TEXAS WATER DEVELOPMENT BOARD

REPORT 13

RECONNAISSANCE OF THE CHEMICAL QUALITY OF SURFACE WATERS OF THE SAN JACINTO RIVER BASIN, TEXAS

By

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FOREWORD

On September 1, 1965 the Texas Water Commission (formerly, before February 1962, the State Board of Water Engineers) experienced a far-reaching realignment of functions and personnel, directed toward the increased emphasis needed for planning and developing Texas' water resources and for administering water rights.

Realigned and concentrated in the Texas Water Development Board were the investigative, planning, development, research, financing, and supporting functions, including the reports review and publication functions. The name Texas Water Commission was changed to Texas Water Rights Commission, and responsibility for functions relating to water-rights administration was vested therein.

For the reader's convenience, references in this report have been altered, where necessary, to reflect the current (post September 1, 1965) assignment of responsibility for the function mentioned. In other words credit for a function performed by the Texas Water Commission before the September 1, 1965 realignment generally will be given in this report either to the Water Development Board or to the Water Rights Commission, depending on which agency now has responsibility for that function.

Texas Water Development Board

John J. Vandertulip

John J. Vandertulip
Chief Engineer

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RECONNAISSANCE OF THE CHEMICAL QUALITY OF SURFACE WATERS OF THE SAN JACINTO RIVER BASIN, TEXAS

ABSTRACT

Surface water in the San Jacinto River Basin is of excellent chemical quality, and is suitable for most municipal, industrial, and agricultural purposes.

The kinds and quantities of minerals dissolved in surface water of the basin are related principally to the geology of the runoff area and to rainfall and streamflow characteristics, but the quality of the water is also affected by industrial activities.

The rocks exposed in the San Jacinto River Basin are sedimentary deposits that range in age from Miocene(?) to Recent. The formations crop out in belts parallel to the Gulf Coast; the older rocks are exposed in the northern part of the basin, and successively younger rocks crop out toward the coast. Throughout much of the basin, the readily soluble materials have been leached from the surface rocks and soils by the abundant rainfall. Consequently, the water in streams is usually low in concentration of dissolved minerals.

Water from the outcrop areas of the Catahoula Sandstone, Lagarto Clay, and Oakville Sandstone in the upper part of the San Jacinto River Basin has dissolved-solids concentrations ranging from 100 to 200 ppm (parts per million); water from the outcrop areas of formations younger than the Lagarto Clay has less than 150 ppm dissolved solids.

Surface water of the study area is soft to moderately hard. Water draining from the upper one-third of the basin, where the Lagarto Clay and older formations crop out, is moderately hard; runoff from the remainder of the basin, where formations younger than the Lagarto crop out, is usually soft.

The chloride concentration in the surface water is generally less than 50 ppm, and streams draining formations younger than the Lagarto Clay generally have concentrations of less than 25 ppm. Higher chloride concentrations observed in Cypress Creek and Buffalo Bayou are probably the result of oil-field brine having reached the streams.

Lake Houston, the only large water-supply reservoir in the basin, contains water of excellent quality. Water available for storage at potential reservoir sites is also of excellent quality.

In the northern part of the basin the activities of man have caused little change in the chemical quality of surface water. In the area downstream from Lake Houston the flow in most of the streams is partly maintained by sewage and industrial effluents from the Houston metropolitan area, and by return flow of irrigation water. The chemical quality of the streams draining the Houston metropolitan area was not studied but is probably poor.

RECONNAISSANCE OF THE CHEMICAL QUALITY OF SURFACE WATERS OF THE SAN JACINTO RIVER BASIN, TEXAS

INTRODUCTION

The investigation of the chemical quality of the surface waters of the San Jacinto River Basin, Texas, is part of a statewide reconnaissance study. This report is the third in a series presenting the results of the study and summaries of available chemical-quality data. Reports on the Sabine and Neches River Basins have been previously prepared (Hughes and Leifeste, 1964, 1965), and future reports are planned for each major river basin in Texas.

Knowledge of the quality of the water that will be available is essential in planning any water-use project, because the chemical character of the water determines its suitability for domestic, irrigation, or industrial purposes. For public supply, of course, water must serve all three of these purposes. If raw water is not satisfactory for a specific use, then chemical analyses are necessary to determine the type or extent of treatment needed.

In addition to determining the suitability of water for specific uses, chemical-quality data are needed for the (1) inventory of water resources, (2) detection and control of pollution of water supplies, (3) study of techniques for preventing salt-water encroachment into coastal streams and aquifers, (4) planning for reuse of water, and (5) demineralization of water.

A network of daily chemical-quality stations on principal streams in Texas is operated by the U.S. Geological Survey in cooperation with the Texas Water Development Board and with Federal and local agencies. However, this network has not been adequate to inventory completely the chemical quality of the surface waters of the State. To supplement the information being obtained by the network, a cooperative statewide reconnaissance by the U.S. Geological Survey and the Texas Water Development Board was begun in September 1961. In this study, samples for chemical analyses have been collected periodically at numerous sites throughout Texas so that some quality-of-water information would be available 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 period September 1961 to April 1964, water-quality data were collected concerning the principal streams, the major reservoirs, a number of potential reservoir sites, and many tributaries in the San Jacinto River Basin.

Water quality in the Houston metropolitan area and in the tidal reaches of the streams was not studied during this investigation because the water resources of the area probably will not be developed for use.

Agencies which have cooperated in the collection of chemical-quality and streamflow data include the U.S. Army Corps of Engineers, the San Jacinto River Authority, the city of Houston, the Harris County Flood Control District, and the Texas State Department of Health.

SAN JACINTO RIVER DRAINAGE BASIN

General Description

The San Jacinto River drains an area of about 4,000 square miles in southeast Texas (Figure 1). The fan-shaped drainage basin is about 85 miles long, averages about 50 miles wide, and includes all or part of eight counties. It is bounded on the north and east by the Trinity River Basin, and on the west by the Brazos River Basin.

The San Jacinto River Basin slopes from an altitude of about 325 feet in the headwaters to sea level. The northern two-thirds of the basin is a gently rolling area, most of which is heavily timbered. The southern one-third of the basin is a level, nearly featureless prairie. Only the few broad, shallow valleys of the present streams and remnants of older streams are below the general level of the coastal plain. Pine, oak, and other trees grow along the streams, but much of the southern area is covered with coarse grasses.

The San Jacinto River is formed by the confluence of the West and East Forks about 20 miles northeast of Houston in Harris County (Figure 2). The confluence was submerged by the filling of Lake Houston in 1954. The West Fork heads in southwest Walker County and flows southeastward for about 70 miles to Lake Houston. Principal tributaries are Lake, Spring, and Cypress Creeks. The East Fork heads in eastern Walker County and flows generally southward for about 50 miles. Principal tributaries are Winters, Peach, and Caney Creeks, and Luce Bayou. From Lake Houston, the San Jacinto River flows southeastward across Harris County into Galveston Bay. Buffalo Bayou, the principal tributary to the San Jacinto River downstream from the confluence of its two forks, drains the Houston area and enters the San Jacinto River about 9 miles above the mouth.

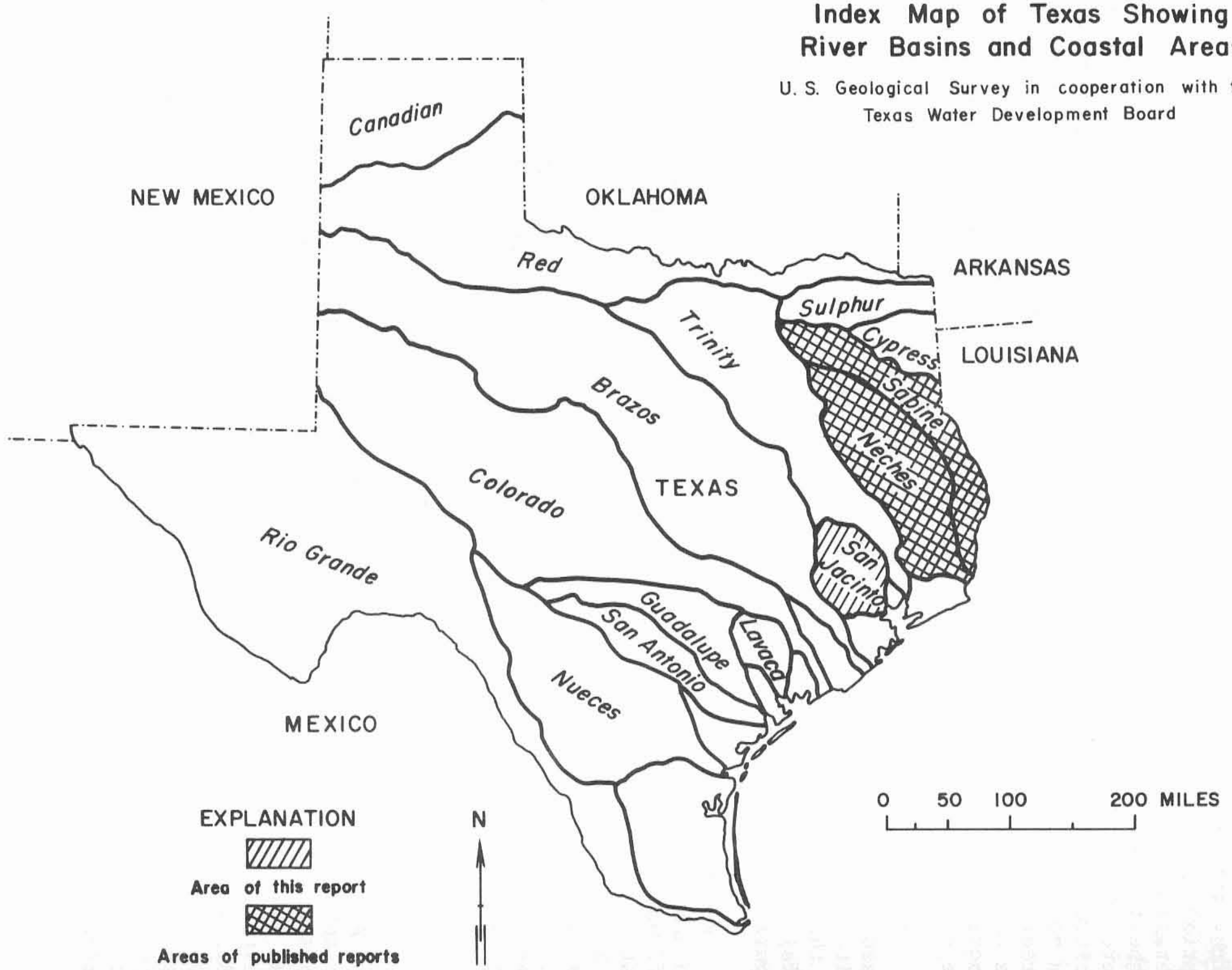
The San Jacinto River Basin has a moist, subhumid climate, characterized by long hot summers and mild winters (Thornthwaite, 1952, p. 32). Average precipitation ranges from about 43 inches per year in the west to about 50 inches in the east. For the entire basin, the annual average is about 46 inches, which exceeds the average for the State of Texas by about 60 percent. Mean annual precipitation in the basin, average monthly precipitation at two U.S. Weather Bureau stations, and annual precipitation for the period 1930-62 at one station are shown on Figure 2.

