TEXAS WATER DEVELOPMENT BOARD

REPORT 29

BASE-FLOW STUDIES

UPPER GUADALUPE RIVER BASIN, TEXAS

Quantity and Quality

March 1965

By

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INTRODUCTION

This investigation was made by the U.S. Geological Survey, Water Resources Division, under provisions of the 1965 cooperative agreement with the Texas Water Development Board providing for the investigation of the water resources of Texas.

Purposes of the investigation were to: (1) determine the interchange of ground and surface waters in the channel; (2) evaluate the effects of geology and man-made environmental changes on the quantity and chemical quality of the water; and (3) evaluate the suitability of the water for municipal, industrial, agricultural, and recreational uses when flow in the Guadalupe River was sustained entirely by ground-water effluent and when evaporation and transpiration were at a minimum. The investigated reach of 54.0 river miles extends downstream from the headwaters of the Guadalupe River above Hunt to the stream-gaging station at Comfort (Figure 11).

The investigation was begun on March 15, 1965, 34 days after appreciable rainfall or surface runoff had occurred. Hydrographs for the stream-gaging stations on Johnson Creek near Ingram and on the Guadalupe River at Comfort show that discharge in the two streams was nearly constant (Figure 1). Both evaporation and transpiration probably were near the minimum for the year. Rainfall on the watershed during the night of March 16 caused surface runoff, and the completion of the fieldwork was postponed. No rain fell during the following nine days, and hydrographs showed a slowly diminishing discharge on Johnson Creek and the Guadalupe River at Comfort (Figure 1). Although river discharge was not the minimum base flow, streamflow was entirely sustained by ground-water effluent. The fieldwork was resumed on March 24 and completed on March 25, 1965.

BASIN FEATURES

Location

The North and South Forks Guadalupe River rise in western Kerr County, in the heart of the beautiful central Texas "Hill Country." The two forks flow

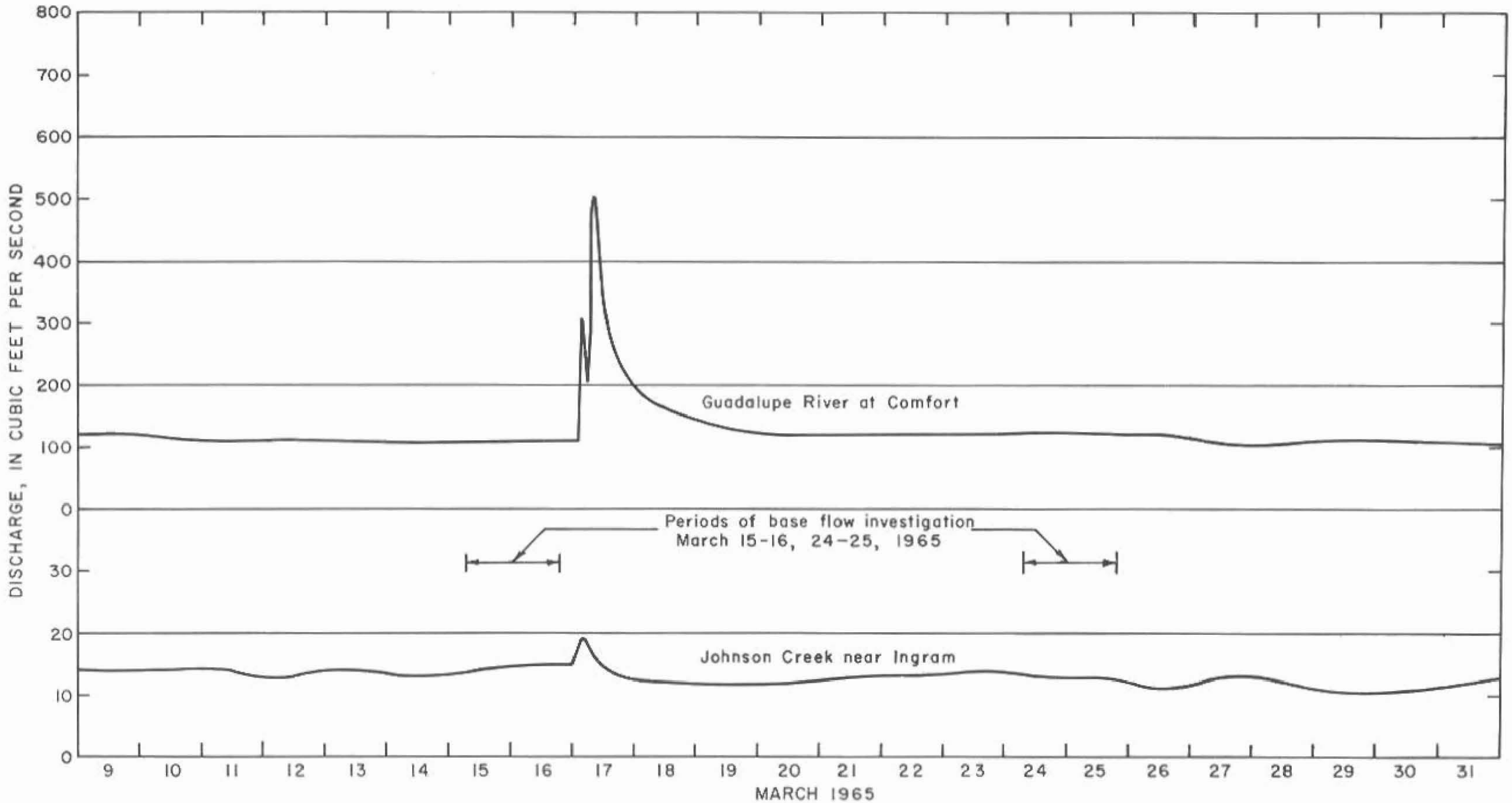

Figure 1

Hydrographs for Stream-Gaging Stations, Guadalupe River at Comfort and Johnson Creek near Ingram

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eastward until they join near Hunt to form the Guadalupe River. The river continues east-southeastward through the Kerrville recreation area, through Comfort--the downstream limit of the study area--and into Canyon Reservoir 13 miles above New Braunfels and 40 miles below Comfort. (See Figure 11.)

Topography, Soils, and Land Use

From the headwaters of the river to Kerrville, the terrain of the Guadalupe River basin is rocky and moderately dissected by many small streams, some of which are fed by springs issuing from beds of limestone (Figure 2). The highest point in the area upstream from Kerrville is about 2,400 feet above mean sea level, and the elevation at Kerrville is about 1,640 feet. From Hunt to Kerrville, the Guadalupe River channel is incised in the upper member of the Glen Rose Limestone; the river meanders through its narrow valley, flowing intermittently over rapids or through long pools of natural or man-made origin. The channel bed is composed alternately of limestone and of highly porous alluvial deposits. Juniper, scrub live-oak trees, and sparse stands of native grasses exist on the rocky hills and slopes; cypress, sycamore, willow trees, and native grasses grow on the valley floor (Figure 2). Because of the terrain and shallow stony soil, the land is used only for recreation and the raising of livestock.

In the part of the Guadalupe River basin from Kerrville to Comfort (elevation 1,370 feet), the topography is rolling, and the alluvial valleys widen (Figure 3). Compared with the basin above Kerrville, the soil is deeper, of better quality, and capable of supporting cypress, pecan, sycamore, and live-oak trees as well as native grasses and some small grain crops (Figure 3). The river channel here is very similar to that in the upper part of the study area. The land is used largely for raising of livestock, small grain crops, and some pecans.

During the drier summer months, many pump diversions for irrigation and domestic purposes (Figure 4) are put into operation on the Guadalupe River and its tributaries; however, at the time of this investigation diversions were not observed.

Climate

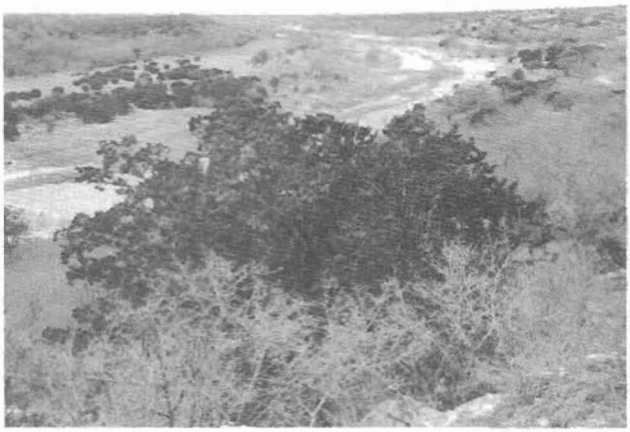
The climate may be classed as semiarid and subhumid. In the upper part of the study area, the annual rainfall averages about 28 inches; in the lower part, the average annual rainfall is about 32 inches. Precipitation is nearly evenly distributed throughout the year, but much occurs as intense rainstorms of short duration. The mean temperature for July is about 81°F; some extremes of more than 100°F have been recorded during the summer months. The mean temperature for January is about 47°F; a few extremes of less than 0°F have been recorded during the winter months. The average length of the growing season is about 220 days.

GENERAL GEOLOGY

The rock units of Early Cretaceous age are exposed in the Guadalupe River basin upstream from Comfort (Figure 5). The general dip of the rocks is

A. Southwestern exposure of fracture (gully) at Lynxhaven resort (site 24), showing cavernous character of Edwards and associated limestones

B. North Fork Guadalupe River channel



C. North Fork Guadalupe River--the terrain and small on-channel dam

Figure 2

Moderately Dissected Limestone Terrain in the Upper Reaches

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A. Cypress Creek (site 93) with dense growth of cypress and other trees.

B. One of several overgrown and refuse-choked tributaries

C. Third Creek (site 67) polluted by chemical and sewage effluent

D. Part of the wide fertile flood plain near Comfort

Figure 3

Alluvial Valleys and Vegetation in the Lower Reaches

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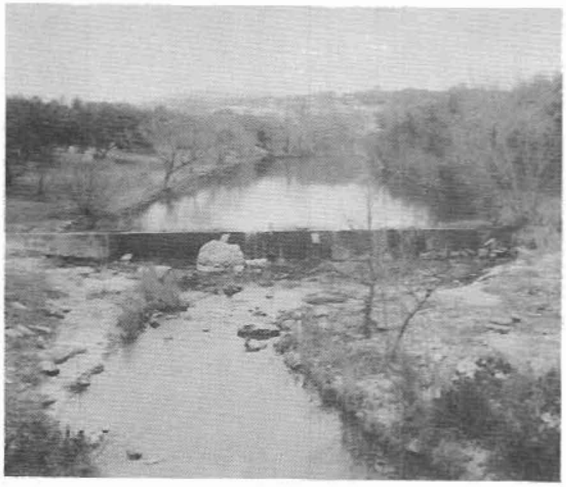
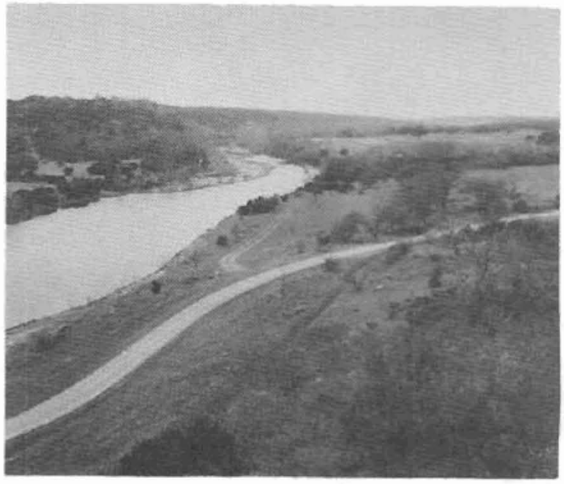
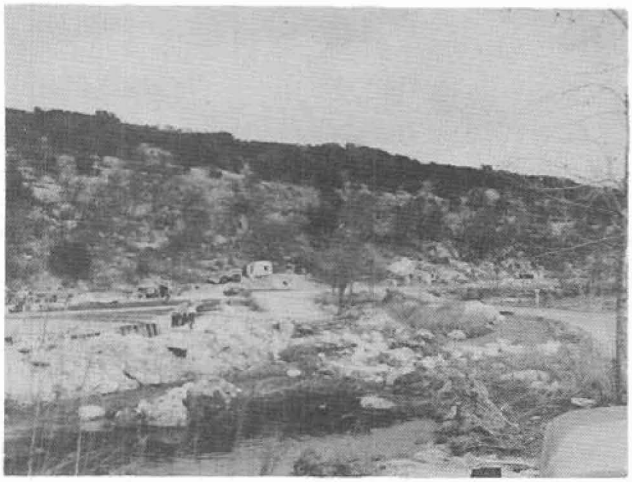


