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BASE-FLOW STUDIES

CIBOLO CREEK, TEXAS

Quantity and Quality, March 5-7, 1963

By

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INTRODUCTION

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

The purpose of the investigation was to determine the gains or losses of flow in Cibolo Creek, changes in the chemical quality, and suitability for use of the water during a period when flow was sustained by sewage effluent and ground-water discharge. The reach investigated is from a point near Schertz (about 3½ miles below Selma) in Guadalupe County to the mouth of Cibolo Creek in Karnes County (Figure 1), a distance of 80 river miles.

Supporting data not given in the text, tables, and figures are available in the files of the U.S. Geological Survey in Austin, Texas.

Location and General Features

The 80-mile reach of Cibolo Creek included in this study begins at a point just upstream from Randolph Air Force Base at Schertz, Texas. The creek flows in a southeasterly direction along the Bexar and Guadalupe County line, through the eastern part of Wilson County, and then flows into the San Antonio River near Panna Maria in Karnes County. The area of the drainage basin under study is approximately 580 square miles. Tributaries that were flowing at the time of the study were an unnamed tributary entering from the right bank at mile 0.1, Martinez Creek, and Elm Creek.

The altitude is about 685 feet above msl (mean sea level) at the head of the study reach and about 225 feet above msl at the mouth. For the study reach the slope of the channel is about 5.6 feet per mile. Universal City, Randolph Air Force Base, Stockdale, and Converse are the largest towns within the drainage area.

General Geology

Rocks of Cretaceous and Tertiary age crop out in the study area. These rocks dip to the southeast and the bands formed by the dissected edges of the strata trend in a generally northeast-southwest direction. From the head of

