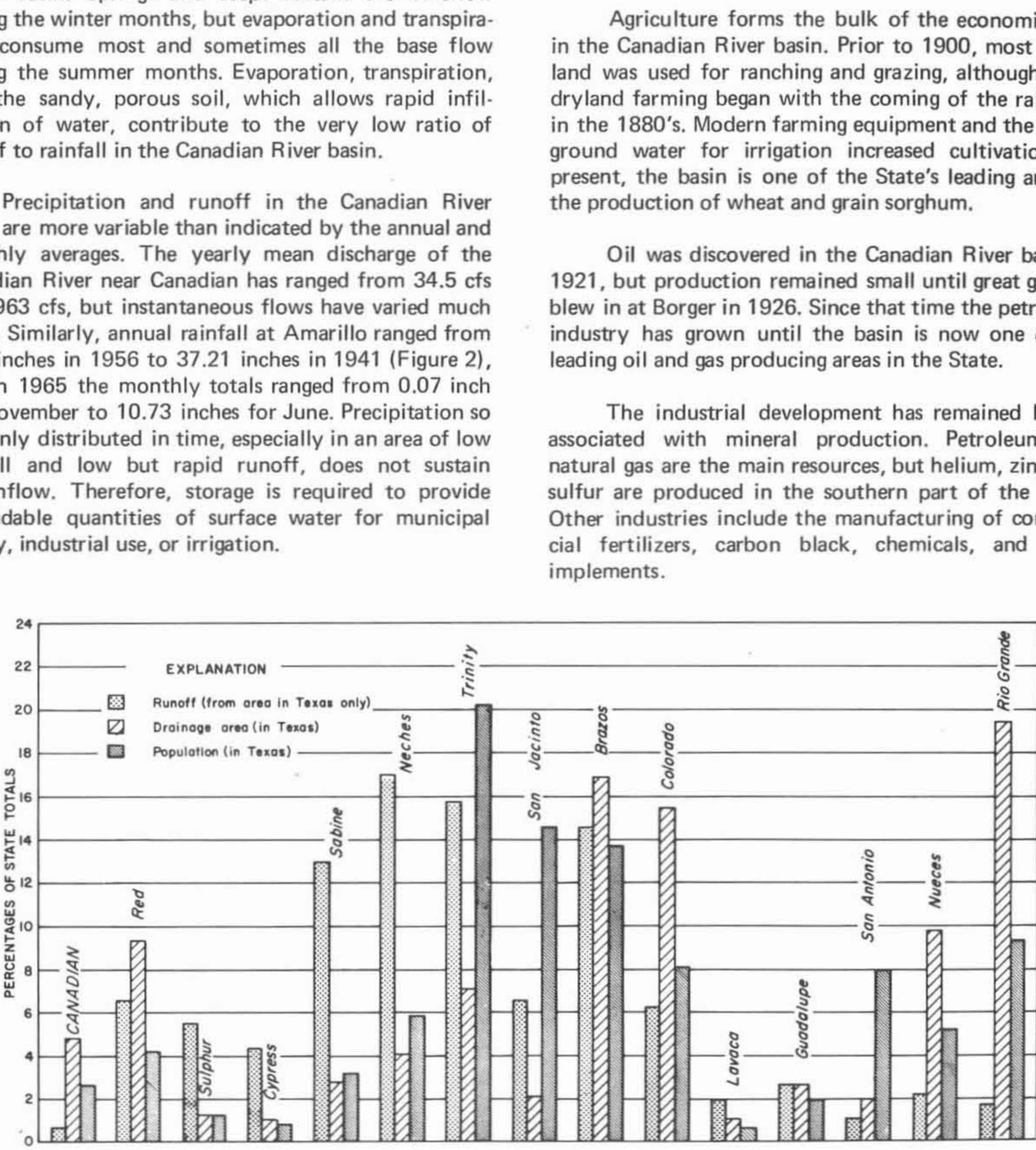

Figure 3.--Annual Runoff, Drainage Area, and 1960 Population of Major River Basins in Texas, as Percentages of State Totals

Development of Surface-Water Resources

Runoff in the Canadian River basin averages less than 1 inch per year, which is about 0.7 percent of the State's total runoff (Figure 3). Thus, the quantity of surface water available for development is considerably less than the average for the State, and the only large surface-water development project in the basin is Lake Meredith, built by the U.S. Bureau of Reclamation on the Canadian River near Sanford.

Storage of water in Lake Meredith began in October 1964. Total capacity of this reservoir is 1,408,000 acre-feet, and when full it will inundate parts of Hutchinson, Moore, and Potter Counties (Figure 2). The reservoir provides water for the Canadian River Municipal Water Authority and is used for flood control, recreation, and to supplement ground-water supplies of 11 cities within the Canadian, Red, Brazos, and Colorado River basins. Lake Rita Blanca on Rita Blanca Creek is the only other reservoir larger than 5,000 acre-feet in the Texas part of the basin. This 12,100 acre-foot lake, completed in 1939 and operated by U.S. Fish and Wildlife Service, is used for recreation only.

Surface water is expected to contribute only a small percentage of the municipal and industrial water supply of the basin for the next 50 years and essentially all irrigation will depend upon ground-water supply. If the full irrigation potential in the Canadian River basin is to be realized, surface water from outside the basin must be made economically available.

CHEMICAL QUALITY OF THE WATER

Chemical-Quality Records

The U.S. Geological Survey began collecting chemical-quality data on surface waters of the Canadian River basin in Texas in 1948, when a daily sampling station on the Canadian River near Tascosa and a weekly sampling station on the Canadian River near Amarillo were established. Since 1950 the Amarillo station has been a daily sampling site; the Tascosa station was discontinued in 1953. During 1950 and 1951 a daily station was operated on the Canadian River near Borger. Miscellaneous chemical-quality data have been collected by the Geological Survey at additional sites since 1950.

Data were collected over a wide range of water-discharge rates in order to evaluate water quality in relation to discharge. At low flows, concentrations of dissolved minerals are likely to be high and areas having pollution and salinity problems can be identified. Data collected during medium and high flows indicate the probable quality of the water that would be stored in reservoirs.

The periods of record of all data collection sites are given in Table 2 and the locations are shown on Figure 8. The chemical-quality data for the daily stations are summarized in Table 3 and the complete records are published in an annual series of U.S. Geological Survey Water-Supply Papers and in reports of the Texas Water Development Board (see tables at end of references). Results of all the periodic and miscellaneous analyses are given in Table 4. This report includes data for four locations on the Canadian River outside of Texas: At Logan, New Mexico; at Glenrio, New Mexico; near Roll, Oklahoma; and near Bridgeport, Oklahoma. Data for Coldwater Creek near Hardesty, Oklahoma, are also contained in this report.

Periodic sampling by the Texas State Department of Health at eight sites in the Canadian River basin provided additional data that were useful in evaluating water-quality conditions.

Streamflow Records

Streamflow in the Canadian River basin in Texas was first measured in 1924, when the U.S. Geological Survey established streamflow stations on the Canadian River near Amarillo and near Canadian. At the end of 1966, one reservoir-content station and four streamflow stations were being operated. Discharge measurements have also been made at other sites where samples were collected for chemical analyses. The periods of record for all streamflow stations in the Canadian River basin are given in Table 2 and the locations are shown on Figure 8.

Records of discharge, stage of streams, and contents and stages of lakes or reservoirs for 1924-25 and 1938-60 have been published in the annual series of U.S. Geological Survey Water-Supply Papers (see tables at end of references). Beginning with the 1961 water year, streamflow records have been released by the Geological Survey in annual reports for each state (U.S. Geological Survey, 1961-66). Summaries of discharge records have been published giving monthly and annual totals (U.S. Geological Survey, 1955, 1964b; Texas Board of Water Engineers, 1958).

Relation of Quality of Water to Use

Quality-of-water studies usually are concerned with determining the suitability of water for its proposed use. The source and significance of some of the water-quality constituents and properties that must be considered in evaluating a water supply are shown in Table 1.

The suitability of water for various uses is determined largely by the kind and amount of these constituents and properties in water. The U.S. Public

Table 1.--Source and Significance of Dissolved-Mineral Constituents and Properties of Water

