TEXAS WATER DEVELOPMENT BOARD

REPORT 88

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

By

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

ABSTRACT

The kinds and quantities of minerals dissolved in surface waters of the Guadalupe River basin are related principally to the geology of the area and to rainfall and streamflow characteristics; but industrial influences, particularly the disposal of oil-field brines, affect the quality in some areas.

Rocks exposed in the basin range in age from Cretaceous to Quaternary. The upper half of the basin is underlain mostly by the Edwards and associated limestones and the Glen Rose Limestone. Streams that traverse these outcrops usually contain less than 250 ppm (parts per million) dissolved solids but are very hard. The principal chemical constituents are calcium and bicarbonate.

The chemical quality of water in streams that drain younger formations in the lower half of the basin is variable. The dissolved-solids content of water in the lower reach of Plum Creek averages more than 500 ppm, apparently because of oil-field brine pollution. The inflow of water from Plum Creek degrades the quality of water in the San Marcos and Guadalupe Rivers. However, the extent of degradation has decreased in the past several years, apparently because of the underground injection of oil-field brine. Nevertheless, the dissolved-solids concentrations of water in the San Marcos River and the Guadalupe River below its junction with the San Marcos River average more than 250 ppm. Water in each stream is very hard. Waters in other streams in the lower half of the basin generally contain less than 250 ppm dissolved solids and are soft or moderately hard.

The chloride concentration in surface waters of the basin generally averages less than 20 ppm, except where streams are polluted by brine from oil fields.

The concentrations of chemical constituents in surface waters throughout much of the basin are within limits recommended by the U.S. Public Health Service for domestic use. The waters are suitable for most irrigation uses. However, the waters in many streams in the upper half of the basin and some streams in the lower half are hard or very hard and will require softening for some industrial uses.

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

INTRODUCTION

The investigation of the chemical quality of surface waters of the Guadalupe River basin, Texas, is a part of a statewide reconnaissance. The chemical quality of surface waters in each of the major river basins is being studied, and a series of reports summarizing the results of the studies is being prepared by the U.S. Geological Survey in cooperation with the Texas Water Development Board. (See list of references.)

The purpose of this report is to present available chemical-quality data and interpretations that will aid in the proper development, management, and use of the surface-water resources of the Guadalupe River basin. In the study, the following factors were considered: the nature and concentrations of mineral constituents in solution; the geologic, hydrologic, and cultural influences that determine the water quality; and the suitability of the water for domestic supply, industrial use, and irrigation.

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 inventory completely the chemical quality of surface waters in the State. To supplement the information being obtained by the network, a cooperative statewide reconnaissance by the U.S. Geological Survey and Texas Water Development Board was begun in September 1961. During this investigation, samples for chemical analysis have been collected periodically at numerous sites throughout Texas so that some quality-of-water information would be available for 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 reconnaissance, water-quality data were collected for the principal streams, the major reservoir, a number of potential reservoir sites, and many tributaries in the Guadalupe River basin.

Agencies that have cooperated in the collection of chemical-quality and streamflow data include the U.S. Army Corps of Engineers, Guadalupe-Blanco River Authority, Edwards Underground Water District, Bexar Metropolitan Water District, city of San Antonio, and Texas State Department of Health.

THE GUADALUPE RIVER BASIN AND ITS ENVIRONMENT

Physical Features

The Guadalupe River basin (excluding the drainage area of the San Antonio River, which will be discussed in a separate report) is an area of more than 6,000 square miles in south-central Texas and includes parts of two physiographic sections—the Edwards Plateau of the Great Plains Province and the West Gulf Coastal Plain of the Coastal Plain Province (Figure 1). These physiographic sections within the basin are separated by the Balcones Escarpment, a southeastward-facing remnant of the Balcones Fault scarp. Although the Edwards Plateau is partly protected from erosion by a cap of very resistant limestone, broad valleys have been cut into its surface. Between these valleys, remnants of the resistant limestone form steep cliffs. The resulting terrain is rough and rugged, and the soil mantle is very thin except along the major stream valleys.

The West Gulf Coastal Plain within the Guadalupe basin extends from the Balcones Escarpment to the Gulf of Mexico. In this section, the rolling to moderately hilly country of the interior merges with the level, nearly featureless prairie of the Gulf Coast.

The Guadalupe River is formed by the confluence of the North and South Forks Guadalupe River near Hunt in Kerr County. From the confluence of its North and South Forks, the Guadalupe River flows southeastward for more than 250 river miles to San Antonio Bay.

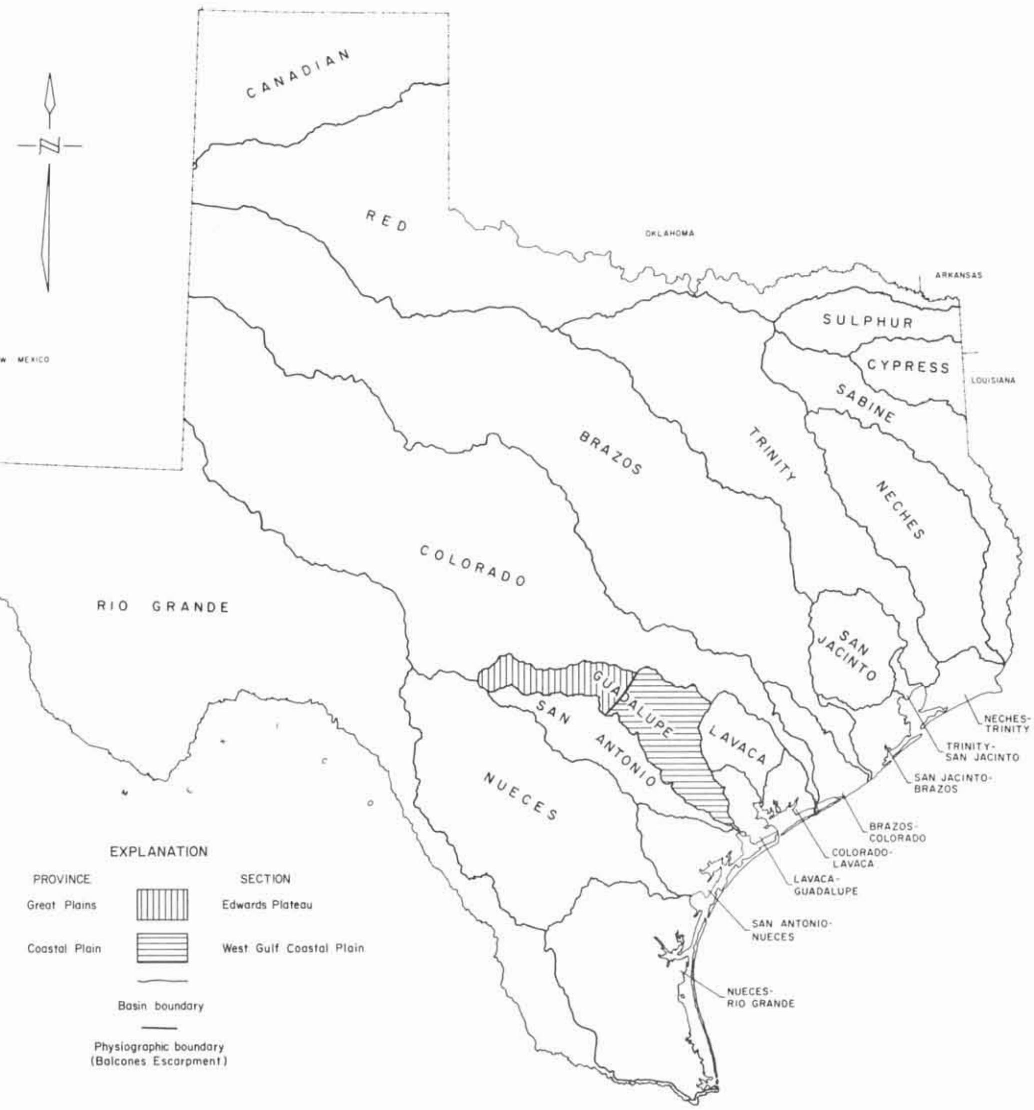

Figure 1.--River Basins in the State and Physiographic Sections of the Guadalupe River Basin

The principal tributaries, in downstream order, are Johnson Creek, Comal and San Marcos Rivers, and Peach, Sandies, and Coleto Creeks.

Cultural Features and Economic Development

In 1960 the population of the Guadalupe River basin was about 170,000, more than 60 percent of which was urban. Eight cities had more than 5,000 inhabitants in 1960; the largest of these is Victoria, which is on the divide between the Guadalupe River basin and the Lavaca-Guadalupe coastal basin. In 1960 Victoria had a population of 33,047, of which 31,395 was in the Guadalupe River basin.

Agriculture contributes substantially to the economy of the basin. Principal agricultural and livestock products include wool and mohair from the Edwards Plateau section, and poultry, beef cattle, dairy products, cotton, grain, grain sorghum, and vegetables from the Coastal Plain section.

Manufacturing, which is also important to the economy of the basin, is concentrated in or near the larger cities and generally is related to the production of gravel, brick, tile, and cement. Quarries for the production of crushed limestone and material for cement are situated along the Balcones Escarpment, and large gravel and sand plants are operated at Victoria. Other industries scattered throughout the basin include flour mills, cotton mills, and textile plants.

The production of oil and natural gas is another important industry in the Guadalupe River basin. Production of oil in the basin began in 1922 with discovery of the great Luling field in Caldwell and Guadalupe Counties. Since then, oil fields have been developed in many other parts of the basin (Figure 5).

SURFACE-WATER DISTRIBUTION

Precipitation

Precipitation within the Guadalupe River basin is unevenly distributed, both areally and seasonally. Average annual precipitation ranges from about 26 inches in the western part of the basin to more than 36 inches in the eastern part. Mean annual precipitation in the basin for the 1931-60 period, average monthly precipitation at two U.S. Weather Bureau stations, and annual precipitation at one station for the 1931-65 period are shown on Figure 2. These data show that precipitation in the western part of the basin usually is minimum in winter and maximum in late spring and early fall. In the eastern part of the basin, precipitation, though usually minimum in the winter, is more uniformly distributed throughout the year.

Precipitation throughout the basin fluctuates much more than is indicated by the monthly averages. During the 1931-65 period, for example, precipitation at Kerrville ranged from less than 0.05 inch in several months to 19.94 inches in September 1936. Precipitation so unevenly distributed in time does not sustain streamflow.

Runoff and Streamflow

Streamflow Records

Streamflow records in the Guadalupe River basin date from 1902, when the U.S. Geological Survey established the stream-gaging station Guadalupe River near Cuero. The longest period of record is for the station Guadalupe River near Spring Branch, which has been operated continuously since 1922. More than 20 years of discharge records are available for several other stations.

As of October 1, 1966, the U.S. Geological Survey operated 19 streamflow, 1 reservoir-content, 1 stage, 4 low-flow partial-record, and 6 crest-stage partial-record stations in the basin. During the reconnaissance period, streamflow was measured at many miscellaneous sites where water samples were collected for chemical analysis. The periods of record for all streamflow stations in the Guadalupe River basin are given in Table 6; the locations of the stations are shown on Figure 10. Records of discharge and stage of streams from 1903 to 1906 and from 1915 to 1960 have been published in the annual series of U.S. Geological Survey Water-Supply Papers. (See table in the list of references.) Beginning with the 1961 water year, streamflow records have been released by the Geological Survey on a state-boundary basis (U.S. Geological Survey, 1961, 1962, 1963, 1964b, 1965a, 1966). Summaries of discharge records giving monthly and annual totals have been published by the U.S. Geological Survey (1960, 1964a) and the Texas Board of Water Engineers (1958).

Variations of Runoff and Streamflow

Runoff is that part of precipitation that appears in surface streams; it is the same as streamflow unaffected by artificial diversion, storage, or other works of man in or on stream channels (Langbein and Iseri, 1960, p. 17).

Before June 1964, when impoundment began in Canyon Reservoir, flow of streams in the drainage area of the Guadalupe River was affected only slightly by diversion or storage. Consequently, in the following summary of runoff, historical streamflow records for the period of the 1940-63 water years were used to show the general pattern of areal runoff within the basin.

Average runoff, as measured at six streamflow stations, is shown in Figure 2. In some areas near the eastern edge of the Edwards Plateau, large springs add considerable quantities of water to the flow of streams. Comal Springs, which discharge to the Comal River, and San Marcos Springs, which discharge to the San Marcos River, are the largest. The relation between precipitation and surface runoff for these areas is obscured; consequently, runoff data for the drainage areas of the Comal and San Marcos Rivers are omitted from Figure 2. Average runoff from other subbasins ranged from 2.3 to 4.3 inches. Lowest annual runoff is from the drainage area upstream from Comfort, where precipitation averages less than 30 inches annually; highest annual runoff is from the drainage area of the Blanco River, where precipitation averages more than 34 inches annually.

Data on Figure 2 do not indicate the variability of flow in a particular stream. Average water discharge and minimum and maximum daily discharges for the 1940-63 period of concurrent record for eight streamflow stations are given in Table 1. These data indicate that streamflow is variable throughout the basin. For example, discharge of the Guadalupe River at Comfort averaged 141 cfs (cubic feet per second), but the daily discharge ranged from 0 to 25,300 cfs. Farther downstream at Victoria, the discharge of the Guadalupe River averaged 1,539 cfs, but the daily discharge ranged from 14 to 54,000 cfs.

Because streamflow and runoff within the Guadalupe River basin are unevenly distributed in area and time, storage projects are required to provide dependable quantities of surface water for municipal and industrial use.

Table 1.--Summary of Water Discharge at Selected Sites in the Guadalupe River Basin, Water Years 1940-63

STATION (FIG. 10)	STREAM AND LOCATION	WATER DISCHARGE (CUBIC FEET PER SECOND)		
		AVERAGE	MINIMUM DAILY	MAXIMUM DAILY
11	Guadalupe River at Comfort	141	0	25,300
12	Guadalupe River near Spring Branch	255	0	44,600
17	Guadalupe River above Comal River at New Braunfels	351	0	46,500
22	Comal River at New Braunfels	273	5.5	13,900
27	Blanco River at Wimberley	116	.7	36,900
29	San Marcos River at Luling	331	43	25,000
32	Plum Creek near Luling	89.8	0	15,000
38	Guadalupe River at Victoria	1,539	14	54,000

Surface-Water Resources Development

Four reservoirs in the Guadalupe River basin have storage capacities of 5,000 acre-feet or more. The capacity, owner, and location and use of these reservoirs are listed in Table 9; the locations are shown on Figure 10.

Canyon Reservoir, constructed on the Guadalupe River by the U.S. Army Corps of Engineers in cooperation with the Guadalupe-Blanco River Authority, is the largest reservoir in the basin. The reservoir, which is used for both flood control and conservation storage, has a capacity of 740,900 acre-feet, of which 354,700 acre-feet is for flood control. The other major reservoirs in the basin are used for the generation of hydroelectric power.

CHEMICAL QUALITY OF THE WATER

Chemical-Quality Records

The systematic collection of chemical-quality data on surface waters of the Guadalupe River basin by the U.S. Geological Survey was begun in 1942 when a sampling station was established on the Guadalupe River near Spring Branch. Data obtained from this station, until it was discontinued in 1945, consisted of chemical analyses of filtrates from samples collected by the U.S. Soil Conservation Service for the determination of suspended sediment. Usually only specific conductance and chloride determinations were made on these filtered samples.