Runoff is defined as that part of precipitation appearing in surface streams, and is the same as streamflow unaffected by artificial diversions or storage (Langbein and Iseri, 1960, p. 17). The natural runoff pattern in the southern part of the San Jacinto River Basin has been altered by the construction of Lake Houston and by the urbanization of the Houston area, but streamflow in that part of the basin above Lake Houston has been affected only

Figure 1

Index Map of Texas Showing River Basins and Coastal Areas

U. S. Geological Survey in cooperation with the Texas Water Development Board



slightly by diversions or storage. Seasonal distribution of rainfall, storm intensity, temperature, types and density of vegetation, surface slope, soils, and permeability of aquifers also affect the amount of runoff from a drainage basin.

About 20 percent of the precipitation in the San Jacinto River Basin appears in the streams as runoff. The mean annual runoff as measured at 9 streamflow stations for water years 1945-63 is shown on Figure 2. According to these data, average annual runoff from subbasins has ranged from 6.5 to 14.0 inches. The highest average runoff is in Brays Bayou which drains the Beaumont Clay outcrop where infiltration of rainfall is slower than in the more sandy parts of the San Jacinto River Basin. Brays Bayou also drains the urbanized Houston area, where the natural runoff pattern has been altered by the construction of buildings, streets, storm sewers, and by other developments. In other parts of the basin, the average annual runoff generally increases from west to east. The general progressive increase of runoff from west to east is however less uniform than the progressive increase of precipitation.

Runoff from the northern two-thirds of the San Jacinto River Basin, as measured at the former stream-gaging station--San Jacinto River near Huffman (site 15)--averaged 9.5 inches annually for the period 1937-53. Annual runoff at the Huffman station, expressed as mean discharge in cubic feet per second (cfs) and as inches per year, is shown for the period of record in a graph on Figure 2.

Runoff and precipitation in the basin fluctuate much more than indicated by the annual averages. The yearly mean discharge of the San Jacinto River near Huffman during the 1937-53 period of record ranged from 237 to 6,240 cfs; but instantaneous flows ranged from 49 to 253,000 cfs. Similarly, annual rainfall at Huntsville ranged from 31.50 inches in 1955 to 64.10 inches in 1946 (Figure 2), but in 1962 the monthly totals ranged from 0.99 inches for May to 8.93 inches for September. Precipitation so unevenly distributed in time does not sustain streamflow. Therefore, storage projects are required to provide dependable quantities of surface water for municipal or industrial use.

Population and Municipalities

Although the San Jacinto River Basin constitutes only about 2 percent of the total area of Texas, the population of the basin is more than 14 percent of the State total. (See Figure 3.) In 1960 the population of the basin was more than 1,400,000. The population was principally urban and was centered around Houston, the largest city in Texas. The population of Houston in 1960 was 938,219, and that of the urbanized Houston area (which includes Houston and the closely surrounding area) was more than 1,100,000. Outside the Houston metropolitan area, the San Jacinto River Basin has no large cities; only two, Conroe and Cleveland, with populations of 9,192 and 5,838, respectively, had populations of more than 5,000 in 1960. At that time Huntsville, on the divide between the San Jacinto and Trinity Rivers, had a population of 11,999.

Economic Development

From an agrarian beginning, the economy of the San Jacinto River Basin has become predominantly industrial. The greatest industrial development in the basin is centered in and around Houston, which, since the opening of its ship

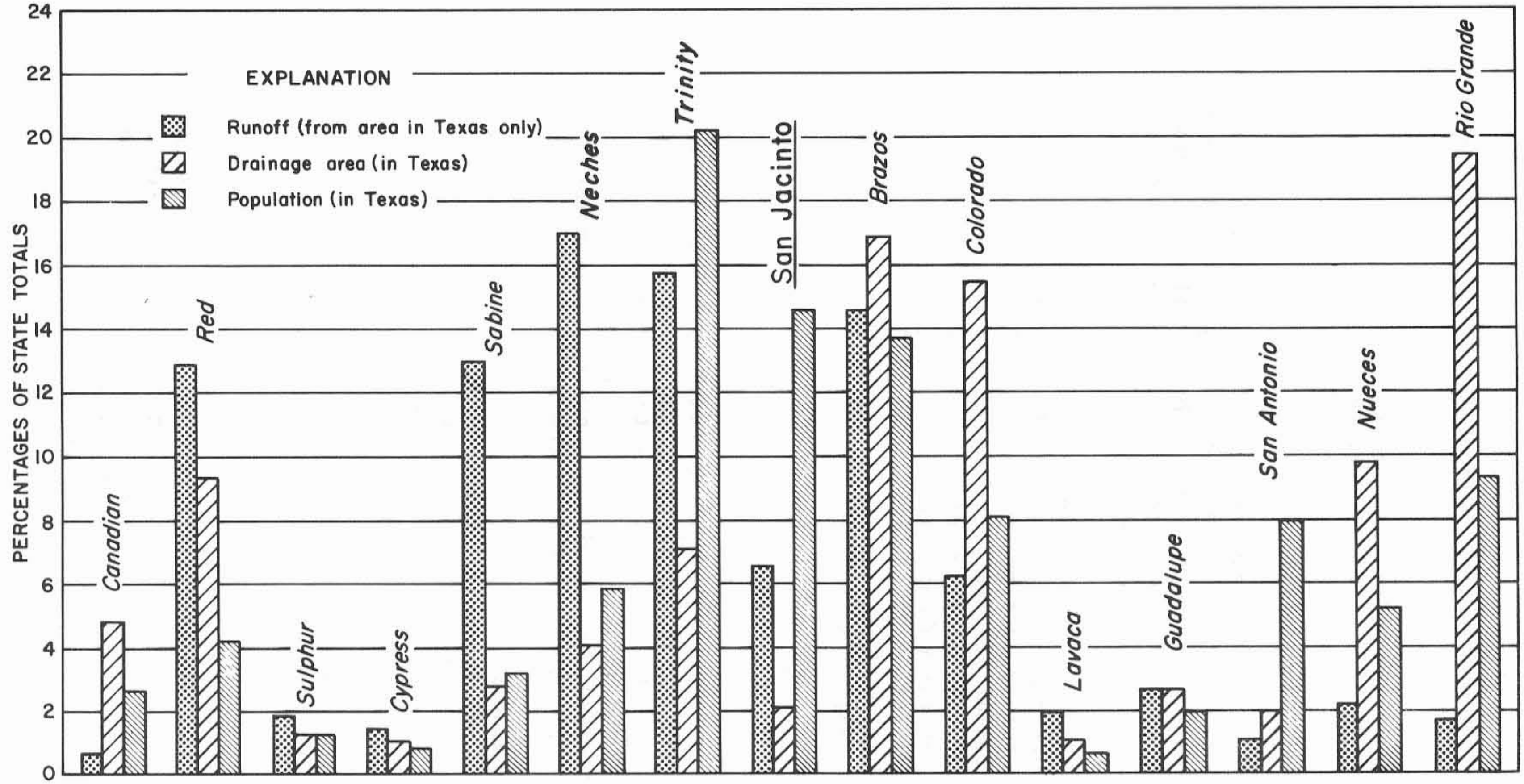


Figure 3

Average Annual Runoff, Drainage Area, and 1960 Population of Major River Basins in Texas, as Percentages of State Totals

Adjacent coastal areas have been included in basin totals. (Data from Texas Water Development Board)

U. S. Geological Survey in cooperation with the Texas Water Development Board

channel in 1914, has become the leading port and industrial center in Texas. Houston is nearer the vast raw materials of the interior than is any other Texas port; hence the enormous supplies of oil, gas, sulfur, wood, cotton, grain, and other raw materials as well as the abundance of water for industrial use have attracted diverse industries to the area.

Petroleum refining and the associated manufacture of petrochemicals is the principal industry in the Houston area. As early as 1902 oil was produced at Humble in Harris County, and subsequently oil fields have been developed throughout the San Jacinto River Basin (Figure 8).

Lumbering is another important industry in the San Jacinto River Basin. In the northern, heavily timbered part of the basin, many sawmills are operated and lumber is produced in large quantities from southern yellow pine and hardwood. Forest products are a major source of income to Conroe and Cleveland, the largest cities in the forested section of the basin.

Although the population of the San Jacinto River Basin is largely urban, agriculture is very important to the economy. The rapidly growing population has stimulated agricultural production by creating a large market for local farm produce. Rice and vegetables are the principal crops; vegetables are grown throughout the basin, but rice is grown only in the southern part. Beef cattle and dairy herds are raised throughout much of the basin, especially in the southern part. Despite urbanization, Harris County in 1960 ranked first among Texas counties in beef-cattle production, second in dairying, and was among the leading counties in hog and poultry production.

Development of Surface-Water Resources

Runoff in the San Jacinto River Basin averages more than 9 inches per year. Although the basin has only about 2 percent of the total area of the State, it contributes more than 6 percent of the State's total runoff (Figure 3). Thus, the quantity of surface water available for development in the basin is considerably greater than the average for the State. However, Lake Houston is the only general-purpose water-development project in the basin.

Table 1 lists the capacity, owner, location, and use of San Jacinto River Basin reservoirs having capacities of 5,000 acre-feet or more. Lake Houston, completed in 1954, on the San Jacinto River in Harris County, is a water-supply reservoir owned and operated by the city of Houston. In addition to using the water as part of its municipal supply, the city of Houston supplies raw water to various industries. The San Jacinto River Authority has rights to the low flow of the river and, through an agreement with the city, this amount is diverted directly from the lake and delivered to users in the Baytown area.

In 1964, 102,000 acre-feet of water was used for irrigation in the San Jacinto River Basin (Gillett and Janca, 1965). According to data from the Texas Water Development Board and The University of Texas Bureau of Business Research (Written communication, 1965), 163,150 acre-feet of water was used for municipal and 387,120 acre-feet for industrial purposes in 1964. The two agencies estimate that for the year 2020, municipal and industrial water requirements will be over 2,000,000 acre-feet, much of which will be imported from outside the basin.

Table 1. Reservoirs with capacities of 5,000 acre-feet or more in the San Jacinto River Basin

The purpose for which the impounded waters are used is indicated by the following symbols: M, municipal; I, industrial; Ir, irrigation; Mi, mining; R, recreation; FC, flood control; FW, fish and wildlife

Name of reservoir	Year operation began	Stream	Total storage capacity (acre-feet)	Owner	County	Use
Lake Houston	1954	San Jacinto River	158,200	City of Houston	Harris	M, I, Ir, Mi, R
Sheldon Reservoir	1943	Carpenters Bayou	5,420	Texas Parks and Wildlife Department	do	FW
Barker Reservoir	1945	Buffalo Bayou	a/ 204,800	U.S. Government	do	FC
Addicks Reservoir	1948	South Mayde Creek	a/ 204,460	do	do	FC

a/ Flood-control storage capacity only; no conservation storage.

CHEMICAL QUALITY OF THE WATER

Chemical-Quality Records

The collection of chemical-quality data on surface waters of the San Jacinto River Basin by the U.S. Geological Survey began in 1941, when a sampling station was established on the West Fork San Jacinto River near Humble. Data, obtained for intermittent periods until September 1946, consisted of chemical analyses of filtrates from samples collected by the U.S. Soil Conservation Service for the determination of suspended matter. Usually only specific conductance and chloride determinations were made on these filtered samples.

A daily sampling station was established on the San Jacinto River near Huffman in 1945 and was operated for intermittent periods until April 1954, when impoundment began in Lake Houston. Currently the only daily sampling station in the basin is the West Fork San Jacinto River near Conroe, established in 1961.

Collection of chemical-quality data for this reconnaissance began in 1961 and continued through April 1964. Samples were collected periodically from the principal tributary streams and from Lake Houston. Single samples were collected at several additional sites.

