BULLETIN 6411

CHEMICAL QUALITY OF SURFACE WATERS IN THE HUBBARD CREEK WATERSHED, TEXAS

Progress Report, September 1963

By

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INTRODUCTION

The Problem

The West Central Texas Municipal Water District, Abilene, Texas, has constructed a reservoir on Hubbard Creek near Breckenridge, Texas (impoundment began September 1962). The impounded water will be used as a public-water supply for several cities in west-central Texas. Cities now within the water district are Abilene, Albany, Anson, and Breckenridge.

Oil production in the Hubbard Creek watershed began in 1920. In April 1961 there were 5,400 producing oil and gas wells, 782 depleted wells, and 5,193 dry holes upstream from Hubbard Creek Dam (written communiciation, West Central Texas Municipal Water District, 1961). A large number of dry holes and abandoned wells were not properly plugged and shallow ground-water aquifers in many parts of the watershed have been contaminated by salt water (written communiciation, J. H. Samuell, 1937). Also, the water quality of Hubbard Creek and most of its tributaries is affected by oil-field brines that reach the streams as surface runoff or as effluent ground water. Concentrations of dissolved constituents, especially chloride, in the base flow of the streams are above the recommended maximum limits for domestic use.

Chemical-quality records collected on Hubbard Creek near Breckenridge since April 1955 show that the water at this station is not of acceptable quality for domestic use except during high flows. Records for this station for water years 1955-57 indicated that the annual weighted-average concentration of chloride would be about 45 to 50 ppm (parts per million). This concentration is well within the acceptable chloride limits for most uses, and on this basis the construction of the dam was started. Thereafter, a large increase in chloride concentration occurred. In 1958 the weighted-average concentration of chloride was almost three times that of previous years, and by 1962 had increased to almost 200 ppm. However, a weighted-average chloride concentration of 200 ppm would be of acceptable quality for domestic use if the yearly runoff were mixed in a reservoir and if evaporation effects are not considered. Obviously, the concentrating effect of evaporation on the dissolved solids in the reservoir cannot be ignored.

Because of a high area-depth ratio and the local climate, yearly evaporation from Hubbard Creek Reservoir will be high--so high, indeed, that about half the time the amount of water evaporated from the reservoir after filling will be greater than the inflow (written communication, Freese, Nichols, and

Endress, 1962). During some years, and especially during drought periods, the chloride concentration of the water in the reservoir probably will exceed the recommended maximum limit for domestic use of 250 parts per million (U. S. Public Health Service, 1962). That is, if the quality of the inflow is not improved.

Previous Investigations

A salt-water reconnaissance survey of the Hubbard Creek watershed was made by the Texas State Department of Health in May 1961. The survey indicated that several areas are potential sources of chloride contamination (written communication, J. D. Goff and J. R. Morgan, 1961). The survey by the Texas State Department of Health disclosed:

> "...that Hubbard Creek contained chloride concentrations of approximately 1,000 ppm near Hubbard Creek Reservoir Dam. This chloride increased progressing upstream and approaching oil fields. When no flow was visible, there was evidence of previous brine flows because of salt deposits on the banks and stream beds.
>
> Many pits were found being utilized for attempted disposal of brines that are produced in oil recovery operations in this area."

The report by the Texas State Department of Health concluded that:

> "Generally the brines from the oil fields in the Hubbard Creek Reservoir watershed do not enter watercourses by surface routes. However, sub-surface migration of these brines along the beds of the streams draining the area is considered to be taking place according to laboratory analysis of the samples collected. Discharge of the brines into the watercourses in this manner is difficult to detect by a visual investigation.
>
> The high chloride concentrations found in oil-field brine produced from the counties involved and the volume reported are such that the entry of it into the watercourses and the continued discharge to the environs by the use of pits is likely to seriously impair the quality of the water in the Hubbard Creek Reservoir."

The firm of Conselman, Jenke, and Tice, Abilene, Texas, contracted with the West Central Texas Municipal Water District in December 1961 to prepare a report on "Salt-Water Contamination in the Hubbard Creek Reservoir Watershed of Shackelford, Stephens, Callahan, and Eastland Counties, Texas." Among other important findings, their report concludes in part that:

> "1. The Hubbard Creek Reservoir Watershed is naturally clean, and its geologic setting is stratigraphically quite favorable, particularly as compared to areas north and west....

2. Streams entering Hubbard Creek Reservoir are now carrying excessive concentrations of dissolved chlorides and other salts as compared to the normal content to be expected from leaching of the outcrops traversed.

3. The chief source of these abnormal chlorides is industrial brine produced in connection with oil and gas operations, which have been and continue to be intensive in the area.

4. Industrial brines have reached the watershed from (1) surface leakage of salt-water pits, producing wells, water injection wells, lease lines, tanks, heaters, treaters, and abandoned dry holes; (2) leaching of salt-impregnated areas by runoff; (3) seepage of salt-water pits into the shallow subsurface; (4) subsurface seepage from salt water disposal wells pumping brine into the annulus, with pressures and volumes in excess of the capacity of subsurface reservoirs; (5) waterflood injection wells which unintentionally inject brine into reservoirs other than those to be repressured; (6) abandoned shot-holes and core-holes which receive lateral salt water migration from other sources; and (7) occasional deliberate disposal of brine by dumping into surface watercourses."

Freese, Nichols, and Endress, Consulting Engineers, Fort Worth, Texas, completed a report on chloride routing studies of Hubbard Creek Reservoir in June 1962. Their conclusions are as follows:

"...with the degree of chloride contamination now being observed on Hubbard Creek, the resulting concentrations in Hubbard Creek Reservoir can be expected to rise above the limit recommended by the U. S. Public Health Service (250 parts per million) during drouth periods. The only apparent means to prevent this occurrence is to reduce the man-made pollution on the watershed and bring the mineral content of the runoff back down to the levels measured prior to 1958. Specifically, the overall average chloride concentration in the stream flow must be reduced to 50 ppm or less if the lake water is to meet Public Health Service standards on a continuous and dependable basis.

Unless there is some further increase in pollution on Hubbard Creek, the reservoir will not become unduly salty for a few years after impoundment begins. Judging from the chloride routing analyses included in this study, some five to ten years will elapse between closure of the dam and the increase of chlorides in the lake to more than 250 ppm, with the quality of the runoff as it exists at present.

Early quality measurements of the U.S. Geological Survey on Hubbard Creek, from 1955 to 1957, encourage the belief that the chloride content can be held below 50 ppm if proper attention is given to the handling of oil-field brines and other similar wastes within the watershed boundaries."

The West Central Texas Municipal Water District has studied the cause of the progressive increase of chloride as measured at the station on Hubbard Creek near Breckenridge. They believe that there is a correlation between the number of injection permits and the increase in chloride (Austin P. Hancock, written communication, 1963). Figure 1 was prepared from data furnished by Mr. Hancock on the number of permits. The relation of chloride concentration to the number of permits is too pronounced to be fortuitous.

Purpose of the Study

In December 1961 the U. S. Geological Survey, in cooperation with the West Central Texas Municipal Water District and the Texas Water Commission, began a study of the surface-water resources of the Hubbard Creek watershed. The purpose of the study is to determine the chemical quality of surface waters; to determine the source areas and extent of rapidly increasing dissolved solids, especially chloride; to show the effect of remedial measures in reducing the amount of dissolved solids reaching the Hubbard Creek Reservoir; to determine stratification patterns in Hubbard Creek Reservoir; to record and analyze the effects of withdrawals from the bottom of the reservoir on stratification patterns; and to determine the optimum rate at which saline water can be released from the bottom of the reservoir without withdrawal of the better water in the upper layers.

For this study, the daily streamflow and chemical-quality station on Hubbard Creek near Breckenridge that was established in April 1955 will be continued. In February 1962 daily streamflow and chemical-quality stations were established on Big Sandy Creek near Breckenridge, Hubbard Creek near Albany, and Salt Prong Hubbard Creek near Albany; all three stations are above the area to be inundated by Hubbard Creek Reservoir. In October 1962 daily stations were established on Deep Creek at Moran and North Fork Hubbard Creek near Albany. Two additional daily stations, Hubbard Creek near Sedwick and Snailum Creek near Albany, and a continuous specific conductance recorder at the reservoir outlet will be established in the spring of 1964. In addition, streamflow measurements will be made and samples collected for chemical analyses about 4 times a year at each of 13 sites on tributaries. Other instrumentation and stations will be added as needed.

This is a progress report summarizing the data collected through April 1963 and indicates the present quality of the inflow to the reservoir and some of the source areas of chlorides. Another progress report will be prepared at the end of the 1964 water year.

SUMMARY

The surface waters of Hubbard Creek watershed were by nature originally low in chloride content. However, at present the chloride content of many of the streams is high. Chemical-quality records indicate a progressive increase in chloride since about 1955, and this increase in chloride coincides with an increase in water-flood projects in the oil fields.