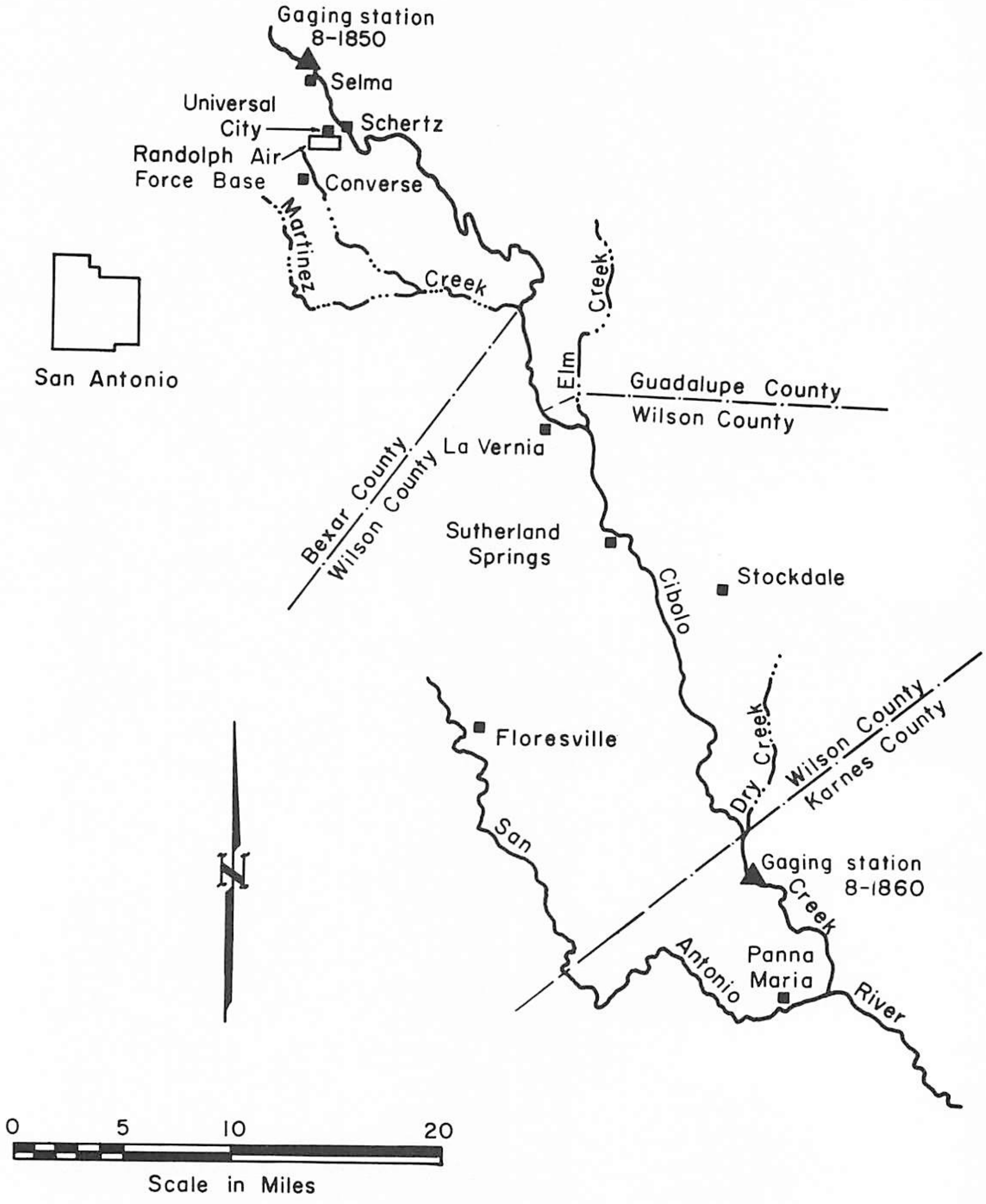

Figure 1
Map Showing Reach of Cibolo Creek Investigated in March 1963

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the study reach to the San Antonio River, Cibolo Creek successively crosses outcrops of the formations listed in Table 1, beginning with the Taylor Marl of Cretaceous age and ending with the Catahoula Tuff of Tertiary age (Plate 1). Table 1 was prepared from Anders (1957, 1960) and Arnow (1959).

RELATION OF BASE FLOW AND CHEMICAL QUALITY TO GEOLOGY

This investigation was made March 5-7, 1963, when the flow of Cibolo Creek was sustained entirely by ground water and sewage effluent. During this study, there was no flow at the gaging station on Cibolo Creek at Selma, which is $3\frac{1}{2}$ miles upstream from the study reach. During the investigation the water discharge was practically constant at the gaging station on Cibolo Creek near Falls City (measuring site No. 17, Plate 1).

The discharge was determined at 18 sites and water samples for chemical-quality analysis were collected at 14 of these sites. The results of discharge measurements are given in Table 2 and the chemical analyses are given in Table 3. Chemical analyses of base flow collected on other dates are included for sites 2 and 17. Comparison of these analyses with analyses of samples collected during this study indicates that the quality of base flow does not vary greatly with time. Data shown graphically in Figure 2 indicate changes in chemical quality and changes in flow throughout the reach.

Analyses of four samples collected from Cibolo Creek and of two samples collected from tributary streams are presented graphically in Figure 3. The total height of each vertical bar graph is proportional to the total concentration of anions (negatively charged constituents) or cations (positively charged constituents) expressed in equivalents per million. The bar is divided into segments to show the concentration of individual cations and anions.

In the following discussion the study reach has been subdivided where significant changes in geology occur, as these changes affect quantity and quality of flow. The quantity and quality of flow and changes that occur are discussed beginning at the upstream end.

Reach From Mile 0 to Mile 23

In the first 23 miles the flow was sustained entirely by sewage effluent. At mile 0 the streambed was dry. Just below this point 0.21 cfs (cubic feet per second) of effluent from Universal City sewage plant was flowing in a small tributary and into a pool in the channel of Cibolo Creek, but there was no surface flow out of the pool. At mile 0.9 the streambed was dry and at about mile 1.0 sewage effluent from Randolph Air Force Base was entering Cibolo Creek from the right bank. The plant operator stated that the effluent amounted to 850,000 gallons per day and that the flow of effluent from the plant was almost constant.