CONSTITUENT OR PROPERTY	SOURCE OR CAUSE	SIGNIFICANCE
Silica (SiO_2)	Dissolved from practically all rocks and soils, commonly less than 30 ppm. High concentrations, as much as 100 ppm, generally occur in highly alkaline waters.	Forms hard scale in pipes and boilers. Carried over in steam of high pressure boilers to form deposits on blades of turbines. Inhibits deterioration of zeolite-type water softeners.
Iron (Fe)	Dissolved from practically all rocks and soils. May also be derived from iron pipes, pumps, and other equipment. More than 1 or 2 ppm of iron in surface waters generally indicates acid wastes from mine drainage or other sources.	On exposure to air, iron in ground water oxidizes to reddish-brown precipitate. More than about 0.3 ppm stains laundry and utensils reddish brown. Objectionable for food processing, textile processing, beverages, ice manufacture, brewing, and other processes. U.S. Public Health Service (1962) drinking-water standards state that iron should not exceed 0.3 ppm. Larger quantities cause unpleasant taste and favor growth of iron bacteria.
Calcium (Ca) and magnesium (Mg)	Dissolved from practically all soils and rocks, but especially from limestone, dolomite, and gypsum. Calcium and magnesium are found in large quantities in some brines. Magnesium is present in large quantities in sea water.	Cause most of the hardness and scale-forming properties of water; soap consuming (see hardness). Waters low in calcium and magnesium desired in electroplating, tanning, dyeing, and in textile manufacturing.
Sodium (Na) and potassium (K)	Dissolved from practically all rocks and soils. Found also in ancient brines, sea water, industrial brines, and sewage.	Large amounts, in combination with chloride, give a salty taste. Moderate quantities have little effect on the usefulness of water for most purposes. Sodium salts may cause foaming in steam boilers and a high content may limit the use of water for irrigation.
Bicarbonate (HCO_3) and carbonate (CO_3)	Action of carbon dioxide in water on carbonate rocks such as limestone and dolomite.	Bicarbonate and carbonate produce alkalinity. Bicarbonates of calcium and magnesium decompose in steam boilers and hot water facilities to form scale and release corrosive carbon dioxide gas. In combination with calcium and magnesium, cause carbonate hardness.
Sulfate (SO_4)	Dissolved from rocks and soils containing gypsum, iron sulfides, and other sulfur compounds. Commonly present in mine waters and in some industrial wastes.	Sulfate in water containing calcium forms hard scale in steam boilers. In large amounts, sulfate in combination with other ions gives bitter taste to water. Some calcium sulfate is considered beneficial in the brewing process. U.S. Public Health Service (1962) drinking-water standards recommend that the sulfate content should not exceed 250 ppm.
Chloride (Cl)	Dissolved from rocks and soils. Present in sewage and found in large amounts in ancient brines, sea water, and industrial brines.	In large amounts in combination with sodium, gives salty taste to drinking water. In large quantities, increases the corrosiveness of water. U.S. Public Health Service (1962) drinking-water standards recommend that the chloride content should not exceed 250 ppm.
Fluoride (F)	Dissolved in small to minute quantities from most rocks and soils. Added to many waters by fluoridation of municipal supplies.	Fluoride in drinking water reduces the incidence of tooth decay when the water is consumed during the period of enamel calcification. However, it may cause mottling of the teeth, depending on the concentration of fluoride, the age of the child, amount of drinking water consumed, and susceptibility of the individual. (Maier, 1950)
Nitrate (NO_3)	Decaying organic matter, sewage, fertilizers, and nitrates in soil.	Concentration much greater than the local average may suggest pollution. U.S. Public Health Service (1962) drinking-water standards suggest a limit of 45 ppm. Waters of high nitrate content have been reported to be the cause of methemoglobinemia (an often fatal disease in infants) and therefore should not be used in infant feeding. Nitrate has been shown to be helpful in reducing inter-crystalline cracking of boiler steel. It encourages growth of algae and other organisms which produce undesirable tastes and odors.
Dissolved solids	Chiefly mineral constituents dissolved from rocks and soils. Includes some water of crystallization.	U.S. Public Health Service (1962) drinking-water standards recommend that waters containing more than 500 ppm dissolved solids not be used if other less mineralized supplies are available. Waters containing more than 1,000 ppm dissolved solids are unsuitable for many purposes.
Hardness as $CaCO_3$	In most waters nearly all the hardness is due to calcium and magnesium. All the metallic cations other than the alkali metals also cause hardness.	Consumes soap before a lather will form. Deposits soap curd on bathtubs. Hard water forms scale in boilers, water heaters, and pipes. Hardness equivalent to the bicarbonate and carbonate is called carbonate hardness. Any hardness in excess of this is called non-carbonate hardness. Waters of hardness as much as 60 ppm are considered soft; 61-120 ppm, moderately hard; 121-180 ppm hard; more than 180 ppm, very hard.
Specific conductance (micromhos at 25°C)	Mineral content of the water.	Indicates degree of mineralization. Specific conductance is a measure of the capacity of the water to conduct an electric current. Varies with concentration and degree of ionization of the constituents.
Hydrogen ion concentration (pH)	Acids, acid-generating salts, and free carbon dioxide lower the pH. Carbonates, bicarbonates, hydroxides, and phosphates, silicates, and borates raise the pH.	A pH of 7.0 indicates neutrality of a solution. Values higher than 7.0 denote increasing alkalinity; values lower than 7.0 indicate increasing acidity. pH is a measure of the activity of the hydrogen ions. Corrosiveness of water generally increases with decreasing pH. However, excessively alkaline waters may also attack metals.

Health Service drinking water standards (U.S. Public Health Service, 1962) are usually accepted as recommended limits for evaluating waters for domestic and municipal uses. The recommended limits for selected constituents are listed in the following table.

CONSTITUENT	MAXIMUM CONCENTRATION (PPM)
Sulfate	250
Chloride	250
Nitrate	45
Fluoride	[a] 1.0
Dissolved solids	500

[a] Based on temperature records for Amarillo.

These limits should not be exceeded when water of better quality can be made available. However, many people use water which exceeds one or more of these limits without discernible ill effects. Two analyses from Lake Meredith show the water stored there exceeded the recommended dissolved-solids limit (Table 4). The dissolved-solids concentration in Lake Meredith increased from 621 ppm (parts per million) in November 1965 to 706 ppm in April 1966. Concentrations of all chemical constituents except silica, fluoride, and nitrate increased during this period. The lake was still in process of being filled, and the weighted-average analysis for Canadian River near Amarillo may be a better indication of the eventual quality of the water that will be stored.

These two analyses, together with the chemical-quality record obtained at the daily station Canadian River near Amarillo, indicate that the dissolved-solids concentration in the reservoir probably will always exceed the recommended limit of 500 ppm established by the U.S. Public Health Service. During extended dry periods, evaporation may cause the dissolved solids to approach 1,000 ppm. Water of this concentration can still be used for public supply where better water is not available.

Although most small streams in the basin contain waters of good quality, the main stem of the Canadian River usually exceeds the limits for dissolved solids and fluoride, and high nitrate concentrations are sometimes found in reaches downstream from sewage plant outfalls.

The quality requirements vary greatly for most industrial applications. One requirement of most industries is that concentrations of constituents in the supply remain relatively constant. Hardness and corrosive characteristics are also important to industry. Excessive hardness is objectionable because it forms scale in pipes, boilers, and other equipment where water is heated or evaporated. Corrosion is usually associated with high dissolved-solids concentrations, especially if chlorides are high. Lake Meredith water will probably be very hard (above 180 ppm) and may require treatment for some industrial needs. The scale-producing hardness, however, may reduce or negate corrosion problems.

There are no immediate plans to use surface water for irrigation in the Canadian basin. Only lawn and garden watering from Lake Meredith municipal supplies can be expected. On the basis of the system for classifying irrigation waters of the U.S. Salinity Laboratory Staff (1954, p. 81), Lake Meredith water should have a low sodium hazard, but the salinity hazard may be high, requiring special management and plant selection for lawns and gardens.

Factors Affecting Chemical Quality of Water

The chemical quality of surface water depends on a number of factors, most important of which are geology, patterns and characteristics of streamflow, and the activities of man.

Geology

The amounts and kinds of minerals dissolved in water that drains from areas where municipal and industrial influences are small depend principally on the chemical composition and physical structure of the rocks and soils traversed by the water.

The rocks in the Canadian River basin range in age from Late Permian to Holocene (Figure 4). The Ogallala Formation of Tertiary age overlies rocks of Cretaceous, Jurassic, Triassic, and Permian age and is at the surface throughout the plains area of the basin and in a major part of the "breaks" area. The older rocks of Triassic and Permian age are exposed largely in the "breaks" area along and near the canyon of the Canadian River. Small areas of Permian rocks are also exposed in Hemphill and Hansford Counties. Cretaceous and Jurassic rocks crop out in a few small areas near the northwest corner of the basin, and alluvial sediments of Quaternary age are exposed along the canyon floors of the Canadain River, Wolf Creek, and Coldwater Creek. Windblown deposits in the form of sand dunes mantle an area in northern Hemphill County.

Low flow of most of the tributaries of the Canadian and North Canadian Rivers is sustained by seeps and springs issuing principally from the Ogallala Formation and to a lesser degree from the Dockum Group of Triassic age. Streams that drain from the Ogallala Formation, which consists of light colored gravel, sand, silt, clay, and white limy material called "caliche," and from the Dockum Group, which consists of sandstone and red shale, contain a mixed (calcium, magnesium, sodium, bicarbonate) type of water. Dissolved-solids contents of these waters are low.

The Canadian River in Texas traverses rocks of the Dockum Group, rocks of Permian age, and Holocene alluvial deposits. The Permian rocks, which consist of halite (salt), gypsum, anhydrite, red shale, sandstone, and some limestone, yield water containing high equivalent amounts of sodium, calcium, chloride, and sulfate. The small amount of fresh water that is released by the Permian rocks is probably water that has moved from the Cretaceous beds or from the Ogallala Formation.

Chemical analyses of water from the Canadian River and one typical analysis of water from Palo Duro Creek, which drains rocks of the Ogallala Formation, are shown graphically in Figure 5. The total height of each vertical bar is equivalent to the total concentration of anions (negatively charged constituents) or cations (positively charged constituents) expressed in epm (equivalents per million). The bars are divided into segments to show concentration of the individual constituents. The water in the Canadian River is usually of a mixed type containing higher equivalent amounts of calcium, magnesium, sodium, bicarbonate, sulfate, and chloride than are found in tributary streams.

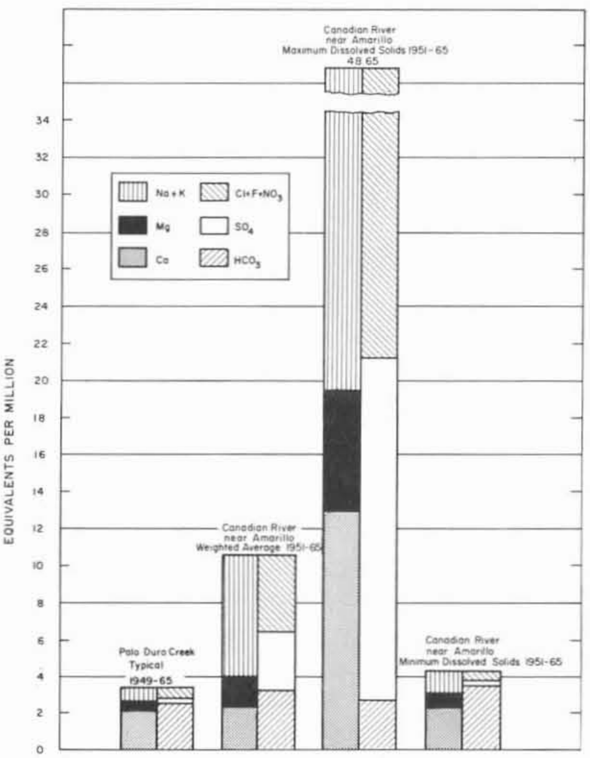

Figure 5.--Comparison of Dissolved Constituents in Water From Palo Duro Creek and the Canadian River

During extreme low flow, most of the surface water derived from the Ogallala Formation and Dockum Group is consumed by evapotranspiration. Flow in the Canadian river is then probably sustained almost entirely by water from the Permian rocks. At such times, dissolved-solids content is greatly increased and the water has higher equivalent amounts of sodium, chloride, and sulfate than of other constituents.