Salt springs near the "Old Albany Salt Works" on a tributary of Salt Prong Hubbard Creek are the only known source of natural contamination. The flow from these springs is small and enters Lake McCarty, which is about 6 miles

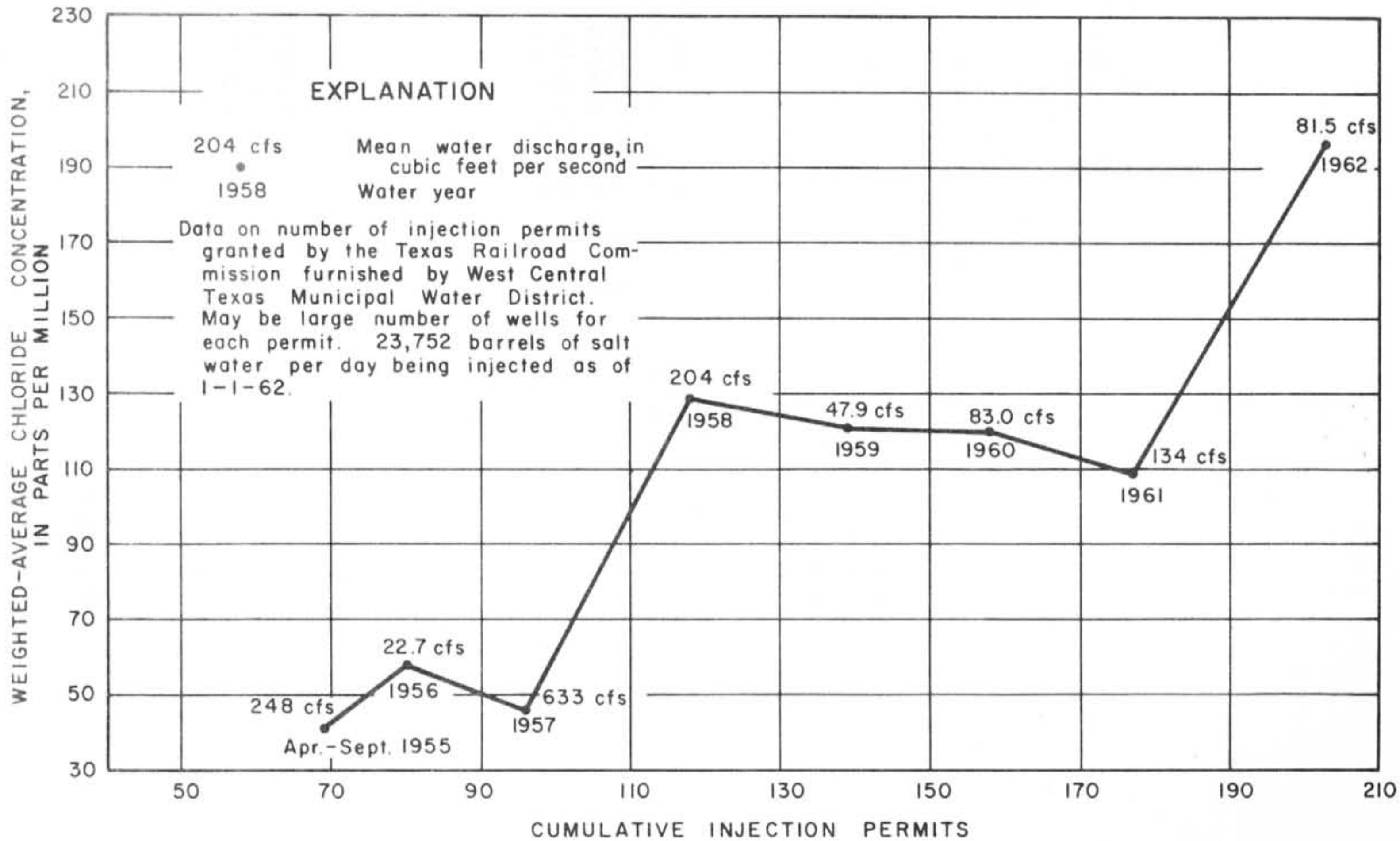

Figure 1

Relation of Chloride Concentration of Hubbard Creek near Breckenridge to Number of Injection Permits in Hubbard Creek Watershed

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southwest of Albany. Lake McCarty is the water supply for Albany. The springs have no appreciable effect on the quality of water in Hubbard Creek Reservoir.

Saline flows, dead vegetation, and salt encrustations along waterways near oil fields occur throughout the watershed. A major source area of chloride contamination is above the station on Salt Prong Hubbard Creek near Albany. If the runoff from the area above this station during February to September 1962 had been diverted out of the watershed, 45 percent less chloride would have passed the outflow station on Hubbard Creek near Breckenridge. The source of the high chloride can be isolated even more closely. North Fork Hubbard Creek, a tributary of Salt Prong Hubbard Creek that drains an intensively developed oil field west of Albany, contributed 81 percent of the chloride load that passed the station on Salt Prong during the period November 1962 to April 1963. The drainage area above the station on North Fork is only one-third of the drainage area above the station on Salt Prong.

The drainage area above the station on Big Sandy Creek near Breckenridge contributes less chloride per unit area than the drainage area above the station on Hubbard Creek near Albany. Most of the abnormally high chloride water (one sample of low flow contained 10,500 ppm chloride) in Big Sandy sub-basin is in Battle Creek and its tributaries that drain oil-field areas. Source areas of saline water above the station on Hubbard Creek near Albany are mostly above the station on Deep Creek near Moran and on Hubbard Creek above the mouth of Deep Creek. One sample of low flow from a tributary of Deep Creek west of Moran contained 13,600 ppm of chloride.

Lake Cisco, the water supply of Cisco, stores runoff from the upper reaches of Big Sandy Creek. Chemical analyses of water from Lake Cisco indicate that the water is usually less than 15 ppm chloride. Other chemical analyses of water from ponds and lakes throughout the watershed indicate that if contamination is substantially reduced or eliminated, the water of Hubbard Creek Reservoir would be of excellent quality most of the time, and would be of acceptable quality even during those years when evaporation from the reservoir exceeds the inflow.

DESCRIPTION OF AREA

Location and Extent

The area drained by Hubbard Creek extends from northern Callahan County and northwestern Eastland County across eastern Shackelford County and western Stephens County to the Clear Fork Brazos River 10 miles north of Breckenridge, Texas (Figure 2). The drainage area above U. S. Highway 183, northwest of Breckenridge, and 8 miles above the mouth is 1,111 square miles.

Drainage

Deep Creek, which has a larger drainage area than Hubbard Creek above their junction, starts in Callahan County southwest of Putnam and flows northeast and then north to join Hubbard Creek south of State Farm Road 601. Mexia Creek is the largest tributary of Deep Creek (Figure 19).

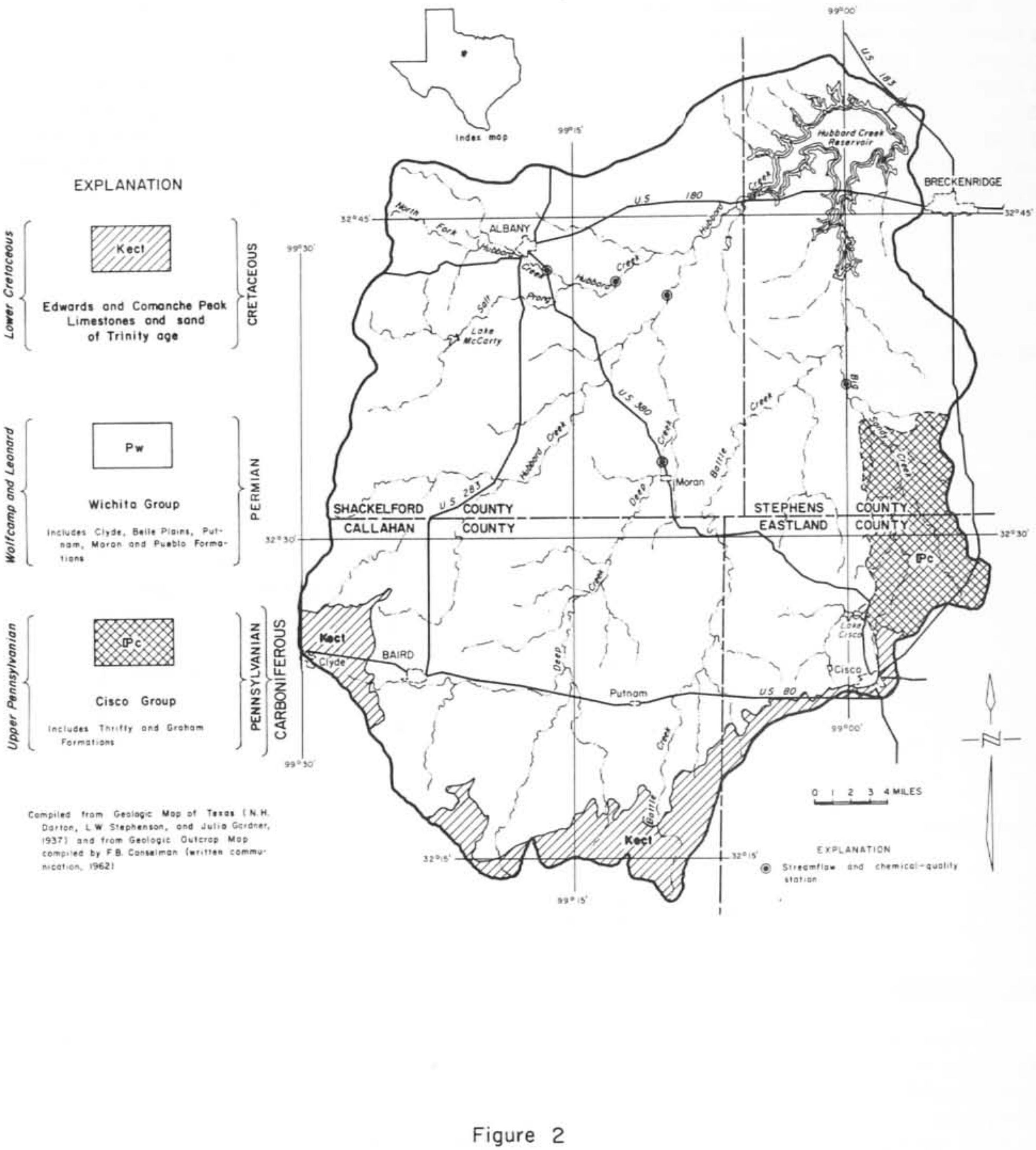

Figure 2

Geologic Map of the Hubbard Creek Watershed

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Salt Prong Hubbard Creek and its principal tributary, North Fork Hubbard Creek, drain areas entirely within Shackelford County. Salt Prong starts in the south-central part of the county and flows into Hubbard Creek about 4 miles above U. S. Highway 180. North Fork Hubbard Creek begins west of Albany near the center of the county and enters Salt Prong about 3 miles southeast of Albany.