Data were collected over a wide range of water-discharge rates. At low flows, concentrations of dissolved minerals are likely to be highest and the data commonly indicate where pollution and salinity problems exist. Data collected during medium and high flows indicate the probable quality of the water that would be stored in reservoirs. Stream-gaging stations were selected as sampling sites in order that chemical analyses could be considered in relation to water discharge. A few miscellaneous analyses of samples collected in the San Jacinto River Basin by the U.S. Geological Survey before 1961 have also been included in this report.

The periods of record of all data-collection sites are given in Table 4 and the locations are shown on Plate 1. The chemical-quality data for the daily stations are summarized in Table 5, and the complete records are published in an annual series of U.S. Geological Survey Water-Supply Papers and in reports of the Texas Water Development Board (see References). Results of all the periodic and miscellaneous analyses are given in Table 6.

The Texas State Department of Health makes available to the U.S. Geological Survey the data collected in its statewide stream-sampling program, which includes the periodic determination of pH, biochemical oxygen demand, total solids, dissolved oxygen, chloride, chlorine demand, and sulfate at four locations in the San Jacinto River Basin. The data-collection sites of the State Department of Health are listed below; they are at U.S. Geological Survey gaging stations and the numbers refer to locations shown on Plate 1.

Location no.	Data-collection site
5	West Fork San Jacinto River near Conroe
12	East Fork San Jacinto River near Cleveland
13	Caney Creek near Splendora
14	Peach Creek at Splendora

Streamflow Records

Streamflow in the San Jacinto River Basin was measured as early as 1924, when the U.S. Geological Survey established a streamflow station on the West Fork San Jacinto River near Conroe. The station, discontinued in 1928, was reestablished in 1939. In addition to the station near Conroe, the U.S. Geological Survey in 1963 operated 16 streamflow stations on tributaries and 3 reservoir-content stations. During this reconnaissance, measurements were also made at other sites where water samples were collected for chemical analysis. The periods of record for all the streamflow stations in the San Jacinto River Basin are given in Table 4, and the locations are shown in Plate 1.

Records of discharge, stage of streams, and contents and stages of lakes or reservoirs from 1924 to 1960 have been published in the annual series of U.S. Geological Survey Water-Supply Papers (see References). Beginning with the 1961 water year, streamflow records have been released by the U.S. Geological Survey in annual reports for each state (U.S. Geological Survey, 1961, 1962, 1963). Summaries of discharge records have been published giving monthly and annual totals (U.S. Geological Survey, 1939, 1960; Texas Board of Water Engineers, 1958).

Environmental Factors and Their Effect on the Chemical Quality of the Water

All water from natural sources contains mineral constituents dissolved from the rocks and minerals of the earth's crust. The kinds and quantities of dissolved minerals in surface water depend on a number of environmental factors, some of the more important of which are geology, patterns and characteristics of streamflow, and the activities of man.

Geology

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

The availability of the minerals in rocks and soils is decreased by leaching. In arid or semiarid regions most soils and the rocks from which they originated are incompletely leached and still contain large amounts of readily soluble material. Conversely, in some areas of high rainfall, rocks that originally contained large quantities of readily soluble minerals have been leached by circulating water until the mantle rock and residual soil contain relatively small amounts of readily soluble minerals. In the San Jacinto River Basin, where the annual precipitation averages about 46 inches, circulating water has leached much of the soluble minerals from the soils and near-surface rocks. Consequently, the dissolved-solids content of surface runoff and ground-water inflow to streams is generally low throughout most of the basin.

Geologic formations exposed in the San Jacinto River Basin consist of sedimentary deposits that range in age from Miocene(?) to Recent (Figure 4). These deposits were derived largely from the limestone and marl of Cretaceous formations, and from the sands, gravels, silts, and clays of Tertiary formations older than the Catahoula Sandstone (Lang, Winslow, and White, 1950, p. 35).

The formations crop out in belts roughly parallel to the Gulf Coast; the older rocks are exposed in the northern part of the basin, and successively younger rocks crop out toward the coast. Because the beds dip toward the southeast at an angle steeper than the slope of the land surface, each formation is encountered at progressively greater depths in that direction. However, the rate of dip is variable because of deformation of the strata by upthrusts of massive salt domes and other geological factors.

Chemical analyses of selected low-flow samples of surface waters are shown diagrammatically on Figure 4 to relate chemical composition to geology. Each analysis is represented by a circle--of which the scale for the radius gives an area proportional to the total ionic concentration of the sample in equivalents per million. The segments of the circle indicate the percentage composition.

North of Conroe the drainage area of the West Fork San Jacinto River is underlain largely by Lagarto Clay and Oakville Sandstone of Tertiary age. These formations are similar; together they constitute a thick section of light-colored, massive, calcareous clay and silt beds interbedded with thin layers of lime-cemented sand and gravel. Water of the West Fork that drains from these rocks is of the calcium bicarbonate type.

Downstream from Conroe, tributaries of the West Fork drain areas underlain by the Willis Sand of Tertiary age and the Lissie Formation of Quaternary age. These deposits are composed predominantly of fine to coarse sand containing gravel, silt, and clay interbedded with the sand. Waters from these areas are of the sodium chloride type.

Exposed rocks in the drainage area of the East Fork north of Cleveland are the Lagarto Clay, Oakville Sandstone, and Willis Sand. During periods of low flow, when most of the streamflow is sustained by ground-water inflow, sodium and chloride predominate in the water of the East Fork near Cleveland.

Downstream from Cleveland, waters contributed to the East Fork by tributaries contain exceptionally low concentrations of dissolved solids. Water of Caney Creek, which is a mixture of runoff from the Lagarto Clay, Oakville Sandstone, Willis Sand, and Lissie Formation, is of the mixed sodium-calcium chloride-bicarbonate type. Water from Peach Creek, which drains from the Willis Sand and Lissie Formation, is of the sodium chloride type.

Streamflow

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

In the San Jacinto River Basin most of the total flow in streams consists of surface runoff, but streamflow records show that the low flow of many streams is maintained by ground water.

The relation of dissolved-solids concentration to water discharge in two tributary streams is shown on Figure 5. Peach Creek drains the eastern part of the basin where ground water entering streams is extremely low in dissolved-solids content, usually less than 100 ppm (parts per million). The maximum dissolved-solids concentrations observed in Peach Creek during low flows was only 76 ppm. Spring Creek drains from the western part of the San Jacinto River Basin; ground water that enters streams from this area, though low in dissolved solids, is generally more mineralized than water from the eastern part of the basin. The dissolved-solids concentrations in Spring Creek are highest during periods of low flow but, even during lowest flow, are usually less than 300 ppm.

Figures 6 and 7 show the differences in the mineral content and chemical composition of the West Fork San Jacinto River near Conroe and the East Fork San Jacinto River near Cleveland at different streamflows. In these figures the curves showing percentages of ions are based on concentrations in equivalents per million. The dissolved-solids content of both the West and East Forks varies considerably for all discharge rates. However, the dissolved-solids concentrations in water of both streams are usually maximum at low streamflow; and the quality of the water improves as streamflow increases. At most rates of flow, calcium is the predominant cation and bicarbonate and chloride are the predominant anions in water of the West Fork near Conroe. At low flows, water of the East Fork near Cleveland is of the sodium chloride type. Data on the chemical quality of flood flows for the East Fork, though limited, show that at high flows the water is of the calcium bicarbonate type. The transition in water type is gradual; Figure 7 indicates that at flows of less than 200 cfs the water is of the sodium chloride type, and at flows of more than 1,000 cfs the water is of the calcium bicarbonate type.

Activities of Man

The activities of man often have a deteriorative effect on the chemical quality of water. Oil-field brine, municipal and industrial wastes, and irrigation return flows increase the concentration of dissolved material in streams. Evaporation from storage projects also increases the dissolved-solids concentration of the remaining water.

Oil is produced in many areas in the San Jacinto River Basin (Figure 8). Brine is produced in nearly all oil fields and it may, if improperly handled, eventually reach the streams. The composition of oil-field brine varies; but the principal chemical constituents in order of magnitude of their concentrations (in ppm) are generally chloride, sodium, calcium, and sulfate. Chemical-quality data collected from the San Jacinto River near Huffman from 1945 to 1954 indicated the possibility of some oil-field-brine pollution; the sodium and chloride concentrations of the water during low flow varied greatly. Also, chemical-quality data collected during this reconnaissance indicate that some brine is reaching the streams in the Cypress Creek and Buffalo Bayou subbasins.

The deteriorative effect of municipal and industrial wastes on the quality of water in surface streams that drain the Houston metropolitan area was not studied during this investigation. The flow in most of these streams is, however, partly maintained by sewage and industrial effluents and by return flow of

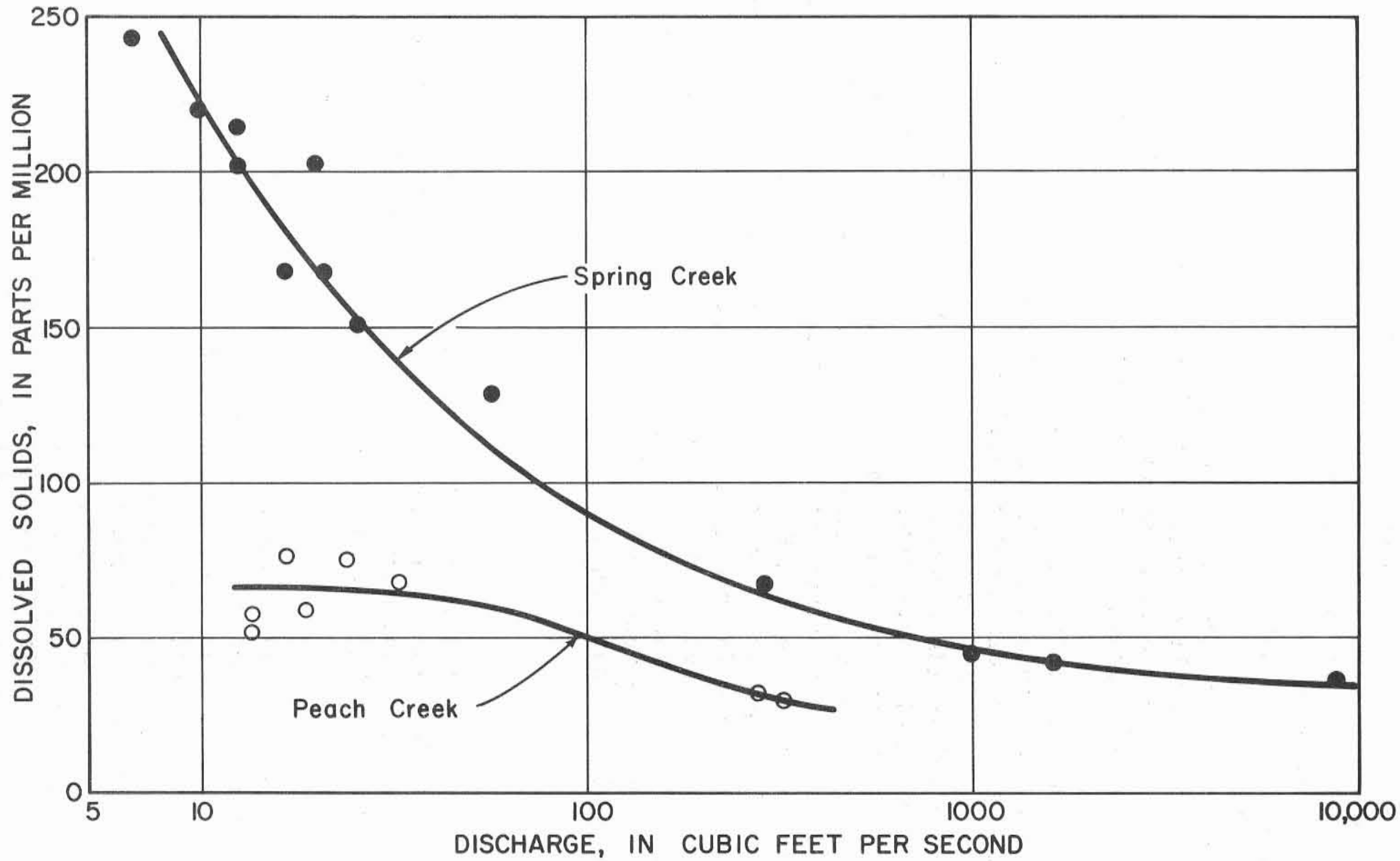


Figure 5

Relation of Concentration of Dissolved Solids to Water Discharge in Two Tributaries of the San Jacinto River