Storm runoff from the runways and other surface areas of Randolph Air Force Base empties into Cibolo Creek just downstream from the sewage outfall. Also, wash water from vehicle and airplane maintenance discharges from the storm sewer and is by-passed into a large open pit in the creek gravels near the stream. This pit acts as an oil and grease trap and allows the water to seep into Cibolo

Table 1.--Summary of exposed rock formations in the Cibolo Creek study reach

System	Series	Group	Formation and member		Characteristic
Tertiary	Miocene		Catahoula Tuff		Predominantly tuff, tuffaceous clay, sandy clay, bentonitic clay, and sandstone. Yields small to moderate quantities of fresh to moderately saline water to wells in study area.
	Eocene	Jackson	Undifferentiated		Clay, silt, tuffaceous sand, and volcanic ash. Yields small amounts of fresh to moderately saline water to wells in area.
		Claiborne	Yegua Formation		Sand, silt, and clay. Yields small quantities of slightly to moderately saline water to wells in study area.
			Cook Mountain Formation		Clay and shale containing small amounts of sand, silt, limestone, glauconite, and selenite. Yields small amounts of highly mineralized water to wells in study area.
			Sparta Sand		Predominantly medium to fine sand, some shale. Yields moderate amounts of water of fair to good quality in area of outcrop.
			Mount Selman Formation	Weches Greensand Member	Glauconitic sand and shale, fossiliferous. Not an important fresh-water aquifer in study area.
				Queen City Sand Member	Medium to fine sand and interbedded shale. Yield and quality of water vary over a wide range. Generally yields moderate amounts of water of good to fair quality to wells in area.
				Reklaw Member	Clay and shale, becoming sandy near outcrop. Yields small amounts of water of poor quality near outcrop.
			Carrizo Sand		Coarse to fine sand, small amounts of clay. Yields large amounts of fresh to slightly saline water.
		Wilcox	Undifferentiated		Medium to fine sand and clay. Yield and quality of water vary over a wide range.
	Paleocene	Midway	Wills Point Formation		Arenaceous clay containing numerous arenaceous and calcareous concretions. Not known to yield water in study area.
Cretaceous	Gulf	Navarro	Kemp Clay, Escondido Formation, and Corsicana Marl		Clay and marl. Not known to yield water in study area.
			Taylor Marl		Marl and calcareous clay. Not known to yield water in study area.

Creek through the gravel and sand banks. Total discharge from effluent and seepage from storm-sewer pit (1.77 cfs) was measured about 0.1 mile below the sewage plant and pit.

All flow in this reach appears to be sewage effluent and apparently none comes from outcrops of the Taylor Marl, the Navarro Group, and the Wills Point Formation. These rocks are composed of clay and marl. Arnow (1959, p. 16-17) states that these stratigraphic units are not known to yield water to wells in Bexar County.

The initial flow, which is from the sewage disposal plant at Universal City (site 2), was 0.21 cfs and contained 575 ppm (parts per million) of dissolved solids and 2.7 ppm of ABS (alkyl benzene sulfonate). (See Table 3.) ABS is the suds-producing ingredient in most household detergents and is not removed by normal sewage treatment. A concentration of 1 ppm of ABS in tap water will produce suds.

The water supply of Randolph Air Force Base comes from several wells in the Edwards Limestone. Water from a typical well has about 300 ppm of dissolved solids (Table 4), whereas the sewage effluent from Randolph Air Force Base had 448 ppm of dissolved solids. The increase in dissolved solids in the sewage effluent over that of the water supply is about average. Figure 3 shows a bar graph of an analysis of sewage effluent from Randolph Air Force Base (site 4) as well as bar graphs of analyses of water from downstream sites.

The concentration of ABS (0.97 ppm) in effluent from Randolph Air Force Base is almost double the limit set by the Drinking Water Standards of the U.S. Public Health Service; the dissolved-solids concentration limit is not exceeded. The nitrate content, 21 ppm, is about half the maximum concentration permitted by the Standards. At site 6 (mile 12.1) the chemical quality of the water is similar to the water supply of Randolph Air Force Base (Tables 3 and 4). The ABS is negligible and the nitrate is greatly reduced.