A. Small recreational dam near Kerrville



B. Johnson Creek and State Fish Hatchery near Mountain Home (site 47)



C. Dam construction at resort on South Fork Guadalupe River

Figure 4

Moderately Rugged Topography and Small Irrigation and Recreational Dams in the Upper Reaches

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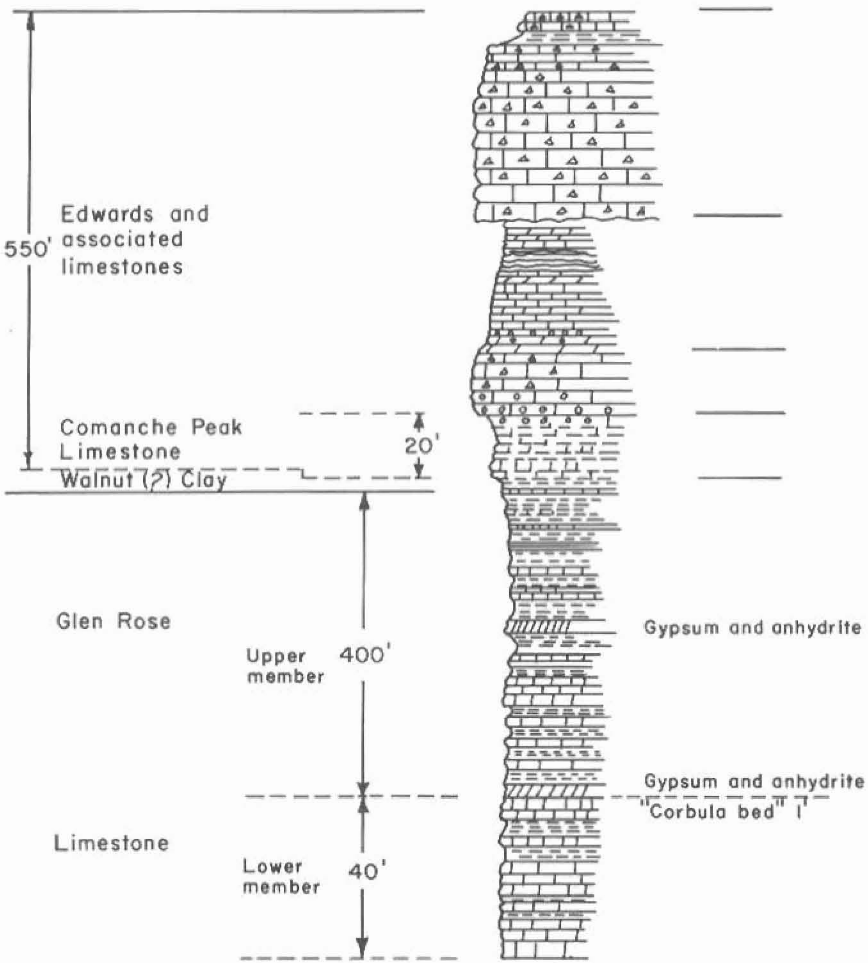

Limestone, massive, light grey to buff, cherty, hard, weathers dark brown to blackish, moderately honeycombed. Moderately permeable along fractures. Ledge forming. Fossil rudistids and oysters. Generally not water bearing.

Dolomite and dolomitic limestone, thin bedded to flaggy, dark brown, soft, sugary, some beds extensively honeycombed. Springs and seeps along outcrop near base. Forms upper part of aquifer.

Limestone, massive, light grey to cream, hard, cherty, medium to fine grained. Moderately permeable along fractures. Water bearing.

Limestone, marly, nodular, soft, grey. Fossil *Exogyra texana* fairly common. Numerous seeps and springs along outcrop. Forms lower part of aquifer.

Chiefly soft shale and clay beds alternating with thin limestone or dolomite beds. Relatively impermeable. Weathers brown to buff. Fresh surface of shale is yellowish brown or blue. Fossil "ox hearts" common. Ledges form "stair step" topography.

Two gypsum and anhydrite beds are prominent, imparting a high sulfate content to ground water. Both beds are water bearing in study area.

Corbula texana Whitney Zone is immediately overlain by the lower gypsum and anhydrite bed. Nodular marl dolomitic, grading downward to fairly massive limestone. Fairly permeable along fractures. (Only the upper 40 feet of the lower member of the Glen Rose Limestone is exposed in report area.) Probably not water bearing in study area where it crops out.

Figure 5

Composite Geologic Section in Kerr County

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southeastward toward the Balcones Fault Zone at about 10 feet per mile. The rock units are the Glen Rose Limestone, Walnut(?) Clay, Comanche Peak Limestone, Edwards Limestone, and Georgetown Limestone. The Walnut(?) was mapped with the upper member of Glen Rose Limestone on Figure 11.

Glen Rose Limestone

The Glen Rose Limestone consists of alternating beds of limestone, dolomite, and silty clay; and two beds of gypsum and anhydrite, one about 200 feet below the top of the formation and the other about 170 feet lower.

Edwards and Associated Limestones

The Comanche Peak, Edwards, and Georgetown Limestones collectively are called the Edwards and associated limestones (Petitt and George, 1956, p. 16). They are hydrologically connected and together form one of the important aquifers in the study area. The potential yield of this aquifer depends on the amount of soluble material removed from the limestones along their bedding planes and in the fractured zones. The Edwards and associated limestones generally cap the topographic divides and crop out in about three-fourths of the study area. Numerous seeps and springs are associated with the outcrop area (Figure 6).

Quaternary Alluvium

Quaternary alluvial deposits cover the wider valleys. Gravel bars in the upper reaches of the study area are of minor hydrologic importance. In the lower reaches downstream from Ingram, where the channel gradient decreases and the valley widens, the alluvial material is more widespread and hydrologically important.

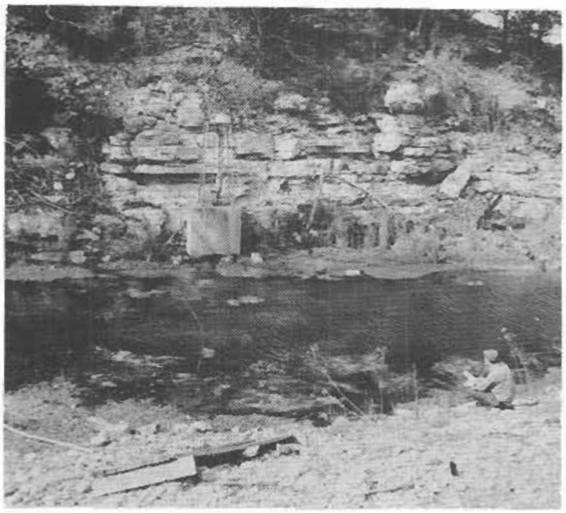
Depending upon the river stage and the elevation of the ground-water table, the alluvial deposits will absorb or contribute streamflow. Because the slope of the bedrock surface and the channel are about the same, some of the water absorbed by the alluvium upstream is returned as channel gains farther downstream.

GEOHYDROLOGY

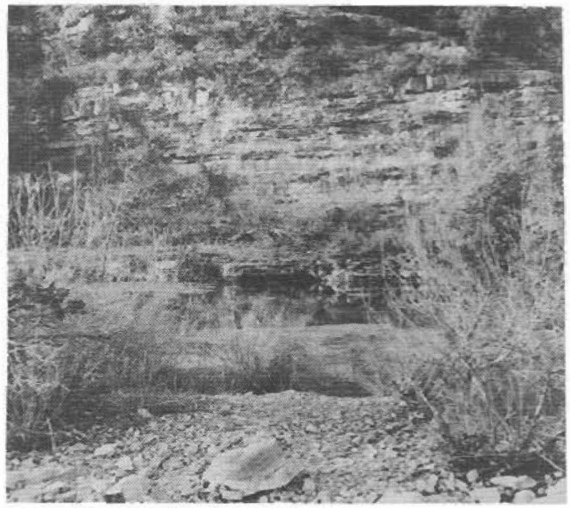
Base flow of the upper Guadalupe River and its tributaries is sustained entirely by ground-water effluent. The main source of the base flow in the study area is the discharge of water from the aquifers (water-bearing rocks).

The principal aquifers are the lower part of the Edwards and associated limestones and two gypsum and anhydrite beds in the Glen Rose Limestone. The gypsum and anhydrite beds, each about 25 feet thick, occur about 200 feet and about 370 feet below the top of the Glen Rose Limestone. About 90 percent of the base flow is contributed by the Edwards and associated limestones in the study area.

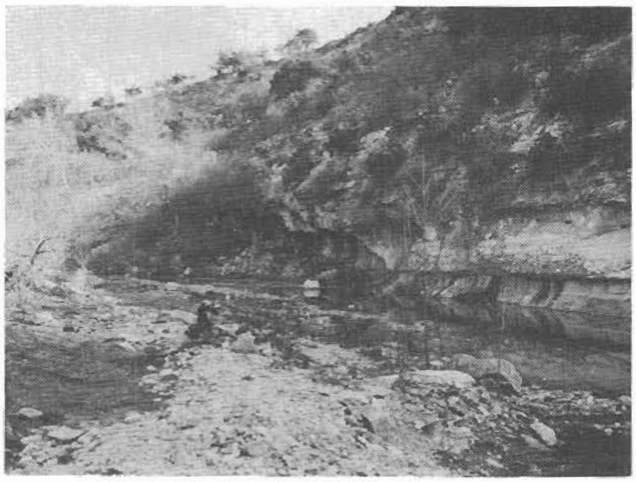
Potential yields of the aquifers depend on the permeability and thickness of the water-bearing rocks. Permeability of water-soluble rocks, such as



A. Boxed-in spring along fracture in Edwards and associated limestone beds (site 6). Discharge was about 0.3 cubic feet per second.



B. Uppermost perennial springs on South Fork Guadalupe River at Lynxhaven (site 24). Discharge varies from a trickle to about 30 cubic feet per second.



C. Ponded spring area in channel of Sycamore Draw (between sites 23 and 24)

Figure 6

Seeps and Springs along the North and South Forks Guadalupe River

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limestone, dolomite, gypsum, and anhydrite, depends on the secondary solution characteristics, such as caverns and channels dissolved along bedding planes and fractures.

Although both the amount and the chemical quality of the base flow are closely related to the source, they vary considerably because of seasonal and man-made environmental changes. Rainfall of slow to moderate intensity may be absorbed by the outcropping limestone, and during the summer months evapotranspiration is high. Part of the rainfall that penetrates the fractures percolates downward and eventually reappears in the stream valleys as seeps and springs.

Discharge was measured or estimated at 95 sites, and water samples for chemical analysis were collected at 83 sites in the study area. Results of the discharge measurements are recorded in Table 1 and the chemical analyses of the water samples are given in Table 2. These data, shown graphically in Figure 7, define changes in chemical quality and streamflow. In general, the flow and dissolved-solids concentrations in the upper Guadalupe River increased downstream. Some noticeable net losses in streamflow were measured, however, throughout the study reach.

Chemical analyses of three water samples from the Guadalupe River and five from tributary streams are shown graphically in Figure 8. The total height of each vertical bar is proportional to the total concentration of anions (negatively charged constituents) or cations (positively charged constituents) expressed in epm (equivalents per million). The bars are divided into segments to show concentration of the individual constituents.