U. S. Geological Survey in cooperation with the Texas Water Development Board

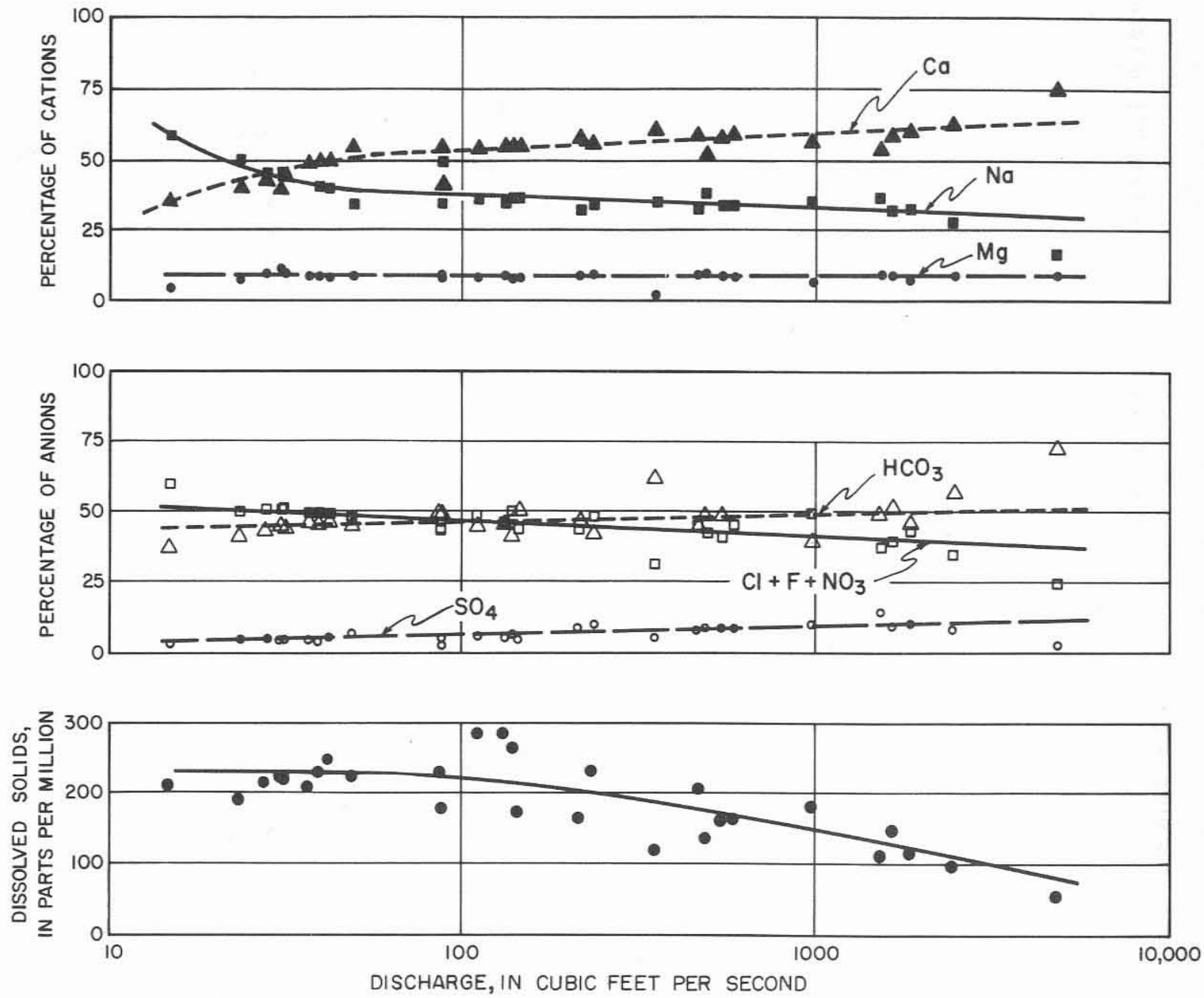


Figure 6

Relations of Dissolved Solids and Percentage of Ions to Water Discharge, West Fork San Jacinto River near Conroe

U. S. Geological Survey in cooperation with the Texas Water Development Board

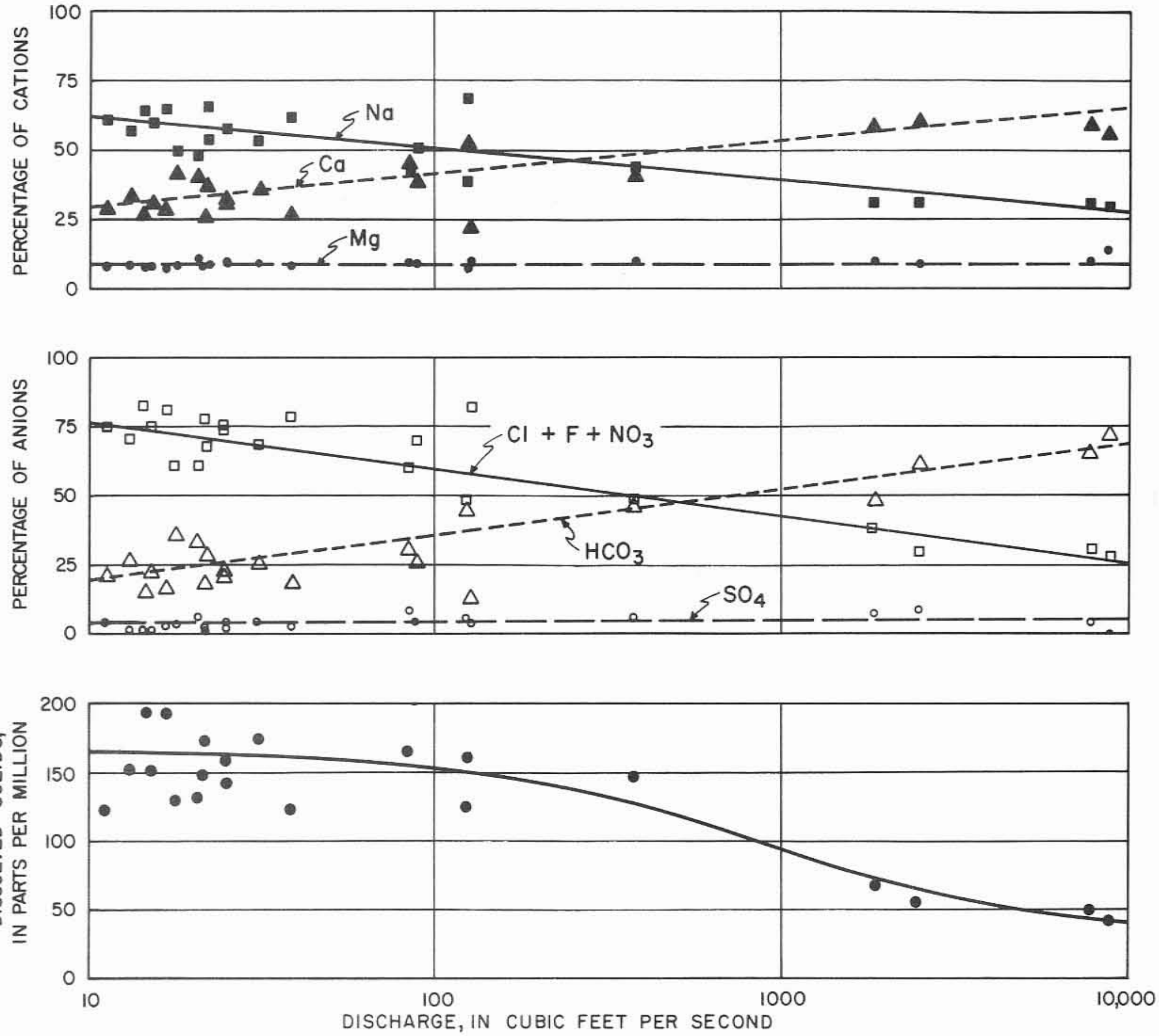


Figure 7

Relations of Dissolved Solids and Percentage of Ions to Water Discharge, East Fork San Jacinto River near Cleveland

U. S. Geological Survey in cooperation with the Texas Water Development Board

irrigation water. Consequently, the water is probably of poor quality. Upstream from Lake Houston, the municipal, industrial, and agricultural use of water from the San Jacinto River has caused only local changes in water quality. This area has no large diversions, and therefore the flow is adequate to dilute the municipal and industrial wastes that are introduced.

Relation of Quality of Water to Use

Quality-of-water studies usually are concerned with determining the suitability of water--judged by the chemical, physical, and biological characteristics--for its proposed use. In the San Jacinto River Basin, surface water is used primarily for municipal and industrial supplies and for irrigation. This report considers only the chemical character of the water and its relation to the principal uses.

All natural water contains dissolved-mineral matter. Most of this mineral matter in water is dissociated into charged particles, or ions. Principal cations (positive-charged ions) in natural water are calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), and iron (Fe). The principal anions (negative-charged ions) are carbonate (CO_3), bicarbonate (HCO_3), sulfate (SO_4), chloride (Cl), fluoride (F), and nitrate (NO_3). Other constituents and properties are often determined to help define the chemical and physical quality of water. Table 2 lists the constituents and properties commonly determined by the U.S. Geological Survey, and includes a résumé of their sources and significance.

Surface water of the San Jacinto River Basin is generally of excellent chemical quality. With a minimum of treatment, the water is suitable for domestic, industrial, and irrigation use.

Domestic Purposes

The use of water for domestic purposes generally is its most essential function. Because of differences in individuals, varying amounts of water used, and other factors, defining the safe limits for the mineral constituents usually found in water is difficult. The limits usually accepted in the United States for drinking water are the drinking-water standards established by the United States Public Health Service. Originally established in 1914 to control the quality of water used on interstate carriers for drinking and for culinary purposes, these standards have been revised several times. The latest revision was in 1962 (U.S. Public Health Service, 1962). These standards have been accepted by the American Water Works Association and by most of the state departments of public health as minimum standards for all public water supplies.

The maximum concentrations permitted by these standards are given for selected constituents in the table on Page 24.

Table 2.--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 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 sodium 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, F. J., 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 intercrystalline 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 1000 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 noncarbonate hardness. Waters of hardness as much as 60 ppm are considered soft; 61 to 120 ppm, moderately hard; 121 to 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.

Constituent	Maximum concentration (ppm)
Sulfate	250
Chloride	250
Nitrate	45
Fluoride	[a] 1.0
Dissolved solids	500

[a] Based on temperature records for Houston.

In the San Jacinto River Basin the concentrations of these constituents are generally much lower than the maximum concentrations recommended by the U.S. Public Health Service.