In 1945, a daily sampling station was established on the Guadalupe River at Victoria; records for this station are continuous to date. Currently, this station is the only daily sampling station in the basin, but chemical analyses are available for many miscellaneous sites.

The periods of record for selected data-collection sites are given in Table 6; the locations are shown on Figure 10. Chemical-quality data for the daily stations are summarized in Table 7, 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 and its predecessor agencies. (See table in the list of references.) Analytical results for samples collected from selected miscellaneous sites are given in Table 8.

Since 1957, the Texas State Department of Health has maintained a statewide stream-sampling program that includes the periodic determination of pH, total solids, chloride, and sulfate at 14 sites in the Guadalupe River basin. Data from this program were made available to the U.S. Geological Survey and were studied during the preparation of this report.

Factors Affecting Chemical Quality of Water

All waters from natural sources contain dissolved minerals, but the chemical character and concentrations of dissolved constituents in surface waters may fluctuate widely in response to differences in environment. Some of the environmental factors that affect the chemical quality of surface waters are variation in geology; patterns and characteristics of streamflow; and activities of man, such as impoundment and diversion, disposition of municipal and industrial wastes, and irrigation.

Waters are classified in various ways to demonstrate similarities and differences in composition. In the following discussion, which relates chemical quality of water to environmental factors, water is classified on the basis of chemical type (principal chemical constituents) and hardness. The chemical type of water is classified according to the predominant cations and anions in equivalents per million. For example, a water is a calcium bicarbonate type if the calcium ions constitute 50 percent or more of the cations and the bicarbonate ions constitute 50 percent or more of the anions. Waters in which one cation and one anion are not clearly predominant are recognized as mixed types and are identified by the names of all the important ions.

On the basis of hardness, waters are classified as soft, moderately hard, hard, and very hard. (See tabulation on page 16.)

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 rocks and soils traversed by the water and on the length of time the water is in contact with the rocks and soils. The amount of minerals in rocks and soils available for solution is decreased by leaching; therefore, in areas of high rainfall, the rocks and soils usually are well leached and generally yield water of low mineralization. In many arid or semiarid regions, the rocks and soils are incompletely leached and often yield large quantities of minerals to circulating waters. In the Guadalupe River basin, where precipitation averages about 32 inches annually, the surface rocks and soils are fairly well leached. Thus, the dissolved-minerals content of surface runoff from much of the basin averages less than 250 ppm (parts per million). Although runoff derived from ground water generally is more highly mineralized than runoff from the surface, the base flow of most streams in the basin seldom exceeds 500 ppm.

Most streams in the Guadalupe River basin traverse more than one geologic formation; consequently, water in some streams usually is a composite of several different geochemical types. Similarly, the mineral composition of a particular formation, and thus the mineralization and chemical character of its effluent ground water, may differ from area to area. In some areas the chemical composition of surface water is altered by municipal or industrial pollutants. For these reasons, the following discussion relating chemical composition of surface waters to geology is very general.

The geology of the Guadalupe River basin has been described by Alexander, Myers, and Dale (1964, p. 29-50). Rocks exposed in the basin consist of sediments that range in age from Cretaceous to Quaternary; the outcrop areas of the various geologic units are shown in Figure 3.

Chemical analyses of surface water collected during periods of low flow are represented diagrammatically (Stiff, 1951) in Figure 3 to relate chemical composition to geology. The shape of each diagram indicates the relative concentration of the principal chemical constituents; the size of the diagram indicates roughly the degree of mineralization.

Headwater streams of the Guadalupe River rise on the Edwards and associated limestones, which include the Georgetown Limestone of the Washita Group and the Kiamichi Formation, Edwards Limestone, Comanche Peak Limestone, and Walnut Clay of the Fredericksburg Group. These rocks, which underlie a large part of the Edwards Plateau section of the basin, consist of limestone, dolomitic limestone, marl, and shale. Low flows of the North and South Forks Guadalupe River and Johnson Creek (Figure 3, sites 1, 3, and 6), which drain from these rocks, generally contain less than 300 ppm dissolved solids, are very hard, and are a calcium bicarbonate type. Similarly, effluent ground water contributed by Comal and San Marcos Springs near the eastern limit of the Edwards outcrop is very hard and the calcium bicarbonate type (Figure 3, sites 21 and 24).

In the wide valleys of the Edwards Plateau section of the Guadalupe River basin, where much of the Edwards and associated limestones have been removed by erosion, the Glen Rose Limestone of Cretaceous age is exposed. The Glen Rose consists principally of limestone and marl interbedded with dolomite and anhydrite. Most streams that traverse the Glen Rose rise in the Edwards and associated limestones; consequently, water in the lower reaches of these streams is a composite. However, much of the drainage area of Turtle, Verde, and Cypress Creeks and the Blanco River is underlain by the Glen Rose Limestone. Low flows of these streams generally are very hard and the calcium bicarbonate type (Figure 3, sites 7, 8, 10, and 27) and are very similar in chemical character to low flows of streams that drain the Edwards and associated limestones.

In the Coastal Plain section of the Guadalupe River basin, the geologic formations, most of which are Tertiary or Quaternary in age, crop out in narrow belts roughly parallel to the coast of the Gulf of Mexico. Rocks from the Grayson Shale of Late Cretaceous age to the Midway Group of Paleocene age were considered as a unit by Alexander, Myers, and Dale (1964, p. 41) and are mapped together on Figure 3. These rocks, which crop out in a belt from 10 to 15 miles wide in the upper part of the Coastal Plain section of the basin, consist largely of clay, shale, marl, limestone, and sandstone. Most streams in this section rise in the Edwards and associated limestones, from which they derive most of their base flow. Upstream from Lockhart in Caldwell County, much of the drainage area of Plum Creek is underlain by rocks between the Midway Group and

Grayson Shale. During low-flow periods, water in Plum Creek at Lockhart usually contains less than 500 ppm dissolved solids and is hard or very hard. Although the principal chemical constituents usually are calcium and bicarbonate (Figure 3, site 30), some of the low flows are the mixed calcium sodium bicarbonate sulfate type.

Other rocks that crop out in the Coastal Plain section of the basin, in downstream order, include the Wilcox Group, Claiborne Group, Jackson Group, Catahoula Tuff, Catahoula Sandstone, Fleming Formation, and Goliad Sand of Tertiary age and the Lissie Formation and Beaumont Clay of Quaternary age. Although these rocks consist largely of sand, sandstone, silt, clay, and gravel, the chemical character of water from shallow wells varies from formation to formation and from site to site within the same formation (Alexander, Myers, and Dale, 1964, p. 77-80). Similarly, low flows of streams that traverse these rocks are somewhat variable in chemical character. Principal tributaries that drain these rocks include Peach, Sandies, and Coleto Creeks. During low-flow periods, the dissolved-solids content of Peach Creek below Dilworth has ranged from less than 150 ppm to more than 1,100 ppm, but generally is less than 500 ppm. The more highly mineralized low flows generally are the sodium sulfate type; whereas waters with a low dissolved-solids content generally are the mixed calcium sodium bicarbonate sulfate type (Figure 3, site 35).

The dissolved-solids concentration of low flows in Sandies Creek near Westhoff has ranged from about 300 ppm to more than 1,200 ppm. The water generally is moderately hard or hard and the sodium bicarbonate type (Figure 3, site 36).

Low flows of Coleto Creek near Schroeder (Figure 3, site 39) generally contain less than 500 ppm dissolved solids and are very hard and the mixed calcium sodium bicarbonate chloride type.

Streamflow

In many streams where the flow is not regulated by upstream reservoirs, the concentration of dissolved minerals varies inversely with the water discharge. The concentration usually is minimum during periods of high flow when most of the water is surface runoff that has been in contact with soluble minerals of the exposed rocks and soils for a short time. Conversely, the concentration usually is maximum during periods of low flow when the water is predominantly effluent ground water that has been in contact with the rocks and soils for a sufficient time to dissolve more of the soluble minerals. Figure 4 shows this general relationship to be true for the Guadalupe River at Victoria during the period of the 1949-63 water years, before completion of Canyon Reservoir. However, the scatter of points in Figure 4 shows that the inverse relation between streamflow and concentration of dissolved solids is not precise. Obviously, the salt content of the Guadalupe River at Victoria has varied considerably at all rates of water discharge. Although much of this variation is related to the diversified geology and to the pattern of runoff from subbasins, the intermittent inflow of brine from oil fields is responsible for part of the variation.

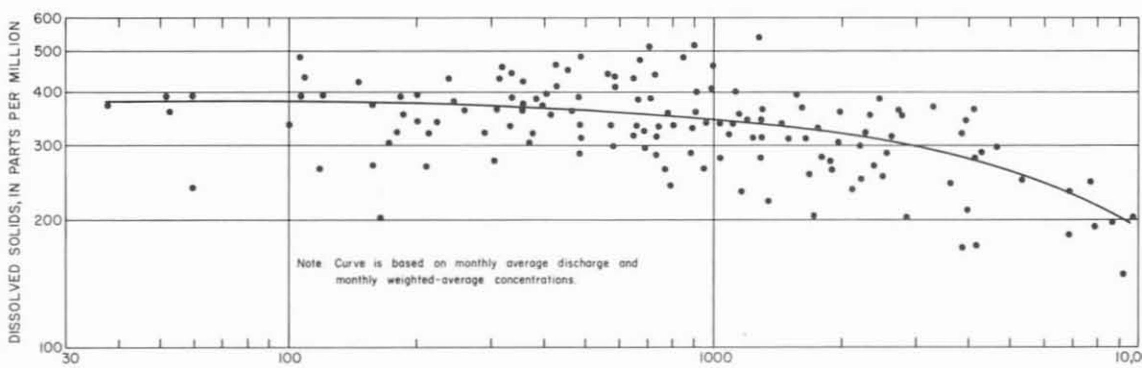

Figure 4.--Relation of Concentration of Dissolved Solids to Water Discharge, Guadalupe River at Victoria, Water Years 1949-63

Activities of Man

The activities of man often debase the chemical quality of surface water. Depletion of flow by diversion and consumptive use, loss of water because of increased evaporation, and return flow of irrigation usually increase the dissolved-solids concentration of water in streams or reservoirs. Similarly, the disposition of industrial and municipal wastes into a stream degrades the chemical quality.

Because most cities and industries in the Guadalupe River basin obtain their water supply from wells, the chemical quality of surface water has been affected only slightly by diversion or storage. The basin has no large cities; only Victoria had more than 20,000 inhabitants in 1960. Consequently, the disposition of municipal and industrial wastes has caused only local changes in the quality of surface water, and natural streamflow generally is adequate to dilute the municipal and industrial wastes that are introduced into streams.

According to an inventory by the Texas Water Commission (Gillett and Janca, 1965, p. 39), 11,537 acre-feet of water was used to irrigate 10,826 acres in the Guadalupe River basin in 1964. Because of the small amount of water used, return flow of irrigation has not seriously degraded the quality of surface water.

Oil is produced in many areas in the Guadalupe River basin (Figure 5). Brine is produced in nearly all oil fields and if improperly handled eventually enters surface streams. According to an inventory by the Texas Railroad Commission in 1961, more than 94 percent of the salt water produced in oil fields of the Guadalupe River basin was injected underground to prevent and abate pollution (Texas Water Commission and Texas Water Pollution Control Board, 1963, p. 6). The rest of the salt water was disposed of in unlined surface pits or directly into surface watercourses. From the unlined pits, much of the brine has percolated into the ground and has seeped, or eventually will seep, into streams. Some of the brine has been washed by the surface runoff directly into streams. Although use of unlined pits for the disposition of brine has been curtailed greatly in the past several years, seepage of brine from salt-impregnated areas near the abandoned pits may continue for long periods. In addition, injected brine may move upward along fault zones or improperly cased wells and eventually reach surface streams.

Although the composition of oil-field brine varies, the principal chemical constituents, in order of magnitude of their concentrations (in ppm), usually are chloride, sodium, calcium, and sulfate. Generally, an erratic variation of the sodium chloride content of water in streams that drain areas where oil fields are located is presumptive evidence that oil-field brine is entering the streams.

In February 1944, a reconnaissance by the U.S. Geological Survey showed that about 15 cfs of brine from oil fields in Caldwell and Guadalupe Counties in the vicinity of Luling was being discharged into Plum Creek and San Marcos River (Hastings and Broadhurst, 1944, p. 2). Although most of the brine produced in oil fields near Luling is now being injected underground, chemical analyses of water recently collected from Plum Creek near Luling indicate that some brine still is reaching the stream (Table 8, site 32).

Daily chemical-quality records for the Guadalupe River at Victoria indicate that the disposition of oil-field brine has resulted in some deterioration of water quality in the lower reach of the mainstem. (See Table 7 and Figure 11.) However, dissolved-solids duration data (Figure 6) indicate generally that the quantity of brine reaching surface streams has decreased in the past several years. Much of this decrease apparently has resulted from the disposition of brine by injection. According to records of the Railroad Commission of Texas, the number of injection wells in the Guadalupe River basin increased from 8 in 1950 to 63 in 1966.

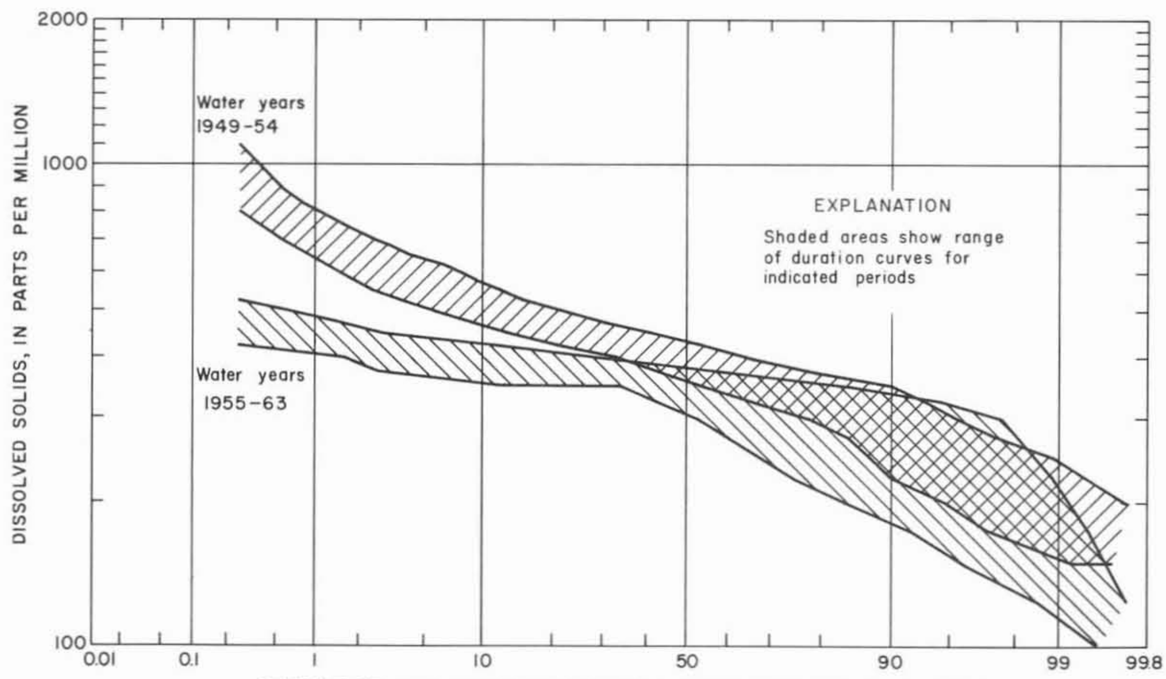

Figure 6.--Comparison of Range of Annual Duration Curves of Dissolved-Solids Concentration, Guadalupe River at Victoria, Water Years 1949-54 and 1955-63

Daily Variations of Water Quality

Some of the previous sections have shown that the quality of surface water in the Guadalupe River basin varies not only from location to location on the same stream but also from time to time at any specified location. The daily variations in concentration of dissolved solids at a particular location can be shown by a duration curve. Such a curve shows the percent of days of flow during which specified concentrations of dissolved solids were equaled or exceeded, without regard to sequence of occurrence. Figure 7 is a duration curve for the Guadalupe River at Victoria during the 1949-54 period, before construction of Canyon Reservoir. Figure 7 shows that the dissolved-solids concentration equaled or exceeded 440 ppm on 10 percent of the days, 390 ppm on 25 percent, 350 ppm on 50 percent, 310 ppm on 75 percent, and 255 ppm on 90 percent. These data also are given in Table 2, as is the equivalent data for sulfate, chloride, and hardness. Table 2 also gives the concentrations of dissolved solids, chloride, sulfate, and hardness that were equaled or exceeded at the Victoria station during 10, 25, 50, 75, and 90 percent of the days of flow during the 1955-63 water years.