Streamflow

The patterns and characteristics of streamflow generally affect the chemical quality of water in streams. In most streams where the flow is not regulated by upstream reservoirs, the concentrations of dissolved-mineral constituents vary inversely with the flow of the stream. The base flow, or low sustained flow, of a stream is predominantly water that has entered the stream as ground-water effluent. Usually this water has been in contact with rocks and soils for a sufficient time to dissolve part of their soluble minerals. At high stages most of the flow of a stream consists of surface runoff. This water has been in contact with the exposed rocks and soils for only a short time. Therefore, the dissolved-solids concentration of a stream is usually lowest during periods of high flow.

The Canadian River basin has two very different drainage patterns. In the plains area, where there is no well-developed drainage, surface runoff collects in hundreds of depression ponds or playas. Almost all the water evaporates, but some infiltrates into the soil and reaches the water table to become ground water. This ground water may be pumped from wells or may reappear as seeps and springs along the streams or drainageways that have cut through the water table.

In the "breaks" area, tributary streams have dissected the Ogallala Formation to form deep and narrow canyons. The slope of most of the tributaries to the Canadian River and North Canadian River is usually very steep and surface runoff is quite rapid. Streamflow is characterized by very short periods of high to extremely high flow followed by long periods of very little or no flow. Therefore, water from most of the tributary streams is usually of very good quality. The water is of the calcium bicarbonate type and the dissolved-solids concentration is usually less than 250 ppm, as typified by Palo Duro Creek in Figure 5. However, some creeks may have much higher dissolved-solids concentrations.

East Amarillo Creek usually contains dissolved solids in excess of 500 ppm. Single analyses for Punta de Agua, Dixon, and Elk Creeks indicate that during periods of low flow, dissolved solids in these streams would probably exceed 500 ppm. Sodium, sulfate, and chloride are the predominant constituents in these streams and the quality of water is probably degraded by activities of man. In polluted reaches, the water may be of any type, depending on the pollutant introduced into the creek.

The Canadian River derives most of its total flow from surface runoff. The basin is subject to thunderstorms of high intensity and short duration. Streamflow in the Canadian correspondingly varies abruptly with this rainfall pattern, and a corresponding abrupt change in the quality of the water usually occurs. During extreme low flow, when the river is sustained almost entirely by ground water, the water is highly mineralized.

Activities of Man

The activities of man have a significant effect on the chemical quality of surface water in the basin. Oil-field brine, municipal and industrial wastes, and to a small extent, return flows from irrigation increase the concentration of dissolved solids in streams. Evaporation from reservoirs also increases the dissolved-solids concentration. On the other hand, storage of dilute flood water in reservoirs and subsequent release of the stored water during low-flow periods will improve the water quality downstream.

Flow in the Canadian River as it enters Texas from New Mexico is largely regulated by the Conchas and Ute Reservoirs in New Mexico. Thus, the quality of water in the Canadian River in Texas is partially determined by the quantity and quality of the water released from these two reservoirs. Lake Meredith near Sanford, Texas, affects the quality of water in the Canadian River below the lake.

Oil and gas are produced over almost the entire area of the Canadian River basin (Figure 6). The heaviest concentration of oil production is in Hutchinson, Ochiltree, Carson, Hansford, Lipscomb, and Roberts Counties. Smaller oil production areas are in Moore, Hemphill, Hartley, and Sherman Counties. Brine, which is produced in nearly all oil fields, may, if improperly handled, eventually reach the streams. The principal chemical constituents in oil-field brines are chloride, sodium, calcium, and sulfate. Some oil-field-brine pollution is probably occurring in some of the tributaries to the Canadian River and in the Canadian River downstream from Amarillo.

Municipal and industrial wastes have a pronounced effect on the quality of water in surface streams in the Canadian River basin. Flow in East Amarillo Creek consists almost entirely of sewage effluent from the city of Amarillo, and low flow in the Canadian River downstream from East Amarillo Creek is maintained entirely or in part by this sewage effluent. During high flow, this waste discharge has little effect on water quality, but during extended low flow periods, water stored in the upstream part of Lake Meredith may be degraded in quality. Other municipalities and many industrial areas throughout the Canadian River basin probably contribute to the deterioration of water quality.

Ground water is used extensively throughout the plains area for irrigation. However, probably very little return flow is contributed to the streams in the Canadian River basin, and very little, if any, alteration of chemical quality of surface streams can be attributed to irrigation.

Geographic Variations in Water Quality

Maps showing geographic variations of dissolved solids, hardness, and chloride have been prepared using the discharge-weighted average concentrations (Figure 9). The discharge-weighted average approximates the chemical character of the water that would be found if all the water passing a given location during a period were impounded and thoroughly mixed in a reservoir. No adjustments for evaporation, rainfall, or chemical change that might occur in storage are made. For many of the streams, chemical-quality data are limited, especially for flood flows; therefore, the information on the maps is generalized. All the streams will at times have concentrations exceeding those shown.

Dissolved Solids

The Canadian River generally contains water with dissolved solids above 500 ppm. In crossing the Panhandle, the Canadian traverses areas of Permian rocks that probably have a degrading effect on the quality of the water because a progressive increase in dissolved solids is noted downstream. Part of this degradation of water quality may also be attributed to oil-field and municipal pollution.

The dissolved-solids duration curve for the Canadian River near Amarillo (Figure 7) shows that the dissolved solids equaled or exceeded 900 ppm 50 percent of the time. The weighted-average dissolved solids for 1951-65 was 651 ppm.

Waters in most of the tributaries of the Canadain River contain dissolved-solids concentrations less than 250 ppm. Streams that drain the outcrop areas of the Ogallala Formation and Dockum Group generally contain waters with concentrations less than 250 ppm dissolved solids (Figure 9). Some tributaries draining the Ogallala, Dockum, and Upper Permian rocks contain water with dissolved-solids concentrations of 250 to 500 ppm or more at times.

Hardness

The water of the Canadian River entering Texas is very hard (more than 180 ppm) and it maintains this hardness as it passes through the State. The weighted-average hardness for the Canadian River at Amarillo from 1951 to 1965 was 199 ppm.

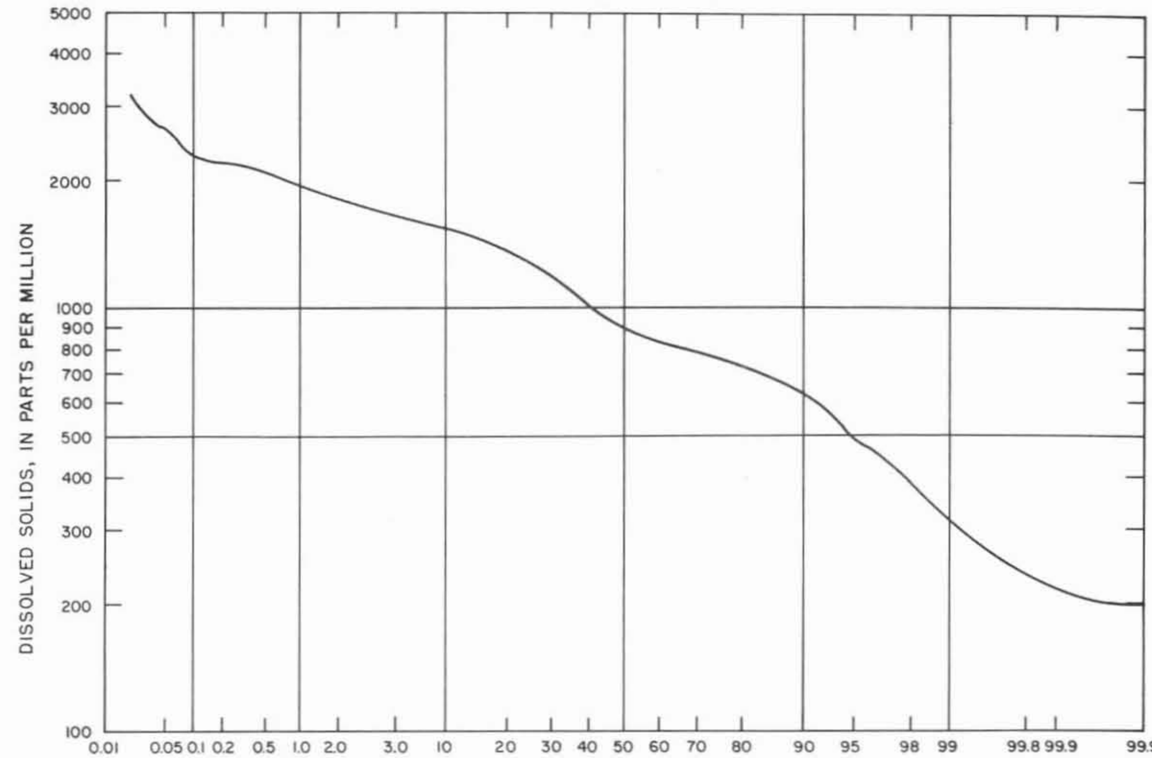

Figure 7.--Duration Curve for Dissolved Solids of Canadian River Near Amarillo, Water Years 1951-65

Water of tributaries to the Canadian River is moderately hard (61-120 ppm), hard (121-180 ppm), or very hard. Almost all streams draining the Ogallala Formation and Dockum Group contain hard water, whereas streams draining the Upper Permian rocks usually contain very hard water. Some tributaries drain areas where all three of these rock units crop out, and the water in these areas may be hard or very hard, depending on the amount of streamflow.

Chloride

As shown on Figure 9, the water of the mainstem of the river exceeds 100 ppm chloride as it crosses the State. The weighted-average chloride at the Amarillo station for 1951-65 was 140 ppm.