Waters of the upper Guadalupe River and its tributaries are saturated or nearly saturated with calcium and magnesium bicarbonate dissolved from the limestone formations that crop out throughout the entire study area. An analysis of the water at mile 48.0 (site 7) shows that the calcium content is slightly higher in equivalent amounts than the magnesium, and that combined, the total amount is approximately equivalent to that of the bicarbonate. This chemical composition is typical of water-draining dolomite or impure limestone aquifers (such as that above mile 48.0) and is representative of the water throughout the study area, except in Third Creek near Legion where the stream was contaminated.

In the following sections, the study area is subdivided according to notable differences in the character of the rocks or quantity of the flow. River mileage on the main stem of the Guadalupe River is measured upstream from the U.S. Geological Survey stream-gaging station at Comfort, which is designated as river mile 0.0. Tributary mileage is measured upstream from the tributary mouth, designated as mile T-0.0.

North Fork Guadalupe River--Miles 54.0 to 34.0 (Sites 1 to 18)

In the upper 20.0 miles of the reach studied, streamflow in the North Fork Guadalupe River increased from 0 to 24.8 cfs (cubic feet per second).

Between miles 54.0 (site 1) and 50.0 (site 4) the main channel and its tributaries were essentially dry, although a few ponds from local runoff were noted. Initial streamflow, which began as a trickle below the pond (Figure 9)

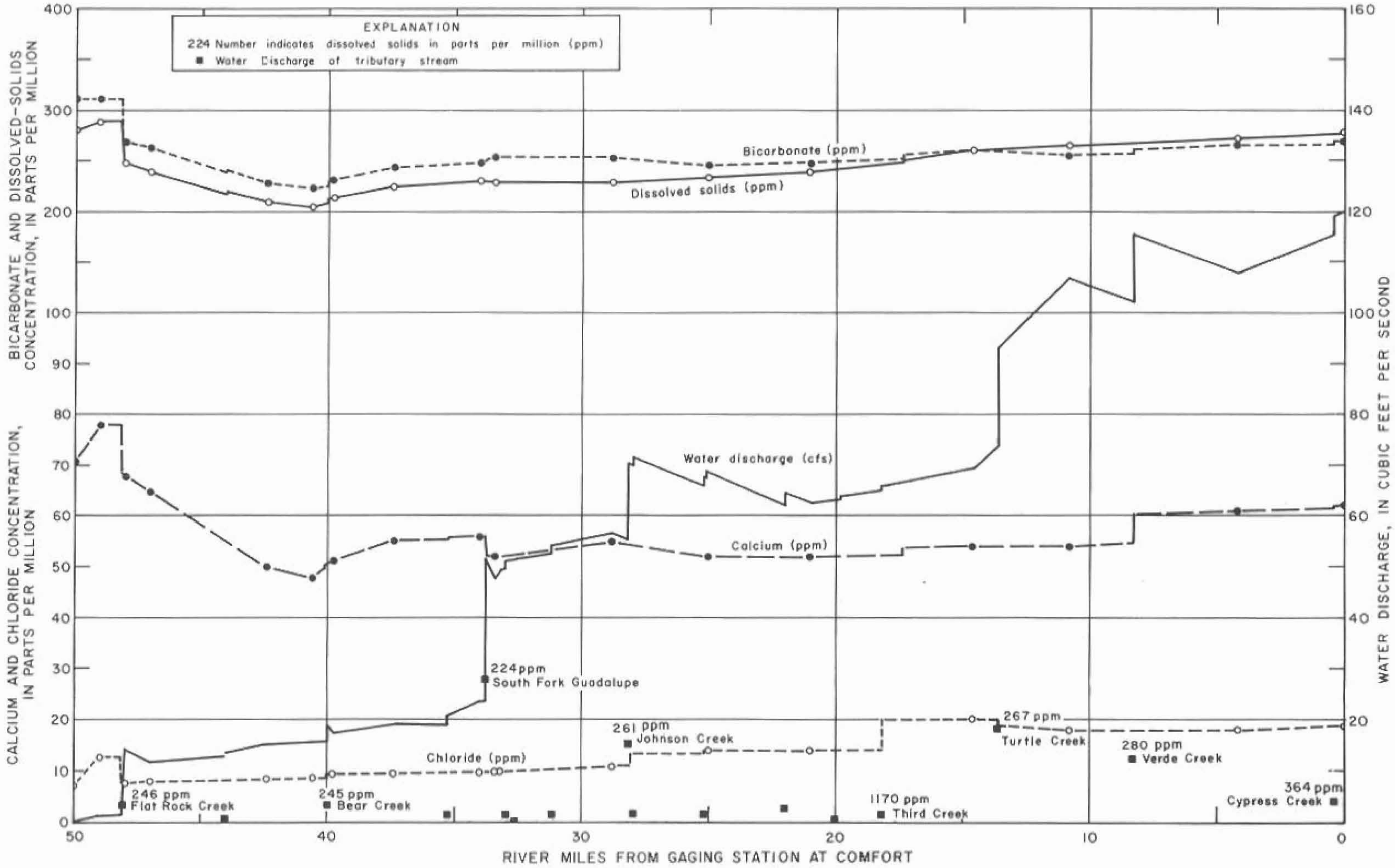

Figure 7

Profiles of Chemical Character and Water Discharge in the Upper Guadalupe River

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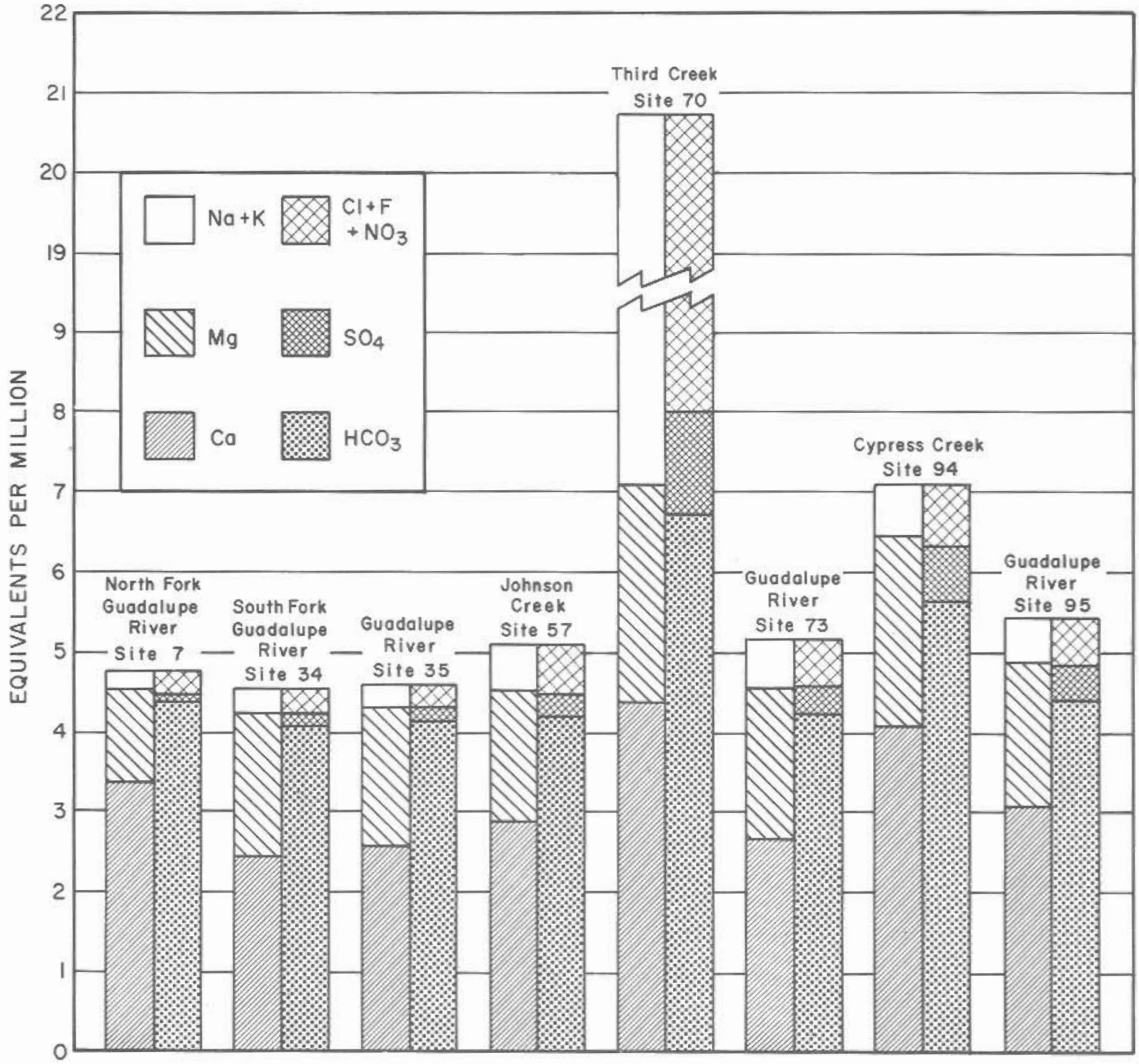

Figure 8

Chemical Quality of the Upper Guadalupe River and Tributaries

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known as Boneyard Water Hole (site 4), was estimated to be 0.01 cfs. Flow increased slightly to an estimated 0.14 cfs at mile 49.0 (site 5). From sites 1 to 5 the Edwards and associated limestones are moderately dissected and consist of thin- to flaggy-bedded dolomitic limestone containing nodular chert beds.

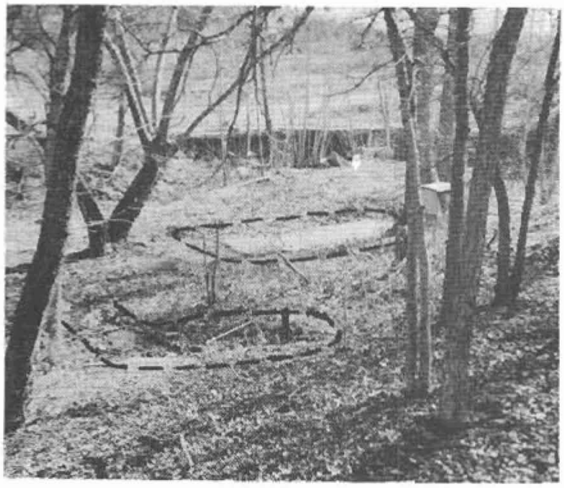
From mile 49.0 (site 5) to mile 48.0 (site 7) streamflow increased from 0.14 cfs to 14.2 cfs, of which 3.99 cfs is from Flat Rock Creek at mile 48.1 (site 6). The remainder of the increase is attributed to seeps and springs along the main channel where the Edwards and associated limestones in the reach is thinly bedded, fossiliferous, and fractured. Differential solutioning causes the cavernous and honeycomb-like weathering. Numerous springs, seeps, and some potholes were observed (Figures 6 and 9). The flow of some of these springs diminished immediately downstream. For example, a loss of about two cfs was recorded between mile 48.0 (site 7) and mile 47.0 (site 8). Intermittent losses of flow may be attributed to underflow in the channel.

From mile 47.0 (site 8) downstream to mile 34.0 (site 18) near the mouth of the North Fork Guadalupe River, streamflow increased from 11.9 cfs to 24.8 cfs. Tributary inflow with sources in the Edwards and associated limestones accounted for 5.5 cfs (or about 43 percent) of the 12.9 cfs increase. The other 7.4 cfs (57 percent) is attributed to direct channel effluent. At mile 40.6 (site 11), the base of the Comanche Peak Limestone (also the base of the Edwards and associated limestones) was noted, the top being exposed near site 10. The Comanche Peak Limestone is a nodular, marly, porous formation--whereas the uppermost beds of the upper member of the Glen Rose Limestone consist of thinly bedded limestone, shale, and dolomite, which tend to restrict the absorption and movement of water. The change in lithology results in numerous seeps and springs (Figure 6) above the contact between the Comanche Peak and the Glen Rose Limestones. The seeps and springs, in turn, account for the direct channel pickup of the remaining 57 percent of the increase in flow at mile 34.0 (site 18).