Industrial Use

The enormous industrial expansion in recent years in the San Jacinto River Basin has caused a corresponding increase in the use of industrial water. The quality requirements vary greatly for almost every industrial application, as is indicated by the water-quality tolerances given in Table 3. One requirement of most industries is that the concentrations of the various constituents of the water remain relatively constant. When concentrations of undesirable substances in water vary, constant monitoring is required, and thus operating expenses are increased.

Hardness is one of the more important properties of water that affects its utility for industrial purposes. 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 materials. The accumulation of scale increases costs for fuel, labor, repairs and replacement, and lowers the quality of many wet-processed products. However, some calcium hardness may be desirable because calcium carbonate sometimes forms protective coatings on pipes and other equipment and reduces corrosion.

The corrosive property of a water receives considerable attention in industrial water supplies. A high concentration of dissolved solids in a water may be closely associated with the corrosive property of the water, particularly if chloride is present in appreciable quantities. Water that contains a large concentration of magnesium chloride may be highly corrosive because the hydrolysis of this salt yields hydrochloric acid.

Table 3.--Water-quality tolerances for industrial applications 1/

[Allowable limits in parts per million except as indicated]

Industry	Turbidity	Color	Color + O_2 consumed	D.C. (ml/1)	Odor	Hardness	Alkalinity (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	General 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
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 composition 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.

Because the water of the San Jacinto River Basin is generally soft and low in dissolved solids, very little treatment is necessary to make it suitable for use by most industries.

Irrigation

The chemical composition of a water is an important factor in determining its usefulness for irrigation, because the quality of the water should not adversely affect the productivity of the land irrigated. 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 applying it; 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.

The most important characteristics in determining the quality of irrigation water, according to the U.S. Salinity Laboratory Staff (1954, p. 69), are: (1) total concentration of soluble salts, (2) relative proportion of sodium to other cations, (3) 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 solution, and may make the soil saline. The increased salinity of the soil may drastically reduce crop yields by decreasing the ability of the plants to take up water and essential plant nutrients from the soil solution. The 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. This adverse effect on soil structure caused 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 hazard. 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

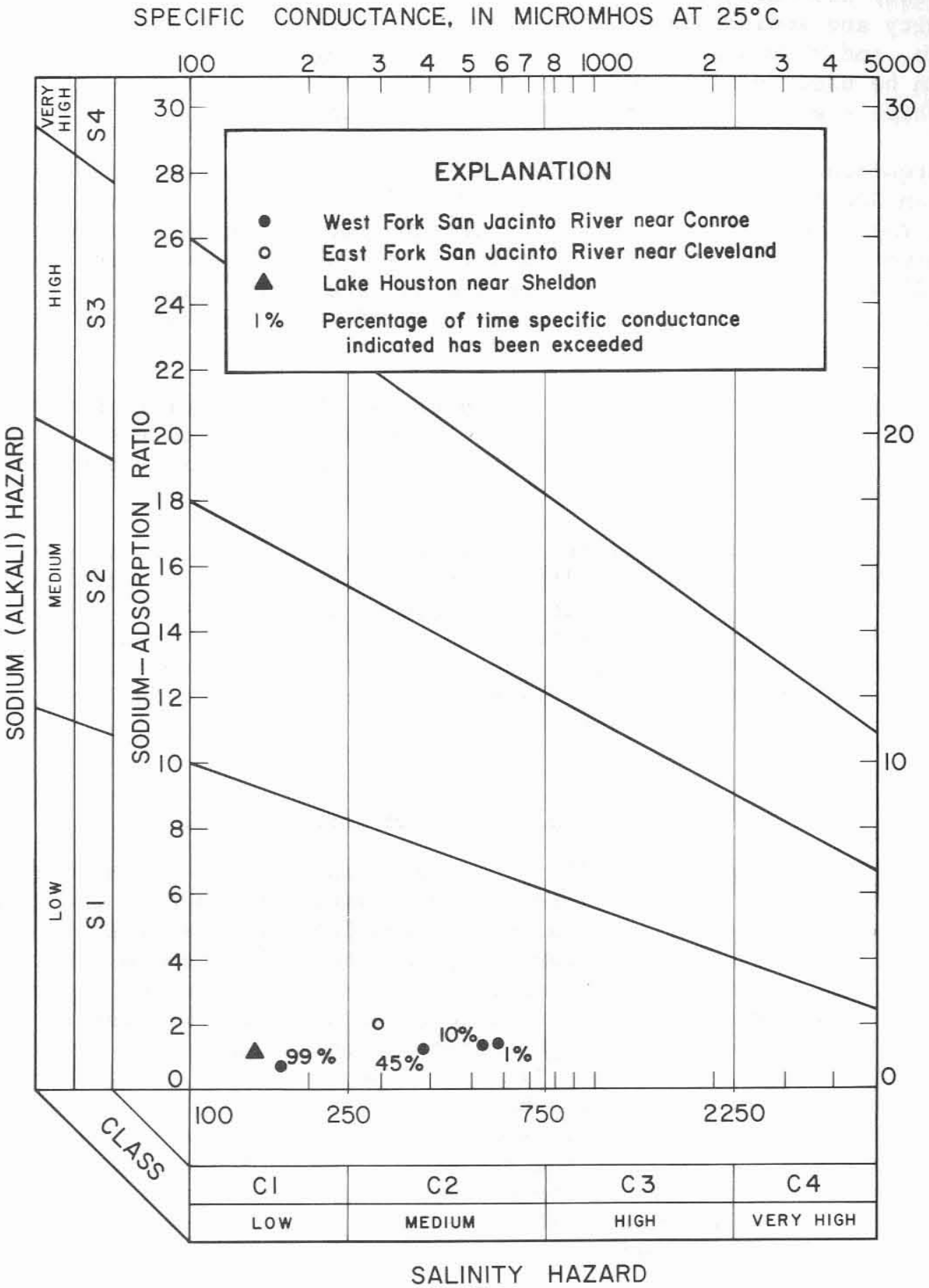


Figure 9

Classification of Irrigation Waters, San Jacinto River Basin

(Diagram Adapted from U.S. Salinity Laboratory Staff, 1954, p. 80)

U. S. Geological Survey in cooperation with the
Texas Water Development Board

availability of water for leaching, ratio of applied water to precipitation, and crops grown) also 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 range encompasses those waters which can be used for irrigation of most crops on most soils as well as those waters which are usually unsuitable for irrigation.

Representative data from analyses of water from the West and East Forks of of the San Jacinto River and from Lake Houston are plotted on Figure 9. Also shown is the percentage of time that the specific conductance exceeded the indicated value for the West Fork San Jacinto River near Conroe during the period 1962 to 1963. The data show that the sodium hazard for water of the San Jacinto River Basin is low and that the salinity hazard generally ranges from low to medium.

A few determinations of boron in waters of the San Jacinto River Basin have been made by the Geological Survey. In these determinations the concentrations are low, indicating that boron is not a problem in irrigation waters of the basin.

Surface water for irrigation in the San Jacinto River Basin is used almost entirely for rice production. Although the concentrations of chemical constituents tolerated by rice varies with the 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 San Jacinto River Basin generally meets all quality requirements for rice irrigation.

Geographic Variations in Water Quality

Variations of dissolved solids, hardness, and chloride with geographic location are shown in the maps on Plate 2. 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 adjustments for evaporation, rainfall, or chemical changes that might occur during storage. For many of the streams chemical-quality data are limited, especially data on the chemical quality of flood flows; therefore, the boundaries of the areas on the maps are general. All the streams will at times have concentrations exceeding those shown for their respective areas, but the averages shown on the map are indicative of the type of water that could be stored in reservoirs. Comparison of these maps with the geologic map (Figure 4) shows that the quality of water contributed by different sections is related to the surface geology.

The southeastern part of the basin, which includes the Houston metropolitan area and tidal reaches of the streams, is shown without pattern on the maps on Plate 2, because water quality there was not studied during this investigation.

Dissolved Solids

The concentration of dissolved solids in surface water of the San Jacinto River Basin is generally less than 250 ppm (Plate 2). Water from the outcrop areas of the Catahoula Sandstone, Lagarto Clay, and Oakville Sandstone generally has dissolved-solids concentrations ranging from 151 to 250 ppm. Water from the outcrops of younger formations generally has concentrations less than 100 ppm. Exceptions to these general relationships were observed in the Cypress Creek and Buffalo Bayou subbasins where waters draining from the Willis Sand and Lissie Formation had dissolved-solids concentrations of more than 100 ppm, apparently because of oil-field-brine pollution.

The West Fork San Jacinto River near Conroe (site 5) is within the 151-250 ppm range shown on Plate 2. For the 2-year period of record, from October 1961 to September 1963, the weighted-average concentration at this station was 172 ppm. The analyses showing annual maximum and minimum dissolved-solids concentrations and the annual weighted averages for the station are shown in Table 5.

Time-weighted averages are usually higher than discharge-weighted averages, and for the West Fork San Jacinto River near Conroe the time-weighted averages are much higher. The duration curve for concentrations of dissolved solids for the Conroe station (Figure 10) shows that 200 ppm dissolved solids has been equaled or exceeded more than 50 percent of the time.

Hardness

Surface water of the San Jacinto River Basin generally is soft to moderately hard. In the northern part of the basin water from the outcrop of the Catahoula Sandstone, Lagarto Clay, and Oakville Sandstone is moderately hard (61-120 ppm). Water from the younger formations is generally soft, having less than 60 ppm hardness.

Chloride

The weighted-average concentrations of chloride in surface waters of the study area are generally less than 50 ppm. Water containing 25 to 50 ppm chloride is typical of streams draining outcrop areas of the Catahoula Sandstone, Lagarto Clay, and Oakville Sandstone. Water from outcrops of younger formations generally has concentrations less than 25 ppm. Exceptions to the generally low concentrations of chloride occur in the Cypress Creek and Buffalo Bayou subbasins where water was found to have chloride concentrations as high as 265 ppm, apparently associated with brine from oil fields. In Lake Houston (site 16) the chloride content has ranged from 21 to 56 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 discharge-weighted average concentration of silica in the San Jacinto River near Huffman (site 15) for the period from December 1949 to October 1953 was 10 ppm. Most of the streams usually contain less than 15 ppm. However, the concentration of silica often is more than 20 ppm in water of the West Fork San Jacinto River near Conroe (site 5), which drains from outcrop areas of Catahoula Sandstone, Lagarto Clay, and Oakville Sandstone. The discharge-weighted average concentration of silica at the Conroe station for the 2-year period from October 1961 to September 1963 was 17 ppm.