Reach From Mile 23 to Mile 50

Most of the base flow of Cibolo Creek at the mouth comes from this reach. Ground water enters the stream from rocks of the Wilcox and Claiborne Groups. According to Anders (1957, p. 7, 13) the Wilcox Group is composed of clay, silt, medium to fine sand and sandstone, sandy shale, and clay and thin beds of lignite. Wells producing from the Wilcox yield moderate to large quantities of water. The Carrizo Sand of the Claiborne Group is composed primarily of massive beds of medium to coarse sand, and may contain gravel 5 millimeters or more in diameter (Anders, 1957, p. 13, 14). Anders stated that: "Recharge to the Carrizo sand is from precipitation on the area of outcrop. Where the outcrop is cut by the San Antonio River and Cibolo Creek, water is discharged from the aquifer to the streams because the water table is above the stream level--that is, the formation receives water from precipitation at a greater rate than it can transmit the water downdip."

The maximum flow in this reach (18.2 cfs) was measured at mile 49.8 and most of this flow probably was contributed by the Carrizo Sand. Measurements indicate that about 5 cfs of the 18.2 cfs was contributed by the Wilcox Group.

A flow of 1.61 cfs was measured near the mouth of Martinez Creek. A large part of the water measured in Martinez Creek is outflow from small lakes and ponds on the golf course of Randolph Air Force Base. The water in these lakes comes mostly from wells that tap the Edwards Limestone. The chemical quality of Martinez Creek indicates that water from some of these wells is of poor quality. Water from Elm Creek, which enters at mile 36, contained a greater concentration of dissolved solids than any other water sampled during the investigation. Though the flow of Elm Creek was too small (0.1 cfs) to have an appreciable effect on the quality of the main stream, the high chloride content may indicate pollution. Elm Creek has several tributaries that drain one of the largest oil fields in the area.

Reach From Mile 50 to Mile 81.7

In this reach the quantity of flow remains about constant. Some gains or losses in flow are indicated by the measurements but are not considered significant because of the possibility of unmeasured underflow in the sand and gravel channel. Some of the formations in this reach undoubtedly contribute small quantities of water because the dissolved-solids concentration increases from 406 to 637 ppm and some inflow would be necessary to balance natural losses from evapotranspiration.

The rocks in this reach are the Queen City Sand and Weches Greensand Members of the Mount Selman Formation; the Sparta Sand, Cook Mountain, and the Yegua Formation of the Claiborne Group; the Jackson Group, undifferentiated; and the Catahoula Tuff. Anders (1957, p. 16-18; 1960, p. 26) stated that all of these rocks except the Weches Greensand Member and Catahoula Tuff yield small or moderate amounts of water of poor quality to wells in Wilson County. He stated that the Weches Greensand Member is not known to yield water to wells in Wilson County and that the Catahoula Tuff is the best shallow aquifer, producing fresh to slightly saline water, in Karnes County.

RELATION OF QUALITY OF WATER TO USE

Standards published by the U.S. Public Health Service (1962) show limits of concentration of dissolved constituents which should not be exceeded in drinking water used on interstate common carriers. These standards, which are generally accepted as a basis for determining the suitability of a water for domestic or municipal use, require that chloride or sulfate concentration not exceed 250 ppm, nitrate not exceed 45 ppm, alkyl benzene sulfonate (ABS) be limited to 0.5 ppm, and the dissolved solids be less than 500 ppm.

This investigation was made during a period when all the flow was either sewage effluent or ground-water seepage. The flow would probably represent the maximum concentration of dissolved solids. Flood runoff will have a much lower dissolved-solids content and be suitable for domestic and irrigation use and for many industrial uses.

The water of Cibolo Creek down to site 14 at mile 49.8 contained less dissolved constituents than the maximum permitted by the Standards, except for the initial flow, which contained more than 0.5 ppm of ABS. However, the concentration of ABS at site 6 was reduced to 0.14 ppm and continued to decrease until it was 0.0 ppm at site 18. Below mile 49.8 the dissolved-solids concentration in places exceeded 600 ppm. However, the limits were exceeded only slightly and the water would be usable for domestic and municipal purposes. The water is very hard and should be softened before using as a domestic or municipal supply. The range of hardness is from 248 ppm at site 4 to 305 at site 18. The waters of some of the tributaries contain even greater amounts of hardness (Table 3).