Calcium content decreased from 68 ppm (parts per million) at mile 48.0 (site 7) to 48 ppm at mile 40.6 (site 11). Bicarbonate content also decreased from 268 ppm at mile 48.0 (site 7) to 224 ppm at mile 40.6 (site 11). Moreover, a corresponding decrease in total dissolved solids from 248 ppm to 205 ppm occurred at these sites,. A higher concentration of minerals in the ground-water effluent and tributary inflow of 3.02 cfs from Bear Creek and 1.55 cfs from Honey Creek resulted in an increase to 230 ppm dissolved solids at mile 34.0 (site 18).

South Fork Guadalupe River--Miles T-14.9 to T-0.0 (Sites 19 to 34)

The drainage area of the South Fork Guadalupe River is similar in topography and lithology to that of the North Fork Guadalupe River (Figure 2). From miles T-14.9 (site 19) to T-0.3 (site 34), flow increased from an estimated 0.2 cfs to 27.9 cfs. Flow, estimated downstream from a ponded area at mile T-14.9 (site 19), was intermittent in the alluvial channel underlain by the permeable Edwards and associated limestones to mile 11.6 (site 24). At site 24, at the Lynxhaven resort area, a flow of 10.1 cfs was measured downstream from a large pool (Figure 6), which inundates the uppermost permanent springs on the South Fork Guadalupe River. The dissolved-solids content of the water at mile T-11.6 (site 24) was 279 ppm. The spring flow is from large fractures penetrating permeable beds of the Edwards and associated limestones.



A. Springs at sinkhole near Hunt used for domestic purposes

B. Sinkhole in unnamed tributary near Kerr Wildlife Management Area

C. Uppermost perennial spring area (Boneyard Water Hole) on North Fork Guadalupe River (site 4)

Figure 9

Few of Many Sinkholes in the Edwards and Associated Limestones in the Upper Reaches

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According to the proprietor of Lynxhaven, these springs have not ceased flowing during the last 46 years. Spring flow has varied from a trickle during the summer of 1956 to approximately three times the 10.1 cfs measured March 15, 1965. No evidence of faulting was noted at this location.

From mile T-11.6 (site 24) downstream to mile T-0.3 (site 34) near the mouth of the South Fork Guadalupe River, streamflow increased to 27.9 cfs. Tributary inflow accounted for approximately 6 cfs, while direct channel gains from springs in the bedrock and the alluvium downstream from mile T-11.6 (site 24) contributed the remaining 12 cfs. The contact between the Comanche Peak Limestone and the upper member of the Glen Rose Limestone may be observed at mile T-6.2 (site 30). The Edwards and associated limestones, as in the North Fork Guadalupe, was the predominant contributor of ground-water effluent to the South Fork Guadalupe River.

Dissolved-solids concentrations of the water were only 210 ppm at mile T-5.7 (site 31), but were 224 ppm at mile T-0.3 (site 34). The patterns of the dissolved constituents in both the North and South Forks Guadalupe River were found to be similar (as shown by the bar graph in Figure 8).

Guadalupe River--Miles 34.0 to 28.8 (Sites 18 to 41)

During the night of March 16, 1965, the study was interrupted at mile 31.2 (site 40) by a rainfall averaging about 1.2 inches throughout the drainage area. The investigation was continued on March 24, 1965, after the normal low-flow recession had resumed. Hydrographs for the stream-gaging stations at Johnson Creek near Ingram and the Guadalupe River at Comfort (Figure 1) illustrate the effect of the rainfall on the streamflow.

From the junction of the North and South Forks Guadalupe River near Hunt, mile 33.4 (site 35) to mile 28.8 (site 41), the river channel is cut in the upper member of the Glen Rose Limestone, which underlies the alluvial deposits throughout this reach.

On March 24 measurements of the streamflow between mile 34.0 (site 18) and mile 31.2 (site 40) were repeated and water samples for chemical analyses again were collected. The resulting records are similar to those made before the rain (Tables 1 and 2), and only the March 24 investigation is discussed here.

Below the confluence of the North and South Forks Guadalupe River at mile 33.4 (site 35), the streamflow was 47.9 cfs. The combined flow of the two forks at sites 18 and 34 on March 24 totaled 51.5 cfs--indicating a net loss of 3.6 cfs at site 35. The loss in flow may be attributed to underflow in the alluvium. The flow increased to 56.8 cfs between mile 33.4 (site 35) and mile 28.8 (site 41), immediately upstream from the mouth of Johnson Creek. Of the total 8.9 cfs increase, 2.8 cfs was tributary inflow from Tegener and Kelly Creeks. The remaining 6.1 cfs probably was underflow in the alluvium in the vicinity of mile 33.4 (site 35).

The chemical quality of the water analyzed at mile 33.4 (site 35) and at mile 28.8 (site 41) was almost identical. The results of analyses of water from the different aquifers are similar.

Johnson Creek Tributary to the Guadalupe River--Miles T-19.4 to T-0.4 (Sites 42 to 57)

The entire reach of Johnson Creek, between mile T-19.4 (site 42) and mile T-0.4 (site 57), was investigated prior to the March 16 rainfall. The investigation was repeated at site 57 on March 24, however, for comparison with the results from the March 16 study. The discharge measurements and the analyses compared favorably. The hydrograph for the stream-gaging station at Johnson Creek near Ingram (Figure 1) also shows the close agreement of the results of the two investigations.

From mile T-19.4 (site 42) downstream to mile T-0.4 (site 57), streamflow increased from 0 to 15.1 cfs. The basin characteristics are similar to those in the North and South Forks Guadalupe River.

At mile T-19.4 (site 42) a pond was formed by local runoff and slight seepage from the caprock of the Edwards and associated limestones, but the channel between mile T-19.4 (site 42) and mile T-13.6 (site 43) was dry. The initial flow was estimated to be 0.07 cfs at mile T-13.6 below a pond originating from small seeps. This flow moved as underflow through the gravel channel deposit and then reappeared as surface flow approximately 0.1 mile downstream.

At mile T-11.6 (site 45) the streamflow was 0.79 cfs in Johnson Creek. In the next 2.0 miles downstream to mile T-10.6 (site 48), tributary inflow totaled 3.92 cfs. At mile T-10.5 (site 49), flow in Johnson Creek abruptly increased to 10.9 cfs. The increase in streamflow coincided with the Comanche Peak-upper member of the Glen Rose Limestone contact, although the contact was obscured by alluvial gravel deposits. Tributary inflow accounted for about 4.2 cfs of the 6.8 cfs increase in flow from mile T-10.5 (site 49) to mile T-0.4 (site 57). The remaining 2.6 cfs increase was attributed to direct channel gains.

Chemical analyses indicate that the water in Johnson Creek and its tributaries is similar to that in the North and South Forks Guadalupe River. Dissolved-solids concentration of the water from Fessenden Creek (site 48) and from near the mouth of Johnson Creek (site 57) are 269 and 265 ppm, respectively.

Guadalupe River--Miles 28.8 to 14.6 (Sites 41 to 73)

The streamflow increased from 56.8 cfs at mile 28.8 (site 41) to 79.4 cfs at mile 14.6 (site 73), but streamflow diminished in two short reaches ending at mile 25.0 (site 61) and at mile 21.0 (site 64).

The streamflow at mile 25.0 (site 61) was 68.6 cfs. The total inflow, however, from all tributaries at the junction of Johnson Creek and the Guadalupe River near site 41 is about 76.6 cfs (15.1 cfs from Johnson Creek, 1.88 cfs from Indian Creek, 1.67 cfs from Goat Creek, 1.11 cfs from Bear Creek, and 56.8 cfs from the Guadalupe River at site 41). Therefore, a net loss of 8.0 cfs in the channel upstream from site 61 is indicated. The streamflow at site 64 was only 62.8 cfs, but tributary inflow between miles 25.0 (site 61) and 21.0 (site 64) totaled 2.5 cfs and the total loss of streamflow in the reach was 8.3 cfs. Thus, a total net loss of 16.3 cfs is indicated between miles

28.8 (site 41) and 21.0 (site 64), a channel-loss rate of 2.09 cfs per mile. The channel loss was to the permeable dolomitic limestone bed of the upper member of the Glen Rose Limestone. This bed is partially exposed and underlies the alluvial channel gravels found in this reach (Figure 10). Moreover, a small reservoir behind a low-head dam at Kerrville tends to increase the hydrostatic head upon the underlying vuggy limestone and accelerate the movement of water through the limestone. The irrigation and municipal pumps adjacent to the reservoir were not in operation during the investigation.

Inflow of the more highly mineralized water from Johnson Creek raised the dissolved solids slightly to 234 ppm at mile 25.0 (site 61).

From mile 21.0 (site 64) to mile 14.6 (site 73), the flow increased from 62.8 to 79.4 cfs. Of the 16.6 cfs (or 26 percent) increase in flow, only 2.8 cfs (or 4 percent) was tributary inflow; therefore, the channel gained in this reach nearly as much as it lost between site 41 and site 64.

The noticeable reduction in tributary inflow between sites 64 and 73 probably is due to the increased width of the alluvium across which the tributaries meander. The reduced gradient and thicker alluvial cover (Figure 3C and D) result in the loss of flow in many smaller tributaries crossing the alluvium.

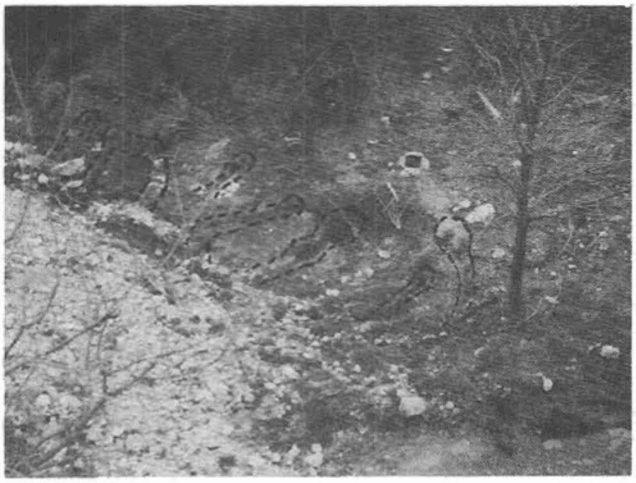
The largest inflow observed in the tributaries was 1.18 cfs in Third Creek at mile 18.2 (site 70), where the field conductance was 2,700 micromhos, or approximately 4 times that observed at any other site. The investigation revealed some of the sources of the contaminated water. The creek flow originated as seeps from the base of the Edwards and associated limestones, and increased as it traversed the cultivated alluvial valley northeast of the town of Legion--where a hospital water-treatment plant regenerated an ion-exchange demineralizer at intervals of two to three days. During the regeneration cycle of about 1.5 hours, an average of 15,000 gallons of highly mineralized water was discharged directly into Third Creek. The investigation was made between regeneration cycles when the water was of better quality. The analysis of water from near the mouth of Third Creek (Figure 3B) showed the dissolved-solids concentration to be 1,170 ppm. The more concentrated mineral constituents of the water were sodium, chloride, and nitrate (Figure 8). The nitrate may have entered the stream through seeps along the channel. The source of the nitrate was a sewage-evaporite basin used to irrigate cropland in the area. The reach of Third Creek upstream from the sewage-evaporite basin and the water-treatment plant contained water of much better quality, similar to that observed in the rest of the study area.

Contaminated inflow from Third Creek increased the dissolved-solids concentration of the water in the Guadalupe River at mile 14.6 (site 73) to 262 ppm. A marked increase in sodium and chloride was found. No contamination was noted at site 73, as the investigation was made between regeneration cycles. A slug of contaminated water may appear in the main channel at site 73 during periods of regeneration discharge.

Guadalupe River--Miles 14.6 to 0.0 (Sites 73 to 95)

Downstream from mile 14.6 (site 73) to mile 4.2 (site 89) only the larger tributaries, Turtle Creek and Verde Creek, contributed significant inflow.