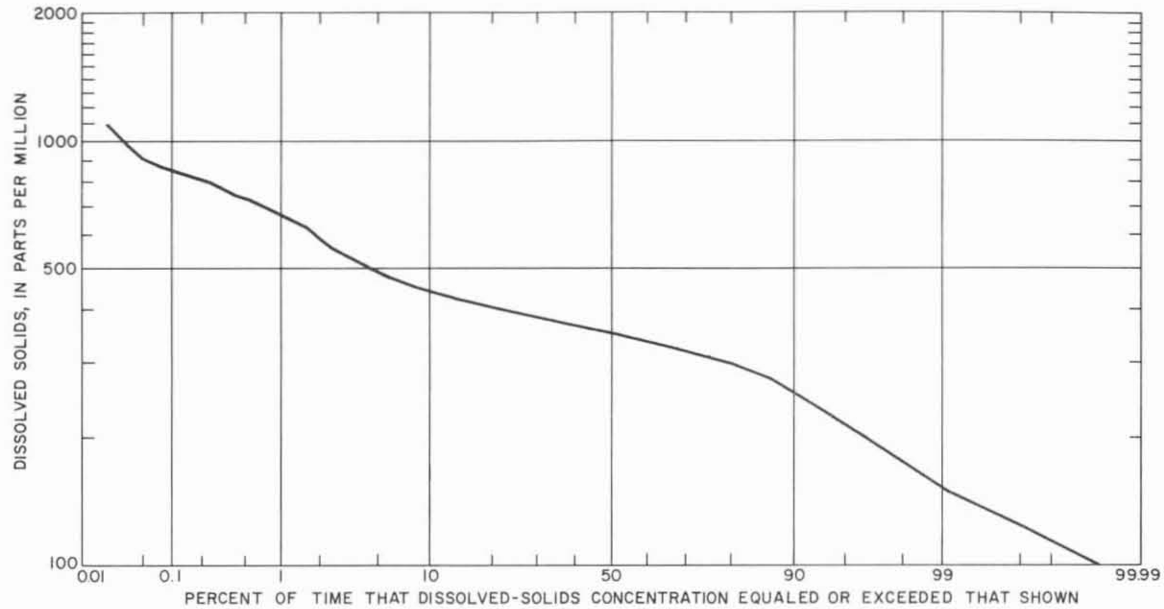

Figure 7.--Duration Curve of Dissolved Solids, Guadalupe River at Victoria, Water Years 1949-54

Although daily samples were collected from the Guadalupe River at Victoria during the two periods for which duration data are shown in Table 2, a complete chemical analysis of each daily sample was not feasible. Therefore, two or more daily samples usually were composited for chemical analysis on the basis of specific conductance, supplemented by data on river stage. For this frequency study, the dissolved-solids content of each daily sample was estimated from the relation of specific conductance to dissolved solids. These data were used to prepare dissolved-solids duration curves, such as Figure 7, from which the dissolved-solids values in Table 2 were compiled. Next, curves showing the relation of dissolved solids to concentrations of sulfate, chloride, and hardness were plotted (Figure 8). Then, for each value of dissolved solids in the table, corresponding concentrations of sulfate, chloride, and hardness were tabulated. The resulting Table 2 shows that the total dissolved-solids and chloride concentrations were somewhat less variable during the 1955-63 water years than during the 1949-54 water years. Part of this decrease in daily variations of dissolved solids and chloride probably has resulted from the underground injection of brine from oil fields.

Chemical-quality frequency data collected from a stream before the construction of a large reservoir is not directly comparable to data collected from the stream after reservoir regulation begins. Regulation of flood flows in Canyon Reservoir may smooth out chemical-quality variations at downstream sites during some periods. However, impoundment in the reservoir may decrease flow during other periods and cause an increase in the salinity of water at downstream sites.

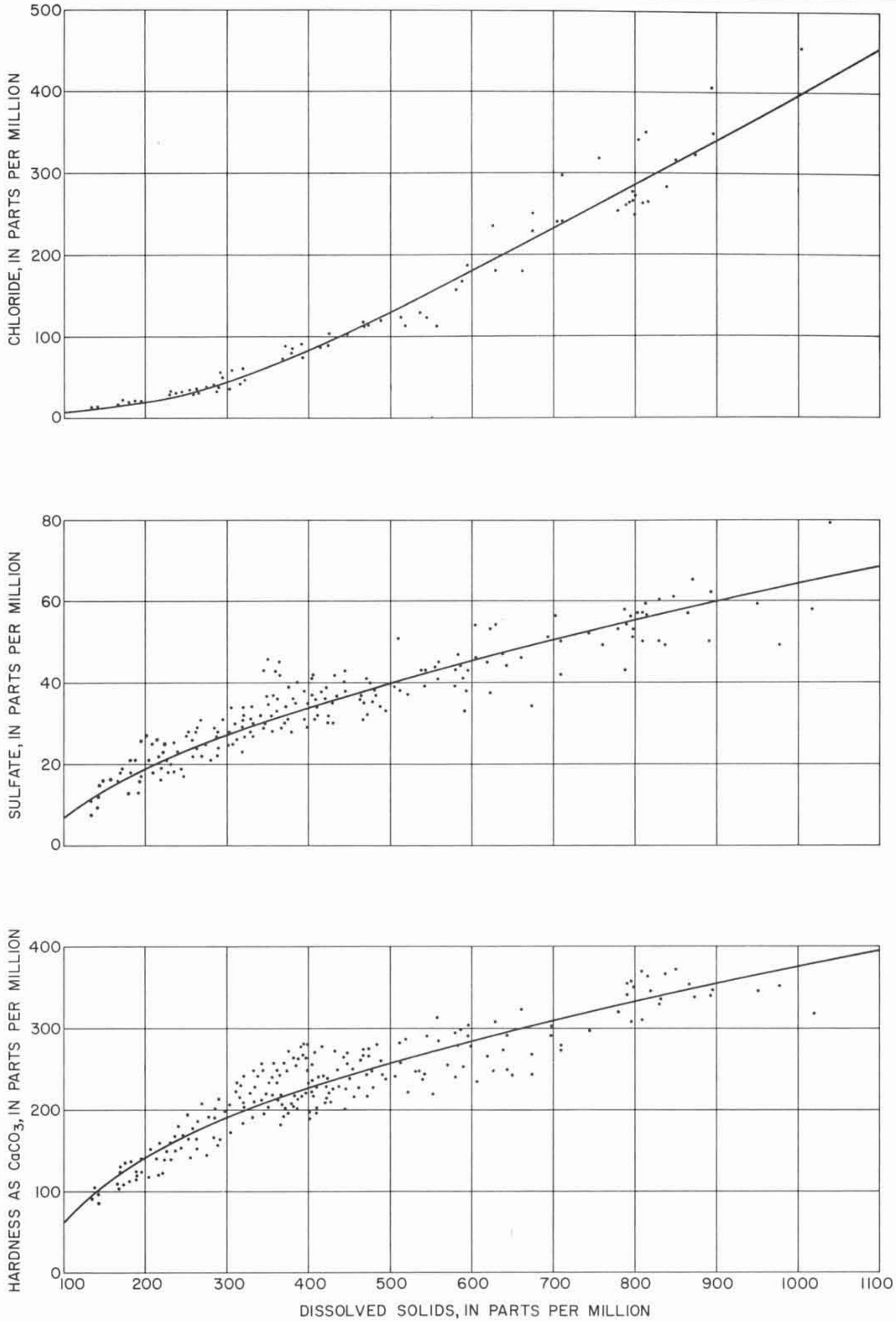

Figure 8

Relation of Dissolved Solids to Chloride, Sulfate, and Hardness, Guadalupe River at Victoria

Table 2.--Concentrations of Selected Constituents and Hardness (in Parts Per Million) That Were Equaled or Exceeded for Indicated Percentage of Days of Flow, Guadalupe River at Victoria

CONSTITUENT	PERCENT OF DAYS 10	25	50	75	90
1955-63 water years					
Sulfate (SO_4)	34	32	30	27	22
Chloride (Cl)	82	72	58	45	26
Dissolved solids	395	370	335	300	240
Hardness as $CaCO_3$	225	215	205	190	165
1949-54 water years					
Sulfate (SO_4)	36	33	31	28	24
Chloride (Cl)	102	81	64	49	30
Dissolved solids	440	390	350	310	255
Hardness as $CaCO_3$	240	225	210	195	170

Geographic Variations of Water Quality

Variations of dissolved solids, hardness, and chloride with geographic locations are shown on the maps on Figure 11. These maps are based on the discharge-weighted average concentrations, as calculated from chemical-quality data. The discharge-weighted average represents approximately the chemical character of the water if all the water passing a point in the stream during a period were impounded in a reservoir and mixed, with no adjustment for evaporation, rainfall, or chemical change that might occur during storage. For many of the streams, chemical-quality data (especially for flood flows) are limited; therefore the boundaries of the areas on the maps are general. All the streams will at times have concentrations greater than those shown for their respective areas, but the averages shown on the maps are indicative of the type of water that would be stored in reservoirs.

Dissolved Solids

The concentration of dissolved solids in surface water of the upper half of the Guadalupe River basin generally is less than 250 ppm. In the lower half of the basin the dissolved-solids concentrations of several streams average more than 250 ppm. Throughout much of its length, the San Marcos River contains more than 250 ppm dissolved solids. Much of the flow in the upper reach of the San Marcos River is effluent ground water contributed by San Marcos Springs. The dissolved-solids content of water contributed by San Marcos Springs averages about 330 ppm. In its lower reach, the principal tributary of the San Marcos River is Plum Creek. As noted previously, the disposition of oil-field brine has caused some deterioration of the quality of water in the lower reach of Plum Creek. Available chemical-quality data indicate that the dissolved-solids concentration of Plum Creek near Luling averages more than 500 ppm. Although the inflow of water from Plum Creek degrades the quality of water in the lower reaches of both the San Marcos and Guadalupe Rivers, the average dissolved-solids content does not exceed 500 ppm in either stream. During the 1949-65 water years, the discharge-weighted concentration of dissolved solids in the Guadalupe River at Victoria averaged 288 ppm.

Chemical analyses of samples collected during medium and high flows indicate that the dissolved-solids content of Peach Creek averages less than 100 ppm. The dissolved-solids concentrations of other streams in the lower half of the basin generally average between 101 and 250 ppm.

Hardness

The upper half of the Guadalupe River basin is underlain largely by the Edwards and associated limestones and the Glen Rose Limestone. Water draining from these rocks generally is very hard (Figure 11). Water draining from the younger formations in the lower half of the basin generally is soft or moderately hard—except in the drainage area of Plum Creek, where the water is hard. Throughout the length of the mainstem Guadalupe River, the water generally is very hard.

Chloride

The chloride concentration in surface waters of the Guadalupe River basin generally averages less than 50 ppm, and many streams contain less than 20 ppm. However, in the lower reach of Plum Creek, the inflow of oil-field brine has increased the average chloride concentration to more than 100 ppm.

Other Constituents

Other constituents of importance in the evaluation of the quality of a water include silica, sodium, bicarbonate, sulfate, fluoride, and nitrate.

The silica content of surface water throughout the basin generally is low. During the 1949-65 water years the discharge-weighted average concentration of silica in the Guadalupe River at Victoria was 15 ppm.

The sodium content of most surface waters in the basin also is low. During the 1949-65 water years, the discharge-weighted concentration of sodium and potassium (Na + K calculated as Na) that passed the station

Guadalupe River at Victoria averaged 29 ppm. Streams that drain the Edwards and associated limestones and the Glen Rose Limestone in the Edwards Plateau section of the basin generally contain less than 15 ppm sodium. During high-flow periods, most streams that drain younger formations in the Coastal Plain section contain less than 20 ppm sodium; however, during low-flow periods, when the proportion of effluent ground water increases, the sodium concentration in most of these streams often exceeds 100 ppm.

Bicarbonate is the principal anion in streams that traverse the outcrop areas of the Edwards and associated limestones and the Glen Rose Limestone. The bicarbonate content of water in these streams usually ranges from 200 to 300 ppm. The bicarbonate content of streams that drain younger formations is more variable but generally averages less than 200 ppm. The discharge-weighted average concentration of bicarbonate in the Guadalupe River at Victoria during the 1949-65 water years was 190 ppm.

Sulfate concentrations in streams that drain the Edwards and associated limestones and the Glen Rose Limestone generally are less than 30 ppm. Medium and high flows of most streams that drain younger formations also contain less than 30 ppm sulfate. The discharge-weighted average concentration of sulfate in the Guadalupe River at Victoria during the 1949-65 water years was 27 ppm.

Concentrations of nitrate and fluoride generally are low in surface waters of the Guadalupe River basin. During the 1949-65 water years, the discharge-weighted concentrations of nitrate in water that passed the station Guadalupe River at Victoria averaged 3.7 ppm. The fluoride concentration in water that passed the station during the 1950-56 water years averaged 0.3 ppm and never exceeded 0.6 ppm.

Water Quality in Reservoirs

Canyon Reservoir, the only large water-supply reservoir in the Guadalupe River basin, stores water that is low in dissolved solids (usually less than 250 ppm), hard or very hard, and the calcium bicarbonate type. Maximum concentrations of chloride and sulfate in samples collected from the reservoir were 15 and 16 ppm, respectively.

Water Quality at Potential Reservoir Sites

One of the principal objectives of this reconnaissance was to appraise the quality of water available for storage at potential reservoir sites. The locations of six potential reservoir sites are shown on Figure 10. In the following discussion, evaluations of the water quality at these sites, are based on present conditions. Continued municipal and industrial growth in some areas will increase the waste-disposal burdens of the streams and may cause significant changes in water quality before some of the reservoirs can be built.

Ingram.—The quality of water that would be stored in Ingram Reservoir can be inferred from the analyses of samples collected from Johnson Creek near Ingram. Although all of the samples were collected during low flow, the maximum dissolved-solids, chloride, and sulfate contents of the samples were 271 ppm, 25 ppm, and 13 ppm, respectively; and the maximum hardness was 225 ppm. If the reservoir fills during a period of average rainfall and runoff, the stored water probably will contain less than 250 ppm dissolved solids, 15 ppm chloride, and 15 ppm sulfate but will be hard or very hard.