The tributaries of the Canadian River that drain areas of Ogallala and Dockum rocks, about one-half of the total, have a chloride concentration of less than 25 ppm (Figure 9). The remaining half of the tributaries contain water with chloride concentrations less than 100 ppm, except Dixon Creek near Borger and Elk Creek near Canadian. Dixon Creek, which drains a rather extensive area of Permian rocks and which lies entirely within a concentrated oil-field area, contained 558 ppm chloride on April 29, 1966. In addition, the creek is used by the city of Phillips for disposal of sewage effluent. Elk Creek usually contains waters having a chloride concentration of less than 150 ppm.

Other Constituents

Other important constituents in evaluating the chemical quality of water include silica, sodium, bicarbonate, sulfate, fluoride, and nitrate.

Almost all the streams in the Canadian River basin contain from 15 to 30 ppm silica. The weighted-average silica concentration of the Canadian River near Amarillo for the period 1951-65 was 24 ppm. Kiowa, Dixon, and East Amarillo Creeks usually contain more than 30 ppm silica.

Sodium concentrations are generally less than 50 ppm in tributary streams in the Canadian River basin. Of the streams containing more than 50 ppm sodium, almost every one is polluted by sewage or oil-field brine. The weighted-average sodium concentration of the Canadian River near Amarillo for the period 1951-65 was 152 ppm.

Bicarbonate, with concentrations often greater than 200 ppm, is generally the principal anion in all unpolluted streams in the Canadian River basin. The weighted-average bicarbonate concentration for the Amarillo station from 1951 to 1965 was 205 ppm.

Sulfate concentrations of mainstem water is usually much greater than in tributaries. The 1951-65 weighted-average sulfate concentration at the Amarillo station was 149 ppm. Sulfate concentrations are usually less than 30 ppm throughout the basin, except for polluted streams and streams having extensive drainage areas of Permian rocks.

Fluoride concentrations range from about 0.5 to 2.4 ppm in streams throughout the basin. The weighted-average fluoride concentration for the Canadian River near Amarillo is 1.1 ppm.

Nitrate concentrations are usually less than 3.0 ppm in tributary streams and in the mainstem, except near Amarillo where concentrations frequently are near 50 ppm. East Amarillo Creek, which receives municipal waste from the city of Amarillo, flows into the Canadian River 1.4 miles upstream from the Amarillo station. This creek, with nitrate concentrations often near 100 ppm, contributed significantly to the 8.8 ppm weighted-average nitrate concentration (1951-65) at the Amarillo station.

PROBLEMS NEEDING ADDITIONAL INVESTIGATION

This reconnaissance of the chemical quality of surface water in the Canadian River basin has shown that the basin has some definite water-quality problems. Although the tributaries of the Canadian River generally contain water of good quality, there are indications of occasional or continued pollution of a number of these streams. The quantity of water in the streams containing good-quality water is so small that major surface-water projects are limited to the Canadian River.

Oil is produced in many sections of the Canadian River basin and brine is produced in nearly all oil fields. In 1961 about 63 percent of the brine was disposed of by means of open surface pits and about 37 percent was injected into wells (Texas Water Commission and Texas Water Pollution Control Board, 1963). The efforts of the Railroad Commission of Texas have reduced the use of surface pits for brine disposal, and no-pit orders are now in effect for most counties in the Canadian River basin. Waterflooding in oil fields, injection of oil-field brines, and other brine disposal should be watched carefully to ensure that brine does not enter fresh ground-water supplies or surface streams.

With the completion of Lake Meredith, the rate of municipal and industrial growth will undoubtedly increase, especially in the vicinity of the lake. This growth will increase the waste-disposal burdens of the stream systems and will require continuous effort by water-pollution control agencies to keep degradation of water quality to a minimum.

The quality of the lake water may be improved or degraded by impoundment. Beneficial effects include reduction of turbidity, silica, color, and coliform bacteria; stablization of sharp variations in chemical quality; entrapment of sediment; and reduction in temperature. Detrimental effects of impoundment include increased growth of algae, reduction of dissolved oxygen, and increases in the concentration of dissolved solids and hardness as a result of evaporation. Further study is needed to determine the significance of these changes in water quality and their relation to the intended uses of the water.

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WATER YEAR	U.S.G.S. WATER-SUPPLY PAPER NO.	T.W.D.B. REPORT NO.
1948	1133	*1948
1949	1163	*1949
1950	1188	*1950
1951	1199	*1951
1952	1252	*1952
1953	1292	*1953
1954	1352	*1954
1955	1402	*1955
1956	1452	Bull. 5905
1957	1522	Bull. 5915
1958	1573	Bull. 6104
1959	1644	Bull. 6205
1960	[a] 1744	Bull. 6215
1961	[a] 1884	Bull. 6304
1962	1944	Bull. 6501
1963	1950	Rept. 7
1964	--	--
1965	--	--

* "Chemical Composition of Texas Surface Waters" was designated only by water year prior to 1956.

[a] In preparation.

The following U.S. Geological Survey Water-Supply Papers contain results of stream measurements in the Canadain River basin, Texas, 1924-25 and 1938-60:

YEAR	WATER-SUPPLY PAPER NO.
1924	587
1925	607
1938	857
1939	877
1940	897
1941	927
1942	957
1943	977
1944	1007
1945	1037
1946	1057
1947	1087
1948	1117
1949	1147
1950	1177
1951	1211
1952	1241
1953	1281
1954	1341
1955	1391
1956	1441
1957	1511
1958	1561
1959	1631
1960	1711

Table 2.--Index of surface-water records in the Canadian River basin

Reference no.	Stream and Location	Drainage Area (sq. miles)	Calendar Years 1901–10	1911–20	1921–30	1931–40	1941–50	1951–60	1961–70
1	Canadian River at Logan, New Mexico	a11,141							
2	Canadian River near Glenrio, New Mexico								
3	Lake Rita Blanca near Dalhart, Texas								
4	Punta de Agua Creek near Channing, Texas								
5	Canadian River near Tascosa, Texas	b19,287							
6	East Amarillo Creek near Amarillo, Texas								
7	Canadian River near Amarillo, Texas	c19,445							
8	Bonita Creek near Amarillo, Texas								
9	Chicken Creek near Amarillo, Texas								
10	Coetas Creek near Amarillo, Texas								
11	Big Blue Creek near Dumas, Texas								
12	Lake Meredith near Sanford, Texas								
13	Canadian River near Borger, Texas								
14	Dixon Creek near Borger, Texas								
15	Red Deer Creek near Canadian, Texas								
16	Canadian River near Canadian, Texas	d22,866							
17	Elk Creek near Canadian, Texas								
18	Lake Marvin near Canadian, Texas								
19	Canadian River near Roll, Oklahoma								
20	Canadian River at Bridgeport, Oklahoma	e25,229							

Discharge — Gage heights only — Gage heights and discharge measurements — Reservoir contents

Periodic discharge measurements — Daily chemical quality — Periodic chemical quality — Water temperature

Table 2.--Index of surface-water records in the Canadian River basin--Continued

Reference no.	Stream and Location	Drainage Area (sq. miles)	Calendar Years 1901–10	1911–20	1921–30	1931–40	1941–50	1951–60	1961–70
21	Coldwater Creek near Hardesty, Oklahoma	f 1,967							
22	Palo Duro Creek near Spearman, Texas	g 960							
23	Kiowa Creek near Darrouzett, Texas								
24	Wolf Creek at Lipscomb, Texas	h 697							

Discharge — **Gage heights only** — **Gage heights and discharge measurements** — **Periodic discharge measurements** — **Daily chemical quality** — **Periodic chemical quality** — **Water temperature**

a 1,110 sq miles of this area is noncontributing.
b Some of this area is noncontributing.
c 4,069 sq miles of this area is noncontributing.
d 4,688 sq miles of this area is noncontributing.
e 4,801 sq miles of this area is noncontributing.
f 1,200 sq miles of this area is noncontributing.
g 520 sq miles of this area is noncontributing.
h 222 sq miles of this area is noncontributing.

Table 3.--Summary of chemical analyses at daily stations on streams in the Canadian River basin

(Analyses listed as maximum and minimum were classified on the basis of the values for dissolved solids only. Values of other constituents may not be extremes. Results in parts per million except as indicated)