A. and B. The Guadalupe River channel at Kerrville, below dam (site 64). The channel bed is composed of extensively honeycombed dolomitic limestone beds in the upper member, Glen Rose Limestone. These porous and permeable beds facilitate considerable streamflow loss.



C. Springs flowing from base of alluvial terrace deposits adjacent to Silver Creek (site 72)

Figure 10

Interchange Between Ground Water and Surface Water Adjacent to the Guadalupe River Channel and Tributaries

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

These two tributaries have a relatively extensive drainage area originating along the southern divide of the upper Guadalupe River basin where the source of the low flow is the Edwards and associated limestones. The intermittent flow fluctuates with the seasons. Smaller tributaries heading in the upper member of the Glen Rose Limestone generally are dry except for periods of local runoff. The small seepage derived from the upper member of the Glen Rose Limestone becomes underflow in the alluvium at the base of the valley walls.

In the Guadalupe River, the streamflow increased from 79.4 cfs at mile 14.6 (site 73) to 107 cfs at mile 10.8 (site 79). Of this 27.6 cfs gain, 18.7 cfs was from Turtle Creek and the remaining 8.9 cfs was direct channel gain. The rate of inflow to the channel between miles 14.6 and 10.8 was 2.34 cfs per channel mile. The sources of the flow were the lower gypsum and anhydrite bed in the upper member of the Glen Rose Limestone and the alluvium.

From mile 10.8 (site 79) to mile 4.2 (site 89) a gain of only 1.0 cfs in total channel flow was noted. The tributary inflow was 13.0 cfs; therefore, the net loss in the channel reach was 12.0 cfs. The average channel loss of 1.82 cfs per mile probably was to the uppermost beds of the lower member of the Glen Rose Limestone.

In the vicinity of mile 4.2 (site 89), water from the lower gypsum bed imparts a slightly higher sulfate content to the water in the stream.

According to the chemical analyses (Table 2), the dissolved solids of the water increased from 262 ppm at mile 14.6 (site 73) to 272 ppm at mile 4.2 (site 89). The increase in the mineral content of the water resulted from the inflow of the more highly mineralized water from Turtle and Verde Creeks, and from the alluvium.

Between mile 4.2 (site 89) and the stream-gaging station at Comfort, mile 0.0 (site 95), tributary inflow was 4.03 cfs--all of it from Cypress Creek.

The headwaters of Cypress Creek are along the northern margin of the Guadalupe River basin and, like those of Verde and Turtle Creeks, derive their initial flow from seeps and springs near the base of the Edwards and associated limestones. Some water is also derived from the lower gypsum bed of the upper member of the Glen Rose Limestone. The most noteworthy springs discharging from the upper member were observed near mile T-7.0 on Cypress Creek; however, the total spring flow was less than 1.0 cfs. According to the owner, Mr. Saur, these springs are a fairly permanent supply for the water hole in Cypress Creek, on his ranch. The slightly higher chloride and sulfate content found at mile T-1.1 (site 94) is due to leaching of the gypsum bed (in the upper member of the Glen Rose Limestone), which is crossed here by Cypress Creek and its tributaries.

At the Comfort stream-gaging station at mile 0.0 (site 95), the flow was 120 cfs, indicating a gain of 12 cfs in the downstream 4.2 miles of the reach investigated. Gain in this reach accounts for most of the loss between mile 10.8 (site 79) and mile 4.2 (site 89). Considering return channel flow and tributary inflow, from mile 10.8 (site 79) to mile 0 (site 95), there was a 4.0 cfs net loss in the two subreaches. Results of the investigation show an overall net loss of streamflow to the aquifers in the Glen Rose Limestone.

Dissolved-solids concentration increased to 279 ppm at the lower limit of the study. Part of this increase was derived from the more highly mineralized inflow from Cypress Creek.

RELATION OF QUALITY OF WATER TO USE

Standards generally quoted in evaluating the quality and safety of water supplies for domestic and municipal uses are listed in the U.S. Public Health Service Drinking Water Standards (1962, p. 34). These standards recommend that chloride or sulfate concentrations do not exceed 250 ppm and that dissolved solids do not exceed 500 ppm. With exception of the water analysis from Third Creek near Legion (Figure 3C), the streamflow sampled in the upper Guadalupe drainage area did not exceed these limits. The water is very hard and, although generally within the limits set by the drinking water standards, probably should be softened for domestic and municipal uses.

The quality requirements of water for industrial purposes differ widely with each industry. For example, water of high-chloride content may be associated with the corrosive property of water. Hardness is objectionable because the resulting scale formed in boilers, pipes, water heaters, and radiators reduces their efficiency.

Calcium carbonate sometimes forms protective coatings on pipe and other equipment, thus reducing corrosion. On the other hand, water high in silica is undesirable for use as boiler feed. Waters of the upper Guadalupe drainage area--with the exception of that in Third Creek near Legion--are of low chloride, sulfate, and silica content, and should be suitable for use by many industries. Nevertheless, all the waters generally are very hard and probably should be softened for industrial purposes.

Because agriculture is the dominant factor in the study area's economy, it is important that its waters be suitable for irrigation. According to the U.S. Salinity Laboratory Staff (1954, p. 69), the most important characteristics in determining the quality of irrigation water are: (1) total concentration of soluble salts; (2) relative proportion of sodium to other cations; and, (3) under some conditions, the bicarbonate concentration as related to the concentration of calcium plus magnesium. Chemical analyses of the study area's water show that it is of medium salinity and low sodium content (except that in Third Creek near Legion). Most of the water is high in bicarbonate, but the high-calcium plus magnesium concentration, as compared with the low-sodium concentration, reduces the alkalinity hazard. Water throughout the upper Guadalupe River drainage area generally is satisfactory for irrigation.

Recreation also plays an important role in the area. Typical water for recreation should be free not only of offensive odors and tastes, but also of floating or suspended substances and any other substance toxic on ingestion or irritating to the skin. All water in the report area, except in Third Creek near the town of Legion, is highly satisfactory for water recreation.

The highest dissolved-solids concentrations in a stream usually occur during periods of low flow when all flow in the stream is ground-water effluent. Ground water generally contains more dissolved solids than does surface runoff, because ground water has been in contact with the rocks for a much longer time. Therefore, probably the maximum concentrations of dissolved solids were observed during this study. Lower concentrations may be expected during periods of surface runoff.

SUMMARY AND CONCLUSIONS

The upper Guadalupe River generally gained flow in the study area. Streamflow increased from about 0.01 cfs at the initial measuring site on the North Fork Guadalupe River, to 120 cfs at the stream-gaging station on the Guadalupe River at Comfort. Many localized channel gains and losses occurred throughout the entire study reach. These have been explained by the different water-bearing qualities of the aquifer or water-bearing rocks traversed by the Guadalupe River and its tributaries. The Edwards and associated limestones contributed about 90 percent of the total 120 cfs measured at the lower limit of the investigated reach. Only a small amount, 10 percent or less, was contributed by the Glen Rose Limestone. Results of the investigation show, moreover, that streamflow is effluent in some channel areas and flow is lost to aquifers in the Glen Rose Limestone in others. Base-flow accretion for the study area averaged about 2.2 cfs per mile of main channel for the continuous water-table elevations and climatic conditions prevailing. Another set of conditions would give different results.

Water throughout the study area was of calcium and magnesium bicarbonate composition, typical of water draining from a limestone terrain. Inflow of more highly mineralized water from five creeks--Johnson, Third, Turtle, Verde, and Cypress--was largely responsible for the progressive downstream increase from 230 ppm to 279 ppm dissolved-solids concentrations in the Guadalupe River.

With the exception of Third Creek near Legion, the water of the upper Guadalupe River and its tributaries meets the chemical requirements of the U.S. Public Health Service Drinking Water Standards (1962, p. 34). The water is very hard, however, and may require softening for domestic, municipal, and industrial uses.

According to standards for irrigation set by the U.S. Salinity Laboratory Staff, the water of the Guadalupe River (except from Third Creek) is classified as having medium salinity and low sodium hazard. In the report area, where the average annual rainfall is about 30 inches, the water is satisfactory for irrigation. Water in the Guadalupe River drainage area is satisfactory for recreation use.

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Table 1.--Summary of water discharge measurements

(All tributaries were inspected; those not listed in this table were dry.)

Site no.	Date	Stream	Location	River mile	Water temp. (°F)	Discharge in cfs Main stream	Discharge in cfs Tributary	Remarks
		Sites 1 through 18 are on the North Fork Guadalupe River and its tributaries.						
	1965 Mar.							
1	15	North Fork Guadalupe River	At county road low-water crossing, 4.0 miles west of headquarters of Kerr Wildlife Management Area and 14 miles west of Hunt, Tex.	54.0	--	Dry	--	Channel bed is composed of boulders and gravel in an outcrop area of the Edwards and associated limestones.
2	15	Boneyard Draw	At mouth, 3.0 miles west of headquarters of Kerr Wildlife Management Area.	52.4	--	--	Dry	Do.
3	15	Indian Creek	At mouth, 2.7 miles west of headquarters of Kerr Wildlife Management Area.	52.0	--	--	Dry	Do.
4	15	North Fork Guadalupe River	0.1 mile below county road low-water crossing, 1.8 miles west of headquarters of Kerr Wildlife Management Area.	50.0	70	a.01	--	A ponded area in the channel known as "Boneyard Water Hole" is the uppermost point of base flow on the North Fork Guadalupe River.
5	15	do	0.5 mile upstream from Flat Rock Creek, 0.7 mile west of headquarters of Kerr Wildlife Management Area.	49.0	74	a/ .14	--	Riffles in channel are formed by transverse limestone ledges.
6	15	Flat Rock Creek	At county road low-water crossing, 0.8 mile southwest of headquarters of Kerr Wildlife Management Area.	48.1	70	--	3.99	Channel bed is composed of gravel, boulders, and limestone ledges; seeps occur along bedding planes.
7	15	North Fork Guadalupe River	At Farm Road 1340 low-water crossing, 0.1 mile east of headquarters of Kerr Wildlife Management Area.	48.0	70	14.2	--	Channel bed is composed of Edwards and associated limestones which form ledges.
8	15	do	At Farm Road 1340 low-water crossing, 1.1 miles east of headquarters of Kerr Wildlife Management Area.	47.0	74	11.9	--	Do.
9	15	Bee Caves Creek	At mouth, 2.9 miles east of headquarters of Kerr Wildlife Management Area.	44.0	70	--	.70	Channel bed is composed of silt, boulders, and gravel underlain by the Edwards and associated limestones.
10	15	North Fork Guadalupe River	At Farm Road 1340 low-water crossing, 3.7 miles east of headquarters of Kerr Wildlife Management Area.	42.4	68	15.1	--	Channel bed and banks formed by Edwards and associated limestones which form ledges.
11	16	do	At Farm Road 1340 low-water crossing, 5.3 miles east of headquarters of Kerr Wildlife Management Area.	40.6	66	15.8	--	Channel bed is composed of boulders and gravels. Numerous seeps and springs occur along the Comanche Peak-upper Glen Rose Limestone contact which is exposed in the channel.
12	16	Bear Creek	At mouth, 5.5 miles east of headquarters of Kerr Wildlife Management Area.	40.0	65	--	3.02	Do.

a/ Estimated.

Table 1.--Summary of water discharge measurements--Continued

(All tributaries were inspected; those not listed in this table were dry.)