Big Sandy Creek, which has the largest drainage area of the three principal tributaries of Hubbard Creek, starts in Eastland County near Cisco and flows generally north across Stephens County to about 8 miles southwest of Breckenridge where it flows into Hubbard Creek Reservoir. The principal tributary of Big Sandy Creek is Battle Creek, which rises in northeastern Callahan County, flows across southeastern Shackelford County and southwestern Stephens County, and flows into Big Sandy Creek a short distance above State Farm Road 576, and 8.2 miles southwest of Breckenridge (Figure 19).

Hubbard Creek Reservoir

Hubbard Creek Reservoir impoundment began in September 1962. Drainage area is 1,107 square miles. Pertinent data for the reservoir are as follows:

Feature	Elevation (feet above mean sea level)	Capacity (acre-feet)	Area (acres)
Top of dam	1,208.0	--	--
Top of earth fuse plug	1,197.0	584,000	22,000
Crest of emergency spillway	1,194.0	521,000	20,500
Top of gates of outlet structure (service spillway)	1,183.0	320,000	15,250
Crest of outlet structure	1,176.5	225,000	12,300
Invert of 48-inch valve	1,134.0	4,000	700

Shoreline: 100 miles at elevation 1,183.0 feet above mean sea level

Physical Setting

Physiography

Physiographically, the Hubbard Creek watershed is in the Osage Plains section of the Central Lowlands province. The Callahan Divide on the south and southwest separates the watershed from the Colorado River Basin. The altitude of the watershed ranges from about 1,200 feet above msl (mean sea level) in the north to about 2,000 feet above msl on the south and west boundaries. Except for moderately rough topography along the divide, the topography is rolling to hilly and the numerous small streams flow generally northeast or northwest into the principal streams. Most of the principal streams have eroded their valleys in outcrop of shale, or in some places shale alternating with thin beds of limestone. Separating the valleys are low ridges of gently northwestward-dipping limestone. Sandstone forms the ridges and underlies the valleys in the eastern part of the area, particularly in Big Sandy Creek sub-basin.

Geology

The following description of the geology of the Hubbard Creek watershed is from a discussion of the geology of the area by Frank B. Conselman (written communication, 1962).

Hubbard Creek watershed is near the eastern margin of the Permian Basin, which is a large structurally downwarped and filled basin underlying northwest Texas and adjoining states. Most of the rocks that crop out in the Hubbard Creek watershed are limestone and thick beds of relatively softer shale, which separate the limestone. The shale between the limestone has been partially eroded leaving a series of ridges or cuestas. The ridges are steep on the east and slope gently to the west about 40 feet per mile, which is the dip of the underlying rocks. These westward-dipping beds of limestone and shale of Permian age were once overlain by nearly horizontal rocks of Early Cretaceous age that have been removed by erosion except along the southern divide.

The oldest rocks crop out in the southeast part of the watershed near Cisco. These rocks are of Pennsylvanian age and are mostly limestones, sandstones, and siltstones.

Outcrops of Permian rocks, which in some areas are notorious as producers of bad water, cover about 95 percent of the watershed. (See Figure 2.) However, these Permian rocks are geochemically unlike the Permian rocks that crop out to the southwest in the Colorado River Basin and in the drainage basins of other streams to the west and northwest. The Lower Permian rocks in the Hubbard Creek watershed are predominately marine and contain negligible quantities of salt and gypsum as compared to the younger gypsum and salt-bearing Permian rocks to the west.

Another important aspect of the rocks and their relation to the quality of surface water is the westward dip of the rock strata. This westward dip coupled with the northeastward trend of the streams minimizes the area of outcrop of each formation crossed by the streams. The watershed is an area of ground-water recharge to the few aquifers present and little or no ground water is effluent to the streams except from alluvium along the streams.

Climate

The climate of the four-county area is typical of much of the West Texas Plains. The mean temperature for July is about 84°F, and the maximum temperature recorded is 112°F. The mean temperature for January is about 44°F, but maximums in the eighties and minimums near 0°F have been recorded. The average growing season is 226 days, extending from late March to early November (Texas Almanac, 1961-1962, p. 636). The average annual precipitation is 25 to 26 inches with no well-defined wet season (Figure 3). Much of the precipitation for the region occurs during storms and thunderstorms with 10 to 20 percent of the annual precipitation occurring in a few days. Irregularities in the annual precipitation pattern are further exemplified by Figure 4 which shows annual water discharge for Hubbard Creek near Breckenridge for the water years 1941-62.

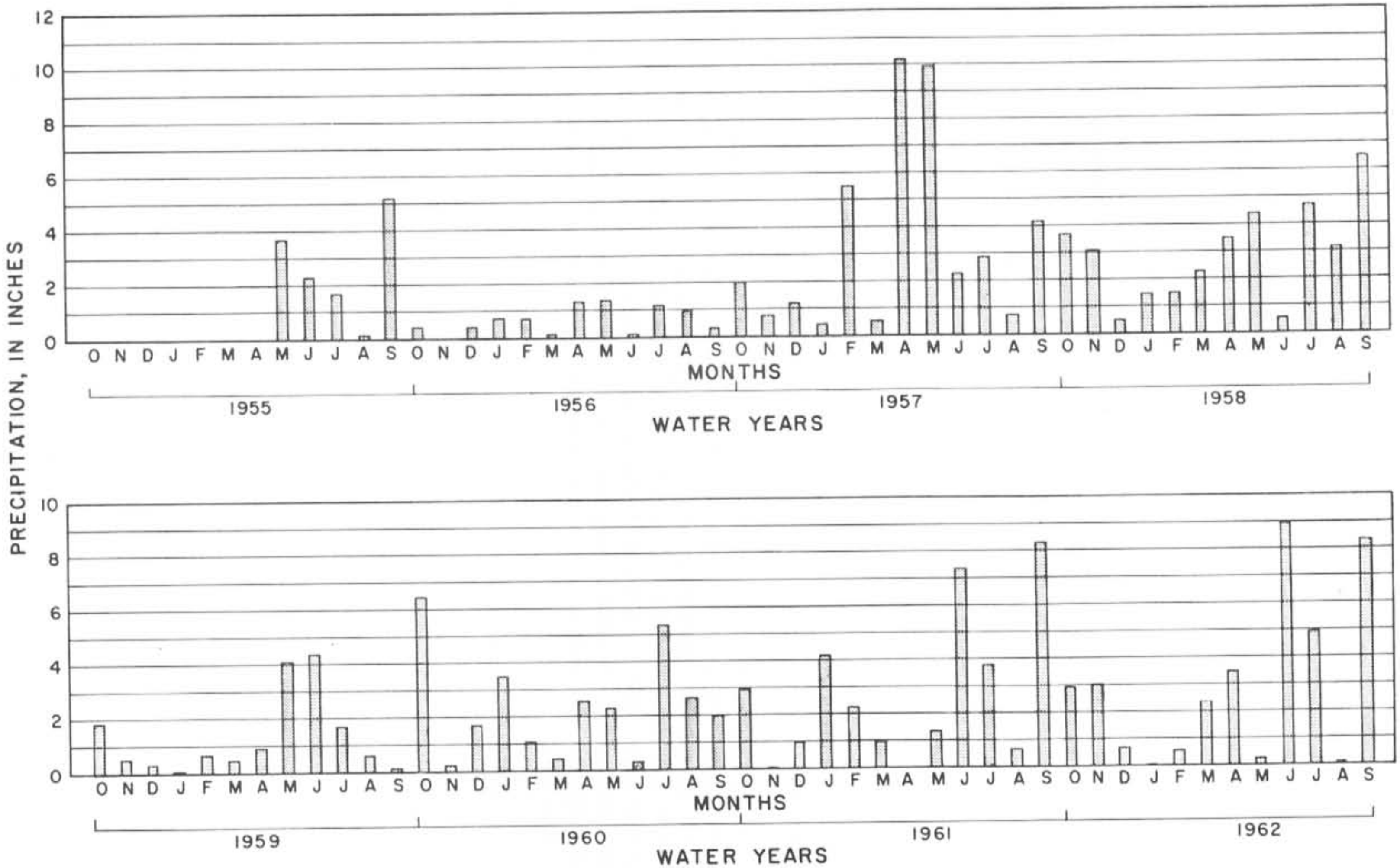

Figure 3

Monthly Precipitation at U. S. Weather Bureau Station, Albany, Texas, May 1955 to September 1962