Date of collection	Mean discharge (cfs)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	[a] Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Dissolved solids: Parts per million	Dissolved solids: Tons per acre-foot	Dissolved solids: Tons per day	Hardness as $CaCO_3$: Calcium, Magnesium	Hardness as $CaCO_3$: Noncarbonate	Sodium adsorption ratio	Specific conductance (micromhos at 25°C)	pH
1. CANADIAN RIVER AT LOGAN, NEW MEXICO																						
July 1957 to Sept. 1957																						
Maximum, Sept. 21-27, 1957	1.0	18		246	91	1890		347		522	3040	--	--	--	5980	8.13	16.1	1000	716	26	9800	7.8
Minimum, Aug. 4----------	952	14		35	6.2	51		197		38	16	--	0.1	--	257	.35	661	113	0	2.1	385	7.7
Water year 1958																						
Maximum, Apr. 9-10, 1958-	1.5	14		167	87	1550	--	378		711	2190	--	--	--	4910	6.68	19.9	774	464	24	7980	7.9
Minimum, July 6----------	1440	13		10	8.6	27	3.3	184		24	17	0.7	.1	--	224	.30	871	136	0	1.0	372	8.1
Weighted average---------	261	15		55	15	85	--	189		146	60	--	.5	--	470	.64	331	198	44	2.6	742	--
Water year 1959																						
Maximum, Mar. 23-25, 1959	1.0	22		192	129	2290	--	438		855	3280	--	--	--	6980	9.49	18.8	1010	651	31	11100	7.9
Minimum, Aug. 24-25------	2880	17		24	5.8	53	--	159		44	19	--	.4	--	242	.33	1880	84	0	2.5	391	7.8
Weighted average---------	68.1	20		39	13	121	--	200		123	90	--	.9	--	505	.69	92.9	151	0	4.3	802	--
Water year 1960																						
Maximum, Apr. 24-25, 1960	1.0	32		145	99	1390	--	356		802	1900	--	.9	--	4540	6.17	12.3	770	478	22	7400	7.8
Minimum, July 2, 5-9-----	5186	21		40	7.5	60	--	224		50	21	--	1.4	--	311	.42	4350	131	0	2.3	503	7.8
Weighted average---------	190	20		48	12	114	--	232		112	81	--	1.2	--	502	.68	258	170	0	3.8	813	--
Water year 1961																						
Maximum, Nov. 29, 1960---	27.0	22		219	85	2830	--	135		688	4270	--	5.0	--	8330	11.3	607	897	540	41	13600	7.4
Minimum, Oct. 17-18------	1640	17		35	9.4	68	--	192		74	30	--	.1	--	328	.45	1110	126	0	2.6	539	7.6
Water year 1962																						
Maximum, July 21-24, 1962	2.8	18		118	62	768	--	316		510	1040	--	1.2	--	2670	3.63	20.2	550	291	14	4510	7.7
Minimum, June 26-27------	327	17		42	7.3	47	--	172		37	41	--	.2	--	277	.38	245	135	0	1.8	465	7.7
Weighted average---------	67.1	16		61	22	179	--	231		243	137	--	.9	--	775	--	140	245	74	4.6	1230	7.9
5. CANADIAN RIVER NEAR TASCOSA, TEXAS																						
June 1948 to Sept. 1948																						
Maximum, Sept. 17, 19-20, 1948------------	6.16	18		92	52	251		192		169	240	--	3.2	--	1220	1.66	20	441	284	--	1920	--
Minimum, July 8, 13-14, 20, 22-----------------	290	17		50	20	114		147		203	85	--	2.2	--	570	.78	446	207	86	--	930	--
Water year 1949																						
Maximum, Feb. 15-18, 20, 1949---------------	22.5	14		78	46	350		243		381	388	0.8	1.8	--	1380	1.88	84	384	184	--	2330	--
Minimum, Nov. 21-30, 1948-	9.89	26		46	17	15		234		17	5.0	--	.2	--	245	.33	6.5	185	0	--	407	--
Weighted average---------	b504	18		45	21	136		209		163	109	--	3.3	--	599	.82	819	199	28	--	990	--
Water year 1950																						
Maximum, Apr. 19-21, 1950	23.3	15		97	54	380		230		529	388	1.0	2.8	--	1580	2.15	99	464	276	--	2520	7.9
Minimum, June 22---------	4739	18		18	6.6	71		171		60	16	--	2.2	--	294	.40	3760	72	0	--	406	8.2
Weighted average---------	b523	19		39	16	136		186		150	101	.7	2.7	--	562	.76	794	164	11	--	919	--

See footnotes at end of table.

Table 3.--Summary of chemical analyses at daily stations on streams in the Canadian River basin--Continued

(Analyses listed as maximum and minimum were classified on the basis of the values for dissolved solids only. Values of other constituents may not be extremes. Results in parts per million except as indicated)

Date of collection	Mean discharge (cfs)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	[a] Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Dissolved solids: Parts per million	Dissolved solids: Tons per acre-foot	Dissolved solids: Tons per day	Hardness as $CaCO_3$: Calcium, Magnesium	Hardness as $CaCO_3$: Noncarbonate	Sodium adsorption ratio	Specific conductance (micromhos at 25°C)	pH
5. CANADIAN RIVER NEAR TASCOSA, TEXAS--Continued																						
Water year 1951																						
Maximum, Mar. 2-3, 14-15, 1951	16.8	16		96	62	521		250		604	560	1.0	1.2	--	1980	2.69	90	494	290	--	3190	7.9
Minimum, May 14, 15, 16	5645	16		26	8.7	71		189		41	40	--	1.2	--	297	.40	4530	101	0	--	515	7.8
Weighted average	c196	18		44	18	147		208		155	121	.8	2.2	--	622	.85	329	184	14	--	1020	--
Water year 1952																						
Maximum, Mar. 18-19, 21-22, 26-27, 1952	1.7	18		79	77	532		306		740	458	1.0	1.8	--	2060	2.80	9.5	514	263	10	3140	8.2
Minimum, July 16-21	980	20		23	9.3	125		177		105	76	.7	4.3	--	450	.61	1190	96	0	5.5	766	8.1
Weighted average	c82.1	21		45	20	178		232		169	152	.9	2.9	--	705	.96	156	194	4	5.5	1210	--
Water year 1953																						
Maximum, Jan. 1-10, 1953	12.5	16		73	50	498		229		386	620	1.0	4.5	--	1760	2.39	59.4	388	200	11	3000	8.1
Minimum, July 16, 19-24	2015	19		34	11	98		184		80	74	.6	1.8	--	413	.56	2250	130	0	3.7	690	8.2
Weighted average	c111	21		38	13	141		187		112	129	.7	2.7	--	556	.76	167	148	0	5.0	934	--
7. CANADIAN RIVER NEAR AMARILLO, TEXAS																						
Water year 1951																						
Maximum, Jan. 21-31, 1951	15.1	36		177	62	400		272		523	520	4.4	66	--	1920	2.61	78	696	474	--	3040	8.0
Minimum, Aug. 10-12	553	16		21	9.1	90		140		85	56	1.2	1.5	--	385	.52	575	90	0	--	602	7.7
Weighted average	198	22		48	20	146		202		158	130	1.0	4.9	--	640	.87	342	202	36	--	1040	--
Water year 1952																						
Maximum, Jan. 5-8, 10, 1952	12.4	58		186	70	377		270		560	502	2.4	65	--	1950	2.65	65.3	752	531	6.0	2950	7.2
Minimum, Sept. 3	251	--		--	--	--		112		--	30	--	--	--	285	.39	193	188	96	--	457	7.6
Weighted average	91.7	40		63	30	177		221		210	176	1.9	14	--	854	1.16	211	280	100	4.6	1380	--
Water year 1953																						
Maximum, Dec. 25-29, 1952	11.4	64		211	81	461		278		656	622	2.6	83	--	2320	3.16	71.4	860	632	6.8	3480	7.7
Minimum, Aug. 5-8, 1953	485	26		30	10	106		196		77	71	1.0	3.0	--	438	.60	574	116	0	4.3	700	8.0
Weighted average	121	41		56	28	164		250		149	158	2.1	26	--	766	1.04	250	254	50	4.5	1220	--
Water year 1954																						
Maximum, Apr. 12, 1954	39	36		221	67	470		151		800	618	1.6	20	--	2310	3.14	243	827	704	7.1	3390	8.1
Minimum, May 10-11, 17-18	2237	25		36	14	79		166		79	68	.8	5.0	--	390	.53	2360	148	12	2.8	650	8.0
Weighted average	171	36		54	25	170		237		156	171	1.6	12	--	754	1.03	348	238	44	4.8	1230	--
Water year 1955																						
Maximum, Feb. 1-10, 1955	21.1	67		138	57	371		346		402	440	2.8	69	--	1720	2.34	98.0	579	296	6.7	2590	7.4
Minimum, Aug. 7-10	797	20		37	11	74		174		64	60	1.2	1.2	--	354	.48	762	137	0	2.7	601	7.8
Weighted average	367	29		48	19	153		214		132	144	1.4	13	--	651	.89	645	198	22	4.7	1080	--
Water year 1956																						
Maximum, July 9, 13, 1956	42.6	39		149	63	453		271		551	572	1.6	11	--	1970	2.68	227	631	420	7.8	3070	8.4
Minimum, Aug. 19-20, 22	249	18		32	10	89		197		62	59	1.2	2.5	--	372	.51	250	121	0	3.5	619	8.0
Weighted average	108	32		63	24	193		215		174	198	1.8	11	--	823	1.12	240	256	54	5.3	1310	--

See footnotes at end of table.

Table 3.--Summary of chemical analyses at daily stations on streams in the Canadian River basin--Continued

(Analyses listed as maximum and minimum were classified on the basis of the values for dissolved solids only. Values of other constituents may not be extremes. Results in parts per million except as indicated)

Date of collection	Mean discharge (cfs)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	[a] Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Dissolved solids: Parts per million	Dissolved solids: Tons per acre-foot	Dissolved solids: Tons per day	Hardness as $CaCO_3$: Calcium, Magnesium	Hardness as $CaCO_3$: Noncarbonate	Sodium adsorption ratio	Specific conductance (micromhos at 25°C)	pH
7. CANADIAN RIVER NEAR AMARILLO, TEXAS--Continued																						
Water year 1957																						
Maximum, Mar. 21, 1957---	37	37		260	79	671		170		888	945	2.0	38	--	3000	4.08	300	974	834	9.3	4490	8.2
Minimum, Sept. 21-30-----	13.0	30		47	9.3	27		218		16	12	.4	2.5	--	252	.34	8.8	156	0	1.0	400	8.2
Weighted average---------	313	19		46	17	148		200		130	141	1.3	5.0	--	613	.83	518	185	21	4.7	1010	--
Water year 1958																						
Maximum, Jan.21-23, 1958-	35.0	20		125	43	456		259		432	570	1.0	14	--	1790	2.43	169	489	276	9.0	2880	8.3
Minimum, Oct. 1-11, 1957-	10.8	27		50	11	40		222		28	29	.8	3.0	--	302	.41	8.81	170	0	1.3	487	8.0
Weighted average---------	633	18		45	15	116		186		125	96	.8	4.7	--	527	.72	901	174	22	3.8	838	--
Water year 1959																						
Maximum, Apr. 8-9, 1959--	33.5	37		188	57	466		202		634	610	1.3	33	--	2130	2.90	193	704	538	7.6	3270	8.2
Minimum, Aug. 23-31------	2332	15		30	10	97		168		91	65	.7	2.5	--	394	.54	2480	116	0	3.9	637	7.8
Weighted average---------	188	24		46	19	153		215		143	134	1.1	11	--	649	.88	329	193	17	4.8	1040	--
Water year 1960																						
Maximum, Mar. 25, 1960---	340	--		--	--	--		175		--	640	--	--	--	2210	3.01	2030	685	542	--	3370	7.9
Minimum, June 8-14-------	3070	52		27	9.1	90		174		69	60	.6	1.2	--	395	.54	3270	105	0	3.8	600	7.1
Weighted average---------	564	21		37	13	137		186		121	112	.7	7.3	--	548	.75	834	146	0	4.9	891	--
Water year 1961																						
Maximum, Jan. 21-31, 1961	44.1	24		122	49	402		309		442	460	1.0	20	--	1670	2.27	199	506	253	7.8	2660	6.9
Minimum, Aug. 19---------	1500	--		--	--	110		166		57	31	.6	3.0	--	317	.43	1280	62	0	6.1	473	7.8
Weighted average---------	287	17		57	22	180		206		221	153	.8	7.5	--	776	1.06	601	232	64	5.1	1240	--
Water year 1962																						
Maximum, Jan. 11-21, 1962	50.9	49		146	48	388		280		486	460	1.4	21	--	1740	2.37	239	562	332	7.1	2750	7.2
Minimum, July 23-26------	390	--		--	--	--		176		67	51	--	--	--	352	.48	371	87	0	--	581	7.9
Weighted average---------	162	21		56	22	202		214		218	183	.9	9.2	--	820	1.12	359	230	64	5.9	1340	7.1
Water year 1963																						
Maximum, Mar. 1-13, 1963-	23.7	40		110	45	363		253		372	428	1.7	56	--	1540	2.09	98.5	460	252	7.4	2430	7.1
Minimum, Sept. 10--------	125	16		--	--	62	5.7	211		29	7.6	.5	.8	0.4	253	.34	85.4	75	0	3.1	438	7.6
Weighted average---------	129	25		55	22	189		220		180	185	1.0	11	--	779	1.06	272	230	57	5.4	1280	7.0
Water year 1964																						
Maximum, May 5, 1964-----	6.8	68		73	69	399		347		326	450	2.8	46	19	1620	2.20	29.7	466	182	8.0	2570	7.8
Minimum, Sept. 28-30-----	37.0	24		47	11	31		227		16	18	--	1.5	.42	261	.35	26.1	162	0	1.1	432	7.6
Weighted average---------	55.4	33		61	24	143		222		136	142	2.0	36	2.5	693	.94	104	254	72	3.8	1110	7.4
Water year 1965																						
Maximum, Aug. 1, 3, 1965-	432	18		171	60	556		194		624	760	--	.5	--	2290	3.11	2671	674	514	9.3	3770	7.3
Minimum, Oct. 29-31, 1964	7.7	22		40	9.3	21		198		12	5.8	--	.2	--	207	.28	4.30	138	0	.8	346	7.4
Weighted average---------	377	17		53	19	160		198		145	170	.7	5.6	.79	668	.91	680	212	54	4.5	1140	7.3