According to criteria established by the U.S. Salinity Laboratory Staff (1954, p. 81), the waters of Cibolo Creek could be used for irrigation if certain controls were practiced. Some of the important elements to be considered in determining the quality of irrigation water are the total concentration of soluble salts and the relative proportion of sodium to other cations (SAR). The water of Cibolo Creek would be <u>low-sodium</u> and <u>medium- to high-salinity</u> water. Low-sodium water can be used for irrigation on most soils without harmful effect. Medium-salinity water can be used if a moderate amount of leaching occurs. Plants with moderate salt tolerance can be grown in most cases without special practices for salinity control. High-salinity water cannot be used on soils with restricted drainage and special management for salinity control must be practiced on other soils. The annual rainfall on the Cibolo Creek watershed is approximately 30 inches; therefore, leaching would probably be sufficient to permit use of high-salinity water for irrigation for short periods of time.

SUMMARY AND CONCLUSIONS

The study shows that:

1. Flow in the first 23 miles of the study reach is sustained by sewage effluent from Universal City and Randolph Air Force Base and no significant losses of flow occur in this reach.

2. Most of the base flow at the mouth of Cibolo Creek originated between miles 23 to 50.

3. Small gains and losses in flow occurred between measuring points in the lower reach, mile 50 to 81.7. The gains were sufficient to offset the losses so that the flow at the head of the reach was the same as at the lower end.

4. The chemical-quality data indicate that the base flow of Cibolo Creek generally meets the Drinking Water Standards of the U.S. Public Health Service (1962). The dissolved-solid content of the water ranged from 350 to 637 ppm. The principal constituents found in the samples were calcium, sodium, sulfate, and chloride. ABS, the principal constituent of present-day detergents, exceeded the limits of the Drinking Water Standards at the head of the study reach but decreased rapidly downstream.

5. According to the standards of the U.S. Salinity Laboratory Staff for irrigation waters, the base flow of Cibolo Creek in the reach studied would be classed as <u>low sodium</u> and <u>medium to high salinity</u>. The annual rainfall on the Cibolo Creek watershed is approximately 30 inches; therefore, leaching would probably be sufficient to permit use of the high-salinity base flow for irrigation for short periods of time.

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Table 2.--Summary of discharge measurements, March 1963

Site No.	Date 1963	Stream	Location	River miles 1/	Water temp. (°F)	Discharge in cfs: Main stream	Discharge in cfs: Tributary	Remarks
	Mar.							
1	5	Cibolo Creek	0.1 mi above Farm Road 78 at Schertz	0	--	0		Gravel streambed
2	5	Unnamed Creek	At Farm Road 78 at Schertz	a .1	62		0.21	Sewerage effluent
3	5	Cibolo Creek	200 ft above Randolph Field sewer plant	.9	--	0		Gravel streambed
4	5	Cibolo Creek	500 ft below Randolph Field sewer plant	1.1	68	1.77		Gravel streambed
5	5	Unnamed Creek	Enters from left bank of Cibolo Creek	a4.5			0	Gravel streambed
6	5	Cibolo Creek	1,000 ft above U.S Highway 90	12.1	63	1.17		Clay streambed
7	5	Santa Clara Creek	1 mi above mouth	a22.0			0	Clay streambed
8	5	Cibolo Creek	400 ft above Farm Road 2538	25.0	66	4.10		Sandstone streambed
9	5	Martinez Creek	2.5 mi above mouth	a26.8	62		1.61	Gravel streambed
10	6	Cibolo Creek	100 ft below Farm Road 775	34.1	58	5.23		Gravel and clay streambed
11	6	Elm Creek	0.3 mi above mouth	a36.0	55		b .1	Gravel streambed
12	6	Cibolo Creek	At county road, 3¼ mi above Southerland Springs	36.7	59	6.13		Gravel and clay streambed
13	6	Cibolo Creek	About 1.0 mi above Southerland Springs	42.9	59	9.76		Soft clay streambed
14	6	Cibolo Creek	At State Highway 97 near Stockdale	49.8	65	18.2		Gravel streambed
15	6	Cibolo Creek	At Farm Road 537	56.4	64	16.0		Gravel streambed
16	6	Cibolo Creek	At Farm Road 541	63.6	64	17.9		Sand streambed
17	7	Cibolo Creek	Gaging station (8-1860) near Falls City	71.7	57	17.4		Gravel streambed
18	7	Cibolo Creek	At Farm Road 81	79.3	57	18.6		Sand streambed

1/ River miles determined from topographic map
a River mile on Cibolo Creek at mouth of tributary.
b Discharge estimated.