Cloptin Crossing.—Chemical-quality data for the Blanco River at Wimberley indicate that if Cloptin Crossing Reservoir fills during a period of average rainfall and runoff, the stored water will contain less than 250 ppm dissolved solids, 20 ppm chloride, and 20 ppm sulfate but will be very hard.

Lockhart.—Chemical analyses of samples collected from Plum Creek at Lockhart indicate that water stored in Lockhart Reservoir will contian less than 250 ppm dissolved solids, 20 ppm chloride, and 50 ppm sulfate but will be hard.

Cuero 1.—Available chemical-quality data indicate that water stored in Cuero 1 Reservoir will be more mineralized than water in the upstream Canyon Reservoir because of the inflow of water from the San Marcos River. However, the stored water probably will contain less than 325 ppm dissolved solids, 50 ppm chloride, and 50 ppm sulfate and will be very hard.

Cuero 2.—Chemical analyses of samples collected from Sandies Creek near Westhoff indicate that water stored in Cuero 2 Reservoir will contain less than 150 ppm dissolved solids, 20 ppm chloride, and 25 ppm sulfate and will be soft.

Confluence.—Confluence Reservoir will store water from the Guadalupe River and the San Antonio River. Daily chemical-quality records for the Guadalupe River at Victoria and San Antonio River at Goliad indicate that the stored water will contain less than 350 ppm dissolved solids, 50 ppm chloride, and 50 ppm sulfate and will be very hard.

Relation of Water Quality to Use

Although other water-quality criteria are important, the suitability of a water for most uses often depends on its chemical quality. All natural waters contain dissolved minerals, most of which are dissociated into charged particles, or ions. The principal cations (positively-charged ions) in natural water are calcium

(Ca), magnesium (Mg), sodium (Na), potassium (K), and iron (Fe). The principal anions (negatively-charged ions) are carbonate (CO_3), bicarbonate (HCO_3), sulfate (SO_4), chloride (Cl), fluoride (F), and nitrate (NO_3). A résumé of the sources and significance of these and other constituents and properties commonly determined by the U.S. Geological Survey to define the chemical quality of water is included in Table 3.

Because the use and planned use of surface water in the Guadalupe River basin is primarily for municipal supply, industrial use, and irrigation, only these uses will be considered in the following discussion.

Municipal Supply

Because of differences in individuals, amounts of water used, and other factors, the safe limits for mineral constituents in water to be used for domestic purposes are difficult to define. The usually accepted criteria for drinking water in the United States are those recommended by the United States Public Health Service. Originally established in 1914 to control the quality of water used on interstate carriers for drinking and culinary purposes, these standards have been revised several times. The latest revision was in 1962 (U.S. Public Health Service, 1962). The limits recommended by these standards for various constituents are included in the following table.

CONSTITUENT	MAXIMUM CONCENTRATION (PPM)
Sulfate	250
Chloride	250
Nitrate	45
Fluoride	[a]0.8
Iron	0.3
Dissolved solids	500

[a] Based on temperature records for Victoria.

The concentrations of sulfate, chloride, nitrate, fluoride, and dissolved solids in surface waters throughout much of the Guadalupe River basin generally are lower than the limits recommended by the U.S. Public Health Service. Available chemical-quality data indicate that the discharge-weighted concentration of dissolved solids in Plum Creek near Luling averages about 600 ppm, which is greater than the 500 ppm limit recommended by the U.S. Public Health Service. However, water containing more than 500 ppm dissolved solids have been used for domestic purposes without adverse effects.

Although iron determinations were not included in chemical analyses of surface water from most miscellaneous sites in the Guadalupe River basin, chemical-quality records for the daily station Guadalupe River at Victoria and analyses of water from wells throughout the basin indicate generally that iron concentrations in surface waters of the basin are within the U.S. Public Health Service recommended limit of 0.3 ppm.

Hardness is another property usually considered in evaluating a water for domestic use. A comparison of hardness-duration data for the Guadalupe River at Victoria (Table 2) and chemical analyses of water from miscellaneous sites (Table 8) with the classification of hardness in the following table shows that most surface waters in the Guadalupe River basin are hard or very hard and will require softening in some areas.

HARDNESS (PPM)	RATING	USABILITY
0 to 60	Soft	Suitable for many uses without further softening.
61 to 120	Moderately hard	Usable except in some industrial applications.
121 to 180	Hard	Softening required by laundries and some other industries.
181+	Very hard	Softening desirable for most purposes.

Industrial Use

The water-quality requirements vary greatly for almost every industrial application. (See Table 4.) Corrosion is the most widespread and probably the most costly water-caused difficulty with which industry must cope. Therefore, the suitability of a water for many industrial uses is determined partly by its corrosiveness. High concentrations of dissolved solids in a water promote corrosion, especially if chloride is present in appreciable quantities. In contrast, calcium hardness forms protective coatings on metal surfaces and thus tends to reduce corrosion. The chloride and dissolved-solids concentrations in surface waters of the Guadalupe River basin are low, and in many streams calcium and bicarbonate are the principal chemical constituents. Therefore, the corrosion potential of surface waters throughout the basin probably is low.

Although some calcium hardness may be desirable for the prevention of corrosion of pipes and other equipment, excessive hardness is objectionable because it contributes to the formation of scale in steam boilers, pipes, water heaters, radiators, and various other equipment where water is heated, evaporated, or treated with alkaline substances. The accumulation of scale lowers

Table 3.--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 indicate 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 stain 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.

Table 4.--Water-Quality Tolerances for Industrial Applications[1]

[Allowable Limits in Parts per Million Except as Indicated]

INDUSTRY	TUR-BID-ITY	COLOR	COLOR + O_2 CON-SUMED	DIS-SOLVED OXYGEN (ml/l)	ODOR	HARD-NESS	ALKA-LINITY (AS $CaCO_3$)	pH	TOTAL SOLIDS	Ca	Fe	Mn	Fe + Mn	Al_2O_3	SiO_2	Cu	F	CO_3	HCO_3	OH	$CaSO_4$	Na_2SO_4 to Na_2SO_3 RATIO	GEN-ERAL[2]
Air conditioning [3]	--	--	--	--	--	--	--	--	--	--	0.5	0.5	0.5	--	--	--	--	--	--	--	--	--	A, B
Baking	10	10	--	--	--	(4)	--	--	--	--	.2	.2	.2	--	--	--	--	--	--	--	--	--	C
Boiler feed:																							
0-150 psi	20	80	100	2	--	75	--	8.0+	3,000-1,000	--	--	--	--	5	40	--	--	200	50	50	--	1 to 1	--
150-250 psi	10	40	50	.2	--	40	--	8.5+	2,500-500	--	--	--	--	.5	20	--	--	100	30	40	--	2 to 1	--
250 psi and up	5	5	10	0	--	8	--	9.0+	1,500-100	--	--	--	--	.05	5	--	--	40	5	30	--	3 to 1	--
Brewing: [5]																							
Light	10	--	--	--	Low	--	75	6.5-7.0	500	100-200	.1	.1	.1	--	--	--	1	--	--	--	100-200	--	C, D
Dark	10	--	--	--	Low	--	150	7.0 →	1,000	200-500	.1	.1	.1	--	--	--	1	--	--	--	200-500	--	C, D
Canning:																							
Legumes	10	--	--	--	Low	25-75	--	--	--	--	.2	.2	.2	--	--	--	--	--	--	--	--	--	C
General	10	--	--	--	Low	--	--	--	--	--	.2	.2	.2	--	--	--	1	--	--	--	--	--	C
Carbonated beverages [6]	2	10	10	--	0	250	50	--	850	--	.2	.2	.3	--	--	--	.2	--	--	--	--	--	C
Confectionary	--	--	--	--	Low	--	--	(7)	100	--	.2	.2	.2	--	--	--	--	--	--	--	--	--	--
Cooling [8]	50	--	--	--	--	50	--	--	--	--	.5	.5	.5	--	--	--	--	--	--	--	--	--	A, B C
Food, general	10	--	--	--	Low	--	--	--	--	--	.2	.2	.2	--	--	--	--	--	--	--	--	--	C
Ice (raw water) [9]	1-5	5	--	--	--	--	30-50	--	300	--	.2	.2	.2	--	10	--	--	--	--	--	--	--	C
Laundering	--	--	--	--	--	50	--	--	--	--	.2	.2	.2	--	--	--	--	--	--	--	--	--	--
Plastics, clear, undercolored	2	2	--	--	--	--	--	--	200	--	.02	.02	.02	--	--	--	--	--	--	--	--	--	--
Paper and pulp: [10]																							
Groundwood	50	20	--	--	--	180	--	--	--	--	1.0	.5	1.0	--	--	--	--	--	--	--	--	--	A
Kraft pulp	25	15	--	--	--	100	--	--	300	--	.2	.1	.2	--	--	--	--	--	--	--	--	--	--
Soda and sulfite	15	10	--	--	--	100	--	--	200	--	.1	.05	.1	--	--	--	--	--	--	--	--	--	--
Light paper, HL-Grade	5	5	--	--	--	50	--	--	200	--	.1	.05	.1	--	--	--	--	--	--	--	--	--	B
Rayon (viscose) pulp:																							
Production	5	5	--	--	--	8	50	--	100	--	.05	.03	.05	<8.0	<25	<5	--	--	--	--	--	--	--
Manufacture	.3	--	--	--	--	55	--	7.8-8.3	--	--	.0	.0	.0	--	--	--	--	--	--	--	--	--	--
Tanning [11]	20	10-100	--	--	--	50-135	135	8.0	--	--	.2	.2	.2	--	--	--	--	--	--	--	--	--	--
Textiles:																							
General	5	20	--	--	--	20	--	--	--	--	.25	.25	--	--	--	--	--	--	--	--	--	--	--
Dyeing [12]	5	5-20	--	--	--	20	--	--	--	--	.25	.25	.25	--	--	--	--	--	--	--	--	--	--
Wool scouring [13]	--	70	--	--	--	20	--	--	--	--	1.0	1.0	1.0	--	--	--	--	--	--	--	--	--	--
Cotton bandage [13]	5	5	--	--	Low	20	--	--	--	--	.2	.2	.2	--	--	--	--	--	--	--	--	--	--

1/ American Water Works Association, 1950.
2/ A--No corrosiveness; B--No slime formation; C--Conformance to federal drinking water standards necessary; D--NaCl, 275 ppm.
3/ Waters with algae and hydrogen sulfide odors are most unsuitable for air conditioning.
4/ Some hardness desirable.
5/ Water for distilling must meet the same general requirements as for brewing (gin and spirits mashing water of light-beer quality; whiskey mashing water of dark-beer quality).
6/ Clear, odorless, sterile water for syrup and carbonization. Water consistent in character. Most high quality filtered municipal water not satisfactory for beverages.
7/ Hard candy requires pH of 7.0 or greater, as low value favors inversion of sucrose, causing sticky product.
8/ Control of corrosiveness is necessary as is also control of organisms, such as sulfur and iron bacteria, which tend to form slimes.
9/ $Ca(HCO_3)_2$ particularly troublesome. $Mg(HCO_3)_2$ tends to greenish color. CO_2 assists to prevent cracking. Sulfates and chlorides of Ca, Mg, Na should each be less than 300 ppm (white butts).
10/ Uniformity of compositions and temperature desirable. Iron objectionable as cellulose adsorbs iron from dilute solutions. Manganese very objectionable, clogs pipelines and is oxidized to permanganates by chlorine, causing reddish color.
11/ Excessive iron, manganese or turbidity creates spots and discoloration in tanning of hides and leather goods.
12/ Constant composition; residual alumina 0.5 ppm.
13/ Calcium, magnesium, iron, manganese, suspended matter, and soluble organic matter may be objectionable.

the quality of many wet-processed products, and increases costs for fuel, labor, repairs, and replacements. Most surface waters of the Guadalupe River basin are hard or very hard and will require softening for some industrial applications. Otherwise, the water is suitable for many industrial uses—or can be made suitable with a minimum of treatment.

Irrigation

The suitability of a water for irrigation depends primarily on its chemical composition. However, the extent to which chemical quality limits the suitability of a water for irrigation depends on many factors, such as: the nature, composition, and drainage of the soil and subsoil; the amounts of water used and the methods of application; the kind of crops grown; and the climate of the region, including the amounts and distribution of rainfall. Because these factors are highly variable, every method of classifying waters for irrigation is somewhat arbitrary.

According to the U.S. Salinity Laboratory Staff (1954, p. 69), the most important characteristics in determining the quality of irrigation water are: (1) the total concentration of soluble salts, (2) the relative proportion of sodium to other cations, (3) the concentration of boron or other elements that may be toxic, and (4) the excess of equivalents of bicarbonate over equivalents of calcium plus magnesium.

High concentrations of dissolved salts in irrigation water may cause a buildup of salts in the soil. The increased soil salinity may reduce crop yields drastically by decreasing the ability of the plants to take up water and essential plant nutrients from the soil solution. This tendency of irrigation water to cause a high buildup of salts in the soil is called the salinity hazard of the water. The specific conductance of the water is used as an index of the salinity hazard.

High concentrations of sodium relative to the concentrations of calcium and magnesium in irrigation water can adversely affect soil structure. Cations in the soil solution become fixed on the surface of the soil particles; calcium and magnesium tend to flocculate the particles, whereas sodium tends to deflocculate them. Deflocculation of the soil particles by sodium decreases the permeability of the soil. This tendency to deflocculate soil particles by high sodium concentrations in an irrigation water is called the sodium hazard of the water. An index used for predicting the sodium hazard is the sodium-adsorption ratio (SAR), which is defined by the equation:

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}},$$

where the concentrations of the ions are expressed in equivalents per million.

The U.S. Salinity Laboratory Staff has prepared a classification for irrigation waters in terms of salinity and sodium hazards. Empirical equations were used in developing a diagram, reproduced in modified form as Figure 9, which uses SAR and specific conductance in classifying irrigation waters. This classification, although embodying both research and field observations, should be used only for general guidance because many additional factors (such as availability of water for leaching, ratio of applied water to precipitation, and crops grown) affect the suitability of water for irrigation. With respect to salinity and sodium hazards, waters are divided into four classes—low, medium, high, and very high. The classification encompasses those waters that can be used for irrigation of most crops on most soils as well as those waters that are usually unsuitable for irrigation. Selection of class demarcation is discussed in detail in the publication by the U.S. Salinity Laboratory Staff (1954)

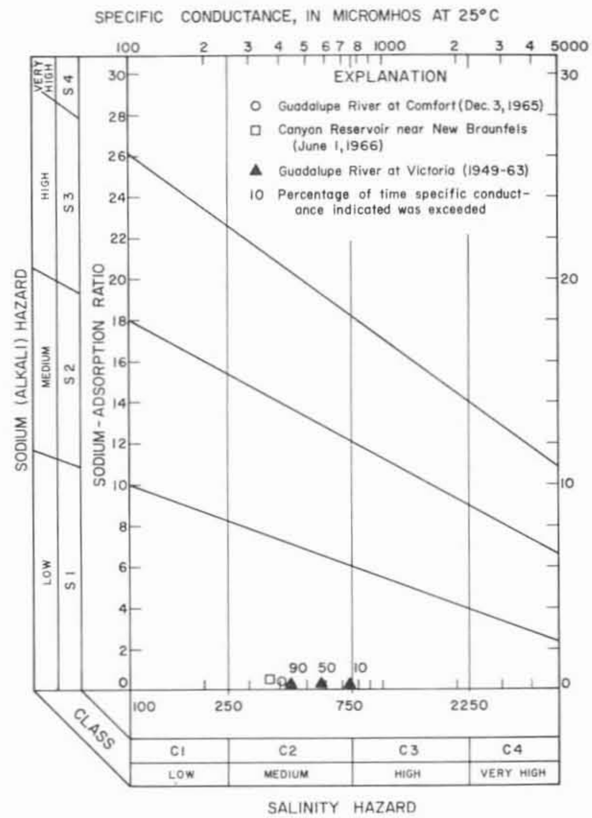

Figure 9.--Classification of Irrigation Waters

The salinity and sodium hazards of water at selected sites in the Guadalupe River basin are given in Table 5 and Figure 9. Because the total dissolved solids and other constituents vary somewhat with change in water discharge, Table 5 shows the sodium and salinity hazards for several discharge ranges. Figure 9 shows that the sodium hazard of water throughout much of the mainstem Guadalupe River is low, whereas the salinity hazard usually is medium. The sodium hazard of water in tributaries generally is low, but the salinity hazard varies. The salinity hazard of tributaries in the upper half of the basin usually is medium. In the lower half of the basin, the salinity hazard of water in Plum Creek, Peach Creek, and Sandies Creek varies from low to high. During periods of low flow, the salinity hazard of water in these streams usually is high but decreases with an increase in flow. The salinity hazard of water in Coleto Creek varies inversely with water discharge (usually from low to medium).