See footnotes at end of table.

Table 3.--Summary of chemical analyses at daily stations on streams in the Canadian River basin--Continued

(Analyses listed as maximum and minimum were classified on the basis of the values for dissolved solids only. Values of other constituents may not be extremes. Results in parts per million except as indicated)

Date of collection	Mean discharge (cfs)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	[a] Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Dissolved solids: Parts per million	Dissolved solids: Tons per acre-foot	Dissolved solids: Tons per day	Hardness as $CaCO_3$: Calcium, Magnesium	Hardness as $CaCO_3$: Non-carbonate	Sodium adsorption ratio	Specific conductance (micromhos at 25°C)	pH
13. CANADIAN RIVER NEAR BORGER, TEXAS																						
Water year 1951																						
Maximum, Sept. 21-30, 1951	--	26		698	504	591		200		431	3180	0.4	--	--	5530	--	--	3810	3650	--	9580	7.8
Minimum, Oct. 2-3, 7-10, 1950	--	15		32	12	84		150		95	60	.5	5.0	--	392	--	--	130	6	--	641	7.8
20. CANADIAN RIVER AT BRIDGEPORT, OKLAHOMA																						
Water year 1949																						
Maximum, Feb. 1-5, 1949	140	--		168	51	265		292		520	300	--	2.0	--	1390	1.89	525	628	389	--	2050	--
Minimum, Feb. 7-9	1701	--		66	15	52		128		142	60	--	2.0	--	404	.55	1860	226	121	--	646	--
Weighted average	942	--		96	27	112		180		259	126	--	2.6	--	787	1.07	2000	350	203	--	1130	--
Water year 1950																						
Maximum, June 20, 1950	360	--		160	64	413		194		558	575	--	10	--	1880	2.56	1830	662	502	--	3000	--
Minimum, May 9-10	108	--		51	12	20		134		88	9.5	--	4.8	--	278	.38	81	176	66	--	420	--
Weighted average	779	--		71	22	123		175		178	144	--	1.9	--	667	.91	1400	268	124	--	1050	--
Water year 1951																						
Maximum, Jan. 28-31, 1951	66	--		211	61	213		373		528	270	--	1.8	--	1600	2.18	285	778	472	--	2300	--
Minimum, Sept. 11-13	205	--		52	12	25		128		104	12	--	3.6	--	288	.39	159	180	74	--	441	7.7
Weighted average	655	--		106	26	76		191		243	90	--	2.0	--	714	.97	1260	372	215	--	1020	--
Water year 1952																						
Maximum, Sept. 1-10, 1952	27.5	20		110	46	458	11	220		486	530	2.6	5.5	--	1780	2.42	132	464	283	--	2860	8.0
Minimum, May 23	2980	--		34	13	15		112		66	4.0	--	5.4	--	192	.26	1570	138	46	--	226	7.9
Weighted average	63.4	--		112	33	127		201		307	143	--	2.5	--	819	1.11	140	415	250	--	1290	--
Water year 1953																						
Maximum, Aug. 21-24, 1953	2850	--		113	37	329	--	244		375	402	--	1.8	--	1440	1.96	11080	436	236	6.9	2320	7.7
Minimum, July 17	1490	--		43	6.9	11		119		54	3.5	--	1.8	--	186	.25	748	136	38	.4	294	7.8
Weighted average	107	--		99	31	d224		204		309	263	--	3.3	--	1070	1.46	309	374	208	5.0	1720	--
Water year 1954																						
Maximum, Aug. 27-31, 1954	54.0	--		94	35	376	--	236		312	510	--	3.1	--	1550	2.11	226	380	186	8.4	2620	8.3
Minimum, Sept. 29-30	47.5	--		44	3.2	22	--	139		3.7	16	--	2.8	--	227	.31	29	123	9	.9	348	8.3
Weighted average	230	--		90	25	151		180		234	191	--	2.5	--	841	1.14	522	328	180	3.6	1330	--
Water year 1955																						
Maximum, Oct. 11, 1954	1550	--		150	50	632	9.6	194		612	825	--	1.8	--	2450	3.33	10250	580	421	11	4000	8.2
Minimum, May 19, 1955	11200	--		40	4.9	17	--	126		30	14	--	4.9	--	173	.24	5230	120	17	.7	265	7.3
Weighted average	457	--		81	25	154	--	184		205	185	--	3.5	--	783	1.06	966	305	154	3.8	1260	--
Water year 1956																						
Maximum, June 22, 1956	22.0	--		104	41	372		288		415	460	--	5.7	--	1550	2.11	92	430	276	7.8	2500	8.3
Minimum, Oct. 1, 3-4, 1955	7725	--		43	7.9	17		128		44	16	--	5.1	--	196	.27	4090	140	35	.6	335	7.9
Weighted average	159	--		78	24	140		199		185	172	--	--	--	732	1.00	314	293	130	3.6	1180	--

See footnotes at end of table.

Table 3.--Summary of chemical analyses at daily stations on streams in the Canadian River basin--Continued

(Analyses listed as maximum and minimum were classified on the basis of the values for dissolved solids only; values of other constituents may not be extremes. Results in parts per million except as indicated)

Date of collection	Mean discharge (cfs)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)[a]	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Dissolved solids: Parts per million	Dissolved solids: Tons per acre-foot	Dissolved solids: Tons per day	Hardness as $CaCO_3$: Calcium, Magnesium	Hardness as $CaCO_3$: Noncarbonate	Sodium adsorption ratio	Specific conductance (micromhos at 25°C)	pH
20. CANADIAN RIVER AT BRIDGEPORT, OKLAHOMA--Continued																						
Water year 1957																						
Maximum, Mar. 11-14, 1957	133	--		114	40	301		244		282	130	--	4.8	--	1340	1.82	481	450	250	6.2	2240	8.5
Minimum, June 20	802	--		47	9.4	33		196		31	23	--	1.8	--	245	.33	531	156	0	1.1	409	7.9
Weighted average	699	--		87	26	156		196		212	198	--	3.6	--	808	1.10	1520	325	164	3.8	1330	--
Water year 1958																						
Maximum, May 30-31, 1958	3605	--		118	48	402	--	258		368	545	--	.8	--	1730	2.35	16840	490	278	7.9	2710	8.2
Minimum, Sept. 7-9	2738	--		54	11	42	--	130		102	40	--	3.3	--	364	.50	2690	180	74	1.4	557	8.0
Weighted average	780	--		71	23	165	--	186		185	201	--	2.7	--	779	1.06	1640	272	119	4.4	1260	--
Water year 1959																						
Maximum, July 6-8, 1959	1320	--		135	42	407		222		392	570	--	2.2	--	1770	2.41	6310	510	328	7.8	2800	8.3
Minimum, May 27	5280	--		30	9.0	114		112		26	16	--	2.6	--	172	.23	2450	112	20	.6	265	8.1
Weighted average	420	--		78	24	131		169		190	169	--	3.6	--	726	.99	823	293	154	3.3	1140	--
Water year 1960																						
Maximum, June 10, 1960	15200	--		123	45	360		226		347	515	--	.1	--	1620	2.20	66480	490	304	7.1	2500	8.4
Minimum, Aug. 30-31	162	--		83	20	57		122		217	61	--	2.9	--	540	.73	236	290	190	1.5	784	8.1
Weighted average	e1060	--		87	30	194		193		253	240	--	2.5	--	940	1.29	2720	340	182	4.6	1500	--

a Includes the equivalent of any carbonate (CO_3) present.
b Discharge records for gaging station near Amarillo. No appreciable inflow between sampling point and gaging station except during period of heavy local rains.
c Mean discharge adjusted to reflect small discharge of sewage effluent entering Canadian River between sampling point and gaging station.
d Calculated from other weighted average constituents.
e Represents 91 percent of flow for water year.