Site no.	Date	Stream	Location	River mile	Water temp. (°F)	Discharge in cfs Main stream	Discharge in cfs Tributary	Remarks
	1965 Mar.							
13	16	North Fork Guadalupe River	0.3 mile below Farm Road 1340 low-water crossing, 5.9 miles east of headquarters of Kerr Wildlife Management Area.	39.8	68	17.7	--	Channel bed is composed of boulders and gravels. Numerous seeps and springs occur along the Comanche Peak-upper Glen Rose Limestone contact which is exposed in the channel.
14	16	North Fork Guadalupe River tributary	At Farm Road 1340 low-water crossing, 5.8 miles east of headquarters of Kerr Wildlife Management Area.	39.7	70	--	[a] 0.04	Channel bed is composed of boulders, sand, and silt. Source of base flow is seeps and springs at base of Comanche Peak Limestone.
15	16	North Fork Guadalupe River	At Farm Road 1340 low-water crossing, 2.2 miles west of Hunt.	37.4	67	19.3	--	Channel bed is composed of gravel and boulders. Water source is from base of Comanche Peak Limestone.
16	16	North Fork Guadalupe River tributary	At county road crossing, 0.4 mile above mouth, 1.5 miles northwest of Hunt.	35.4	64	--	[a] .18	Do.
17	16	Honey Creek	0.2 mile above mouth, 1.4 miles northwest of Hunt.	35.3	65	--	1.55	Do.
18	16	North Fork Guadalupe River	0.3 mile above confluence with South Fork Guadalupe River at Hunt.	34.0	66	24.8	--	Do.
18	24	do	do	34.0	59	23.6	--	Do. (Overlap measurement made at this site for downstream continuation of investigation.)
		Sites 19 through 34 are on the South Fork Guadalupe River and its tributaries.						
19	15	South Fork Guadalupe River	0.4 mile upstream from Mullen Creek, 2.0 miles southwest of Lynxhaven resort.	[1] 14.9	--	[a] .20	--	Channel bed is composed of limestone ledges formed by Edwards and associated limestones. Ponded area in channel is uppermost point of base flow in South Fork Guadalupe River.
20	15	Mullen Creek	At mouth, 1.7 miles southwest of Lynxhaven resort.	[1] 14.4	69	--	[a] .40	Source of base flow is from porous zone in the Edwards and associated limestones.
21	15	South Fork Guadalupe River	300 ft downstream from Mullen Creek, 1.6 miles southwest of Lynxhaven resort.	[1] 14.2	74	.75	--	Do.
22	15	do	At State Highway 39 low-water crossing, 1.3 miles southwest of Lynxhaven resort.	[1] 14.0	69	.73	--	Do.
23	15	do	At State Highway 39 low-water crossing, 0.5 mile southwest of Lynxhaven resort.	[1] 12.6	--	Dry	--	Channel bed is composed of boulders, gravel, and porous limestone. About 0.2 mile above site, all flow is lost to alluvium and porous, fractured, chalky limestone. Channel remained dry for approximately 0.6 mile downstream.

[a] Estimated.
[1] Tributary miles.

Table 1.--Summary of water discharge measurements--Continued

(All tributaries were inspected; those not listed in this table were dry.)

Site no.	Date	Stream	Location	River mile	Water temp. (°F)	Discharge in cfs Main stream	Discharge in cfs Tributary	Remarks
	1965 Mar.							
24	15	South Fork Guadalupe River	At State Highway 39 low-water crossing, 0.1 mile southeast of Lynxhaven resort.	[T]11.6	68	10.1	--	Channel bed and banks are formed by limestone ledges and alluvium. This point is uppermost permanent springs on the South Fork Guadalupe River. Source of base flow is fractures in chalky beds in the Edwards and associated limestones. Historic information since 1919 indicates that springs have never been dry.
25	16	Frank Baker and Spur Branch Creeks	At mouth, 1.5 miles east of Lynxhaven resort.	[T]10.0	60	--	0.61	Channel bed formed by gravel and limestone ledges of Edwards and associated limestones.
26	16	South Fork Guadalupe River	At private road crossing, 2.3 miles east of Lynxhaven resort.	[T] 8.2	67	10.9	--	Do.
27	16	Indian Creek	At mouth, 2.4 miles northeast of Lynxhaven resort.	[T] 8.7	60	--	[a] .05	Gravel and sand channel bed.
28	16	South Fork Guadalupe River	0.3 mile below private low-water crossing, 3.6 miles northeast of Lynxhaven resort.	[T] 7.6	68	11.6	--	Channel bed composed of cemented sand and gravel ("mortar beds") with alluvium. Site is approximately 300 ft downstream from Comanche Peak-upper Glen Rose Limestone contact.
29	16	Buffalo Creek	0.1 mile above mouth, 3.8 miles east of Lynxhaven resort.	[T] 7.0	66	--	1.26	Limestone ledges in channel bed. Spring source is Comanche Peak-upper Glen Rose Limestone contact about 40 ft above channel bed.
30	16	Panther Creek	At mouth, 4.2 miles northeast of Lynxhaven resort.	[T] 6.2	65	--	.35	Channel bed is gravel and boulders and about 30 ft below base of Comanche Peak Limestone.
31	16	South Fork Guadalupe River	At Camp Mystic dam at State Highway 39 low-water crossing, 4.8 miles southwest of Hunt.	[T] 5.7	67	13.4	--	Channel bed is limestone, shale, and sandstone beds of the upper Glen Rose Limestone.
32	16	Cypress Creek	At Camp Mystic low-water crossing near mouth, 4.8 miles southwest of Hunt.	[T] 5.2	65	--	3.57	Gravel and boulders in channel bed overlying upper Glen Rose Limestone.
33	16	South Fork Guadalupe River	At private low-water crossing to YMCA Boys Camp, 2.4 miles southwest of Hunt.	[T] 2.7	67	18.3	--	Channel bed is composed of upper Glen Rose Limestone beds and "mortar bed." Tributaries between sites 32 and 34 lose flow to alluvial terrace deposits, therefore gain is due to pickup of underflow.
34	24	do	At junction of State Highway 39 and Farm Road 1340 at Hunt, 0.3 mile above confluence with North Fork Guadalupe River.	[T] .3	60	27.9	--	Do.

[a] Estimated.
[T] Tributary miles.

Table 1.--Summary of water discharge measurements--Continued

(All tributaries were inspected; those not listed in this table were dry.)

Site no.	Date	Stream	Location	River mile	Water temp. (°F)	Discharge in cfs Main stream	Tributary	Remarks
		Sites 35 through 41 are on the main stem of the Guadalupe River and its tributaries.						
	1965 Mar.							
35	16	Guadalupe River	200 ft below junction of North and South Forks of Guadalupe River, at Hunt.	33.4	66	49.1	--	Alluvial channel overlying upper Glen Rose Limestone.
35	24	do	do	33.4	60	47.9	--	Do. (Overlap measurement made at this site for downstream continuation of investigation.)
36	16	do	At stream-gaging station 8-1655 at bridge on State Highway 39, 0.7 mile east of Hunt.	33.2	68	47.0	--	Alluvial channel overlying upper Glen Rose Limestone.
36	24	do	do	33.2	61	49.7	--	Do. (Overlap measurement made at this site for downstream continuation of investigation.)
37	16	Tegener Creek	At county road crossing, 0.4 mile above mouth, 0.9 mile east of Hunt.	33.0	68	--	1.40	Alluvial channel bed, walls are upper Glen Rose Limestone.
37	24	do	do	33.0	59	--	1.18	Do. (Overlap measurement made at this site for downstream continuation of investigation.)
38	16	Ox Hollow	At mouth, 1.4 miles east of Hunt.	32.6	67	--	a/ .43	Alluvial channel bed, walls are upper Glen Rose Limestone.
38	24	do	do	32.6	61	--	.33	Do. (Overlap measurement made at this site for downstream continuation of investigation.)
39	16	Guadalupe River tributary	At State Highway 39 bridge, 1.9 miles east of Hunt.	31.8	68	--	a/ .22	Channel bed composed of boulders, gravel, and silt overlain by upper Glen Rose Limestone.
39	24	do	do	31.8	62	--	a/ .10	Do. (Overlap measurement made at this site for downstream continuation of investigation.)
40	16	Kelley Creek	At mouth, 2.7 miles east of Hunt.	31.2	67	--	2.03	Channel bed composed of gravel and sand underlain by upper Glen Rose Limestone.
40	24	do	do	31.2	59	--	1.62	Do. (Overlap measurement made at this site for downstream continuation of investigation.)
41	24	Guadalupe River	At county road low-water crossing below New Lake Ingram dam, 0.7 mile west of Ingram.	28.8	60	56.8	--	Channel bed and banks formed by limestone ledges of upper Glen Rose Limestone.

a/ Estimated.

Table 1.--Summary of water discharge measurements--Continued

(All tributaries were inspected; those not listed in this table were dry.)

Site no.	Date	Stream	Location	River mile	Water temp. (°F)	Discharge in cfs		Remarks
						Main stream	Tribu-tary	
			Sites 42 through 57 are on Johnson Creek and its tributaries.					
	1965 Mar.							
42	15	Johnson Creek	At Sproul Ranch Road crossing, 4.9 miles northwest of Mountain Home.	1/19.4	--	0	--	Channel bed and banks composed of Edwards and associated limestones. Uppermost ponded channel area on Johnson Creek.
43	15	do	At bridge on old State Highway 41, 0.6 mile northwest of Mountain Home.	1/13.6	70	.07	--	Channel bed and banks composed of Edwards and associated limestones. Uppermost point of flow on Johnson Creek.
44	15	Johnson Creek tributary	At State Highway 27 bridge, 0.5 mile east of Mountain Home.	1/12.5	67	--	0.28	Channel bed composed of gravel and sand underlain by Edwards and associated limestones. Source of flow is bedding planes and fractures in the limestone.
45	15	Johnson Creek	1,000 ft below dam, 1.1 miles southeast of Mountain Home.	1/11.6	73	.79	--	Channel bed composed of gravel and sand underlain by Edwards and associated limestones. Source of flow is bedding planes and fractures in the limestone. Alluvium in channel bed underlain by vuggy limestone beds of the Edwards and associated limestones.
46	15	Spring Creek	At mouth, 1.2 miles southeast of Mountain Home.	1/11.4	66	--	.57	Do.
47	15	Outflow flume, State of Texas Fish Hatchery	At outlet, 1.8 miles southeast of Mountain Home.	1/10.8	64	--	.69	Channel is concrete flume which transports spring water from Edwards and associated limestones along Fessenden Creek.
48	15	Fessenden Creek	At State Highway 27 bridge, 1.8 miles southeast of Mountain Home.	1/10.6	66	--	2.66	Channel is composed of boulders, gravel, and sand underlain by Edwards and associated limestones.
49	16	Johnson Creek	At Camp Tecaboca low-water crossing, 2.2 miles southeast of Mountain Home.	1/10.5	63	10.9	--	Alluvial channel deposits overlying Comanche Peak-upper Glen Rose Limestone contact, which is main source of spring flow.
50	16	Byas Branch	At mouth, 2.7 miles southeast of Mountain Home.	1/10.1	61	--	.15	Alluvial channel bed deposits. Channel walls formed by Edwards and associated limestones, and upper Glen Rose Limestone. Seeps and springs flow from base of Comanche Peak Limestone about 20 ft above channel bed.

1/ Tributary miles.

Table 1.--Summary of water discharge measurements--Continued

(All tributaries were inspected; those not listed in this table were dry.)

Site no.	Date	Stream	Location	River mile	Water temp. (°F)	Discharge in cfs Main stream	Discharge in cfs Tributary	Remarks
	1965 Mar.							
51	16	Fall Branch	At mouth, 4.0 miles northwest of Ingram.	T/ 4.8	62	--	2.18	Alluvial channel bed deposits. Spring source is upstream at base of Comanche Peak Limestone. No seeps or springs observed in upper Glen Rose Limestone.
52	16	Johnson Creek tributary	At private road culvert, 0.1 mile above mouth, 3.7 miles northwest of Ingram.	T/ 4.1	63	--	.20	Channel bed composed of silt, sand, and gravel underlain by upper Glen Rose Limestone.
53	16	Johnson Creek	At stream-gaging station 8-1660, 3.1 miles northwest of Ingram.	T/ 3.8	66	14.6	--	Channel bed composed of boulders and gravel underlain by limestone ledges of upper Glen Rose Limestone.
54	16	Johnson Creek tributary	At mouth, 0.2 mile below gaging station, 2.9 miles northwest of Ingram.	T/ 3.4	64	--	a/ .001	Alluvial channel deposits underlain by upper Glen Rose Limestone, approximately 120 ft below base of Comanche Peak Limestone.
55	16	do	At mouth, 0.5 mile below gaging station, 2.6 miles northwest of Ingram.	T/ 3.3	63	--	a/ .08	Do.
56	16	Henderson Branch	At bridge on State Highway 27, 1.9 miles northwest of Ingram.	T/ 2.3	68	--	1.56	Alluvial channel bed deposits, underlain by upper Glen Rose Limestone.
57	16	Johnson Creek	0.4 mile above mouth, at Ingram.	T/ .4	67	17.7	--	Do.
57	24	do	do	T/ .4	59	15.1	--	Do. (Second measurement made at this site for downstream continuation of investigation.)