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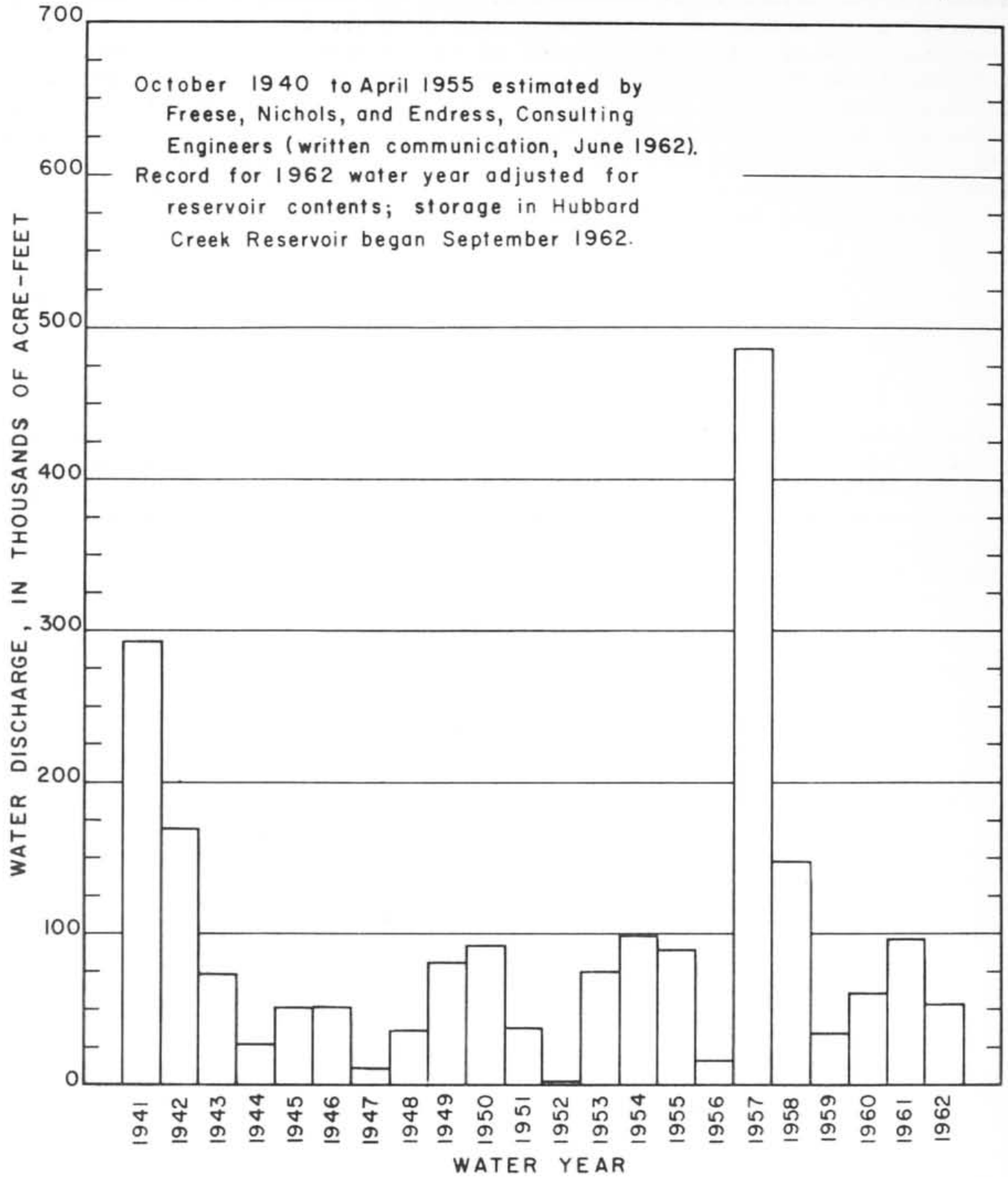

Figure 4

Annual Water Discharge, Hubbard Creek near Breckenridge, Water Years 1941-62

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Probably the most important climatic factor affecting the quality of water in Hubbard Creek Reservoir is evaporation from the surface of the reservoir. The concentrating effect of evaporation will increase the chloride concentration and concentration of other constituents of the reservoir water. Lowry (1960, p. E-9) tabulated monthly reservoir evaporation rates for Texas for the 18-year period from 1940 to 1957. Based on the evaporation rates given by Lowry the net evaporation from Hubbard Creek Reservoir, if the reservoir had been in place during this period, would have been 4.57 feet annually. The maximum net evaporation would have been 6.16 feet for the drought year of 1956 and the minimum would have been 2.61 feet for the abnormally wet year of 1957.

CHEMICAL QUALITY OF WATER

Dissolved-Solids Discharge and Concentration

The dissolved-solids concentration at any point on Hubbard Creek or its tributaries may be greater, equal, or less, than at any upstream or downstream point. The effect of inflow on the concentration downstream depends on the amount of inflow as well as the concentration of the inflow. Assuming no water is lost between the upstream and downstream points the relation between water discharges and dissolved-solids concentrations would be as follows:

$$C_a Q_a + C_b Q_b = C_c Q_c$$

$$C_c = \frac{C_a Q_a + C_b Q_b}{Q_c}$$

Where

C_a = concentration of water at upstream point

Q_a = water discharge at upstream point

C_b = concentration of inflow

Q_b = quantity of inflow

C_c = concentration of water at downstream point

Q_c = water discharge at downstream point

Records for the period February to September 1962 show that the dissolved-solids concentration of Hubbard Creek was increased by inflow from Salt Prong Hubbard Creek and was decreased by inflow from Big Sandy Creek and several small tributaries below the mouth of Salt Prong. Similar changes in concentration are known to occur in other reaches of Hubbard Creek and its tributaries.

Natural base or sustained flow of streams in Hubbard Creek watershed is almost nonexistent except in the lower reaches of Hubbard Creek. During periods of no flow or meager flows, evaporation of ponded pools leaves salt deposits on the banks and streambeds, especially in contaminated reaches of the streams. These deposits are dissolved rapidly by the next runoff event and carried downstream or into Hubbard Creek Reservoir. Because of the irregular precipitation pattern and contamination, salt encrustations are common along the stream channels, and the initial flow of a runoff-event may be highly saline.

The three upstream stations, Big Sandy Creek near Breckenridge, Hubbard Creek near Albany, and Salt Prong Hubbard Creek near Albany record runoff from 80 percent of the 1,111 square miles above the station on Hubbard Creek near Breckenridge. During the period February to September 1962, the three upstream stations recorded three-fourths of the flow recorded at the station on Hubbard Creek near Breckenridge. Percentage relationships of the stations upstream from the primary station for this period are shown in Figure 5.

Hubbard Creek near Breckenridge

The maximum dissolved-solids concentration at the station on Hubbard Creek near Breckenridge was observed in July 1960. Mean discharge for the first 5 days of the month was less than 0.05 cfs (cubic feet per second), and the dissolved-solids content was 5,350 ppm. In June 1961, over half of the total flow for the water year (October 1960 to September 1961) was recorded and the minimum dissolved-solids content was 112 ppm.

The concentration of any particular dissolved constituent in Hubbard Creek near Breckenridge varies with the discharge rate. Bicarbonate, for example, varies only slightly with changes in water discharge, but sodium and chloride, which are the major constituents during low flow, decrease drastically as the water discharge increases. Calcium and magnesium vary with water discharge somewhat like sodium, but the relation of calcium and magnesium to water discharge is not as consistent. The sulfate content of Hubbard Creek apparently depends on from which part of the watershed the flow comes. Saline water passing the station on Hubbard Creek near Breckenridge may or may not be high in sulfate.

Figures 6 and 7 show the daily water discharge and concentration of chloride. Monthly values for water, chloride, and dissolved-solids discharge for the 1962 water year are shown in Figure 8. Weighted averages and extremes for the period of record (1955-62) are given in Table 1.

Big Sandy Creek near Breckenridge

The station on Big Sandy Creek near Breckenridge records the runoff from 298 square miles. Although flow was recorded less than half the time, the runoff measured at the Big Sandy Creek station was almost one-third of the total runoff from Hubbard Creek watershed for the 8-month period February to September 1962 (Figure 5). Chemical quality versus streamflow at this station is similar to that at the station on Hubbard Creek near Breckenridge, but the water is of better quality. As at Hubbard Creek near Breckenridge, the bicarbonate content of Big Sandy Creek shows little relation to flow. Other principal ions vary inversely with the discharge, and sodium and chloride are the major constituents at low flow. The monthly discharges of water, chloride, and dissolved solids from February to September 1962 for the Big Sandy station are shown in Figure 9, and the daily water discharge and chloride concentrations for the period February 1962 to April 1963 are given in Figure 10.