Surface water for irrigation in the Guadalupe River basin is being used principally for supplemental irrigation of pastures and of fields producing hay, feed, and forage in Comal, DeWitt, Gonzales, Guadalupe, and Fayette Counties. On the basis of sodium and salinity hazards, surface water of the basin generally is satisfactory for supplemental irrigation of these crops.

Table 5.--Suitability of Waters for Irrigation

STATION (FIG. 10)	STREAM AND LOCATION	DATE	WATER DISCHARGE (CFS)	SALINITY HAZARD	SODIUM HAZARD
6	Johnson Creek near Ingram	June 3, 1966	8.31	Medium	Low
11	Guadalupe River at Comfort	June 23, 1965	2,030	do	Do.
		July 19, 1965	62.5	do	Do.
14	Canyon Reservoir near New Braunfels	June 1, 1966	--	do	Do.
27	Blanco River at Wimberley	Feb. 11, 1964	17.4	do	Do.
		Apr. 6, 1965	1,420	do	Do.
29	San Marcos River at Luling	Feb. 13, 1964	104	do	Do.
		June 6, 1965	7,210	do	Do.
30	Plum Creek at Lockhart	Jan. 3, 1963	4.37	do	Do.
		Dec. 3, 1965	2,710	do	Do.
32	Plum Creek near Luling	Sept. 18, 1964	1,040	Low	Do.
		June 22, 1965	3.85	High	Do.
35	Peach Creek below Dilworth	Apr. 7, 1964	3.42	do	Do.
		Feb. 18, 1965	4,320	Low	Do.
36	Sandies Creek near Westhoff	Jan. 24, 1965	2,310	do	Do.
		Jan. 28, 1966	15.0	High	Do.
39	Coleto Creek near Schroeder	May 5, 1964	2.17	Medium	Do.
		May 6, 1966	1,100	Low	Do.

Explanation:
Low-salinity water—can be used for irrigation of most crops on most soils.
Medium-salinity water—can be used if a moderate amount of leaching occurs.
High-salinity water—cannot be used on soils with restricted drainage.
Low-sodium water—can be used on almost all soils.

Water of the mainstem Guadalupe River also is used for the irrigation of rice in Calhoun County in the Lavaca-Guadalupe coastal basin. Although the concentration of chemical constituents tolerated by rice varies with stage of growth, investigators generally agree that water containing less than 600 ppm of sodium chloride (350 ppm of chloride) is not harmful to rice at any stage of growth (Irelan, 1956, p. 330). Surface water of the Guadalupe River basin generally meets all quality requirements for rice irrigation.

Other criteria for evaluating the suitability of water for irrigation include the boron content and the excess of equivalents of bicarbonate over equivalents of calcium plus magnesium (residual sodium carbonate). The boron concentration in composites of daily samples collected from the Guadalupe River at Victoria during the 1951-56 water years ranged from 0.03 ppm to 0.75 ppm but usually was less than 0.25 ppm. The discharge-weighted concentration of boron in water passing the Victoria station during this period averaged 0.20 ppm. These data indicate generally that the boron concentration in surface waters of the Guadalupe River basin is low. With regard to residual sodium carbonate, surface waters of the basin usually contain an excess of equivalents of calcium plus magnesium over equivalents of bacarbonate. Thus, the residual sodium carbonate usually is zero.

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YEAR	WATER-SUPPLY PAPER NO.	YEAR	WATER-SUPPLY PAPER NO.
1903	99	1936	808
1904	132	1937	828
1905	174	1938	858
1906	210	1939	878
1915	408	1940	898
1916	438	1941	928
1917	458	1942	958
1918	478	1943	978
1919	508	1944	1008
1920	508	1945	1038
1921	528	1946	1058
1922	548	1947	1088
1923	568	1948	1118
1924	588	1949	1148
1925	608	1950	1178
1926	628	1951	1212
1927	648	1952	1242
1928	668	1953	1282
1929	688	1954	1342
1930	703	1955	1392
1931	718	1956	1442
1932	733	1957	1512
1933	748	1958	1562
1934	763	1959	1632
1935	788	1960	1712

Quality-of-water records for the Guadalupe River basin are published in the following U.S. Geological Survey Water-Supply Papers and Texas Water Development Board reports (including reports formerly published by the Texas Water Commission and Texas Board of Water Engineers):

WATER YEAR	U.S.G.S. WATER-SUPPLY PAPER NO.	T.W.D.B. REPORT NO.
1940-45	--	*1938-45
1946	1050	*1946
1947	1102	*1947
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	1744	Bull. 6215
1961	1884	Bull. 6304
1962	1944	Bull. 6501
1963	1950	Rept. 7

* "Chemical Composition of Texas Surface Waters" was designated only by water year from 1938 through 1955.

Table 6.--Index of Surface-Water Records in the Guadalupe 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	North Fork Guadalupe River at Farm Road 1340	--							
2	North Fork Guadalupe River 0.3 mile above confluence with South Fork Guadalupe River	--							
3	South Fork Guadalupe River at State Highway 39	--							
4	South Fork Guadalupe River 0.3 mile above confluence with North Fork Guadalupe River	--							
5	Guadalupe River at Hunt	276							
6	Johnson Creek near Ingram	115							
7	Turtle Creek at Farm Road 689	--							
8	Verde Creek at mouth	--							
9	Guadalupe River near Comfort	762							
10	Cypress Creek at State Highway 27, at Comfort	--							
11	Guadalupe River at Comfort	836							
12	Guadalupe River near Spring Branch	1,282							
13	Rebecca Creek near Spring Branch	11.0							
14	Canyon Reservoir near New Braunfels	1,425							
15	Guadalupe River at Sattler	1,422							
16	Hueco Springs near New Braunfels	--							
17	Guadalupe River above Comal River at New Braunfels	1,516							
18	Bleiders Creek at New Braunfels	--							
19	Panther Canyon at New Braunfels	--							
20	Dry Comal Creek at New Braunfels	--							

Discharge ··············· Gage heights only ▪▪▪▪▪▪▪▪▪▪▪▪ Gage heights and discharge measurements ‒ ‒ ‒ ‒ ‒ ‒ ‒ ‒ ‒ Reservoir contents •—•—•—•—•—•

Periodic discharge measurements oooooooooooooo Daily chemical quality ▬ ▬ ▬ ▬ ▬ Periodic chemical quality ▰▰▰▰▰▰▰▰▰ Water temperature ~~~~~~~~~~

Table 6.--Index of Surface-Water Records in the Guadalupe 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	Comal Springs at New Braunfels	--							
22	Comal River at New Braunfels	a117							
23	Guadalupe River at New Braunfels	1,624							
24	San Marcos Springs at San Marcos	--							
25	San Marcos River spring flow at San Marcos	a93.0							
26	San Marcos River at San Marcos	a93.0							
27	Blanco River at Wimberley	364							
28	Blanco River near Kyle	424							
29	San Marcos River at Luling	833							
30	Plum Creek at Lockhart	113							
31	Plum Creek near Lockhart	184							
32	Plum Creek near Luling	356							
33	San Marcos River at Ottine	1,249							
34	Peach Creek near Dilworth	445							
35	Peach Creek below Dilworth	462							
36	Sandies Creek near Westhoff	560							
37	Guadalupe River at Cuero (b)	4,877							
38	Guadalupe River at Victoria	5,161							
39	Coleto Creek near Schroeder	365							
40	Coleto Creek near Victoria	514							

Discharge ··············· Gage heights only ■■■■■■■■■■■■ Gage heights and discharge measurements ·–––––––– Reservoir contents

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

a Normal flow of river comes from springs; drainage area not applicable.

b Published as "near Cuero" 1902-06, and as "below Cuero" 1916-35.

Table 7.--Summary of Chemical Analyses at Daily Stations on Streams in the Guadalupe River Basin

(Analyses listed as maximum and minimum were classified on the basis of the values of dissolved solids only; values of other constituents may not be extremes. 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)	Bicarbonate (HCO_3) (a)	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 $CaCO_3$: Non-carbonate	Sodium adsorption ratio	Specific conductance (micromhos at 25°C)	pH
12. GUADALUPE RIVER NEAR SPRING BRANCH																						
Water year 1942																						
Jan. 1-10, 1942...	161			64	23	12		273		22	22		4.5		b296	0.40	129	254	30	0.3	520	
Jan. 21-31........	144			62	22	16		272		21	21		4.5		b290	.39	113	245	22	.4	505	
July 24-31........	96			53	22	13		240		19	23		2.8		b280	.38	72.6	223	26	.4	461	
Sept. 11-20.......	233			69	15	11		b268		12	16		3.0		b295	.40	186	234	14	.3	476	
Sept. 21, 23-30...	162			68	18	15		273		24	17		3.5		b326	.44	143	244	20	.4	489	
Water year 1943																						
Oct. 22-31, 1942..	381			72	18	7.1		271		18	18		4.0		b332	.45	342	254	32	.2	510	
Nov. 1-10.........	283			67	21	14		279		22	19		6.4		b313	.43	239	254	25	.4	499	
Nov. 11-20........	250			68	22	11		282		22	18		3.5		b309	.42	209	260	28	.3	515	
Nov. 21-30........	316			69	18	11		270		19	17		4.0		b300	.41	256	246	24	.3	484	
Dec. 1-10.........	223			70	19	18		280		25	24		4.0		b345	.47	208	252	23	.5	560	
Dec. 11-20........	212			72	22	11		290		23	20		4.0		b313	.43	179	270	32	.3	535	
Dec. 21-31........	261			70	21	10		283		20	19		4.0		b310	.42	218	261	28	.3	510	
Water year 1944																						
Jan. 1-10, 1944...	224			60	18	12		252		16	17		2.8		250	.34	151	224	17	.3	460	
Jan. 11-20	212			67	18	16		278		17	20		3.0		b290	.39	166	241	13	.4	501	
Jan. 21-31........	188			57	19	12		239		19	20		3.2		b265	.36	135	220	24	.4	461	
Feb. 1-10.........	178			63	19	14		257		23	20		2.5		b279	.38	134	235	24	.4	473	
38. GUADALUPE RIVER AT VICTORIA																						
Water year 1946																						
Maximum, Jan. 11-17, 1946.	1,426	--	--	112	36	231		249		79	455	--	4.0	--	1,040	1.41	4,000	428	224	4.9	1,950	--
Minimum Feb. 21-22, 27..	4,116	--	--	44	9.1	31		131		34	49	--	3.5	--	b261	.35	2,900	147	40	1.1	431	--
Weighted average..	1,827	--	--	69	18	83		191		39	160	--	2.6	--	532	.72	2,620	246	90	2.3	881	--
Water year 1947																						
Maximum, Jan. 13-14, 1947.	3,260	--	--	--	--	--		--		--	455	--	--	--	--	--	--	--	--	--	1,900	--
Minimum, Oct. 17, 1946...	26,000	--	--	--	--	--		--		--	20	--	--	--	--	--	--	--	--	--	204	--
Water year 1948																						
Maximum, May 19, 1948....	855	--	--	--	--	--		--		--	695	--	--	--	--	--	--	--	--	--	2,590	--
Minimum, Aug. 31..	776	--	--	--	--	--		--		--	19	--	--	--	--	--	--	--	--	--	266	--
Water year 1949																						
Maximum, Apr. 21, 24, 1949	5,035	11	--	73	21	--		170		--	250	--	6.6	--	b674	.92	9,160	268	129	--	1,180	--
Minimum, Apr. 22, 27-30..	13,780	12	--	35	6.2	30		107		20	47	--	2.8	--	b262	.36	9,750	113	25	1.2	373	--
Weighted average..	1,200	11	--	57	15	48		190		28	86	--	2.7	--	380	.52	1,230	204	48	1.5	632	--
Water year 1950																						
Maximum, Apr. 20-25, 1950	1,706	16	--	80	24	120		172		52	256	0.3	2.5	--	b744	1.01	3,430	298	157	3.0	1,210	7.6
Minimum, May 30-31..	1,610	14	--	42	11	22		154		20	34	--	3.0	--	b230	.31	1,000	150	24	.8	389	7.8
Weighted average..	1,061	15	--	60	17	56		199		32	104	.3	2.2	--	425	.58	1,220	220	56	1.6	711	--

See footnotes at end of table.