Table 3.--Chemical analyses of streams in the Cibolo Creek study reach

(Results in parts per million except as indicated)

Site No.	Stream	Date	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	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Percent sodium	Sodium adsorption ratio	Specific conductance (micromhos at 25° C)	pH	Detergents (ABS)
2	Unnamed tributary---------	Mar. 5, 1963	0.21	--	--	--	--		470	49	65	--	0.0	575	--	278	0	--	--	1,010	6.8	2.7
2	Do----------------------	June 6	.3	23	60	24	70	13	386	51	52	0.3	.7	484	0.66	248	0	36	1.9	856	7.1	--
4	Cibolo Creek-------------	Mar. 5	1.77	18	70	18	54		267	58	46	1.7	21	a448	.61	248	30	32	1.5	756	6.6	.97
6	Do----------------------	do.	1.17	--	--	--	--		228	31	32	--	4.5	300	--	205	18	--	--	524	7.2	.14
8	Do----------------------	do.	4.10	--	--	--	--		180	52	62	--	8.7	350	--	177	30	--	--	624	6.6	.03
9	Martinez Creek------------	do.	1.61	3.7	202	53	194	12	150	534	350	.8	.0	1,420	1.93	722	599	36	3.1	2,190	7.1	.03
10	Cibolo Creek-------------	Mar. 6	5.23	--	--	--	--		171	83	70	--	1.0	385	--	202	62	--	--	659	6.8	.02
11	Elm Creek----------------	do.	.1	--	--	--	--		249	344	750	--	.0	1,880	--	920	716	--	--	3,140	6.8	.02
12	Cibolo Creek-------------	do.	6.13	--	--	--	--		219	88	74	--	4.5	440	--	251	62	--	--	745	7.0	.02
13	Do----------------------	do.	9.76	--	--	--	--		196	77	61	--	4.2	385	--	227	66	--	--	669	6.8	.00
14	Do----------------------	do.	18.2	16	68	11	56		186	94	58	.3	3.0	a406	.55	214	62	36	1.7	691	6.9	.00
15	Do----------------------	do.	16.0	--	--	--	--		206	163	74	--	3.0	535	--	281	112	--	--	885	6.9	.00
16	Do----------------------	do.	17.9	--	--	--	--		211	181	90	--	2.5	585	--	294	121	--	--	953	7.3	.00
17	Do----------------------	Oct. 18, 1962	10.2	15	82	18	118		218	190	112	.3	.2	648	.94	278	100	48	3.1	1,030	7.6	--
17	Do----------------------	Nov. 26	14.0	16	87	21	123		236	205	115	.3	.2	684	.93	504	110	47	3.1	1,090	7.6	--
17	Do----------------------	Jan. 3, 1963	19.2	14	98	19	103		226	198	110	.4	.0	a661	.90	322	138	41	2.5	1,030	7.5	--
17	Do----------------------	Mar. 7	17.4	8.8	95	18	100		212	197	104	.5	2.2	a637	.87	311	138	41	2.5	1,020	7.2	.01
18	Do----------------------	do.	18.6	--	--	--	--		208	198	104	--	1.5	625	--	305	134	--	--	1,010	7.2	.00

a Residue at 180°C.