Sites 58 through 73 are on the main stem of the Guadalupe River and its tributaries.

Site no.	Date	Stream	Location	River mile	Water temp. (°F)	Discharge in cfs Main stream	Discharge in cfs Tributary	Remarks
58	24	Indian Creek	At bridge on county road, 0.2 mile south of Ingram.	28.0	59	--	1.88	Channel bed composed of silt and sand underlain by upper Glen Rose Limestone.
59	24	Goat Creek	At bridge, on State Highway 27 Spur, 3.0 miles east of Ingram.	25.2	59	--	1.67	Gravel and boulder channel deposits underlain by upper Glen Rose Limestone.
60	24	Bear Creek	At mouth, 3.0 miles east of Ingram.	25.1	62	--	1.11	Silt and gravel alluvium channel bed underlain by upper Glen Rose Limestone.
61	24	Guadalupe River	At low-water crossing on J. B. Ranch Road, 3.2 miles east of Ingram.	25.0	63	68.6	--	Channel bed and banks composed of upper Glen Rose Limestone ledges.
62	24	Guadalupe River tributary	At bridge on State Highway 27, 1.5 miles west of Kerrville.	24.2	55	--	a/ .07	Alluvial channel bed deposits underlain by upper Glen Rose Limestone.
63	24	Town Creek	At bridge on State Highway 27, at Kerrville.	22.0	59	--	2.43	Do.

a/ Estimated.
T/ Tributary miles.

(All tributaries were inspected; those not listed in this table were dry.)

Site no.	Date	Stream	Location	River mile	Water temp. (°F)	Discharge in cfs Main stream	Discharge in cfs Tributary	Remarks
	1965 Mar.							
64	24	Guadalupe River tributary	0.2 mile below State Highway 16 bridge and Kerrville Dam at Kerrville.	21.0	64	62.8	--	Upper Glen Rose Limestone ledges form channel bed. Walls of channel are composed of vuggy limestone beds and soft shale beds in upper Glen Rose Limestone.
65	24	Quinlan Creek	At bridge on State Highway 27, at Kerrville.	19.8	59	--	0.49	Do.
66	24	Camp Meeting Creek	At bridge on Farm Road 689, at Legion.	19.1	65	--	a/ .10	Streambed is sand underlain by upper Glen Rose Limestone.
67	25	Third Creek	At culvert on county road, 0.6 mile northeast of Legion.	T/ 2.1	54	--	.77	Alluvial channel bed and banks, and adjacent to Kerrville sewage settlings basin.
68	24	Kerrville Sewage Settling Basin	At outlet works, 0.8 mile northeast of Legion.	18.2	60	--	No flow	Underflow to alluvial area.
69	24	Second Creek	At end of private camp road, 1.4 miles east of Legion.	18.2	60	--	No flow	Pond seepage in alluvial channel.
70	24	Third Creek	At bridge on State Highway 27, 1.2 miles southeast of Legion.	18.2	60	--	1.18	Alluvial channel deposits. Creek carries hospital water treatment plant effluent at regular intervals.
71	25	Guadalupe River tributary	At bridge on State Highway 27, at Guadalupe Heights.	17.8	50	--	a/ .14	Alluvium underlain by caliche bed in upper Glen Rose Limestone.
72	24	Silver Creek	At bridge on State Highway 27, 1.3 miles south of Guadalupe Heights.	15.8	60	--	a/ .13	Do. (Fractures in upper Glen Rose Limestone provide spring outlets from overlying alluvium.)
73	25	Guadalupe River	Near county road junction, 2.6 miles south of Guadalupe Heights.	14.6	59	79.4	--	Do.
			Sites 74 through 77 are on Turtle Creek and its tributaries.					
74	24	Turtle Creek	At bridge on Farm Road 1273, 7.3 miles southwest of Kerrville.	T/11.2	63	--	4.46	Do.
75	24	do	At low-water crossing on county road, 6.3 miles south of Kerrville.	T/ 7.7	62	--	13.6	Channel bed is composed of upper Glen Rose Limestone, gravel and boulders. Some local runoff at this site.
76	24	West Creek	At bridge on Farm Road 2771, 5.7 miles south of Kerrville.	T/ 6.6	62	--	2.28	Channel bed is composed of upper Glen Rose Limestone, gravel, boulders and sand. Base flow only.
77	25	Turtle Creek	At bridge on Farm Road 689, 3.1 miles south of Guadalupe Heights.	T/ 2.0	58	--	18.7	Do.
			Sites 78 through 80 are on the main stem of the Guadalupe River and its tributaries.					
78	25	Nowlin Hollow	At bridge on State Highway 27, 2.1 miles west of Center Point.	13.5	-	--	No flow	Ponded seepage is lost to alluvium overlying upper Glen Rose Limestone.
79	25	Guadalupe River	At bridge on Farm Road 480, at Center Point.	10.8	59	107	--	Channel bed is upper Glen Rose Limestone ledges.

a/ Estimated.
T/ Tributary miles.

Table 1.--Summary of water discharge measurements--Continued

(All tributaries were inspected; those not listed in this table were dry.)

Site no.	Date	Stream	Location	River mile	Water temp. (°F)	Discharge in cfs: Main stream	Discharge in cfs: Tributary	Remarks
	1965 Mar.							
80	25	Steel Creek	At bridge on State Highway 27, at Center Point.	10.4	50	--	a/0.04	Alluvial bed and banks.
			Sites 81 through 86 are on Verde Creek and its tributaries.					
81	25	Verde Creek	At low-water crossing on county road, 8.0 miles southwest of Center Point.	T/11.2	56	--	2.09	Alluvial channel underlain by upper Glen Rose Limestone. Source of flow is from Edwards and associated limestones near headwaters of creek.
82	25	Palmer Creek	At low-water crossing on county road, 7.7 miles southwest of Center Point.	T/ 9.8	57	--	3.78	Do.
83	25	Verde Creek	At low-water crossing on Farm Road 480, 4.6 miles southwest of Center Point.	T/ 7.0	56	--	11.5	Do.
84	25	Spring Creek	At mouth, 2.7 miles southwest of Center Point.	T/ 4.2	--	--	No flow	
85	25	Elm Creek	0.8 mile above mouth, 2.1 miles southeast of Center Point.	T/ .8	--	--	a/ .10	Do.
86	25	Verde Creek	At mouth, 2.2 miles east of Center Point.	8.3	57	--	12.9	Do.
			Sites 87 through 90 are on the main stem of the Guadalupe River and its tributaries.					
87	25	Bluff Creek	At bridge on State Highway 27, 2.6 miles east of Center Point.	7.4		--	a/ .01	Ponded alluvial seepage.
88	25	Cherry Creek	0.3 mile above mouth, 4.3 miles southwest of Comfort.	5.7	53	--	a/ .10	Alluvial channel deposits underlain by upper Glen Rose Limestone.
89	25	Guadalupe River	At low-water crossing, 3.1 miles southwest of Comfort.	4.2	58	108	--	Do. Upper and lower Glen Rose Limestone contact area, indicated by lower gypsum zone of upper Glen Rose Limestone.
90	25	Bruins Creek	At mouth, 3.0 miles southwest of Comfort.	4.1	--	--	No flow	Alluvial channel underlain by lower Glen Rose Limestone.
			Sites 91 through 94 are on Cypress Creek and its tributaries.					
91	25	Cypress Creek	At bridge on Farm Road 1341, 8.3 miles northwest of Comfort.	T/10.4	53	--	.68	Alluvial channel underlain by upper Glen Rose Limestone. Source of flow is springs and seeps near base of Edwards and associated limestones near headwaters of creek.
92	25	do	Downstream from Puter Bottom Creek and adjacent to Farm Road 1341, 7.7 miles northwest of Comfort.	T/ 9.9	53	--	3.19	Upper Glen Rose Limestone, gravel and conglomerate in streambed. Upper gypsum zone of upper Glen Rose Limestone contributes some high sulfate water.

a/ Estimated.
T/ Tributary miles.

Table 1.--Summary of water discharge measurements--Continued

(All tributaries were inspected; those not listed in this table were dry.)

Site no.	Date	Stream	Location	River mile	Water temp. (°F)	Discharge in cfs		Remarks
						Main stream	Tributary	
	1965 Mar.							
93	25	Cypress Creek	At bridge on Farm Road 1341, 3.3 miles northwest of Comfort.	T/4.4	55	--	3.50	Alluvium underlain by upper Glen Rose Limestone.
94	25	do	At bridge on State Highway 27, at Comfort.	.4	55	--	4.03	Do.
95	25	Guadalupe River	At stream-gaging station 8-1670 at bridge on U. S. Highway 87, at Comfort.	0	60	120	--	Alluvial channel deposits overlying lower Glen Rose Limestone.

T Tributary miles.

Table 2.--Chemical analyses of the upper Guadalupe River and tributaries, March 15-16 and 24-25, 1965

(Results in parts per million except as indicated)