Table 7.--Summary of Chemical Analyses at Daily Stations on Streams in the Guadalupe River Basin--Continued

Date of collection	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)	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	Non-carbonate			
38. GUADALUPE RIVER AT VICTORIA--Continued																						
Water year 1951																						
Maximum, June 23-24, 1951.	531	30	0.02	88	24	202	--	172		58	399	0.6	3.0	--	b1,020	1.39	1,460	318	177	4.9	1,670	8.3
Minimum, June 4, 6, 15...	5,117	14	--	34	6.6	16		122		14	22	--	2.5	--	b175	.24	2,420	112	12	.7	303	7.7
Weighted average..	542	16	.08	53	17	52	1.0	195		30	89	.3	2.1	0.23	371	.50	543	202	42	1.6	648	--
Water year 1952																						
Maximum, Apr. 25-26, 1952.	1,054	18	--	85	29	170	--	191		50	351	.2	2.0	--	b830	1.13	2,360	331	174	4.1	1,500	8.2
Minimum, July 23-31......	407	13	.05	32	5.7	16	2.4	114		18	18	.4	2.8	.08	b179	.24	197	103	10	.7	291	7.4
Weighted average..	819	17	--	45	12	36	2.8	166		24	56	.3	2.8	.17	291	.40	643	162	26	1.3	497	--
Water year 1953																						
Maximum, July 14-17, 28-30, 1953.	269	20	--	56	23	119	5.7	159		54	225	.4	1.8	.32	b606	.82	440	234	104	3.4	1,080	7.9
Minimum, Aug. 31, Sept. 1-10......	3,740	16	--	35	6.4	18	4.1	128		18	22	.4	2.8	.14	b187	.25	1,890	114	9	.7	313	7.8
Weighted average..	1,074	17	--	51	14	37	3.7	179		29	61	.3	3.5	.21	319	.43	925	184	38	1.2	538	--
Water year 1954																						
Maximum, Sept. 13-20, 1954	101	24	--	58	24	133	4.8	207		44	225	.3	.8	.19	b650	.88	177	243	74	3.7	1,130	8.2
Minimum, Oct. 26-31, Nov. 1-2, 1953..	4,847	14	--	31	6.3	13	4.0	110		13	19	.3	3.5	.18	b168	.23	2,200	104	14	.6	267	7.7
Weighted average..	548	19	--	46	14	37	3.4	179		27	58	.3	3.2	.22	304	.41	450	172	26	1.2	516	--
Water year 1955																						
Maximum, Oct. 21-31, 1954	148	17	--	50	19	68	3.5	226		34	97	.4	1.5	.18	b410	.56	164	203	18	2.1	727	8.2
Minimum, June 11-20, 1955	722	18	--	41	6.5	24	4.6	136		23	35	.3	3.0	.13	223	.30	435	130	18	.9	378	8.2
Weighted average..	374	18	--	46	12	38	3.6	184		27	51	.3	2.5	.17	293	.40	296	164	14	1.3	507	--
Water year 1956																						
Maximum, June 11-20, 1956	57.4	19	--	57	16	76	4.8	203		31	122	.6	1.0	.16	427	.58	66.2	208	42	2.3	758	8.4
Minimum, May 11-20	329	22	--	47	11	43	4.3	174		23	64	.4	2.0	.14	b304	.41	270	162	20	1.5	524	8.0
Weighted average..	132	16	--	56	16	55	3.9	235		30	72	.4	1.1	.19	368	.50	131	206	13	1.7	639	--
Water year 1957																						
Maximum, July 1-10, 1957.	887	21	--	65	18	40	3.0	229		41	63	--	8.1	--	b404	.55	968	236	48	1.1	636	8.0
Minimum Oct. 23-31, 1956	109	12	--	29	3.0	13	4.9	110		9.2	14	--	.2	--	b142	.19	41.8	86	0	.6	233	8.0
Weighted average..	1,973	13	--	45	7.3	18	4.5	153		21	26	--	4.0	--	227	.31	1,210	142	17	.7	370	--
Water year 1958																						
Maximum, Oct. 4-15, 1957.	1,513	19	--	74	14	36	3.9	248		39	60	--	4.5	--	b398	.54	1,630	242	39	1.0	642	8.0
Minimum, Oct. 17-21	24,460	9.6	.40	31	3.7	7.4	4.4	110		11	10	--	2.0	--	134	.18	8,850	92	2	.3	227	7.9
Weighted average..	3,541	14	--	53	11	20	3.3	183		27	31	--	6.1	--	264	.36	2,520	177	27	.7	441	--

See footnotes at end of table.

Table 7.--Summary of Chemical Analyses at Daily Stations on Streams in the Guadalupe River Basin--Continued

Date of collection	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)	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
38. GUADALUPE RIVER AT VICTORIA--Continued																						
Water year 1959																						
Maximum, Mar. 1-10, 1959	1,523	15	--	72	16	33	2.8	257		39	48	--	6.1	--	b376	0.51	1,550	246	35	0.9	617	8.1
Minimum, May 23-26	2,758	9.6	--	46	9.1	19	3.0	164		19	27	--	2.5	--	216	.29	1,610	152	18	.7	393	7.6
Weighted average	1,580	15	--	60	14	25	2.8	219		28	35	--	5.0	--	303	.41	1,290	207	28	.8	511	--
Water year 1960																						
Maximum, July 5-20, 1960	1,531	21	--	76	16	46		274		37	64	.3	2.2	--	b404	.55	1,670	256	31	1.3	660	7.5
Minimum, June 26-30	13,410	13	--	34	6.0	17		124		16	16	.3	2.0	--	167	.23	6,050	110	8	.7	286	7.2
Weighted average	1,764	16	--	58	13	25		215		27	33	--	3.9	--	288	.39	1,370	198	22	.8	481	--
Water year 1961																						
Maximum, Dec. 1-12, 1960	2,895	21	--	83	17	40		292		38	56	.3	4.9	--	b416	.57	3,250	277	38	1.0	694	7.6
Minimum, Oct. 30-31	18,150	--	--	24	2.2	8.3		82		6.6	9.0	--	.5	--	b100	.14	4,900	69	2	.4	160	7.4
Weighted average	3,865	15	--	53	11	22		188		24	29	--	3.3	--	258	.35	2,690	177	23	.7	428	--
Water year 1962																						
Maximum, Dec. 16-31, 1961	972	14	--	78	19	41		280		42	60	.3	4.9	--	b432	.59	1,130	272	43	1.1	695	7.5
Minimum, Nov. 15-22	4,839	15	--	38	7.2	18		132		21	22	.4	2.8	--	189	.26	2,470	124	16	.7	331	7.0
Weighted average	914	17	--	55	16	35		210		34	47	--	3.3	--	321	.43	793	202	30	1.1	537	7.4
Water year 1963																						
Maximum, Sept. 10-15, 1963	165	18	--	58	18	53		228		34	78	--	1.0	--	372	.51	166	218	32	1.6	663	7.4
Minimum, June 18	500	--	--	--	--	27		157		19	34	--	1.8	--	225	--	--	140	12	1.0	375	7.5
Weighted average	565	15	--	61	15	31		230		31	42	--	3.4	--	316	.43	483	216	27	.9	538	7.5
Water year 1964																						
Maximum, Apr. 1-30, 1964	678	14	--	52	15	28	3.2	206		30	39	.5	3.5	--	364	.50	666	191	0	3.4	500	8.0
Minimum, Sept. 18-19	997	14	--	27	5.5	12		111		7.4	12	--	.8	--	134	.18	361	90	0	.5	217	8.4
Weighted average	568	13	--	51	14	29		203		26	37	--	2.6	--	281	.38	431	184	17	1.2	479	7.5
Water year 1965																						
Maximum, June 15-30, 1965	1,789	13	--	72	15	31		254		33	45	--	3.2	--	337	.46	1,630	241	33	.9	599	7.4
Minimum, Feb. 16-23	9,369	9.4	--	36	4.1	12		120		16	11	--	1.8	--	149	.20	3,770	107	8	.5	264	7.4
Weighted average	1,812	11	--	51	10	20		183		24	26	.3	2.5	--	236	.36	1,160	169	19	.6	418	7.3

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

b Residue at 180°C.

Table 8.--Chemical Analyses of Streams and Reservoirs in the Guadalupe 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)	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 $CaCO_3$ Non-carbonate	Sodium adsorption ratio	Specific conductance (micromhos at 25°C)	pH
1. NORTH FORK GUADALUPE RIVER AT FARM ROAD 1340																						
Mar. 15, 1965.....	14.2	12		68	14	4.6	0.9	268		4.6	7.9	0.2	4.2		248	0.34		227	8	0.1	437	7.2
2. NORTH FORK GUADALUPE RIVER 0.3 MILE ABOVE CONFLUENCE WITH SOUTH FORK GUADALUPE RIVER																						
Mar. 16, 1965.....	24.8							256			9.8							228	18		428	7.4
3. SOUTH FORK GUADALUPE RIVER AT STATE HIGHWAY 39																						
Mar. 15, 1965.....	10.1	11		72	20	4.7	0.8	314		4.6	8.4	0.2	3.2		279	0.38		262	4	0.1	450	7.5
4. SOUTH FORK GUADALUPE RIVER 0.3 MILE ABOVE CONFLUENCE WITH NORTH FORK GUADALUPE RIVER																						
Mar. 24, 1965.....	27.9	5.9		49	22	5.5	0.7	250		7.2	9.9	0.2	0.8		224	0.30		213	8	0.2	403	7.8
5. GUADALUPE RIVER AT HUNT																						
July 19, 1965.....	33.7	12		50	19	6.3	1.2	244		6.8	10	0.1	0.2		226	0.31		203	3	0.2	399	7.8
Nov. 4............	38	11		48	20	6.2	1.0	240		5.6	10	.2	.2		220	.30		204	7	.2	405	7.4
Apr. 25, 1966.....	579	9.8		43	12	4.0	2.1	180		7.4	7.4	.3	2.0		177	.24		157	9	.1	327	7.3
6. JOHNSON CREEK NEAR INGRAM																						
Nov. 17, 1964.....	11.3	12		57	20	16		262		11	22	0.3	1.2		268	0.36		224	10	0.5	474	7.5
Apr. 8, 1965......	12.4	10		26	22	11		162		13	22	.3	1.2		186	.25		155	23	.4	351	7.6
May 9.............	12.4	12		56	19	19		264		12	21	.1	.2		269	.37		218	1	.6	481	7.2
June 15...........	16.6	13		54	22	10		250		12	20	.3	1.0		255	.35		225	20	.3	461	7.1
July 19...........	9.81	16		54	20	19		262		10	22	.3	.5		271	.37		217	2	.6	470	7.7
Sept. 27..........	8.24	15		41	27	15		242		11	25	.3	.0		253	.34		214	16	.4	465	7.3
Nov. 4............	11.2	12		52	21	15		250		9.4	23	.3	.0		256	.35		216	11	.4	470	7.6
Feb. 17, 1966.....	9.87	8.4		50	20	13	1.2	241		11	23	.2	.2		246	.33		207	10	.4	459	7.6
June 3............	8.31	13		54	19	13	1.4	248		8.4	20	.1	.2		251	.34		213	10	.4	456	7.6
7. TURTLE CREEK AT FARM ROAD 689																						
Mar. 25, 1965.....	18.7	6.7		62	22	6.8	1.1	270		19	14	0.2	2.0		267	0.36		245	24	0.2	441	7.7
8. VERDE CREEK AT MOUTH																						
Mar. 25, 1965.....	12.9	6.7		74	18	7.0	1.0	276		21	14	0.3	1.8		280	0.38		258	32	0.2	500	7.7
10. CYPRESS CREEK AT STATE HIGHWAY 27, AT COMFORT																						
Mar. 25, 1965.....	4.03	6.4		82	29	15		345		33	26	0.4	1.8		364	0.50		324	42	0.4	600	7.5

See footnotes at end of table.

Table 8.--Chemical Analyses of Streams and Reservoirs in the Guadalupe River Basin for Locations Other Than Daily Stations--Continued

Date of collection	Discharge (cfs)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	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
11. GUADALUPE RIVER AT COMFORT																						
Oct. 12, 1964	138	13		66	20	13		277		18	17	0.3	5.5		289	0.39		247	20	0.4	498	7.7
Nov. 17	93.3	11		61	22	12		274		16	19	.3	.0		276	.38		242	18	.3	491	7.4
Apr. 8, 1965	106	5.5		52	23	13		251		18	19	.3	1.2		255	.35		224	18	.4	463	7.5
May 10	107	8.6		56	23	14		266		18	18	.3	1.2		249	.34		234	16	.4	497	7.5
June 15	127	11		54	25	11		254		22	20	.3	1.8		270	.37		238	30	.3	498	6.9
June 23	3,030	8.8		46	8.3	3.8	3.2	171		11	5.8	.2	3.8		175	.24		149	9	.1	306	7.0
July 19	62.5	13		58	22	17		262		22	21	.3	3.8		286	.39		235	20	.5	506	7.4
Nov. 4	65.2	12		56	22	12		256		18	20	.3	1.8		268	.36		232	22	.3	491	7.4
Dec. 3	213	9.6		48	18	9.6	2.0	218		14	16	.3	1.0		226	.31		194	15	.3	405	7.3
June 3, 1966	86.3	12		62	24	11	2.0	282		20	17	.1	.2		287	.39		253	22	.3	506	7.7
12. GUADALUPE RIVER NEAR SPRING BRANCH																						
Feb. 22, 1961	a1,380	12		76	21	13		302		21	18	0.1	10		b330	0.45		276	28	.3	557	7.7
Mar. 30, 1964	144	9.6		67	19	11		265		23	17	.3	3.0		280	.38		245	28	.3	496	7.3
13. REBECCA CREEK NEAR SPRING BRANCH																						
Mar. 30, 1964	3.31	6.2		51	11	7.1	1.6	190		15	13	0.2	1.2		199	0.27		172	17	0.2	367	7.6
14. CANYON RESERVOIR NEAR NEW BRAUNFELS																						
Oct. 1, 1964		9.4		49	12	10		199		13	11	0.3	0.8		204	0.28		172	8	0.3	355	7.4
Nov. 2		10		50	11	4.4	3.2	194		12	8.8	.3	2.2		197	.27		170	11	.1	338	8.0
Mar. 3, 1965		6.9		64	17	12		264		15	15	.3	.5		261	.35		230	13	.3	456	8.0
June 2		7.7		72	15	11		276		16	15	.3	.2		273	.37		241	15	.3	485	7.9
Aug. 2		7.6		50	13	12		208		14	13	.2	.2		212	.29		178	8	.4	378	7.4
Feb. 1, 1966		9.9		63	15	7.8	2.1	244		14	14	.1	1.2		247	.34		219	19	.2	444	7.6
June 1		7.1		49	13	8.3	2.2	198		14	14	.3	.8		206	.28		176	13	.3	377	7.4
Sept. 1		--		--	--	--	--	241		12	13	--	--		--	--		214	16	--	425	7.8
15. GUADALUPE RIVER AT SATTLER																						
Sept. 4, 1962	17.6	13		52	20	11		236		19	16	0.3	0.0		b256	0.35		212	19	0.3	441	7.1
Dec. 2, 1963	71.0	11		61	18	11		242		18	22	.3	1.8		262	.36		226	28	.3	468	7.4
17. GUADALUPE RIVER ABOVE COMAL RIVER AT NEW BRAUNFELS																						
Oct. 1, 1964	446	10		48	9.8	3.3	2.9	174		11	6.4	0.0	4.2		182	0.25		160	17	0.1	316	7.5
Mar. 2, 1965	340	8.6		80	14	6.3	1.1	283		16	13	.2	7.2		285	.39		257	25	.2	500	7.3
May 3	297	7.7		41	14	7.6	1.4	169		18	14	.2	2.8		190	.26		160	21	.3	343	7.5
Nov. 1	231	11		77	11	6.0	1.7	269		12	10	.2	4.6		266	.36		236	16	.2	469	7.4
Jan. 3, 1966	292	9.9		78	14	8.1	1.6	286		16	13	.3	4.5		286	.39		252	18	.2	500	7.4

See footnotes at end of table.