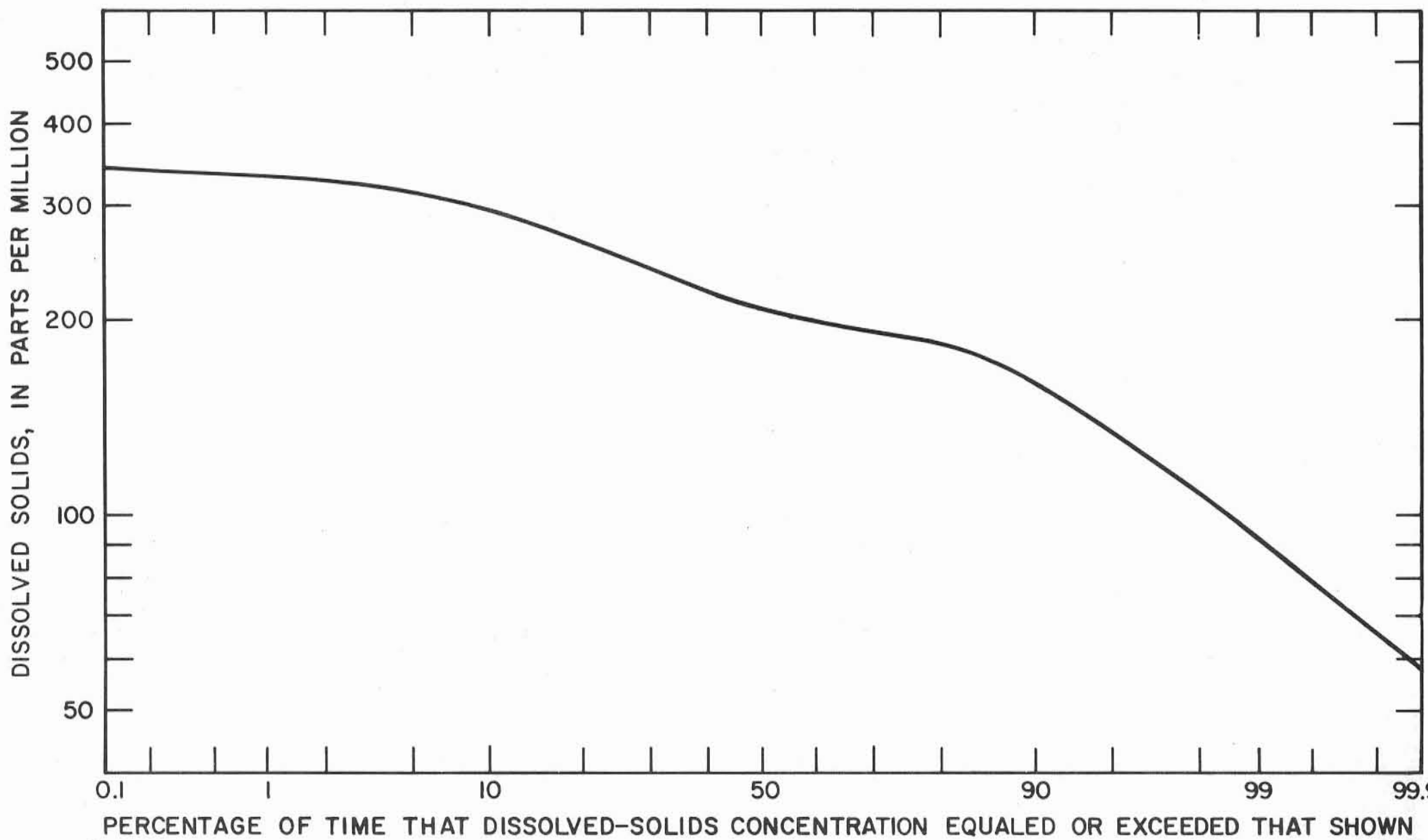


Figure 10

Duration Curve of Dissolved Solids for West Fork San Jacinto River near Conroe, Water Years 1962-63

U. S. Geological Survey in cooperation with the Texas Water Development Board

Sodium concentrations are generally less than 50 ppm in most streams of the study area. The discharge-weighted average concentrations of sodium and potassium (Na + K, calculated as Na) in the San Jacinto River near Huffman for the period from December 1949 to October 1953 and in the West Fork San Jacinto River near Conroe for the period from October 1961 to September 1963 were 21 and 23 ppm, respectively. Sodium is the principal cation in waters draining from the outcrop areas of Willis Sand, Lissie Formation, and Beaumont Clay. These waters usually are low in all dissolved constituents.

Bicarbonate is the principal anion in waters draining the Catahoula Sandstone, Lagarto Clay, and Oakville Sandstone outcrop areas. The weighted-average concentration for the West Fork San Jacinto River near Conroe for the period from October 1961 to September 1963 was 82 ppm. The concentrations of bicarbonate in water from areas underlain by the younger formations are usually much lower.

Sulfate concentrations are generally less than 15 ppm in most streams of the study area. The weighted-average concentrations of sulfate for the San Jacinto River near Huffman ranged from 5.0 to 9.2 ppm.

Concentrations of fluoride and nitrate are low in all surface waters in the study area. Fluoride and nitrate concentrations generally are less than 0.4 ppm and 2.5 ppm, respectively.

Water Quality in Reservoirs

Lake Houston is the only large water-supply reservoir in the San Jacinto River Basin. Results of chemical analyses of water from Lake Houston (Table 6) show that the water is soft, low in dissolved-mineral content, and of excellent quality for domestic, industrial, and irrigation use. Dissolved-solids concentrations ranged from 68 to 141 ppm from July 1961 to April 1964. Maximum concentrations of chloride and sulfate were 50 and 7.2 ppm, respectively.

Water Quality at Potential Reservoir Sites

One of the principal objectives of the reconnaissance was to appraise the quality of the water available for storage at potential reservoir sites. Many sites studied by various Federal, State, and local agencies are shown on Figure 11. Some of the sites are alternate proposals, and the construction of some of the reservoirs would preclude the construction of others.

The reconnaissance has shown that at present the chemical quality of water is generally good throughout that part of the San Jacinto River Basin upstream from the Houston metropolitan area. In areas unaffected by pollution, reservoirs (wherever constructed in the future) will store water low in dissolved solids and suitable for domestic, industrial, and irrigation use. Evaluations of the water quality at several of the proposed sites, discussed in the following paragraphs, are based on 1964 conditions. Industrial influences in the basin may, of course, cause significant changes in water quality before some of the reservoirs can be built.

Lake Conroe (Formerly Honea Reservoir)

A permit has been issued by the Texas Water Rights Commission for the construction of a reservoir on the West Fork San Jacinto River northwest of Conroe. Although a major tributary, Lake Creek, enters the West Fork between the Lake Conroe damsite and the daily station near Conroe (site 5), chemical-quality data obtained at the station are indicative of the type of water to be stored in the proposed reservoir. Periodic data obtained at State Highway 105 near Conroe (site 2), above the mouth of Lake Creek, show little difference between water quality at this point and at the daily station. The records indicate that water from Lake Conroe will contain less than 200 ppm dissolved solids and will be moderately hard.

Spring Creek Damsites

Two potential reservoir sites on Spring Creek are indicated on Figure 11. Periodic chemical-quality data obtained at the Spring Creek stream-gaging station, near Spring (site 7), showed the water to be of excellent quality. Furthermore, according to these data, the water to be stored in a future reservoir during a period of average rainfall and runoff would probably contain less than 100 ppm dissolved solids and would be very soft.

Cypress Creek Damsite 2

During low flows the chloride concentration of Cypress Creek near Westfield (site 9) is of a magnitude which suggests that minor pollution by oil-field brines is occurring. However, flood flows are of excellent quality; and water to be stored in a future reservoir on Cypress Creek would contain probably less than 200 ppm dissolved solids and would be soft.

Cleveland Damsite

Water of the East Fork San Jacinto River near Cleveland (site 12) is of excellent quality, even at low flow, and the chemical-quality data show that a reservoir at the Cleveland damsite would store soft water containing about 120 ppm dissolved solids.

Caney Creek Damsite

According to periodic chemical-quality data for Caney Creek near Splendora (site 13), water impounded in a reservoir on Caney Creek would be soft and contain less than 100 ppm dissolved solids.

Peach Creek Damsites

Water of Peach Creek, sampled periodically near Splendora (site 14), is very low in all dissolved constituents; the maximum dissolved-solids concentration observed was 76 ppm. The water is very soft.

Problems Needing Additional Investigation

This reconnaissance of the chemical quality of surface water in the San Jacinto River Basin has shown that, in general, the basin is remarkably free of water-quality problems. Specifically, however, two streams--Cypress Creek near Westfield and Buffalo Bayou near Addicks--show indications of pollution. High-chloride concentrations in low-flow waters in these streams indicate that oil fields may be contributing brine to surface waters in the drainage areas of Cypress Creek and Buffalo Bayou.

Throughout the San Jacinto River Basin, oil is produced in many areas and brine is produced in nearly all oil fields. Most of the brine is reportedly reinjected into wells; but, in 1961, disposal of 20 percent of the brine produced was by means of open surface pits or surface water courses (Texas Water Commission and Texas Water Pollution Control Board, 1963). Water-flooding in oil fields and the reinjection of oil-field brines should be watched carefully to ensure that brine does not enter fresh ground-water supplies or surface streams.

Continued municipal and industrial growth of Conroe and Cleveland in the northern part of the basin will cause an increase in the water-disposal burdens of the stream system. Meanwhile, the impoundment of water in reservoirs upstream from the two cities will cause a reduction of streamflow now utilized for the assimilation of municipal wastes. Consequently, continued municipal and industrial growth will require that wastes be consistently treated to the maximum extent if gross pollution of streams is to be avoided in the future.

Impoundment of water will likewise result in some changes of water quality. Beneficial effects will include: the reduction of turbidity, silica, color, and coliform bacteria; the evening-out of sharp variations in chemical quality; the entrapment of sediment; and a reduction in temperature. On the other hand, detrimental effects of impoundment will include: an increase in the growth of algae; the reduction of dissolved oxygen; and an increase of dissolved solids and hardness as a result of evaporation. As the water resources of the San Jacinto River Basin are developed, the magnitude and significance of the probable changes in water quality will necessitate detailed studies of the resulting problems.

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Quality-of-water records for the San Jacinto 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	Water Year	U.S.G.S. Water-Supply Paper No.	T.W.D.B. Report
1940-45	--	*1938-45	1955	1402	*1955
1946	1050	*1946	1956	1452	Bull. 5905
1947	1102	*1947	1957	1522	Bull. 5915
1948	1133	*1948	1958	1573	Bull. 6104
1949	1163	*1949	1959	1644	Bull. 6205
1950	1188	*1950	1960	--	Bull. 6215
1951	1199	*1951	1961	--	Bull. 6304
1952	1252	*1952	1962	1944	Bull. 6501
1953	1292	*1953	1963	--	Rept. 7
1954	1352	*1954			

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

Numbers of U.S. Geological Survey Water-Supply Papers containing results of stream measurements in the San Jacinto River Basin, 1924-60:

Year	Water-Supply Paper No.	Year	Water-Supply Paper No.	Year	Water-Supply Paper No.
1924	588	1936	808	1948	1118
1925	608	1937	828	1949	1148
1926	628	1938	858	1950	1178
1927	648	1939	878	1951	1212
1928	668	1940	898	1952	1242
1929	688	1941	928	1953	1282
1930	703	1942	958	1954	1342
1931	718	1943	978	1955	1392
1932	733	1944	1008	1956	1442
1933	748	1945	1038	1957	1512
1934	763	1946	1058	1958	1562
1935	788	1947	1088	1959	1632
				1960	1712

Table 4.--Index of surface-water records in the San Jacinto River Basin

Reference no.	Stream and Location	Drainage Area (sq. miles)	Calendar Years 1921–30	1931–40	1941–50	1951–60	1961–65
1	Lake Raven near Huntsville						
2	West Fork San Jacinto River at State Highway 105 near Conroe						
3	Lake Creek at Farm Road 1419 near Magnolia						
4	Lake Creek near Conroe						
5	West Fork San Jacinto River near Conroe	809					
6	Stewarts Creek at U.S. Highway 75 near Conroe						
7	Spring Creek near Spring	409					
8	Cypress Creek at U.S. Highway 290 near Houston						
9	Cypress Creek near Westfield	285					
10	West Fork San Jacinto River near Humble	1,741					
11	East Fork San Jacinto River at State Highway 150 near Coldspring						
12	East Fork San Jacinto River near Cleveland	325					
13	Caney Creek near Splendora	105					
14	Peach Creek at Splendora	117					
15	San Jacinto River near Huffman	2,800					