Site no.	Stream	Date (1965)	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 1/: Parts per million	Dissolved solids 1/: Tons per acre-foot	Dissolved solids 1/: 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
4	North Fork Guadalupe River	Mar. 15	a/ 0.01	--	--	--	--	--	311	--	7.3	--	--	280	0.38	0.01	240	0	--	425	6.9
5	do	do	a/ .14	--	--	--	--	--	312	--	13	--	--	290	.40	.11	262	6	--	494	7.6
6	Flat Rock Creek	do	3.99	11	64	17	4.5	0.9	265	5.2	8.1	0.1	4.8	b/ 246	.33	2.65	230	12	0.1	425	7.6
7	North Fork Guadalupe River	do	14.2	12	68	14	4.6	.9	268	4.6	7.9	.2	4.2	b/ 248	.34	9.51	227	8	.1	437	7.2
8	do	do	11.9	--	65	16	--	--	264	--	8.1	--	--	240	.33	7.71	226	10	--	400	7.6
9	Bee Caves Creek	do	.70	--	--	--	--	--	297	--	10	--	--	b/ 275	.37	.52	252	8	--	450	7.7
10	North Fork Guadalupe River	do	15.1	--	50	17	--	--	228	--	8.5	--	--	210	.29	8.56	196	9	--	377	7.5
11	do	Mar. 16	15.8	7.2	48	18	4.9	.9	224	5.6	8.7	.2	1.5	b/ 205	.28	8.75	194	10	.2	370	7.6
12	Bear Creek	do	3.02	--	--	--	--	--	224	--	11	--	--	245	.34	2.00	224	8	--	436	7.5
13	North Fork Guadalupe River	do	17.7	--	51	18	--	--	232	--	9.4	--	--	215	.29	10.3	200	10	--	387	7.4
14	Unnamed tributary to North Fork Guadalupe River	do	a/ .04	--	--	--	--	--	304	--	16	--	--	290	.39	.03	268	19	--	512	7.4
15	North Fork Guadalupe River	do	19.3	--	55	17	--	--	244	--	9.7	--	--	225	.31	11.7	208	8	--	404	7.5
16	Unnamed tributary to North Fork, Guadalupe River	do	a/ .18	--	--	--	--	--	331	--	11	--	--	305	.41	.15	280	8	--	486	7.6
17	Honey Creek	do	1.55	--	--	--	--	--	276	--	13	--	--	260	.35	1.09	238	12	--	452	7.8
18	North Fork Guadalupe River	do	24.8	--	--	--	--	--	256	--	9.8	--	--	240	.32	16.1	228	18	--	428	7.4
18	do	Mar. 24	23.6	8.1	56	18	5.6	.9	248	7.6	9.8	.2	1.5	b/ 230	.31	14.7	214	10	.2	407	7.8
20	Mullen Creek	Mar. 15	a/ .40	--	--	--	--	--	312	--	9.3	--	--	275	.38	.30	266	10	--	504	7.5
21	South Fork Guadalupe River	do	.75	--	--	--	--	--	290	--	9.3	--	--	260	.35	.53	248	10	--	480	7.5
22	do	do	.73	--	--	--	--	--	284	--	11	--	--	255	.35	.50	240	7	--	461	7.5
24	do	do	10.1	11	72	20	4.7	.8	314	4.6	8.4	.2	3.2	b/ 279	.38	7.61	262	4	.1	450	7.5
25	Frank Baker Creek	Mar. 16	.61	--	--	--	--	--	320	--	9.4	--	--	285	.39	.47	272	10	--	480	7.7
26	South Fork Guadalupe River	do	10.9	--	--	--	--	--	288	--	8.7	--	--	255	.35	7.50	242	6	--	450	7.7
27	Indian Creek	do	a/ .05	--	--	--	--	--	379	--	11	--	--	335	.46	.05	314	4	--	540	7.7
28	South Fork Guadalupe River	do	11.6	--	--	--	--	--	255	--	8.9	--	--	230	.31	7.20	216	7	--	380	7.7
29	Buffalo Creek	do	1.26	--	--	--	--	--	247	--	8.4	--	--	220	.30	.75	210	8	--	377	7.9
30	Panther Creek	do	.35	--	--	--	--	--	312	--	11	--	--	280	.38	.26	270	14	--	500	7.8
31	South Fork Guadalupe River	do	13.4	--	--	--	--	--	234	--	9.1	--	--	210	.29	7.60	200	8	--	380	7.9
32	Cypress Creek	do	3.57	--	--	--	--	--	282	--	8.5	--	--	250	.34	.24	236	5	--	444	7.8
33	South Fork Guadalupe River	do	18.3	--	--	--	--	--	252	--	9.6	--	--	225	.31	11.1	218	12	--	380	7.8
34	do	Mar. 24	27.9	5.9	49	22	5.5	.7	250	7.2	9.9	.2	.8	b/ 224	.30	16.9	213	8	.2	403	7.8
35	Guadalupe River	Mar. 16	49.1	--	--	--	--	--	258	--	11	--	--	235	.32	31.2	222	11	--	426	7.4
35	do	Mar. 24	47.9	7.0	52	21	5.4	.9	254	6.8	10	.2	1.0	b/ 229	.31	29.6	216	8	.2	410	7.9
36	do	Mar. 16	47.0	--	--	--	--	--	256	--	11	--	--	230	.32	29.2	222	12	--	422	7.5
36	do	Mar. 24	49.7	--	--	--	--	--	250	--	10	--	--	225	.31	30.2	214	9	--	393	7.8
37	Tegener Creek	Mar. 16	1.40	--	--	--	--	--	284	--	16	--	--	265	.36	1.00	248	16	--	474	8.0
37	do	Mar. 24	1.18	--	--	--	--	--	298	--	15	--	--	275	.37	.88	260	16	--	494	7.9
38	Ox Hollow	Mar. 16	a/ .43	--	--	--	--	--	376	--	18	--	--	345	.47	.40	340	32	--	613	7.6
38	do	Mar. 24	a/ .33	--	--	--	--	--	376	--	18	--	--	345	.47	.31	336	28	--	620	7.7
39	Unnamed tributary to the Guadalupe River	Mar. 16	a/ .22	--	--	--	--	--	346	--	17	--	--	315	.43	.19	312	28	--	591	7.7
39	do	Mar. 24	a/ .10	--	--	--	--	--	344	--	17	--	--	315	.43	.09	314	32	--	600	7.6
40	Kelly Creek	Mar. 16	2.03	--	--	--	--	--	318	--	15	--	--	290	.39	1.59	276	16	--	510	7.8
40	do	Mar. 24	1.62	--	--	--	--	--	326	--	14	--	--	295	.40	1.29	284	17	--	536	7.6
41	Guadalupe River	do	56.8	--	--	--	--	--	254	--	11	-	--	230	.31	35.3	228	20	--	417	7.8
43	Johnson Creek	Mar. 15	.07	--	--	--	--	--	248	--	21	--	--	250	.34	.05	216	13	--	447	7.8
44	Unnamed tributary to Johnson Creek	do	.28	--	--	--	--	--	268	--	19	--	--	265	.36	.20	230	10	--	469	7.8
45	Johnson Creek	do	.79	--	--	--	--	--	202	--	20	--	--	210	.28	.45	176	10	--	362	7.9
46	Spring Creek	do	.57	--	--	--	--	--	228	--	12	--	--	220	.30	.34	196	9	--	384	7.7

1/ Calculated from the relation of epm of bicarbonate and chloride to determined dissolved solids.
a/ Estimated.
b/ Calculated from determined constituents.

Table 2.--Chemical analyses of the upper Guadalupe River and tributaries, March 15-16 and 24-25, 1965--Continued

(Results in parts per million except as indicated)

Site no.	Stream	Date (1965)	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 1/ Parts per million	Dissolved solids 1/ Tons per acre-foot	Dissolved solids 1/ Tons per day	Hardness as $CaCO_3$ Calcium, Magnesium	Hardness as $CaCO_3$ Noncarbonate	Sodium adsorption ratio	Specific conductance (micromhos at 25°C)	pH
47	State Fish Hatchery (in flume)	Mar. 15	0.69	--	--	--	--	--	256	--	24	--	--	265	0.36	0.49	224	14	--	474	7.8
48	Fessenden Creek	do	2.66	10	58	20	16		261	9.2	24	0.3	3.2	b/ 269	.37	1.93	227	13	0.5	470	7.7
49	Johnson Creek	Mar. 16	10.9	--	--	--	--	--	244	--	22	--	--	250	.34	7.31	214	14	--	452	7.6
50	Byas Branch	do	.15	--	--	--	--	--	268	--	13	--	--	255	.34	.10	232	12	--	452	7.9
51	Fall Branch	do	2.18	--	--	--	--	--	250	--	26	--	--	260	.35	1.53	228	23	--	472	7.9
52	Unnamed tributary to Johnson Creek	do	.20	--	--	--	--	--	339	--	14	--	--	320	.44	.17	300	22	--	575	7.7
53	Johnson Creek	do	14.6	--	--	--	--	--	276	--	22	--	--	275	.38	10.8	244	18	--	465	7.8
55	Unnamed tributary to Johnson Creek	do	a/ .08	--	--	--	--	--	321	--	19	--	--	315	.43	.07	290	27	--	545	7.6
56	Henderson Branch	do	1.56	--	--	--	--	--	268	--	18	--	--	265	.36	1.12	236	16	--	466	7.8
57	Johnson Creek	do	17.7	--	--	--	--	--	264	--	22	--	--	265	.36	12.7	230	14	--	470	7.7
57	do	Mar. 24	15.1	8.6	58	20	13		257	13	21	.3	1.0	b/ 261	.35	10.6	227	16	.4	490	7.8
58	Indian Creek	do	1.88	--	--	--	--	--	281	--	16	--	--	275	.37	1.40	248	18	--	550	7.6
59	Goat Creek	do	1.67	--	--	--	--	--	272	--	22	--	--	275	.37	1.24	246	23	--	492	8.0
60	Bear Creek	do	1.11	--	--	--	--	--	267	--	19	--	--	265	.36	.79	268	49	--	501	7.6
61	Guadalupe River	do	68.6	6.8	52	21	7.5	1.1	246	10	14	.2	.5	b/ 234	.32	43.3	216	14	.2	420	7.7
62	Unnamed tributary to Guadalupe River	do	a/ .07	--	--	--	--	--	328	--	25	--	--	330	.45	.06	304	35	--	603	7.8
63	Town Creek	do	2.43	--	--	--	--	--	248	--	21	--	--	250	.34	1.64	232	29	--	470	7.5
64	Guadalupe River	do	62.8	--	--	--	--	--	248	--	14	--	--	240	.33	40.7	218	15	--	433	7.8
65	Quinlan Creek	do	.49	--	--	--	--	--	270	--	22	--	--	275	.37	.36	252	30	--	520	7.9
66	Camp Meeting Creek	do	a/ .10	--	--	--	--	--	306	--	18	--	--	300	.41	.08	280	29	--	545	7.4
67	Third Creek	Mar. 25	.77	--	--	--	--	--	312	--	24	--	--	315	.43	.65	284	28	--	581	7.8
68	Kerrville Sewage Settling Basin	Mar. 24	.00	--	--	--	--	--	422	--	121	--	72	--	--	--	284	0	--	1,210	7.0
69	Second Creek	do	.00	--	--	--	--	--	373	--	20	--	--	--	--	--	332	26	--	690	7.8
70	Third Creek	do	1.18	5.3	88	33	314		412	61	434	.8	27	b/ 1,170	1.59	3.73	355	18	7.3	2,070	7.4
71	Unnamed tributary to Guadalupe River	Mar. 25	a/ .14	--	--	--	--	--	420	--	50	--	--	450	.61	.17	438	94	--	880	7.9
72	Silver Creek	Mar. 24	a/ .13	--	--	--	--	--	358	--	20	--	--	345	.47	.12	308	14	--	700	7.7
73	Guadalupe River	Mar. 25	79.4	5.5	54	23	14		260	16	20	.3	1.2	b/ 262	.36	56.2	229	16	.4	473	7.6
74	Turtle Creek	Mar. 24	4.46	--	--	--	--	--	248	--	11	--	--	235	.32	2.83	214	11	--	410	7.7
75	do	do	13.6	--	--	--	--	--	286	--	12	--	--	270	.37	9.91	260	26	--	480	7.7
76	West Creek	do	2.28	--	--	--	--	--	315	--	21	--	--	310	.42	1.91	296	38	--	548	7.6
77	Turtle Creek	Mar. 25	18.7	6.7	62	22	6.8	1.1	260	19	14	.2	2.0	b/ 267	.36	13.5	245	24	.2	441	7.7
79	Guadalupe River	do	107	--	--	--	--	--	256	--	18	--	--	265	.36	76.6	228	18	--	465	7.9
80	Steel Creek	do	a/ .04	--	--	--	--	--	392	--	70	--	--	470	.64	.05	424	103	--	878	7.4
81	Verde Creek	do	2.09	--	--	--	--	--	296	--	13	--	--	295	.40	1.66	264	22	--	500	7.6
82	Palmer Creek	do	3.78	--	--	--	--	--	264	--	11	--	--	260	.35	2.65	236	20	--	451	7.7
83	Verde Creek	do	11.5	--	--	--	--	--	289	--	14	--	--	290	.39	9.00	260	23	--	500	7.6
86	do	do	12.9	6.7	74	18	7.0	1.0	276	21	14	.3	1.8	b/ 280	.38	9.75	258	32	.2	500	7.7
88	Cherry Creek	do	a/ .10	--	--	--	--	--	402	--	14	--	--	480	.65	.13	460	130	--	850	7.5
89	Guadalupe River	do	108	6.5	61	21	13		266	19	18	.3	1.8	b/ 272	.37	79.3	238	20	.4	467	7.8
91	Cypress Creek	do	.68	--	--	--	--	--	254	--	19	--	--	265	.36	.49	240	32	--	468	7.8
92	do	do	3.19	--	--	--	--	--	267	--	24	--	--	285	.39	2.45	254	35	--	530	7.9
93	do	do	3.5	--	--	--	--	--	280	--	26	--	--	300	.41	2.84	270	40	--	542	7.7
94	do	do	4.03	6.4	82	29	15		345	33	26	.4	1.8	b/ 364	.50	3.96	324	42	.4	600	7.5
95	Guadalupe River	do	120	6.9	62	22	13		270	20	19	.3	2.5	b/ 279	.38	90.4	245	24	.4	475	7.8

1/ Calculated from the relation of epm of bicarbonate and chloride to determined dissolved solids.
a/ Estimated.
b/ Calculated from determined constituents.