Table 8.--Chemical Analyses of Streams and Reservoirs in the Guadalupe River Basin for Locations Other Than Daily Stations--Continued

Date of collection	Discharge (cfs)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	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 $CaCO_3$: Non-carbonate	Sodium adsorption ratio	Specific conductance (micromhos at 25°C)	pH
21. COMAL SPRINGS AT NEW BRAUNFELS																						
May 25, 1934		--	--	--	--	--		268		30	12	--	--	--	--	--		264	--	--	--	--
Apr. 10, 1938		--	--	75	17	3.3		266		23	13	0.0	5.0	--	267	0.36		257	39	0.1	--	--
June 24, 1941		--	--	63	17	18		272		23	12	--	3.7	--	271	.37		227	4	.5	--	--
Aug. 13		--	--	--	--	--		272		23	11	--	--	--	--	--		--	--	--	--	--
Sept. 16		12	--	73	17	1.8		264		24	12	.1	4.4	--	279	.38		252	36	.1	--	--
Apr. 2, 1942		11	--	70	17	11		274		22	12	.1	4.0	--	282	.38		244	20	.3	--	--
Jan. 10, 1944		--	--	78	17	5.5		280		23	13	--	5.5	--	280	.38		264	35	.1	--	--
Jan. 22		11	0.02	74	16	6.2	3.0	270		23	12	.4	5.5	--	284	.39		250	33	.2	--	7.5
Mar. 23		--	--	--	--	--		270		24	12	--	--	--	--	--		--	--	--	--	--
Oct. 9, 1945		--	--	76	18	2.8		274		20	14	--	5.6	--	271	.37		264	39	.1	--	--
Feb. 1, 1947		--	--	80	20	2.1		286		28	14	--	4.0	--	289	.39		282	47	.1	--	7.4
Aug. 7, 1951		13	.03	74	17	7.2	.4	274		22	12	.0	4.5	0.11	b292	.40		254	30	.2	507	7.5
June 24, 1957		14	--	75	18	8.1	1.2	271		24	16	.4	4.8	--	294	.40		260	38	.2	497	7.8
Aug. 8		14	--	74	17	7.8	1.1	271		22	13	.6	4.8	--	287	.39		254	32	.2	502	7.4
Oct. 4		12	.00	72	18	7.6	.9	276		22	14	.3	4.2	--	b302	.41		254	28	.2	498	7.6
Jan. 14, 1958		11	--	75	16	7.6	1.2	276		22	14	.4	4.8	--	b298	.41		253	27	.2	493	8.0
Apr. 9		13	--	75	16	7.7	1.1	274		21	14	.3	5.1	--	b302	.41		254	30	.2	501	7.1
July 16		12	--	75	17	7.7	.9	271		22	14	.2	5.3	--	b290	.39		257	35	.2	505	7.0
Jan. 16, 1959		11	--	72	15	17		280		22	13	.3	6.8	--	b296	.40		241	12	.5	508	7.4
June 18		9.4	.03	76	15	7.5	1.0	276		23	12	.2	6.1	.12	286	.39		251	25	.2	502	6.9
Nov. 23		--	--	--	--	--		277		27	14	--	--	--	--	--		253	26	--	517	6.8
Sept. 29, 1960		--	--	--	--	--		--		22	9.0	--	--	--	--	--		--	--	--	--	--
Mar. 2, 1961		--	--	--	--	--		282		22	14	--	--	--	--	--		252	21	--	518	7.5
Aug. 9		--	--	--	--	--		280		22	16	--	--	--	--	--		254	24	--	508	7.1
Mar. 7, 1962		--	--	--	--	--		276		22	14	--	--	--	--	--		248	22	--	502	7.4
Feb. 25, 1965		--	--	--	--	--		--		24	14	--	--	--	--	--		--	--	--	--	--
May 18		--	--	--	--	--		286		--	13	--	--	--	--	--		--	--	--	508	7.3
Aug. 26		--	--	--	--	--		284		23	11	--	--	--	--	--		256	--	--	518	6.7
Feb. 18, 1966		--	--	--	--	--		284		22	12	--	--	--	--	--		260	28	--	520	7.2
24. SAN MARCOS SPRINGS AT SAN MARCOS																						
Oct. 4, 1937		--	--	90	15	17		268		22	51	--	--		b335	0.46		284	--	0.4	--	--
May 16, 1947		11	0.05	90	20	7.1	5.4	334		19	22	0.8	3.0		b349	.47		306	40	.2	602	7.2
Mar. 23, 1955		13	--	82	21	5.2	.5	309		17	16	1.0	4.6		b334	.45		291	38	.1	556	7.4
July 12		--	--	--	--	--		307		--	16	--	--		--	--		278	--	--	563	7.6
June 18, 1959		9.2	.03	84	18	10	1.3	307		25	20	.2	8.5	0.15	327	.44		284	32	.3	567	7.1
Nov. 25, 1959		--	--	--	--	--		307		24	20	--	--		--	--		282	30	--	579	7.3
Sept. 30, 1960		--	--	--	--	--		298		20	18	--	--		--	--		268	24	--	545	7.6
Mar. 2, 1961		--	--	--	--	--		310		23	22	--	--		--	--		280	26	--	585	7.8
Aug. 3		--	--	--	--	--		250		22	22	--	--		--	--		234	29	--	503	7.3
Mar. 12, 1962		--	--	--	--	--		304		22	21	--	--		--	--		276	27	--	570	7.0
Feb. 28, 1963		--	--	--	--	--		308		22	20	--	--		--	--		288	36	--	571	7.4
Sept. 13		--	--	--	--	--		300		26	20	--	--		--	--		284	38	--	571	7.0
Mar. 6, 1964		--	--	--	--	--		316		22	16	--	--		--	--		290	31	--	574	7.6
Aug. 17		--	--	--	--	--		312		23	16	--	--		--	--		284	28	--	558	7.6
May 18, 1965		--	--	--	--	--		314		24	20	--	--		--	--		284	26	--	569	7.3
Aug. 26		--	--	--	--	--		308		24	17	--	--		--	--		290	38	--	578	6.9
Feb. 18, 1966		--	--	--	--	--		304		24	20	--	--		--	--		288	39	--	585	7.3
Aug. 24		--	--	--	--	--		310		22	19	--	--		--	--		286	32	--	575	7.2

See footnotes at end of table.

Table 8.--Chemical Analyses of Streams and Reservoirs in the Guadalupe River Basin for Locations Other Than Daily Stations--Continued

Date of collection	Discharge (cfs)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	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 $CaCO_3$: Non-carbonate	Sodium adsorption ratio	Specific conductance (micromhos at 25°C)	pH
25. SAN MARCOS RIVER SPRING FLOW AT SAN MARCOS																						
July 26, 1965......	193	11		38	17	13		166		26	18	0.2	5.0		210	0.29		165	29	0.4	368	7.9
27. BLANCO RIVER AT WIMBERLEY																						
Apr. 4, 1962.......	42.0	7.1		56	17	12		218		28	17	0.3	3.5		b248	0.34		210	31	0.4	428	7.3
Aug. 22............	22.0	11		52	17	7.5	0.9	214		17	15	.3	2.0		228	.31		200	24	.2	407	7.3
Sept. 26...........	227	6.4		46	7.0	3.3	1.5	158		7.6	5.8	.2	1.2		157	.21		144	14	.1	273	6.8
Nov. 28............	32.7	12		40	18	7.1	1.5	171		26	14	.3	3.8		b210	.29		174	34	.2	366	7.5
Jan. 3, 1963.......	46.0	8.5		76	17	7.1	.8	272		23	14	.3	3.8		284	.39		260	36	.2	501	6.9
Apr. 19............	57.8	12		70	14	7.2	1.0	250		18	14	.3	3.2		b270	.37		232	27	.2	455	7.2
June 12............	20.0	11		52	15	6.5	1.9	200		20	13	.3	1.5		219	.30		191	28	.2	372	7.5
July 18............	13.7	11		50	19	7.8	1.6	206		26	16	.3	.8		234	.32		203	34	.2	390	7.2
Aug. 21............	13.6	11		50	18	7.5	1.5	202		25	14	.3	.5		227	.31		199	33	.2	404	6.9
Sept. 24...........	11.4	12		52	19	7.8	1.6	208		33	14	.3	1.2		243	.33		208	37	.2	421	7.0
Feb. 11, 1964......	17.4	7.3		66	18	6.9	1.2	248		27	14	.3	4.0		267	.36		238	36	.2	469	8.0
June 30............	12.4	11		48	19	11		204		31	14	.6	.0		235	.32		198	31	.3	410	7.1
Sept. 9............	10.6	13		45	20	11		191		40	14	.3	.0		237	.32		195	38	.3	415	7.0
Nov. 19............	43.0	12		71	15	7.9	1.5	273		16	11	.3	3.2		271	.37		238	15	.2	463	7.7
Apr. 6, 1965.......	1,420	9.7		69	9.4	4.1	1.9	240		11	7.1	.1	3.2		234	.32		211	14	.1	411	6.8
Apr. 7.............	396	9.6		77	11	5.4	1.4	271		13	9.0	.3	2.8		262	.36		237	15	.2	473	7.3
Apr. 9.............	231	9.1		78	11	5.8	1.3	270		13	12	.2	5.3		269	.37		240	18	.2	467	7.3
July 26............	81.8	10		57	15	11		220		22	14	.2	4.2		241	.33		204	24	.3	430	7.4
Nov. 22............	89.2	9.8		71	15	7.1	1.4	256		20	15	.2	3.2		269	.37		238	28	.2	473	7.1
Dec. 27............	254	7.8		61	16	7.3	1.1	232		18	13	.2	5.8		244	.33		216	26	.2	423	7.3
Apr. 13, 1966......	109	--		--	--	--	--	210		--	14	--	3.2		--	--		200	28	--	413	7.5
July 26............	59.3	11		54	16	7.7	1.4	203		25	14	.4	2.2		232	.32		201	34	.2	412	7.6
29. SAN MARCOS RIVER AT LULING																						
Feb. 23, 1944......	a323	--		139	40	215		c271		114	452	--	--		1,090	1.48		512	289	4.1	2,100	--
Feb. 25, 1959......	340	11		80	17	52		357		24	45	0.2	0.0		405	.55		270	0	1.4	706	7.4
Sept. 12, 1961.....	a335	9.9		100	30	149		231		88	292	.3	3.5		b846	1.15		373	184	3.4	1,410	7.2
Mar. 13, 1963......	160	8.9		76	20	28		266		33	55	.3	3.0		355	.48		272	54	.7	637	6.9
July 17............	97.2	12		61	18	18		231		26	32	.3	3.2		284	.39		226	36	.5	478	7.0
Sept. 23...........	90.9	12		62	17	19		232		26	31	.3	4.5		286	.39		224	34	.6	502	6.9
Dec. 5.............	96.4	12		78	21	14		272		29	38	.3	4.5		331	.45		281	58	.4	615	6.6
Feb. 13, 1964......	104	9.2		82	19	26		296		31	42	.3	3.5		359	.49		282	40	.7	624	8.1
Mar. 18............	105	9.2		80	21	24		292		31	46	.2	1.8		357	.49		286	46	.6	646	7.3
July 1.............	109	8.8		60	19	17		237		27	28	.2	2.8		280	.38		228	34	.5	496	7.3
Sept. 9............	77.8	13		59	19	18		232		27	31	.3	1.8		283	.38		225	35	.5	506	7.0
Nov. 19............	147	11		83	19	20		300		28	36	.3	2.2		348	.47		285	39	.5	608	7.2
Jan. 23, 1965......	841	12		61	3.4	13		159		48	5.7	.5	6.5		228	.31		166	36	.4	377	7.2
Jan. 29............	250	11		82	19	29		276		35	56	.3	3.8		372	.51		282	56	.8	655	7.0
Apr. 7.............	1,920	12		50	12	6.5	1.9	188		17	12	.3	4.8		208	.28		174	20	.2	368	7.8
Apr. 13............	496	11		79	16	17		279		26	29	.1	3.5		319	.43		263	34	.5	580	7.1
May 13.............	527	10		68	16	21		240		32	33	.3	3.8		302	.41		236	39	.6	539	7.2
June 6.............	7,210	12		56	4.9	11		172		27	8.2	.5	1.8		206	.28		160	19	.4	348	6.9
July 22............	269	11		64	19	21		252		27	31	.2	5.0		302	.41		238	31	.6	532	7.4
Apr. 12, 1966......	288	--		--	--	--		278		--	41	--	--		--	--		270	42	--	609	7.4

See footnotes at end of table.

Table 8.--Chemical Analyses of Streams and Reservoirs in the Guadalupe River Basin for Locations Other Than Daily Stations--Continued

Date of collection	Discharge (cfs)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	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 $CaCO_3$: Non-carbonate	Sodium adsorption ratio	Specific conductance (micromhos at 25°C)	pH
30. PLUM CREEK AT LOCKHART																						
Feb. 25, 1959	--	18		94	5.4	76		283		71	67	1.1	23		494	0.67		256	24	2.1	826	7.4
Apr. 4, 1962	0.50	1.7		82	12	91		199		165	82	.7	.0		b559	.76		254	91	2.5	870	7.0
June 4	65	11		70	5.6	65		172		103	63	.4	.8		b439	.60		198	56	2.0	691	6.9
Oct. 24	.90	13		66	4.9	35		161		94	21	.7	.2		b332	.45		184	52	1.1	503	6.6
Jan. 3, 1963	4.37	7.1		88	7.6	52		202		121	50	.6	.8		b443	.60		251	86	1.4	695	7.1
Apr. 18	1.63	8.5		99	10	61		176		202	45	.7	.2		b518	.70		288	144	1.6	786	7.0
May 28, 1964	1.17	11		59	4.6	28		188		45	17	.6	.5		258	.35		166	12	.9	443	7.2
July 1	1.81	9.0		50	3.5	19		173		23	9.4	.5	.0		199	.27		139	0	.7	345	6.8
Sept. 17	72.1	11		64	3.5	13		202		28	3.4	.8	1.5		224	.30		174	9	.4	378	6.9
Sept. 18	2.71	9.3		36	2.0	14		106		33	4.5	.7	.2		152	.21		98	11	.6	254	7.2
Jan. 22, 1965	506	11		60	8.3	24		170		34	37	.4	9.0		268	.36		184	45	.8	462	7.4
Jan. 28	35.3	9.5		54	4.0	25		153		58	12	.5	1.0		239	.33		151	26	.9	399	6.7
Apr. 6	960	11		49	2.6	19		128		42	14	.5	4.8		206	.28		133	28	.7	349	7.3
Apr. 7	61.9	10		64	4.7	22		169		58	17	.4	3.5		263	.36		179	41	.7	454	6.9
Apr. 12	39	7.0		58	4.2	22		180		40	13	.4	.2		234	.32		162	14	.8	413	6.9
Dec. 3	2,710	11		56	2.5	12	3.8	171		30	5.8	.5	4.0		210	.29		150	10	.4	354	6.9
Dec. 29	12.8	7.0		81	7.3	35	4.5	224		82	31	.6	2.2		361	.49		232	48	1.0	598	7.4
June 22, 1966	2.43	5.9		57	6.5	37	5.1	158		83	28	.5	.2		301	.41		168	39	1.2	514	7.4
32. PLUM CREEK NEAR LULING																						
Apr. 4, 1961	a18.0	13		172	24	249		366		190	395	0.7	14		1,240	1.69		528	228	4.7	2,120	7.3
Sept. 12	a390	9.6		115	16	231		198		94	418	.5	3.8		b1,080	1.47		353	190	5.3	1,780	7.0
Mar. 13, 1963	9.14	5.5		164	22	264		284		141	490	.6	2.5		1,230	1.67		500	267	5.1	2,140	7.5
June 10	.53	9.1		116	13	262		400		98	340	.8	.8		1,040	1.41		343	15	6.2	1,760	7.2
July 17	.51	11		106	13	225		328		94	310	.7	.0		921	1.25		318	49	5.5	1,560	7.6
Sept. 23	1.26	13		60	6.4	114		244		40	128	.6	1.0		483	.66		176	0	3.7	858	7.3
Dec. 5	2.46	15		129	15	173		334		81	282	.6	3.2		863	1.17		384	110	3.8	1,530	7.3
Feb. 13, 1964	3.44	7.0		116	12	148		266		90	245	.5	2.8		752	1.02		339	121	3.5	1,330	8.0
Apr. 27	98.2	16		107	11	112		277		75	176	.5	2.0		636	.86		312	85	2.8	1,100	7.1
July 1	2.97	13		85	8.5	109		256		61	148	.6	.0		551	.75		247	37	3.0	971	7.2
Sept. 18	1,040	9.5		35	2.4	12		114		13	10	.3	1.2		139	.19		97	4	.5	238	7.0
Sept. 20	50.5	8.8		39	3.6	26		114		23	36	.3	.2		193	.26		112	19	1.1	347	7.0
Jan. 29, 1965	102	10		58	5.2	40		140		43	64	.5	3.4		293	.40		166	52	1.3	516	7.5
Apr. 7	5.26	11		74	5.2	29		203		53	32	.4	3.0		308	.42		206	40	.9	541	6.8
Apr. 13	43	10		84	8.9	66		214		65	102	.5	.5		442	.60		246	70	1.8	801	6.8
May 13	110	12		67	6.6	55		170		54	80	.5	3.0		362	.49		194	54	1.7	645	7.1
June 18	34.9	13		98	16	142		176		122	245	.4	3.2		727	.99		310	166	3.5	1,270	7.4
June 22	3.85	12		142	17	219		374		125	328	.6	.8		1,030	1.40		424	118	4.6	1,820	7.1
Nov. 24	10.7	15		90	9.1	83		236		58	132	.3	1.5		505	.69		262	68	2.2	914	6.9
Jan. 31, 1966	22.9	6.7		154	19	164	4.3	312		154	280	.5	4.2		940	1.28		464	208	3.3	1,580	7.4
June 21	21.4	13		130	13	160	5.1	252		203	214	.2	.8		863	1.17		378	172	3.6	1,450	6.9

See footnotes at end of table.