Discharge **Gage heights only** **Gage heights and discharge measurements**

Reservoir contents **Periodic discharge measurements** **Daily chemical quality**

Periodic chemical quality **Water temperature**

Table 4.--Index of surface-water records in the San Jacinto River Basin--Continued

Reference no.	Stream and Location	Drainage Area (sq. miles)	Calendar Years 1921–30	1931–40	1941–50	1951–60	1961–65
16	Lake Houston near Sheldon	2,828					
17	Barker Reservoir near Addicks	134					
18	Addicks Reservoir near Addicks	133					
19	Buffalo Bayou near Addicks	293					
20	Buffalo Bayou at Houston	358					
21	Whiteoak Bayou at Houston	84.7					
22	Buffalo Bayou at Main Street, Houston	469					
23	Buffalo Bayou at 69th Street at Houston	476					
24	Brays Bayou at Houston	88.4					
25	Brays Bayou at Broadway Boulevard at Houston	128					
26	Sims Bayou at Houston	64.0					
27	Greens Bayou near Houston	72.7					
28	Halls Bayou at Houston	24.7					

Discharge Gage heights only Gage heights and discharge measurements

Reservoir contents Periodic discharge measurements Daily chemical quality

Periodic chemical quality Water temperature

Table 5.--Summary of chemical analyses at daily stations on streams in the San Jacinto River Basin

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

Date of collection	Mean discharge (cfs)	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids: Parts per million	Dissolved solids: Tons per acre-foot	Dissolved solids: Tons per day	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Percent sodium	Sodium adsorption ratio	Specific conductance (micromhos at 25° C)	pH
5. WEST FORK SAN JACINTO RIVER NEAR CONROE																				
Water year 1962																				
Maximum, Mar. 16-31, 1962	123	24	59	5.4	49		143	14	101	0.3	0.5	323	0.44	107	169	52	39	1.6	571	7.0
Minimum, Jan. 28-31-----	2,245	21	20	3.1	12		52	9.0	25	--	.5	117	.16	709	62	19	29	.7	199	6.2
Weighted average--------	157	21	38	3.9	29		99	10	58	--	.9	213	.29	90.0	112	30	36	1.3	370	--
Water year 1963																				
Maximum, Apr. 1-7, 1963-	110	23	53	5.3	41		134	13	84	.2	.8	286	.39	84.9	154	44	37	1.4	498	7.4
Minimum, Jan. 1---------	4,790	10	14	1.0	3.6		41	.8	8.0	--	.0	57	.08	737	38	4	17	.3	104	6.7
Weighted average--------	249	15	28	2.5	19		72	9.2	36	--	1.0	146	.20	98.2	80	21	34	.9	256	--
10. WEST FORK SAN JACINTO RIVER NEAR HUMBLE																				
Water year 1946																				
Maximum, Nov. 1-7, 9-10, 1945-----------	147		32	5.2	70		90	7.3	122		0.8	347	0.47	138	101	28	60	3.0	556	
Minimum, May 21-23, 23-26, 1946-----------	11,540		6.8	2.1	11		34	5.3	11		.2	110	.15	3,430	26	0	48	.9	95	7.2
15. SAN JACINTO RIVER NEAR HUFFMAN																				
Water year 1946																				
Maximum, Aug. 1-5, 7-10, 1946-----------	325	--	22	3.9	69		77	5.1	108		1.2	299	0.41	262	71	8	68	3.6	494	--
Minimum, Feb. 17-18, 20-23----------------	10,390	--	10	2.7	7.9		35	1.5	16		.5	113	.15	3,170	36	7	32	.6	109	--
Water year 1947																				
Maximum, Sept. 27-29, 1947-----------------	--	--	30	18	187		76	32	325		.8	710	.97	--	149	86	73	6.7	1,240	--
Minimum, Jan. 1-10------	--	--	12	2.9	14		38	4.5	26		.8	135	.18	--	42	11	43	.9	151	--
Water year 1948																				
Maximum, Oct. 12, 1947--	125	--	54	86	665		80	154	1,210		3.0	2,210	3.01	746	488	423	75	13	4,120	--
Minimum, Apr. 24-25, 27-30, 1948-----------	2,902	9.9	16	2.8	30		63	4.1	42		1.2	167	.23	1,310	51	0	56	1.8	238	--
Water year 1949																				
Maximum, Dec. 5-15, 1948	122	15	24	9.8	158		72	17	261		.8	540	.73	178	100	42	77	6.9	1,010	--
Minimum, Mar. 22-26, 31, 1949-------------	12,730	6.2	9.2	3.4	8.5		27	7	18		.8	115	.16	3,450	37	15	33	.6	115	--
Weighted average--------	1,533	9.4	12	3.1	26		39	9.2	41		1.2	157	.21	650	43	11	57	1.7	214	--
Water year 1950																				
Maximum, Sept. 1-10, 1950	143	21	21	4.1	65		65	5.4	106		1.5	272	.37	105	69	16	67	3.4	475	7.6
Minimum, June 3-10------	24,780	11	9.4	3.9	3.9		28	4.0	14		1.5	62	.08	4,150	40	17	18	.3	99	7.0
Weighted average--------	3,727	10	12	2.9	15		36	5.0	27		1.3	121	.16	1,220	42	12	44	1.0	155	--

Table 5.--Summary of chemical analyses at daily stations on streams in the San Jacinto River Basin--Continued

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

Date of collection	Mean discharge (cfs)	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids: Parts per million	Dissolved solids: Tons per acre-foot	Dissolved solids: Tons per day	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Non-carbonate	Percent sodium	Sodium adsorption ratio	Specific conductance (micromhos at 25° C)	pH
15. SAN JACINTO RIVER NEAR HUFFMAN--Continued																				
Water year 1951																				
Maximum, Nov. 21-30, 1950	135	15	23	5.7	97		66	7.6	162		0.5	394	0.54	144	81	27	72	4.7	658	7.3
Minimum, June 12, 15-16, 1951	216	11	--	--	--		33	--	34		2.2	174	.24	101	33	6	--	--	185	7.5
Weighted average	237	17	21	4.5	63		65	6.3	105		1.4	265	.36	170	71	18	66	3.3	468	--
Water year 1952																				
Maximum, Nov. 21-23, 28, 1951	105	17	59	102	865		81	200	1,540		2.0	2,820	3.84	799	566	500	97	16	5,240	7.5
Minimum, Apr. 12-15, 24-28, 1952	11,330	6.4	9.5	3.1	12		29	9.6	18		2.4	79	.11	2,420	36	13	41	.9	123	7.3
Weighted average	777	11	15	3.8	30		43	8.8	50		2.1	155	.21	325	53	18	55	1.8	254	--
Water year 1953																				
Maximum, Oct. 11-20, 1952	53.8	16	24	5.0	101		78	4.7	64		.8	360	.49	52.3	80	16	73	4.9	678	7.4
Minimum, Apr. 30, May 14-20, 1953	18,190	6.6	8.8	1.1	8.2	2.5	28	4.0	12		2.5	60	.08	2,950	26	4	38	.7	103	7.3
Weighted average	1,372	9.4	13	2.1	20		39	5.2	30		2.1	102	.14	378	41	9	51	1.4	181	--

Table 6.--Chemical analyses of streams and reservoirs in the San Jacinto River Basin for locations other than daily stations

(Results in parts per million except as indicated)

Date of collection	Discharge (cfs)	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	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	Percent sodium	Sodium adsorption ratio	Specific conductance (micromhos at 25° C)	pH
1. LAKE RAVEN NEAR HUNTSVILLE																				
Apr. 23, 1964		5.8	16	3.7	17		56	4.2	29	0.1	0.0	104	0.14		55	9	40	1.0	199	6.9
2. WEST FORK SAN JACINTO RIVER AT STATE HIGHWAY 105 NEAR CONROE																				
Nov. 17, 1961	58.1	20	52	4.9	32		140	10	66	0.3	0.2	254	0.35		150	35	32	1.1	456	6.8
Apr. 2, 1962	32.6	23	81	6.2	50		208	17	104	.3	.0	384	.52		228	57	32	1.4	650	7.6
June 18	14.2	25	71	5.4	36		200	6.8	75	.3	.0	318	.43		199	35	28	1.1	567	7.0
July 27	1.73	23	68	5.4	36		209	6.6	64	.3	.2	306	.42		192	20	29	1.1	532	7.1
Oct. 2	13.1	20	53	4.4	25		152	13	46	.3	.2	a242	.33		150	26	26	.9	413	6.9
Nov. 5	11.0	20	37	2.8	23		104	8.8	42	.2	.0	185	.25		104	19	33	1.0	315	6.4
Jan. 14, 1963	86.4	20	48	4.2	23		114	16	54	.2	.2	222	.30		137	44	27	.9	389	6.6
Apr. 29	22.8	23	57	5.0	43		154	12	83	.3	.2	300	.41		162	36	37	1.5	519	7.3
June 3	5.43	7.3	56	4.7	39		152	9.4	78	.2	.0	270	.37		159	34	35	1.3	517	7.0
July 9	12.8	15	24	.0	20		54	6.6	37	.2	.2	130	.18		60	16	42	1.1	231	8.0
Nov. 26	35.4	18	39	3.1	19		98	11	42	.3	.5	181	.25		110	30	28	.8	323	7.4
Jan. 3, 1964	29.5	18	58	3.5	29		144	14	63	.2	.0	257	.35		159	41	28	1.0	459	7.2
Mar. 3	b2,000	8.0	21	1.4	6.3	2.8	66	1.2	12	.2	.5	86	.12		58	4	18	.4	156	6.5
Apr. 23	b60	18	40	2.5	20		107	13	37	.3	.5	184	.25		110	22	29	.8	329	6.7
3. LAKE CREEK AT FARM ROAD 149 NEAR MAGNOLIA																				
Apr. 23, 1964	b25	15	38	4.2	20		99	8.4	46	0.2	0.5	181	0.25		112	31	28	0.8	343	6.9
4. LAKE CREEK NEAR CONROE																				
Apr. 23, 1964	b100	16	32	2.5	24		92	7.4	41	0.2	0.5	169	0.23		90	15	36	1.1	298	6.7
6. STEWARTS CREEK AT U.S. HIGHWAY 290 NEAR CONROE																				
Nov. 30, 1948									19			a94							103	
Dec. 1									15			a130							176	
7. SPRING CREEK NEAR SPRING																				
Mar. 18, 1959	21.0	15	23	4.1	30		64	64	57	0.1	0.0	167	0.23		74	22	47	1.5	312	7.4
Sept. 14, 1961	8,750	15	1.9	1.3	3.7	2.2	15	.0	6.0	.1	.0	37	.05		10	0	38	.5	46	5.8
Oct. 1, 1962	9.86	17	24	5.0	46		63	3.6	88	.2	.0	a219	.30		80	29	55	2.2	398	7.1
Nov. 5	12.4	17	20	4.0	46		58	3.4	82	.2	.0	a216	.29		66	19	60	2.5	369	6.3
Dec. 11	25.7	17	16	4.1	29		42	6.8	56	.1	.0	150	.20		57	22	53	1.7	265	6.0
Jan. 14, 1963	57.0	15	15	3.6	23		34	8.0	46	.2	.0	128	.17		52	24	49	1.4	226	6.0
Feb. 18	288	4.8	5.5	2.2	15		14	4.2	27	.2	.8	67	.09		23	11	59	1.4	125	5.7
Feb. 21	1,630	4.3	4.8	1.6	5.7	2.6	14	4.8	10	.2	.8	42	.06		19	7	36	.6	72	5.7
Apr. 30	19.9	17	24	4.9	43		62	4.4	83	.2	.0	206	.28		80	29	54	2.1	374	6.7
June 5	16.2	16	20	3.4	34		53	4.0	64	.1	.2	168	.23		64	20	54	1.8	321	6.3
July 9	12.2	15	18	3.7	49		50	3.6	86	.2	.2	201	.27		60	19	64	2.7	407	6.1
Nov. 26	6.72	15	27	4.5	56		67	3.2	105	.1	.0	244	.33		86	31	58	2.6	467	7.0
Mar. 4, 1964	1,000	6.2	5.2	1.0	6.7	2.2	16	4.4	9.9	.3	1.8	46	.06		17	4	42	.7	76	6.4
Apr. 23	--	13	12	2.2	15		37	5.0	25	.1	.8	91	.12		39	9	46	1.0	164	6.6

a Residue on evaporation at 180°C.
b Field estimate.