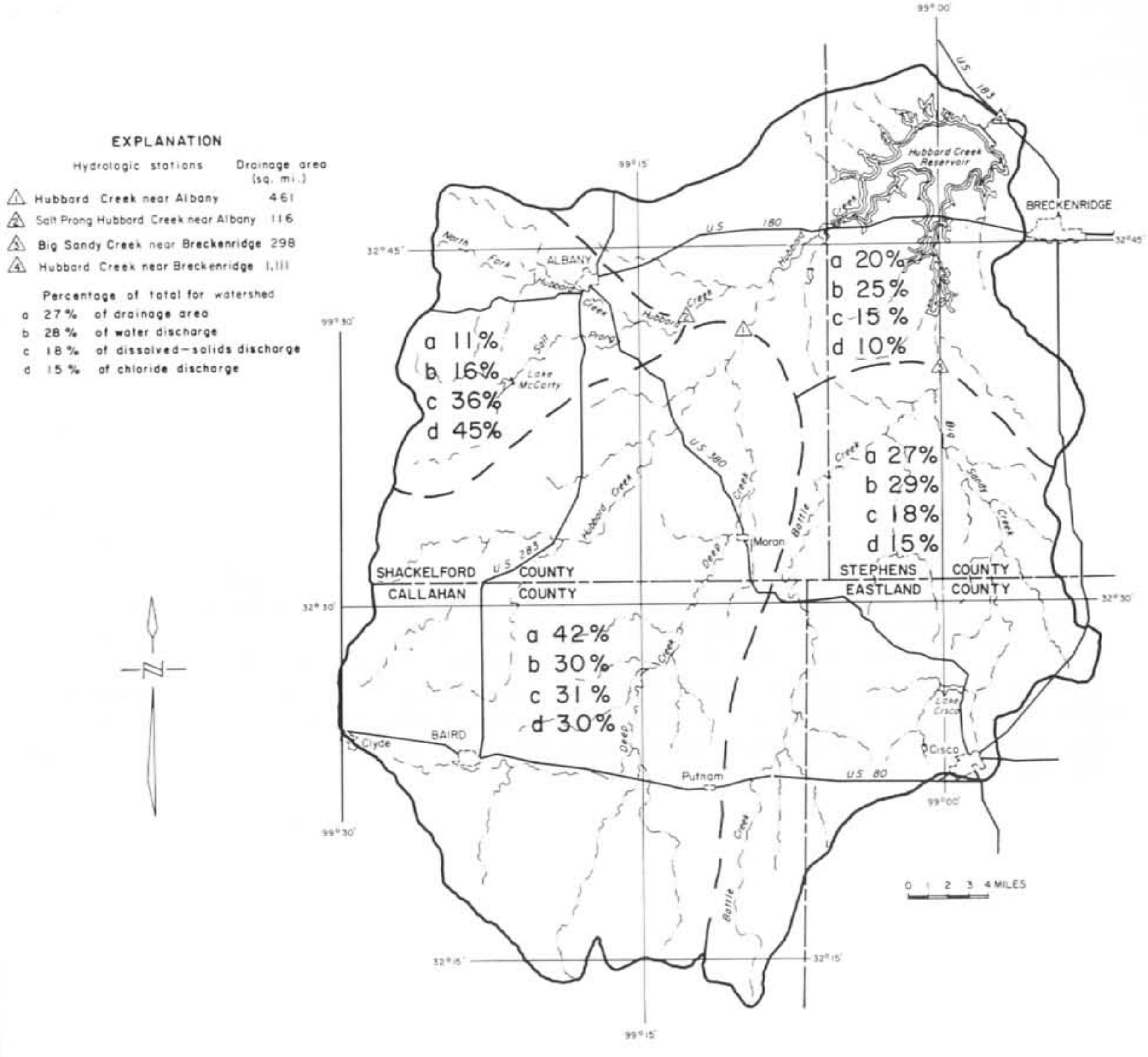

Figure 5

Water, Dissolved-Solids, and Chloride Discharges from Four Subdivisions of Hubbard Creek Watershed, in Percentage of Total for Watershed, February 1 to September 30, 1962

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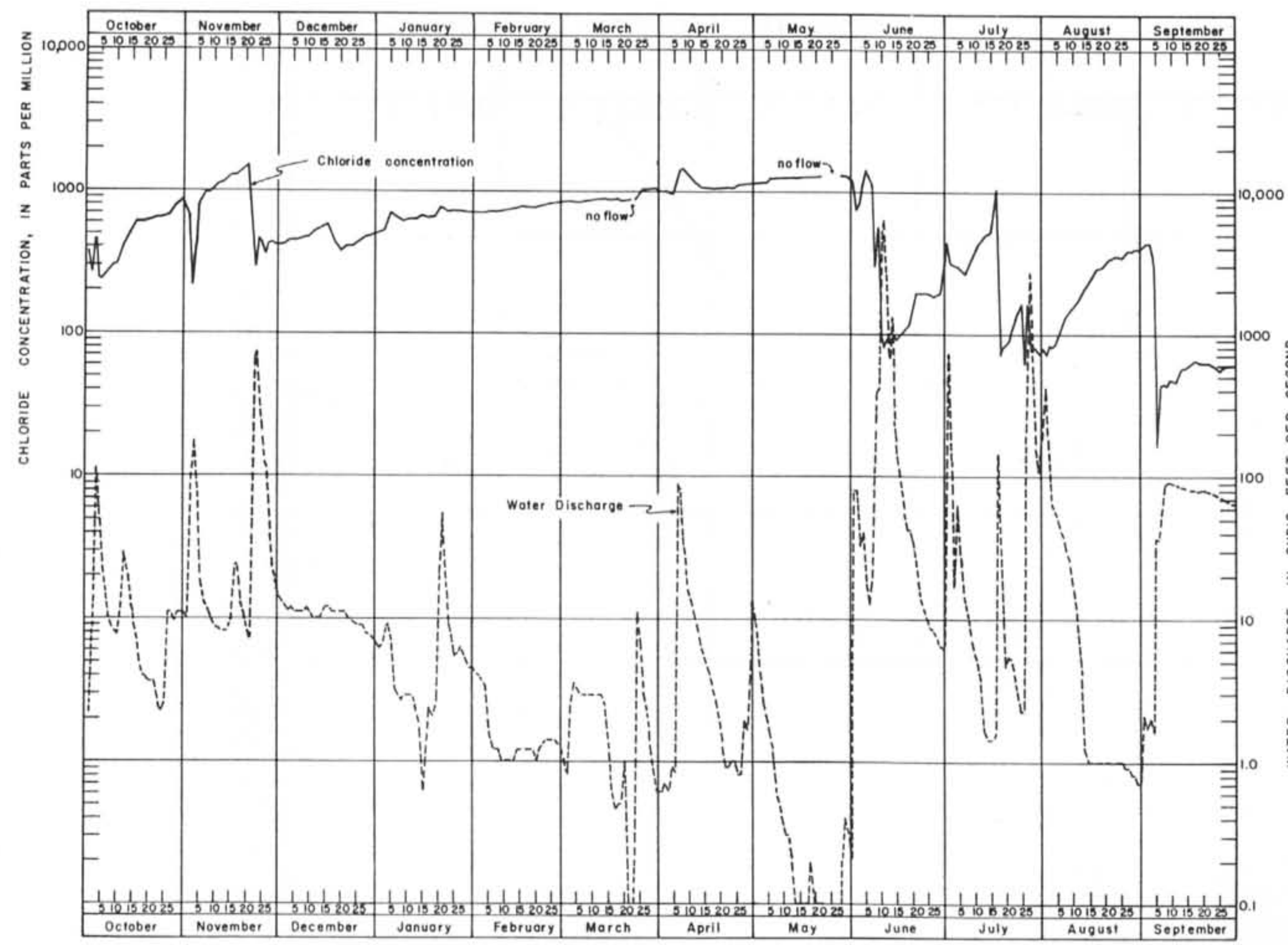

Figure 6

Chloride Concentration and Water Discharge of Hubbard Creek near Breckenridge, 1962 Water Year

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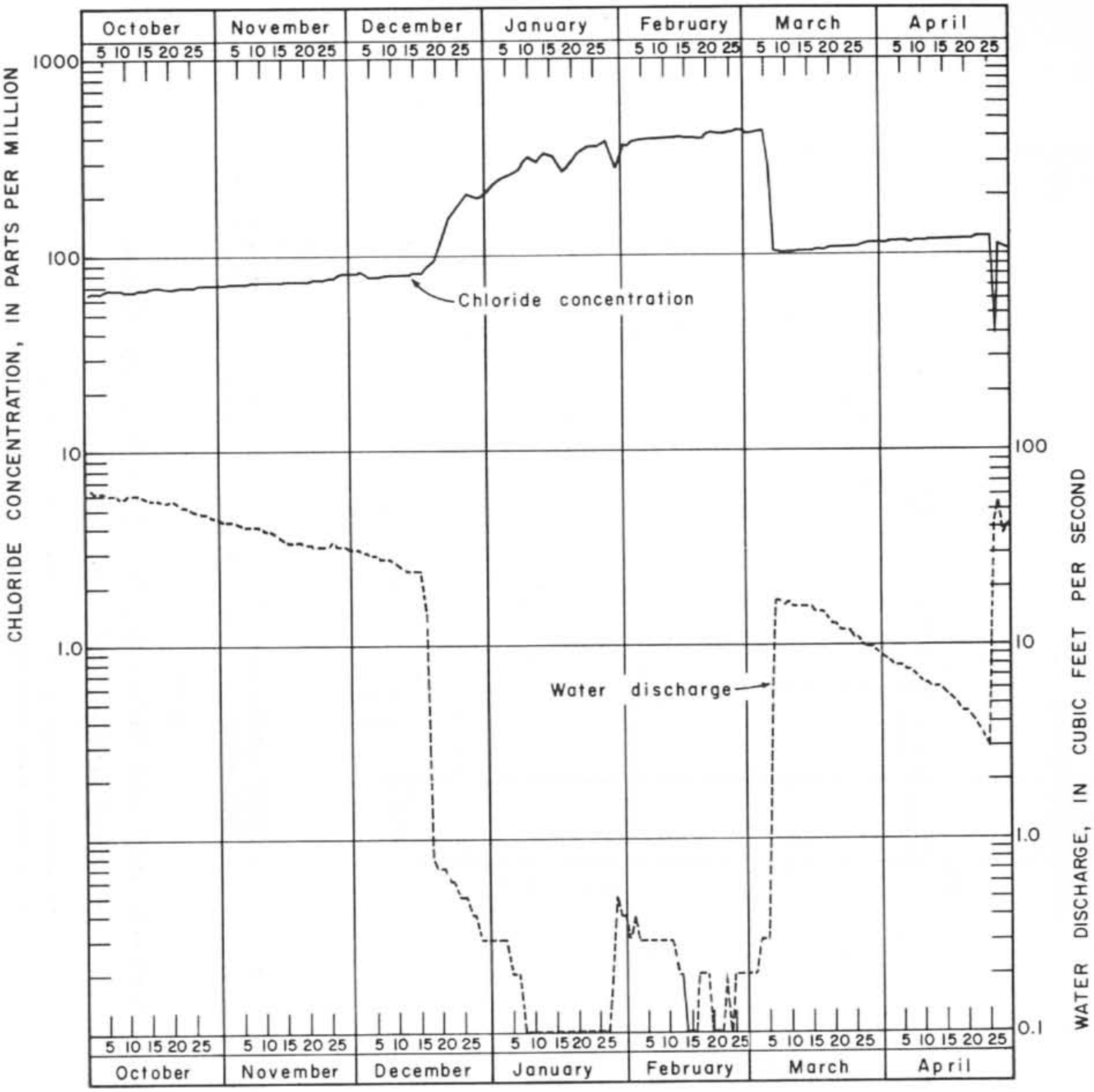