Table 4.--Chemical analyses of streams and reservoirs in the Canadian River basin for locations other than daily stations

(Results in parts per million except as indicated)

Date of collection	Discharge (cfs)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	[a] Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids (calculated): Parts per million	Dissolved solids: Tons per acre-foot	Dissolved solids: Tons per day	Hardness as $CaCO_3$: Calcium, Magnesium	Hardness as $CaCO_3$: Noncarbonate	Sodium adsorption ratio	Specific conductance (micromhos at 25°C)	pH
2. CANADIAN RIVER NEAR GLENRIO, NEW MEXICO																						
Nov. 27, 1964-----	9.5	12		132	77	1740	8.9	325		488	2640	0.6	1.4		5260	7.15	--	648	382	30	8900	7.8
Dec. 18-----------	4.6	15		158	102	1990	10	427		543	2960	.6	1.1		5990	8.15	--	813	463	30	10100	7.8
May 13, 1965------	268	14		54	19	429	6.0	232		165	555	.4	.3		1360	1.85	--	212	22	13	2430	7.6
June 18-----------	73.8	13		53	13	199	4.6	263		109	214	.5	.9		736	1.00	--	184	0	6.4	1290	7.5
Oct. 4------------	336	5.4		48	16	157	5.0	214		158	130	.8	.2		626	.85	--	185	10	5.0	1060	7.7
3. LAKE RITA BLANCA NEAR DALHART, TEXAS																						
June 12, 1951-----	--	2.0		33	15	9.3	4.0	175		21	3.8	0.7	1.5		b181	0.25	--	144	1	0.3	327	7.6
Nov. 18, 1965-----	--	5.7		24	5.9	8.0	5.6	106		14	4.8	.9	.2		121	.16	--	84	0	.4	223	6.5
4. PUNTA DE AGUA CREEK NEAR CHANNING, TEXAS																						
Dec. 28, 1965-----	6.74	25		49	53	71	7.4	432		81	41	3.3	0.2		543	0.74	--	340	0	1.7	902	7.7
6. EAST AMARILLO CREEK NEAR AMARILLO, TEXAS																						
Sept. 13, 1950----	--	72		63	39	164		336		65	228	--	88		b941	1.28	--	318	4	--	1500	7.9
Feb. 10, 1951-----	--	52		65	41	239		577		87	193	5.2	.2		b966	1.31	--	330	0	--	1620	7.8
Mar. 24, 1955-----	13.6	44		52	36	165		302		80	122	3.6	154		806	1.10	--	278	30	4.3	1370	7.0
June 24-----------	14.5	64		57	28	122		288		103	89	2.8	28		b635	.86	--	256	20	3.0	974	--
May 16, 1956------	11.9	99		50	36	137		276		102	110	3.6	90		764	1.04	--	272	46	3.6	1160	8.6
Oct. 3------------	1.94	84		47	34	133		269		92	112	3.2	79		716	.97	--	258	38	3.6	1170	8.4
Jan. 17, 1957-----	22.2	74		62	40	183		522		102	90	2.6	60		871	1.18	--	318	0	4.5	1280	7.6
Aug. 26-----------	20.8	35		45	20	73		201		63	65	2.0	32		434	.59	--	194	30	2.3	707	8.2
Jan. 8, 1958------	10.9	44		56	31	167		476		86	103	2.4	1.0		724	.98	--	268	0	4.4	1210	7.6
Aug. 5------------	21.1	66		58	28	112		264		88	101	1.8	60		645	.88	--	260	43	3.0	988	8.5
Apr. 2, 1959------	9.05	74		50	37	192		530		93	110	2.9	.2		820	1.12	--	277	0	5.0	1290	7.9
Oct. 1------------	15.8	64		52	28	112		318		70	102	2.0	6.6		593	.81	--	244	0	3.1	957	8.2
June 6, 1960------	14.2	50		48	27	98		253		74	76	2.0	59		558	.76	--	232	24	2.8	869	7.2
July 13-----------	17.1	52		58	24	139		445		60	81	2.3	.0		635	.86	--	244	0	3.9	981	7.5
Jan. 30, 1961-----	14.2	50		54	28	181		570		39	90	2.7	.5		725	.99	--	250	0	5.0	1210	7.4
June 7------------	25.6	38		47	20	77		206		50	72	1.6	50		457	.62	--	200	30	2.4	756	7.9
Feb. 4, 1965------	8.24	60		62	36	124		274		99	114	2.9	94		727	.99	--	302	78	3.1	1210	7.5
8. BONITA CREEK NEAR AMARILLO, TEXAS																						
Nov. 24, 1953-----	2.76	22		--	--	--		--		11	8.8	--	1.5		--	--	--	--	--	--	415	--
Jan. 11, 1955-----	2.52	28		--	13	--		--		10	8.2	--	1.5		--	--	--	--	--	--	416	--
Jan. 11, 1956-----	2.64	22		52	13	19		245		12	7.8	--	.7		246	0.33	--	184	0	0.6	417	8.2
Jan. 17, 1957-----	1.95	26		57	13	19		257		14	7.8	--	.6		263	.36	--	195	0	.6	429	8.0
Jan. 8, 1958------	2.43	20		53	14	22		252		14	10	--	.8		258	.35	--	189	0	.7	423	8.1
Dec. 3------------	2.24	--		--	--	--		252		--	16	--	--		--	--	--	194	0	--	466	7.8

See footnotes at end of table.

Table 4.--Chemical analyses of streams and reservoirs in the Canadian River basin for locations other than daily stations--Continued

(Results in parts per million except as indicated)

Date of collection	Discharge (cfs)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	[a/] Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids (calculated)			Hardness as $CaCO_3$		Sodium adsorption ratio	Specific conductance (micromhos at 25°C)	pH
															Parts per million	Tons per acre-foot	Tons per day	Calcium, Magnesium	Noncarbonate			
9. CHICKEN CREEK NEAR AMARILLO, TEXAS																						
Nov. 24, 1953-----	2.31	24		--	--	--		--		9.1	5.0	--	1.5		--	--	--	--	--	--	386	--
Jan. 11, 1955-----	4.08	24		32	7.9	13		152		6.8	4.8	--	2.5		166	0.23	--	112	0	0.5	315	8.2
Jan. 11, 1956-----	4.97	22		48	9.0	11		200		8.0	4.8	--	1.9		b208	.28	--	157	0	.4	336	8.2
Jan. 17, 1957-----	.6	26		66	9.9	18		266		15	6.8	--	2.4		275	.37	--	205	0	.6	438	7.9
Jan. 8, 1958------	3.41	20		46	9.0	12		194		9.2	5.8	--	2.5		200	.27	--	152	0	.4	327	7.9
Dec. 3------------	1.70	--		--	--	--		213		--	225	--	--		--	--	--	185	10	--	860	8.2
Sept. 9, 1964-----	.41	26		43	12	17		216		7.8	4.7	0.5	.0		217	.30	--	157	0	.6	349	7.6
Jan. 7, 1965------	1.54	21		41	13	10		194		10	4.4	.6	1.0		196	.27	--	156	0	.3	324	7.8
July 12-----------	.60	23		26	10	16		153		8.6	4.0	.5	.2		163	.22	--	106	0	.7	261	7.9
Apr. 28, 1966-----	--	23		66	19	59	3.4	300		13	87	.6	.0		419	.57	--	242	0	1.6	722	7.8
10. COETAS CREEK NEAR AMARILLO, TEXAS																						
Nov. 24, 1953-----	1.14	24		--	--	--		--		14	11	--	2.5		--	--	--	--	--	--	370	--
Jan. 11, 1955-----	1.29	32		24	9.6	18		130		15	10	--	3.8		176	0.24	--	100	0	0.8	353	8.1
Jan. 11, 1956-----	1.03	24		51	9.4	14		201		14	10	--	3.4		b230	.31	--	165	0	.5	379	8.2
Jan. 17, 1957-----	.79	24		55	9.8	17		216		17	12	--	4.4		245	.33	--	178	1	.6	401	7.9
Jan. 8, 1958------	1.20	21		51	9.0	16		200		15	12	--	3.0		225	.31	--	165	1	.5	372	8.1
Dec. 3------------	.86	--		--	--	--		213		--	16	--	--		--	--	--	177	2	--	424	7.6
11. BIG BLUE CREEK NEAR DUMAS, TEXAS																						
Apr. 29, 1966-----	1.82	20		40	27	79	5.5	254		141	23	1.1	.2		462	0.63	--	210	2	2.4	722	8.0
12. LAKE MEREDITH NEAR SANFORD, TEXAS																						
Nov. 5, 1965------	--	7.0		48	17	152	4.3	182		145	158	0.7	0.2		621	0.84	--	188	39	4.8	1090	7.2
Apr. 29, 1966-----	--	1.9		60	19	165	5.1	208		172	180	.6	.2		706	.96	--	228	58	4.8	1250	7.2
14. DIXON CREEK NEAR BORGER, TEXAS																						
Apr. 29, 1966-----	5.27	41		151	70	320	13	134		578	558	--	0.2		1800	2.45	--	666	556	5.4	3060	6.6
15. RED DEER CREEK NEAR CANADIAN, TEXAS																						
June 16, 1965-----	40.9	18		40	8.6	23		156		17	24	0.8	3.8		212	0.29	--	135	7	0.9	379	7.5
Oct. 18-----------	58.6	15		45	7.7	32		172		16	38	.7	.8		240	.33	--	144	3	1.2	425	6.9
16. CANADIAN RIVER NEAR CANADIAN, TEXAS																						
Aug. 22, 1950-----	117	--		--	--	--	--	200		179	275	--	--		--	--	--	286	--	--	1480	7.6
Aug. 30-----------	1330	--		--	--	--	--	162		151	210	--	--		--	--	--	216	--	--	1130	7.9
Sept. 7-----------	2950	17		--	--	--	--	188		195	240	--	--		--	--	--	266	--	--	1390	7.8
Sept. 12----------	6570	--		--	--	--	--	172		98	100	--	--		--	--	--	146	--	--	727	7.9
Sept. 21----------	139	--		--	--	--	--	212		165	217	--	--		--	--	--	259	--	--	1330	8.0
Sept. 28----------	1480	--		--	--	--	--	177		102	127	--	--		--	--	--	171	--	--	890	8.0
Oct. 4------------	450	--		--	--	--	--	166		111	134	--	--		--	--	--	172	--	--	904	7.9
Oct. 10-----------	83.0	--		--	--	--	--	241		165	250	--	--		--	--	--	322	--	--	1470	8.1
Oct. 17-----------	20.1	--		--	--	--	--	242		139	260	--	--		--	--	--	311	--	--	1450	8.1
Nov. 3, 1959------	86	13		87	45	364	--	198		210	570	1.4	3.7		1390	1.89	323	400	238	7.9	2410	8.0
Feb. 16, 1960-----	c380	10		101	38	346	--	256		235	498	1.3	2.9		b1400	1.90	1440	410	200	7.4	2350	8.2
Apr. 6------------	2.4	32		70	24	70	--	316		16	106	1.1	.1		b 490	.67	3.18	275	16	1.8	855	8.1
July 25-----------	275	18		80	32	360	--	204		247	488	.9	1.4		b1360	1.85	1010	332	165	8.6	2250	7.7
Oct. 19-----------	4780	12		56	20	145	--	188		100	195	.7	.0		b 660	.90	8520	220	66	4.2	1080	7.7
Jan. 11, 1961-----	97	11		107	46	347	--	268		277	488	4.0	2.4		b1460	1.99	382	455	236	7.1	2360	8.1
Apr. 10-----------	357	13		110	48	355	--	272		262	520	1.8	3.3		b1490	2.03	1440	470	240	7.1	2450	8.3

See footnotes at end of table.