Table 6.--Chemical analyses of streams and reservoirs in the San Jacinto River Basin for locations other than daily stations--Continued

(Results in parts per million except as indicated--Continued)

Date of collection	Discharge (cfs)	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	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	Percent sodium	Sodium adsorption ratio	Specific conductance (micromhos at 25° C)	pH
8. CYPRESS CREEK AT U.S. HIGHWAY 290 NEAR HOUSTON																				
Nov. 8, 1951							69		60						51				334	7.7
9. CYPRESS CREEK NEAR WESTFIELD																				
Mar. 18, 1959	1.0	9.6	31	5.8	101		118	25	140	0.4	0.2	371	0.50		102	5	68	4.4	693	7.3
Sept. 14, 1961	4,980	5.8	3.5	1.3	5.7	2.9	17	3.6	8.5	.2	.0	40	.05		14	0	41	.7	64	5.9
Oct. 2, 1962	6.09	20	37	7.2	69		170	7.4	88	.5	.0	313	.43		122	0	55	2.7	557	7.6
Nov. 5	1.03	11	31	6.0	94		156	11	117	.4	.2	a356	.48		102	0	67	4.0	646	6.6
Dec. 11	7.40	17	18	3.9	50		80	18	60	.3	.0	206	.28		61	0	64	2.8	356	6.2
Jan. 14, 1963	7.03	12	18	3.9	65		82	15	83	.3	.8	238	.32		61	0	70	3.6	429	6.5
Feb. 19	1,040	14	7.0	1.9	53		12	8.6	86	.2	.2	177	.24		25	15	82	4.6	328	5.2
Feb. 21	280	5.5	5.5	1.0	7.4	3.9	17	6.8	10	.3	.2	49	.07		18	4	41	.8	85	5.4
Apr. 30	.34	7.0	41	8.6	193		189	24	265	.5	1.0	a666	.91		138	0	75	7.1	1,170	7.1
June 5	.32	8.7	23	3.5	58		75	12	86	.3	2.5	231	.31		72	10	64	3.0	430	6.4
July 9	14.8	14	15	.1	48		c54	6.6	64	.4	.0	175	.24		38	0	73	3.4	311	8.3
Nov. 26	9.17	1.8	24	3.9	111		104	18	149	.4	2.2	361	.49		76	0	76	5.5	697	7.0
Mar. 4, 1964	618	7.9	7.5	1.3	10		30	5.8	9.4	.3	2.0	59	.08		24	0	48	.9	101	6.2
Apr. 23	6.2	8.6	16	2.9	18		53	14	23	.3	.8	110	.15		52	8	44	1.1	195	6.5
11. EAST FORK SAN JACINTO RIVER AT STATE HIGHWAY 150 NEAR COLDSPRING																				
Apr. 23, 1964	b10	16	38	3.5	20		93	10	46	0.2	0.5	180	0.24		109	33	28	0.8	332	6.6
12. EAST FORK SAN JACINTO RIVER NEAR CLEVELAND																				
Sept. 14, 1961	8,340	5.1	8.7	1.3	4.1	2.3	30	0.0	6.5	0.2	0.0	43	0.06		27	2	23	0.3	77	6.1
Nov. 15	124	9.7	12	3.3	42		22	5.4	78	.2	.2	162	.22		44	25	68	2.8	311	6.1
Jan. 15, 1962	86.5	12	27	4.3	40		54	7.6	85	.2	.0	203	.28		85	41	51	1.9	378	6.6
June 20	24.8	8.5	16	2.5	32		34	3.2	63	.2	.2	143	.19		50	22	58	2.0	279	6.3
July 25	14.2	12	17	3.2	48		30	2.4	93	.2	.0	191	.26		56	31	65	2.8	367	6.5
Sept. 18	20.5	13	18	2.9	23		44	6.0	46	.1	.2	131	.18		57	21	47	1.3	232	6.3
Oct. 3	16.8	12	16	2.5	43		29	4.0	82	.2	.0	a192	.24		50	26	65	2.6	324	5.8
Nov. 8	21.4	11	13	2.4	37		28	2.8	69	.1	.0	149	.20		42	19	66	2.5	278	6.1
Nov. 29	370	10	21	3.0	24		65	7.2	39	.3	.0	a148	.20		65	12	44	1.3	247	6.1
Dec. 10	30.4	14	19	3.1	32		40	6.8	64	.1	.0	a176	.24		60	27	54	1.8	290	6.3
Jan. 15, 1963	83.6	17	25	3.4	27		50	12	57	.2	.2	167	.23		76	35	43	1.3	291	6.1
Feb. 20	1,810	6.1	14	1.5	7.3	2.1	33	7.0	15	.2	.2	69	.09		41	14	27	.5	125	5.7
May 1	21.9	9.6	22	3.3	37		51	3.6	72	.2	.2	173	.24		68	27	54	1.9	325	6.7
June 4	13.0	12	17	2.8	33		40	3.0	63	.1	.0	151	.21		54	21	57	2.0	289	6.5
June 10	17.9	13	18	2.0	25		46	3.6	46	.2	.0	131	.18		53	15	50	1.5	236	6.7
July 22	15.0	10	16	2.5	35		35	3.0	67	.2	.0	151	.21		50	22	60	2.2	289	6.1
Sept. 19	38	11	11	2.1	30		22	2.8	56	.1	.2	124	.17		36	18	64	2.2	236	6.1
Sept. 30	11.1	11	12	2.0	28		25	4.4	52	.1	.2	122	.17		38	18	61	2.0	227	6.2
Dec. 9	24.6	13	17	3.3	35		35	4.8	70	.2	.0	160	.22		56	27	58	2.0	302	6.5
Mar. 4, 1964	7,700	7.0	10	1.0	4.9	1.9	33	1.4	7.9	.3	1.2	52	.07		29	2	25	.4	96	6.4
Mar. 5	2,480	7.8	11	.9	5.3	2.2	34	4.0	8.6	.2	1.5	58	.08		31	3	25	.4	100	6.2
Apr. 23	122	13	22	2.0	18		57	6.0	35	.2	.5	125	.17		63	16	39	1.0	232	6.5

a Residue on evaporation at 180°C.
b Field estimate.
c Includes the equivalent of 4 parts per million of carbonate (CO_3).

Table 6.--Chemical analyses of streams and reservoirs in the San Jacinto River Basin for locations other than daily stations--Continued

(Results in parts per million except as indicated--Continued)

Date of collection	Discharge (cfs)	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (calculated) Parts per million	Dissolved solids Tons per acre-foot	Dissolved solids Tons per day	Hardness as $CaCO_3$ Calcium, magnesium	Hardness as $CaCO_3$ Noncarbonate	Percent sodium	Sodium adsorption ratio	Specific conductance (micromhos at 25°C)	pH
13. CANEY CREEK NEAR SPLENDORA																				
Oct. 1, 1962	14.9	14	6.8	1.5	8.8	0.9	21	2.4	17	0.2	0.0	59	0.08		23	6	44	0.8	94	6.4
Dec. 12	19.5	14	10	2.1	11		30	4.2	20	.1	.0	76	.10		34	9	41	.8	123	5.9
Jan. 16, 1963	35.8	15	20	2.5	11		49	7.6	25	.1	.0	105	.14		60	20	28	.6	180	6.2
Feb. 20	195	5.2	14	1.5	6.2	2.0	37	6.0	14	.2	.8	68	.09		41	11	24	.4	118	6.1
Apr. 30	18.5	12	11	2.1	12		38	3.0	20	.2	.0	79	.11		36	5	43	.9	129	6.7
June 5	12.0	13	8.2	1.6	10		28	1.8	17	.1	.0	66	.09		27	4	45	.8	105	6.3
Nov. 7	71.2	7.5	11	.9	5.5	2.6	28	6.4	11	.1	.2	59	.08		31	8	26	.4	102	6.0
Feb. 25	508	5.8	18	1.2	9.1	2.0	46	4.8	19	.2	.8	84	.11		50	12	27	.6	159	5.9
Apr. 23	31.0	13	17	1.8	10	1.4	51	3.8	19	.0	.2	91	.12		50	8	30	.6	162	6.6
14. PEACH CREEK AT SPLENDORA																				
Oct. 1, 1962	13.4	14	3.0	1.3	9.7	0.8	11	2.0	17	0.2	0.0	53	0.07		13	4	60	1.2	77	5.8
Nov. 6	13.2	14	3.0	1.1	12		10	1.4	20	.1	.0	57	.08		12	4	69	1.5	83	6.3
Dec. 12	18.8	15	4.0	1.9	9.6	.7	13	2.4	19	.1	.0	59	.08		18	7	53	1.0	92	6.0
Jan. 16, 1963	32.8	18	4.0	2.2	12		11	4.4	22	.1	.2	68	.09		19	10	58	1.2	105	5.9
Feb. 20	324	5.5	2.0	1.3	4.6	.8	5	4.4	7.8	.1	1.0	30	.04		10	6	47	.6	46	5.6
Apr. 30	16.4	13	4.0	1.9	16		16	.4	28	.1	.2	72	.10		18	5	67	1.6	115	6.2
Feb. 25, 1964	280	5.3	3.2	1.0	5.9	1.2	9	4.0	7.5	.2	.0	32	.04		12	5	48	.7	59	5.7
Apr. 23	24.0	13	5.0	1.8	17		16	3.0	28	.1	.5	76	.10		20	7	65	1.7	133	6.4
16. LAKE HOUSTON NEAR SHELDON																				
July 24, 1961		6.6	9.5	1.5	11	2.0	29	2.4	21	0.3	0.0	68	0.09		30	6	42	0.9	127	6.2
Nov. 9, 1962		10	18	2.3	29		48	7.2	50	.2	.0	141	.19		54	15	54	1.7	260	6.3
Jan. 15, 1963		8.8	14	1.6	16		39	6.2	26	.2	.0	92	.13		42	10	45	1.1	162	6.2
Apr. 22, 1964		8.9	16	1.7	14		44	7.2	24	.1	.5	94	.13		47	11	40	.9	170	6.6
19. BUFFALO BAYOU NEAR ADDICKS																				
Oct. 23, 1962	114	18	20	4.9	22		88	7.0	26	0.3	0.8	a147	0.20		70	0	40	1.1	241	6.4
Nov. 29	1,220	6.5	8.0	1.7	19		34	5.0	24	.2	.2	82	.11		27	0	60	1.6	149	5.8
Feb. 6, 1963	13.5	8.4	32	6.6	76		120	21	106	.3	.5	310	.42		107	8	61	3.2	572	6.4
Mar. 12	9.19	9.6	58	12	103		212	53	133	.4	.0	473	.64		194	20	53	3.2	861	6.5

a Residue on evaporation at 180°C.