Figure 7

Chloride Concentration and Water Discharge of Hubbard Creek near Breckenridge, October 1, 1962 to April 30, 1963

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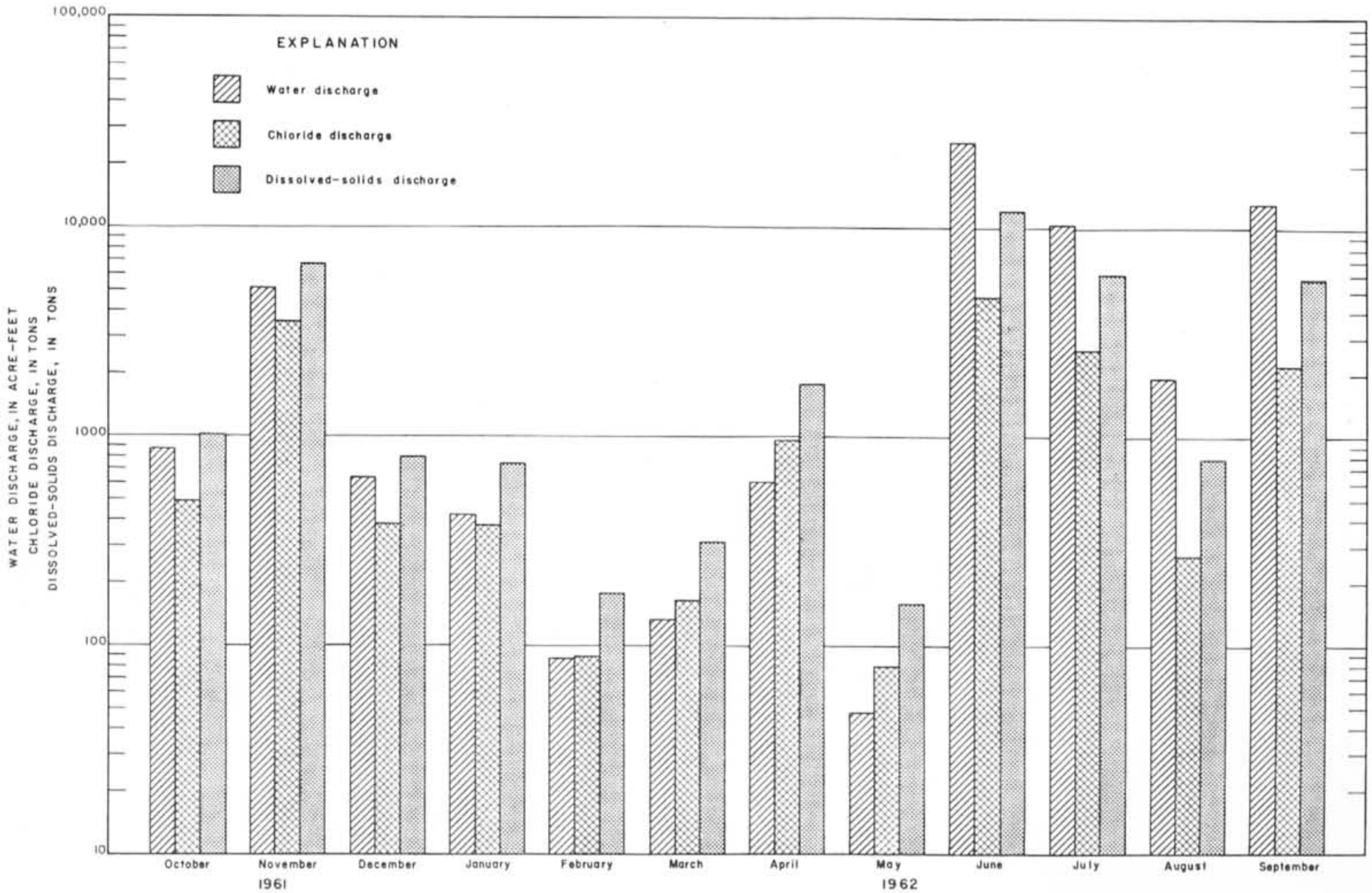

Figure 8

Monthly Water, Chloride, and Dissolved-Solids Discharges, Hubbard Creek near Breckenridge, October 1961 to September 1962

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Table 1.--Weighted average analyses of Hubbard Creek near Breckenridge, Tex., 1955-62

LOCATION.--At gaging station at bridge on U. S. Highway 183, 1 mile downstream from Hubbard Creek Dam, 2.3 miles downstream from Big Sandy Creek, 6.8 miles northwest of Breckenridge, Stephens County, 7 miles upstream from Gonzales Creek, and 8 miles upstream from Clear Fork Brazos River.
DRAINAGE AREA.--1,111 square miles.
RECORDS AVAILABLE.--Chemical analyses: April 1955 to September 1962.
Water temperatures: April 1955 to September 1962.
EXTREMES, 1955-62.--Dissolved solids: Maximum, 5,350 ppm July 1-5, 1960; minimum, 112 ppm June 15, 1961.
Hardness: Maximum, 1,820 ppm July 1-5, 1960; minimum, 72 ppm Feb. 6-8, 1957.
Chloride: Maximum, 3,180 ppm July 1-5, 1960; minimum, 10 ppm June 15, 1961.
Specific conductance: Maximum daily, 9,270 micromhos July 4, 1960; minimum daily, 121 micromhos Apr. 27, 1957.

Analytical results, in parts per million, except as indicated

Water Year	Mean discharge (cfs)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids: Parts per million	Dissolved solids: Tons per acre-foot	Dissolved solids: Tons per day	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Percent sodium	Sodium adsorption ratio	Specific conductance (micromhos at 25° C)
Apr. to Sept. 1955	249	11		37	3.7	25		109	9.5	41	0.4	3.4		192	0.26	129	108	18	34	1.1	331
1956	22.7	11		38	4.4	32		106	11	58	.4	2.7		212	.29	13.0	113	26	38	1.3	386
1957	633	8.4		36	4.1	24		98	10	46	.5	2.9		180	.25	308	107	26	33	1.0	331
1958	204	7.6		50	8.6	61		103	23	129	.5	1.8		332	.45	183	160	76	45	2.1	622
1959	47.9	9.4		51	8.4	56		104	24	121	.2	3.6		325	.44	42.0	162	76	43	1.9	628
1960	83.0	9.4		51	8.7	58		107	25	120	.2	2.7		330	.45	74.0	163	76	44	2.0	601
1961	134	11		47	8.2	51		105	20	109	.3	2.3		300	.41	109	151	65	42	1.8	563
1962	68.5	11		64	13	91		108	27	207	--	--		469	.64	86.7	213	124	48	2.7	885
a1962	81.5	12		62	12	88		107	27	197	--	--		452	.61	99.5	204	116	48	2.7	851

a Includes adjustments for change in storage in Hubbard Creek Reservoir during the 1962 water year.

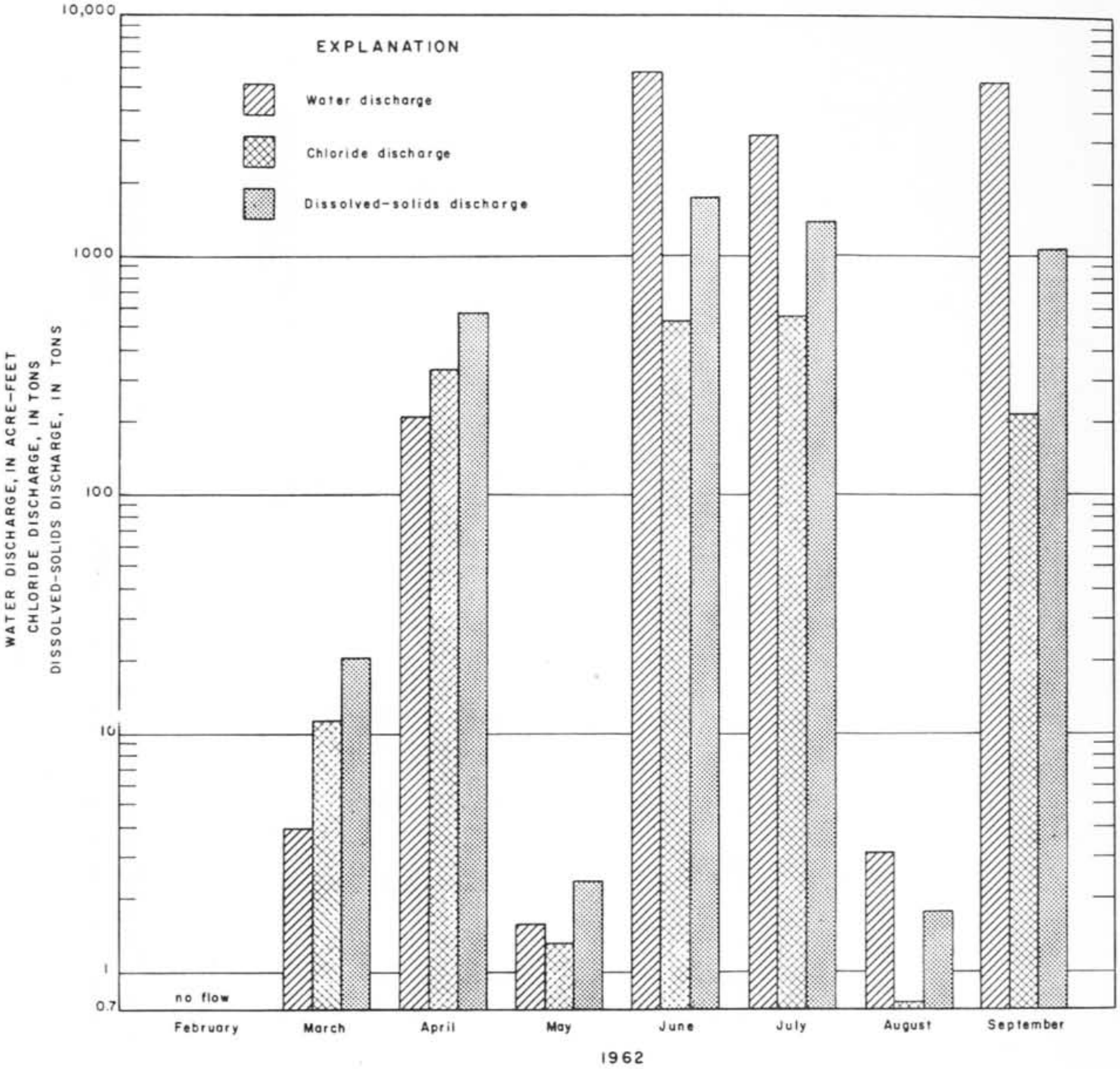

Figure 9

Monthly Water, Chloride, and Dissolved-Solids Discharges, Big Sandy Creek near Breckenridge, February to September 1962