Table 4.--Chemical analysis of water from a typical well supplying Randolph Air Force Base

(Results in parts per million except as indicated)

Silica (SiO_2)	13	Hardness as $CaCO_3$:	
Iron (Fe)	.05	Total	230
Calcium (Ca)	64	Noncarbonate	26
Magnesium (Mg)	17	Percent sodium	16
Sodium (Na) } Potassium (K) }	20	Sodium adsorption ratio	.6
Bicarbonate (HCO_3)	248	Specific conductance (micromhos at 25°C)	494
Sulfate (SO_4)	34	pH	7.2
Chloride (Cl)	22	Date of collection	May 14, 1963
Fluoride (F)	.4		
Nitrate (NO_3)	3.2		
Dissolved solids	312		

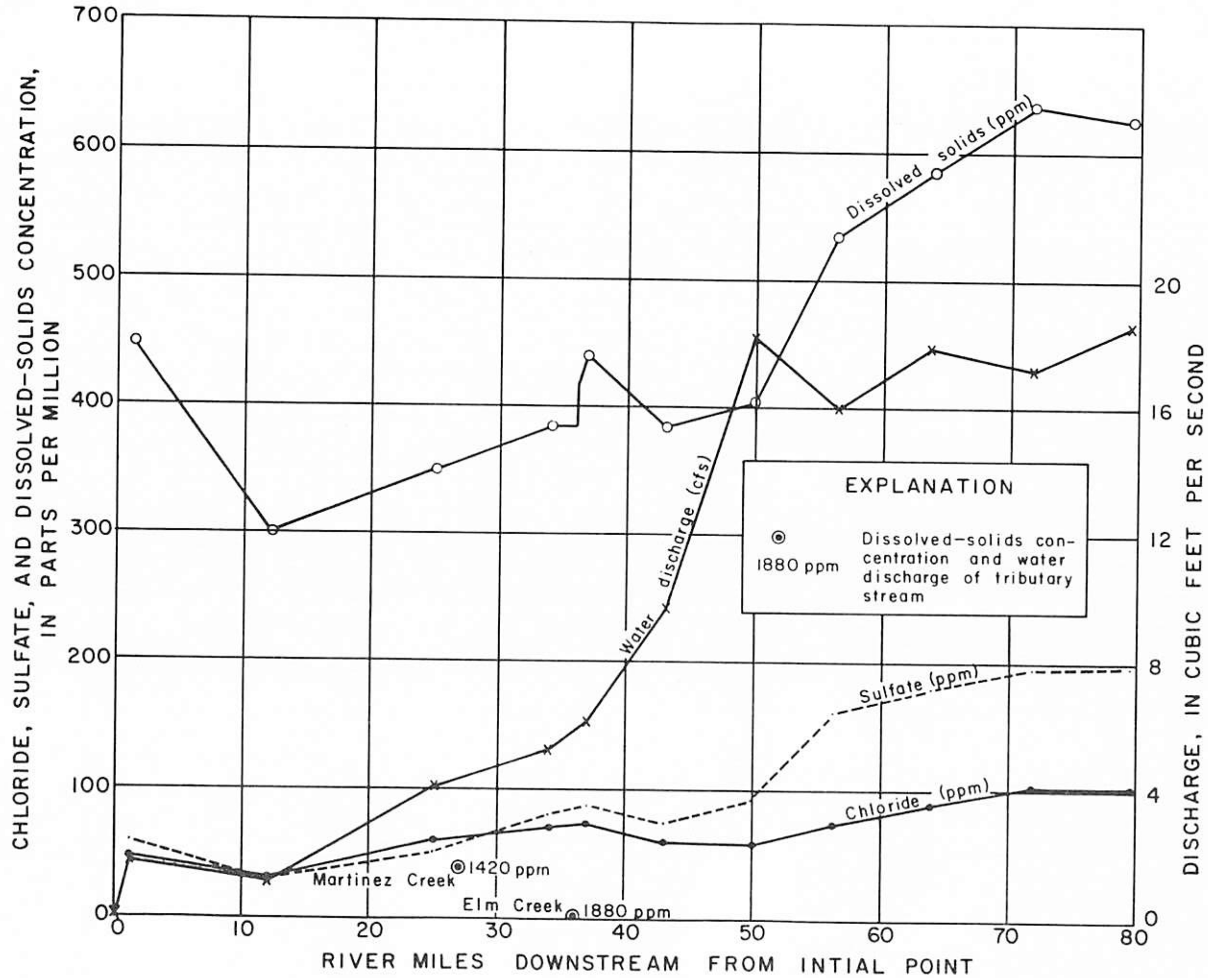

Figure 2

Chloride, Sulfate, and Dissolved-Solids Concentrations and Water Discharge, Cibolo Creek Study Reach, March 5-7, 1963