Table 8.--Chemical Analyses of Streams and Reservoirs in the Guadalupe River Basin for Locations Other Than Daily Stations--Continued

Date of collection	Discharge (cfs)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	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
33. SAN MARCOS RIVER AT OTTINE																						
Mar. 13, 1963	d170	9.1		84	19	41		288		40	70	0.4	0.0		406	0.55		288	52	1.0	728	6.5
July 17	d100	11		62	18	29		236		28	47	.3	2.8		314	.43		228	35	.8	531	7.3
Dec. 5	99.8	12		84	20	35		294		34	63	.3	3.0		396	.54		292	51	.9	716	7.1
Mar. 18, 1964	111	10		84	21	41		294		39	72	.3	2.0		414	.56		296	55	1.0	752	7.2
July 1	125	10		69	18	28		261		30	42	.3	1.5		327	.44		246	32	.8	583	7.2
Sept. 9	79.8	12		60	19	28		228		30	48	.3	1.8		311	.42		228	40	.8	562	6.9
Jan. 29, 1965	367	9.8		71	14	42		230		39	66	.3	4.2		359	.49		234	46	1.2	609	8.1
Apr. 7	2,000	14		73	13	16		252		30	19	.4	4.8		294	.40		236	29	.5	518	7.1
Apr. 13	530	11		81	16	25		272		32	44	.3	3.8		347	.47		268	45	.7	631	7.0
May 13	628	10		63	12	27		206		36	39	.3	3.2		292	.40		206	38	.8	526	7.0
July 22	274	12		72	19	34		274		31	50	.2	4.0		357	.49		258	33	.9	628	7.0
35. PEACH CREEK BELOW DILWORTH																						
Apr. 2, 1962	5.13	15		172	42	155		174		476	212	0.4	0.8		1,160	1.58		602	459	2.7	1,730	7.1
May 7	7.84	20		69	15	62		115		148	84	.3	.2		456	.62		234	140	1.8	763	6.7
June 4	140	12		37	6.4	34		76		64	44	.3	1.0		236	.32		119	56	1.4	421	6.4
Sept. 24	d.05	20		53	8.6	34		118		94	33	.3	.2		b331	.45		168	71	1.1	468	6.5
Oct. 29	205	10		25	1.8	6.7	4.9	81		13	5.8	.4	1.8		109	.15		70	3	.3	184	6.9
Jan. 7, 1963	1.18	13		25	3.1	21		76		33	16	.3	.2		149	.20		75	13	1.1	245	6.5
Mar. 19	.60	19		78	12	60		150		142	72	.3	.0		b478	.65		244	121	1.7	740	7.2
Nov. 12	30.5	8.6		26	3.9	23		38		76	12	.3	3.2		172	.23		81	50	1.1	240	6.1
Dec. 16	42.9	13		21	4.3	37		121		27	14	.5	1.5		178	.24		70	0	1.9	303	6.7
Mar. 4, 1964	1,470	9.2		12	1.5	4.5	4.8	37		12	3.8	.4	1.0		67	.09		36	6	.3	106	6.3
Apr. 7	3.42	17		118	28	73		143		288	106	.3	.5		701	.95		410	292	1.6	1,080	7.1
May 4	1.49	14		64	12	42		154		101	49	.3	.2		358	.49		209	83	1.3	611	6.7
Sept. 22	13.5	12		18	2.0	14		57		23	7.4	.3	1.5		106	.14		53	6	.8	170	6.6
Jan. 23, 1965	373	9.4		19	.6	16		58		23	8.6	.3	1.0		107	.15		50	2	1.0	175	7.3
Jan. 24	78.6	12		14	2.9	18		57		20	9.4	.4	4.0		109	.15		47	0	1.1	174	6.7
Jan. 25	25.6	12		16	2.9	16		55		25	10	.3	2.2		111	.15		52	7	1.0	189	6.4
Feb. 18	4,320	8.1		7.8	1.6	2.8	4.5	30		9.2	2.2	.2	.5		52	.07		26	1	.2	78	6.7
Apr. 19	3.32	11		118	32	91		136		308	135	.3	.2		762	1.04		426	314	1.9	1,200	6.9
Oct. 20	1,430	10		9.0	1.3	4.6	5.1	31		12	3.4	.1	1.2		62	.08		28	2	.4	95	6.4
Nov. 12	109	15		18	3.2	10		62		18	6.3	.3	.8		102	.14		58	7	.6	161	6.6
36. SANDIES CREEK NEAR WESTHOFF																						
Apr. 5, 1962	28.9	10		52	13	169		246		95	175	0.4	1.0		b654	0.89		183	0	5.4	1,110	7.1
May 10	5.88	18		47	12	104		200		77	105	.4	.1		b491	.67		167	3	3.5	816	6.6
June 4	200	11		20	4.3	61		107		35	53	.3	1.8		b260	.35		68	0	3.2	429	6.9
Sept. 27	2.17	26		26	5.2	94		212		29	61	.5	.5		346	.47		86	0	4.4	564	6.5
Nov. 1	30.8	11		14	3.8	112		206		18	75	.5	.2		b362	.49		50	0	6.9	596	6.3
Jan. 11, 1963	6.29	17		25	4.2	83		145		46	64	.4	1.8		312	.42		80	0	4.0	532	6.6
Mar. 22	4.46	15		51	11	137		233		82	137	.4	.0		548	.75		172	0	4.5	933	6.7
Apr. 26	1.82	17		53	12	290		512		50	238	1.2	1.8		b923	1.26		182	0	9.3	1,520	7.7
May 27	.22	39		42	5.6	263		510		42	168	.6	.2		811	1.10		128	0	10	1,290	7.2
July 5	5.82	15		27	6.0	469		536		20	458	1.1	2.5		1,260	1.71		92	0	21	2,160	7.0
Aug. 1	.12	46		35	3.0	257		508		41	140	.6	.2		773	1.05		100	0	11	1,230	7.4
Sept. 6	.13	46		33	3.0	251		492		40	138	.5	.0		754	1.03		95	0	11	1,230	7.1
Oct. 10	.25	30		27	5.0	274		560		36	130	1.0	1.2		779	1.06		88	0	13	1,290	7.2
Nov. 15	7.80	11		18	3.6	203		312		28	150	.9	2.5		570	.78		60	0	11	1,000	7.0
Dec. 19	10.1	12		21	4.3	118		148		41	114	.4	.8		384	.52		70	0	6.1	693	6.7

See footnotes at end of table.

Table 8.--Chemical analyses of streams and reservoirs in the Guadalupe River basin for locations other than daily stations--Continued

Date of collection	Discharge (cfs)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	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 Noncarbonate	Sodium adsorption ratio	Specific conductance (micromhos at 25°C)	pH
36. SANDIES CREEK NEAR WESTHOFF--Continued																						
Feb. 27, 1964	78.2	13		16	4.6	112		204		19	80	0.7	1.5		347	0.47		59	0	6.3	616	6.9
Mar. 4	514	11		12	2.9	31		72		18	22	.1	1.0		133	.18		42	0	2.1	237	6.5
Sept. 23	26.7	13		11	5.5	121		96		11	156	.5	1.5		366	.50		50	0	7.4	676	6.9
Jan. 5, 1965	3.10	15		32	6.8	299		520		28	212	.7	1.2		851	1.16		108	0	12	1,420	7.9
Jan. 24	2,310	9.3		8.5	2.6	13		39		13	7.8	.4	4.2		78	.11		32	0	1.0	131	6.5
Jan. 25	410	11		12	2.2	19		48		18	14	.3	2.8		103	.14		39	0	1.3	176	6.4
Jan. 26	86.9	12		14	2.7	26		58		23	20	.2	2.2		129	.18		46	0	1.7	222	6.6
Feb. 7	1,220	9.2		9.0	2.3	14		38		14	10	.3	1.2		79	.11		32	1	1.1	137	6.5
Mar. 17	9.69	14		78	25	159		240		150	205	.4	.8		750	1.02		298	101	4.0	1,270	7.4
Apr. 21	6.13	17		65	16	243		404		95	230	.6	1.5		867	1.18		228	0	7.0	1,460	7.0
May 19	1,330	13		10	2.2	15		44		13	11	.2	.5		87	.12		34	0	1.1	141	6.3
Nov. 17	10.8	19		44	9.7	117		182		70	129	.3	.2		478	.65		150	1	4.2	855	6.7
Dec. 16	438	15		11	2.7	23	6.2	48		13	30	.3	.8		e126	.17		39	0	1.6	201	6.5
Jan. 28, 1966	15.0	14		69	14	197	7.4	338		121	190	.4	.2		f780	1.06		230	0	5.7	1,320	7.5
May 11	122	14		25	5.0	28	8.1	94		33	32	.2	.2		192	.26		83	6	1.3	327	7.0
39. COLETO CREEK NEAR SCHROEDER																						
Apr. 4, 1962	5.23	21		71	11	82		215		33	134	0.4	0.0		b476	0.65		222	46	2.4	805	7.3
May 10	5.79	22		71	9.5	64		212		26	109	.4	.0		406	.55		216	42	1.9	741	7.2
June 4	247	12		52	3.4	27		140		5.8	58	.2	.1		228	.31		144	29	1.0	427	6.6
July 17	2.07	30		60	7.9	69		186		23	109	.4	.0		b412	.56		182	30	2.2	683	7.4
Sept. 27	7.94	24		76	8.0	56		226		26	93	.5	.0		b428	.58		222	38	1.6	676	7.3
Nov. 1	2.09	28		61	9.7	74		177		30	124	.5	.0		b436	.59		192	47	2.3	731	7.5
Dec. 3	156	21		69	8.7	80		202		35	125	.5	3.0		b457	.62		208	42	2.4	785	6.7
Mar. 20, 1963	3.69	20		71	12	84		205		33	146	.4	.0		b496	.67		226	58	2.4	826	7.4
May 28	d.09	31		72	9.1	70		225		24	113	.4	.0		430	.58		217	32	2.1	734	7.2
July 3	88.8	11		37	1.9	16		114		7.0	22	.2	2.0		153	.21		100	7	.7	263	6.7
Sept. 4	d.18	31		70	9.4	62		232		19	97	.4	.0		403	.55		213	23	1.8	698	7.1
Nov. 13	.22	29		86	8.1	65		280		20	98	.4	.0		444	.60		248	18	1.8	773	7.0
Dec. 17	16.6	11		35	3.8	26		104		12	43	.2	.5		182	.25		103	18	1.1	338	6.6
Feb. 25, 1964	6.99	15		70	8.9	58		208		27	98	.4	.0		379	.52		211	40	1.7	682	7.3
May 5	2.17	15		56	10	73		170		25	123	.3	.0		386	.52		180	41	2.4	713	7.0
July 16	.22	32		63	9.5	68		216		20	102	.6	.0		401	.55		196	19	2.1	694	7.0
Aug. 8	3,000	6.5		46	2.2	4.4	3.0	154		3.6	5.0	.2	.0		147	.20		124	0	.2	266	6.7
Aug. 9	228	10		52	3.0	17		172		6.6	21	.3	.0		195	.27		142	1	.6	349	7.0
Aug. 9	143	--		--	--	--		136		--	17	--	--		--	--		113	2	--	287	7.0
Sept. 18	239	8.6		20	1.7	5.8	3.2	73		3.0	6.4	.2	1.2		86	.12		57	0	.3	147	6.9
Sept. 25	3.98	20		48	5.4	33		158		12	50	.3	.0		247	.34		142	12	1.2	433	7.2
Jan. 7, 1965	1.48	19		56	8.4	60		178		20	96	.3	.0		348	.47		174	28	2.0	600	8.0
Feb. 9	34.8	13		47	4.1	26		158		11	34	.3	.8		214	.29		134	5	1.0	376	7.5
Mar. 17	11.0	13		76	9.4	65		232		30	104	.4	.0		412	.56		228	38	1.9	741	7.8
Apr. 21	4.91	24		69	12	76		200		35	132	.4	.2		447	.61		222	58	2.2	812	7.0
May 21	154	14		38	3.2	14		132		7.0	16	.1	.2		158	.21		108	0	.6	276	7.4
May 25	54.5	22		66	6.7	38		206		17	62	.4	.2		313	.43		192	23	1.2	564	7.1
Nov. 17	4.91	25		70	10	51		216		25	87	.3	.2		374	.51		216	39	1.5	671	7.2
Dec. 17	82.8	15		35	3.9	21	4.5	116		10	34	.2	.5		181	.25		103	8	.9	317	6.8
May 6, 1966	1,100	9.4		24	2.0	10	4.5	86		3.6	16	.2	.2		112	.15		68	0	.5	200	7.1
June 16	21.3	27		80	12	103	5.0	224		41	180	.3	.0		558	.76		249	66	2.8	986	7.5
Sept. 27	2.39	--		--	--	--		215		23	100	--	--		--	--		204	28	--	693	7.7

a Mean daily discharge.
b Residue at 180°C
c Includes the equivalent of 14 parts per million carbonate (CO_3).
d Field estimate.
e Includes 0.12 parts per million strontium (Sr).
f Includes 0.63 parts per million strontium (Sr) and 0.1 parts per million lithium (Li).

Table 9.--Reservoirs With Capacities of 5,000 Acre-Feet or More in the Guadalupe River Basin

(The purposes for which the impounded water is used are indicated by the following symbols: M, municipal; P, hydroelectric power; FC, Flood control; R, recreation.)

NAME OF RESERVOIR	YEAR OPERATION BEGAN	STREAM	[a]TOTAL STORAGE CAPACITY (ACRE-FEET)	OWNER OR OPERATOR	COUNTY	USE
Canyon Reservoir	1964	Guadalupe River	740,900	Guadalupe-Blanco River Authority, U.S. Army Corps of Engineers	Comal	M,FC, R
Lake Dunlap	1928	do	5,900	Guadalupe-Blanco River Authority	Guadalupe	P
Lake McQueeney	1928	do	5,000	do	do	P
H-4 Reservoir	1931	do	6,700	do	Gonzales	P

[a] Total storage capacity is that capacity below the lowest outlet or spillway and is based on the most recent reservoir survey available.