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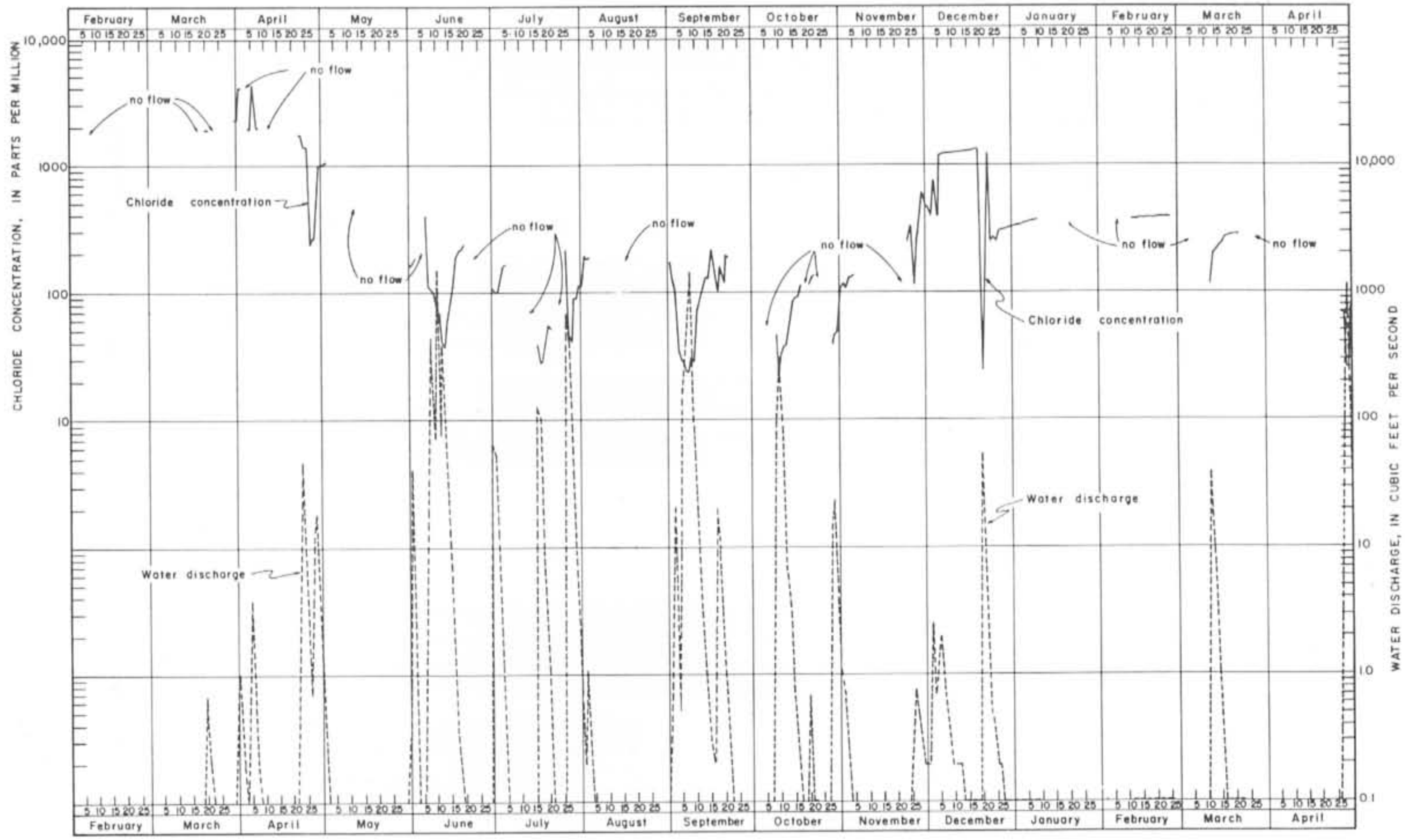

Figure 10

Chloride Concentration and Water Discharge of Big Sandy Creek near Breckenridge, February 1, 1962 to April 30, 1963

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Hubbard Creek near Albany

The station on Hubbard Creek near Albany has the largest drainage area (461 square miles) of any of the three inflow stations above the reservoir. The relation of dissolved-solids load to water discharge at this station is similar to that for Hubbard Creek near Breckenridge. During the first 8 months of record, the area above the Albany station contributed approximately one-third of the total dissolved-solids load and one-third of the water discharge from the watershed (Figure 5). The variation of individual ions with streamflow was similar to the ion-water relationship of Big Sandy Creek near Breckenridge for the 8 months of record, but the dissolved-solids load was double that measured at the Big Sandy Creek station. Data collected at the Albany station are given in Figures 11 and 12.

Salt Prong Hubbard Creek near Albany

Compared to the two other streams above the reservoir previously discussed, Salt Prong Hubbard Creek near Albany (drainage area 116 square miles) is the smallest and the saltiest. During the first 8 months of record, the area above the station on Salt Prong contributed 16 percent of the discharge and 36 percent of the dissolved-solids load from the watershed (Figure 5). Chemical quality versus streamflow was characteristic of a contaminated stream with the first waters of high flows being saline. The bicarbonate ion, as at the other stations, does not change appreciably with changes in flow. The sodium and chloride ions are the major constituents and vary inversely with flow. The calcium and magnesium content increases with the sodium ions but not consistently, and the sulfate ions show little relation to dissolved-solids concentrations or to streamflow. Data for the period of record are given in Figures 13 and 14.

Comparison of Yields

Comparative yields from three subdivisions above the reservoir for the 15 months of record (February 1962 to April 1963) are shown in Figure 15.

Deep Creek at Moran and
North Fork Hubbard Creek near Albany

In November 1962, stations were established on Deep Creek at Moran and North Fork Hubbard Creek near Albany. Almost all the runoff for the first 6 months of station operation occurred during the last week of April. Based on this short period the chemical quality versus streamflow at the two stations seems to conform with the remainder of the watershed.

With little or no flow for most of the period, the chloride concentration at the station Deep Creek at Moran reached 2,200 ppm. The daily water discharge and chloride concentrations are shown on Figure 16.

The station on North Fork Hubbard Creek near Albany had a sustained flow (0.3 to 0.5 cfs) of highly saline water for the 6-month period. The weighted average chloride for the period was 2,520 ppm and concentrations greater than 3,000 ppm chloride were common. Data for the period (November 1962 to April 1963) are shown on Figure 17.