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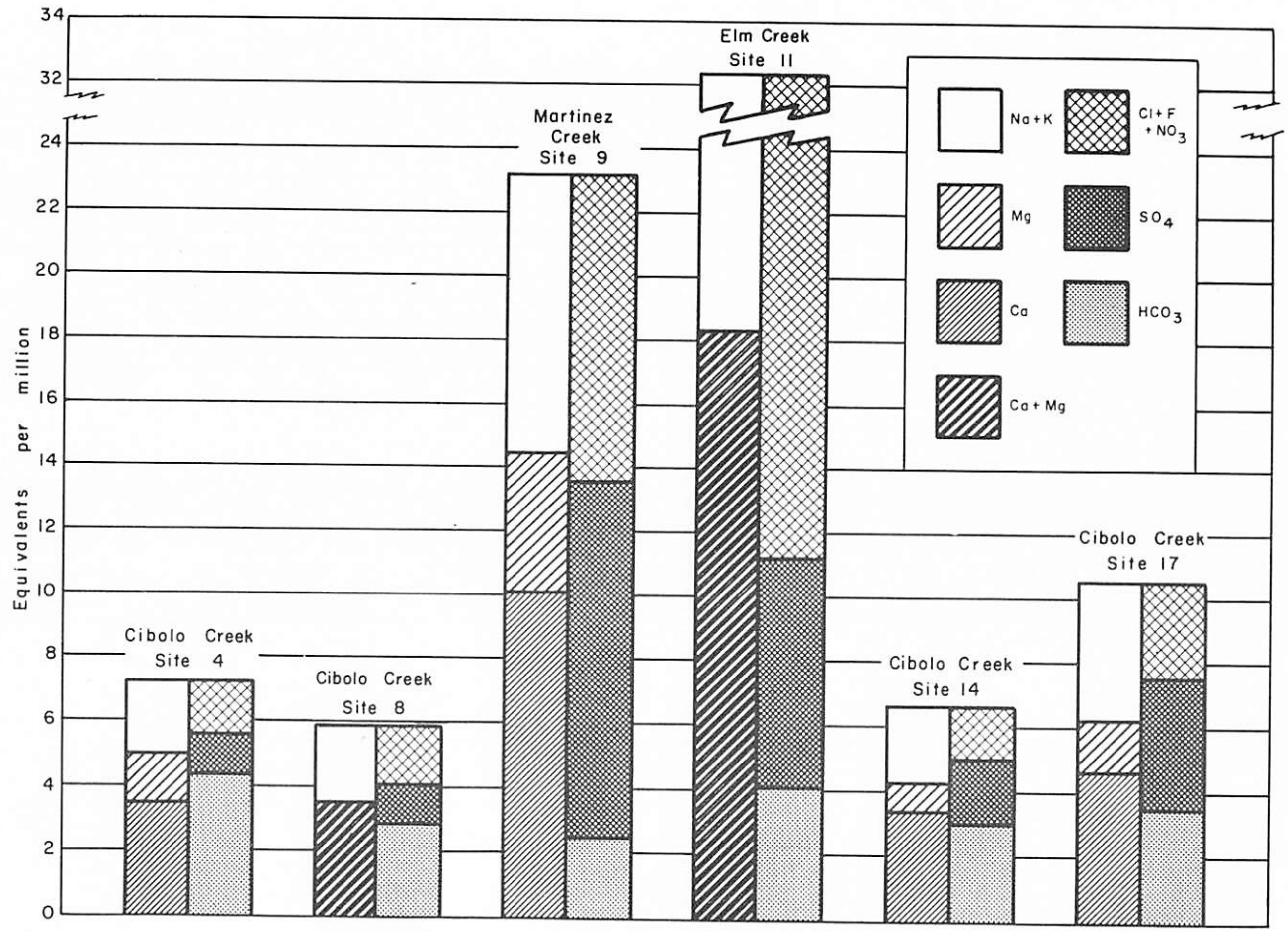

Figure 3

Chemical Analyses of Water, Cibolo Creek Study Reach

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