Table 4.--Chemical analyses of streams and reservoirs in the Canadian River basin for locations other than daily stations--Continued

(Results in parts per million except as indicated)

Date of collection	Discharge (cfs)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	[a] Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids (calculated): Parts per million	Dissolved solids: Tons per acre-foot	Dissolved solids: Tons per day	Hardness as $CaCO_3$: Calcium, Magnesium	Hardness as $CaCO_3$: Non-carbonate	Sodium adsorption ratio	Specific conductance (micromhos at 25°C)	pH
17. ELK CREEK NEAR CANADIAN, TEXAS																						
Apr. 28, 1966-----	0.05	24		54	38	80	4.5	330		32	117	1.3	0.0	--	513	0.70	--	292	22	2.0	910	7.9
18. LAKE MARVIN NEAR CANADIAN, TEXAS																						
Dec. 29, 1965-----	--	11		28	15	41	4.4	232		14	14	0.7	2.2	--	244	0.33	--	132	0	1.5	427	7.2
19. CANADIAN RIVER NEAR ROLL, OKLAHOMA																						
Nov. 15, 1961-----	--	--		--	--	187	--	104		295	220	--	0.5		876	1.19	--	296	211	4.7	1530	7.7
Dec. 6------------	--	--		--	--	294	--	262		255	390	--	.2		1220	1.66	--	390	176	6.5	2020	7.9
Feb. 1, 1962------	--	--		--	--	497	--	172		990	505	--	1.3		2550	3.47	--	805	664	7.6	3430	8.3
Mar. 8------------	--	--		--	--	244	--	280		205	340	--	1.1		1160	1.58	--	392	162	5.4	1610	8.3
Mar. 29-----------	--	--		--	--	59	--	172		185	55	--	.7		546	.74	--	284	143	1.5	778	8.4
June 26-----------	--	--		--	--	196	--	204		175	235	--	--		832	1.13	--	255	88	5.3	1380	7.8
Aug. 29-----------	--	--		--	--	282	--	350		440	360	--	--		1570	2.14	--	640	353	4.8	2310	8.1
Sept. 26----------	--	--		--	--	337	--	202		500	430	--	--		1650	2.24	--	560	394	6.2	2480	7.9
21. COLDWATER CREEK NEAR HARDESTY, OKLAHOMA																						
Nov. 22, 1961-----	3.6	--		--	--	54	--	218		190	34	--	--		542	0.74	5.27	308	130	1.3	786	8.0
Mar. 5, 1962------	4.4	--		--	--	61	--	242		205	40	--	--		568	.77	6.75	336	138	1.4	833	8.0
May 16------------	.1	--		--	--	104	--	274		242	56	--	--		694	.94	.19	330	106	2.5	1000	8.1
May 28------------	6.1	--		--	--	61	--	194		190	38	--	--		512	.70	8.43	278	119	1.6	763	7.9
June 26 at 1500---	704	--		--	--	5.1	--	242		16	2.7	--	--		295	.40	561	208	10	.2	407	7.5
June 26 at 1645---	364	--		--	--	7.4	--	312		16	2.8	--	--		316	.43	310	260	4	.2	489	7.4
June 27-----------	86.5	--		--	--	9.9	--	296		17	11	--	--		320	.44	74.7	254	12	.3	508	7.4
July 6------------	9.4	--		--	--	63	--	276		215	48	--	--		655	.89	16.6	380	154	1.4	941	7.9
Aug. 17-----------	1.2	--		--	--	103	--	254		230	48	--	--		645	.88	2.09	292	84	2.6	934	8.0
Sept. 10----------	.1	--		--	--	72	--	264		245	54	--	--		684	.93	.18	390	174	1.6	992	8.0
22. PALO DURO CREEK NEAR SPEARMAN, TEXAS																						
Sept. 6, 1949-----	0.30	--		52	17	29		258		32	11	--	3.0		271	0.37	--	200	0	0.9	483	--
Sept. 5, 1950-----	125	--		40	8.4	4.2		158		7.8	2.5	--	2.9		144	.20	--	134	5	.2	235	--
Sept. 14----------	66.9	--		35	10	2.1		133		14	3.8	--	5.1		136	.18	--	128	19	.1	231	--
Sept. 25----------	78.6	--		27	9.4	2.1		122		7.0	1.8	--	.9		108	.15	--	106	6	.1	176	--
Sept. 26----------	398	--		42	6.6	66		132		20	103	--	1.4		304	.41	--	132	24	2.5	561	--
Oct. 6------------	7.39	--		52	15	35		173		54	44	--	8.8		b360	.49	--	191	50	1.1	536	--
Oct. 10-----------	1.90	--		42	9.0	11		187		2.0	6.5	--	.4		b208	.28	--	142	0	.4	308	--
May 19, 1951------	630	--		36	5.3	4.8		136		7.8	1.8	--	.8		b172	.23	--	112	0	.2	233	7.6
May 25------------	--	--		52	28	13		236		61	15	--	7.7		b378	.51	--	245	52	.4	534	8.4
July 17, 1962-----	23.0	18		58	9.3	16		217		22	10	0.9	.0		b261	.35	--	183	5	.5	415	6.6
July 25 at 0430---	510	20		53	7.5	5.0	7.5	194		7.8	8.2	.5	.2		b218	.30	--	163	4	.2	349	6.6
July 25 at 0810---	325	18		52	6.6	4.6	7.1	188		8.8	6.5	.5	.2		b215	.29	--	157	3	.2	333	6.5
July 25 at 1045---	215	16		55	6.2	4.1	7.0	197		8.2	5.2	.5	.2		b211	.29	--	163	1	.1	344	6.6
Nov. 19, 1963-----	0.18	6.9		52	21	19		241		40	11	1.3	.2		270	.37	--	216	18	.6	486	7.0
Jan. 22, 1964-----	2.17	27		50	23	22		259		36	10	1.5	.2		297	.40	--	220	7	.6	491	7.7
May 17, 1965------	32.0	17		46	7.1	18		170		28	8.9	.6	1.5		211	.29	--	144	5	.7	358	7.1
June 13-----------	593	16		42	4.9	10		142		13	6.3	.4	9.6		172	.23	--	125	9	.4	301	7.4
Nov. 23-----------	1.68	23		51	29	32	8.1	266		70	24	1.8	.2		371	.50	--	248	30	.9	617	7.1

See footnotes at end of table.

Table 4.--Chemical analyses of streams and reservoirs in the Canadian River basin for locations other than daily stations--Continued

(Results in parts per million except as indicated)

Date of collection	Discharge (cfs)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	[a] Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids (calculated): Parts per million	Dissolved solids (calculated): Tons per acre-foot	Dissolved solids (calculated): Tons per day	Hardness as $CaCO_3$: Calcium, Magnesium	Hardness as $CaCO_3$: Noncarbonate	Sodium adsorption ratio	Specific conductance (micromhos at 25°C)	pH
23. KIOWA CREEK NEAR DARROUZETT, TEXAS																						
Dec. 29, 1965-----	0.38	35		75	20	24	1.4	289		29	43	0.7	3.5		377	0.51	--	270	32	0.6	642	7.2
24. WOLF CREEK AT LIPSCOMB, TEXAS																						
Mar. 13, 1963-----	5.36	30		61	30	182		282		59	265	1.7	0.0		768	1.04	--	276	44	4.8	1330	7.4
Jan. 22, 1964-----	6.38	32		58	28	180		260		61	262	1.6	.5		751	1.02	--	260	46	4.9	1350	8.1
June 10-----------	.78	35		56	29	210		251		68	308	1.5	1.5		832	1.13	--	259	54	5.7	1470	7.3
Oct. 27-----------	.30	34		55	16	69		244		32	82	1.1	.2		409	.56	--	203	3	2.1	686	7.5
Jan. 6, 1965------	6.33	30		34	35	216		192		69	330	1.6	.2		810	1.10	--	229	72	6.2	1440	8.1
May 17------------	17.9	21		64	24	117		274		42	170	1.7	.8		576	.78	--	258	34	3.2	1040	7.5
June 14-----------	227	14		46	6.4	11		172		7.8	10	.5	.2		181	.25	--	141	0	.4	320	6.8
Oct. 19, 1965-----	20.5	28		57	21	136		254		43	190	1.5	.2		602	.82	--	228	20	3.9	1080	7.3
Nov. 23-----------	6.60	30		61	27	188	1.5	274		63	282	1.7	.2		794	1.08	--	264	40	5.0	1450	7.5
June 7, 1966------	--	32		63	21	113	3.7	268		43	162	1.4	.0		571	.78	--	244	24	3.1	1010	7.5

a Includes the equivalent of any carbonate (CO_3) present.

b Residue at 180°C.

c Daily mean discharge.