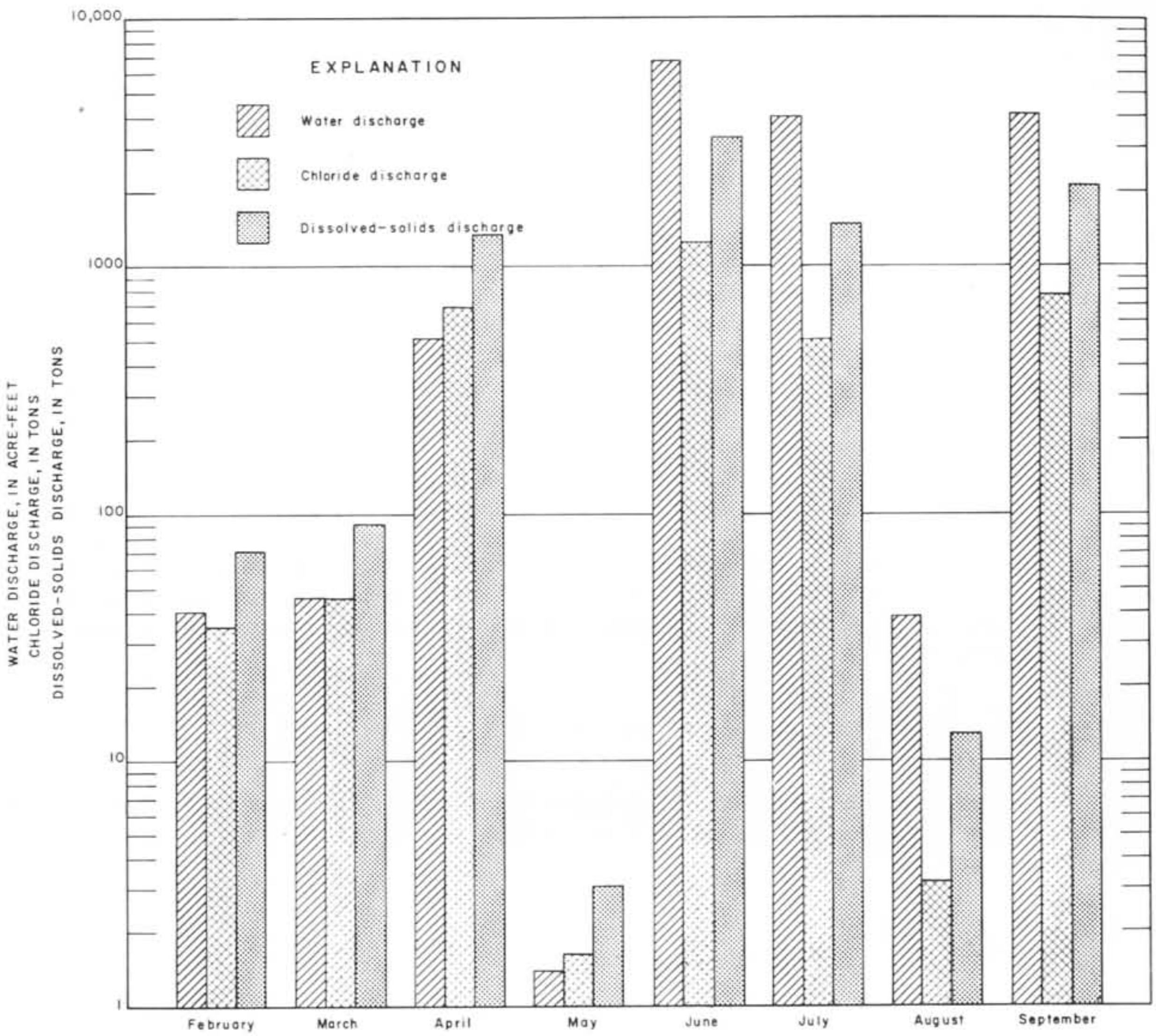

Figure 11

Monthly Water, Chloride, and Dissolved-Solids Discharges, Hubbard Creek near Albany, February to September 1962

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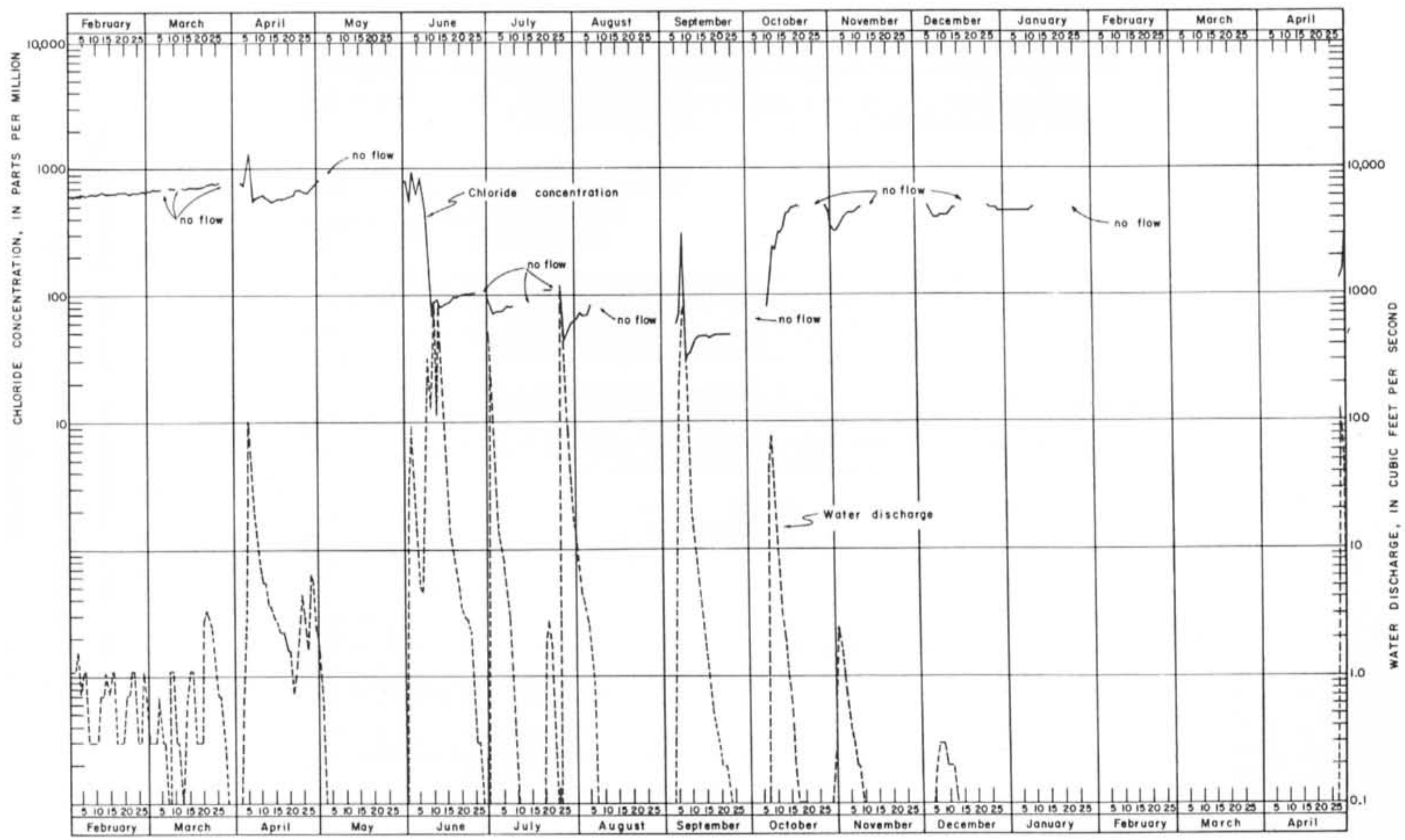

Figure 12

Chloride Concentration and Water Discharge of Hubbard Creek near Albany, February 1, 1962 to April 30, 1963

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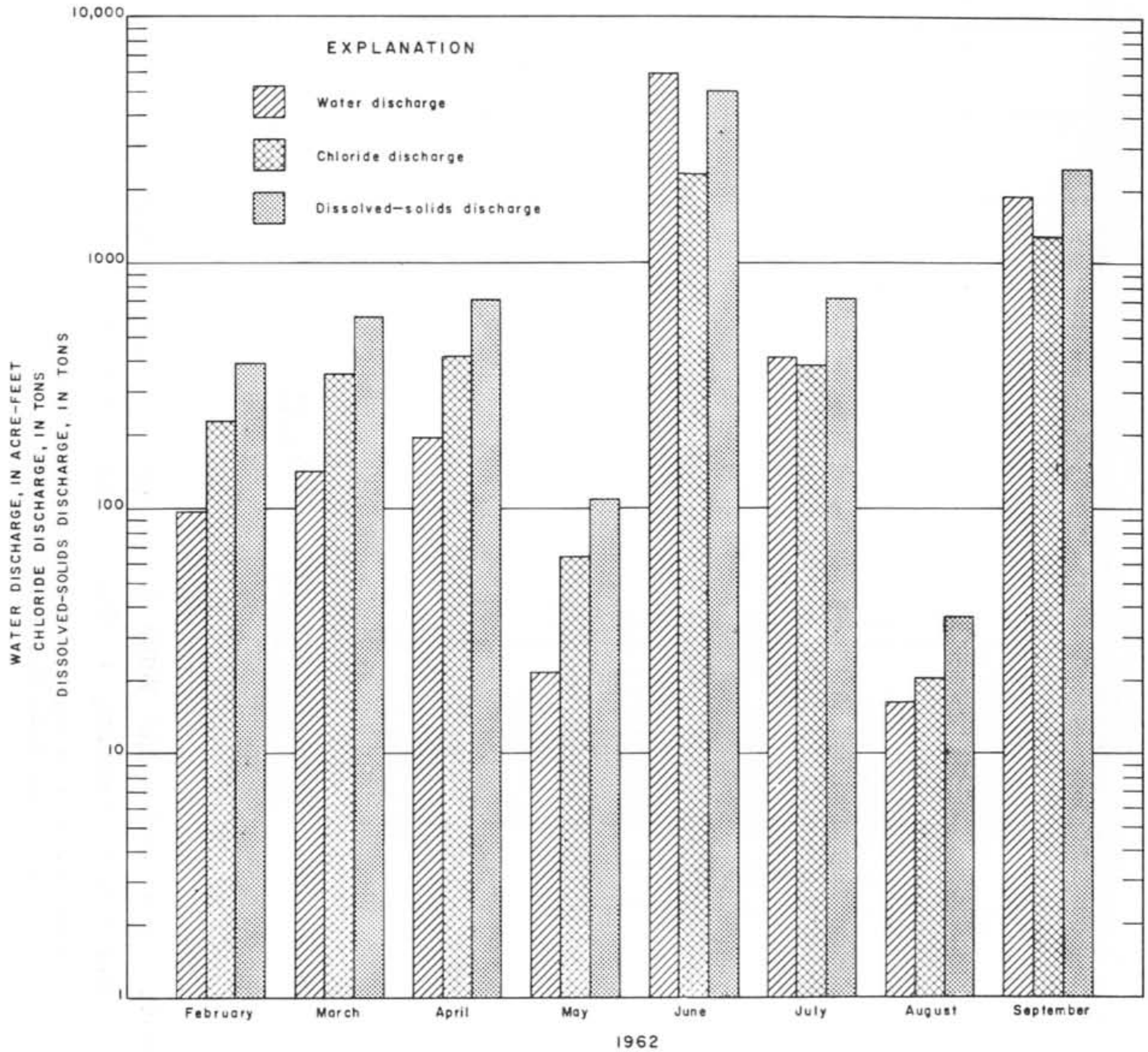

Figure 13

Monthly Water, Chloride, and Dissolved-Solids Discharges, Salt Prong Hubbard Creek near Albany, February to September 1962

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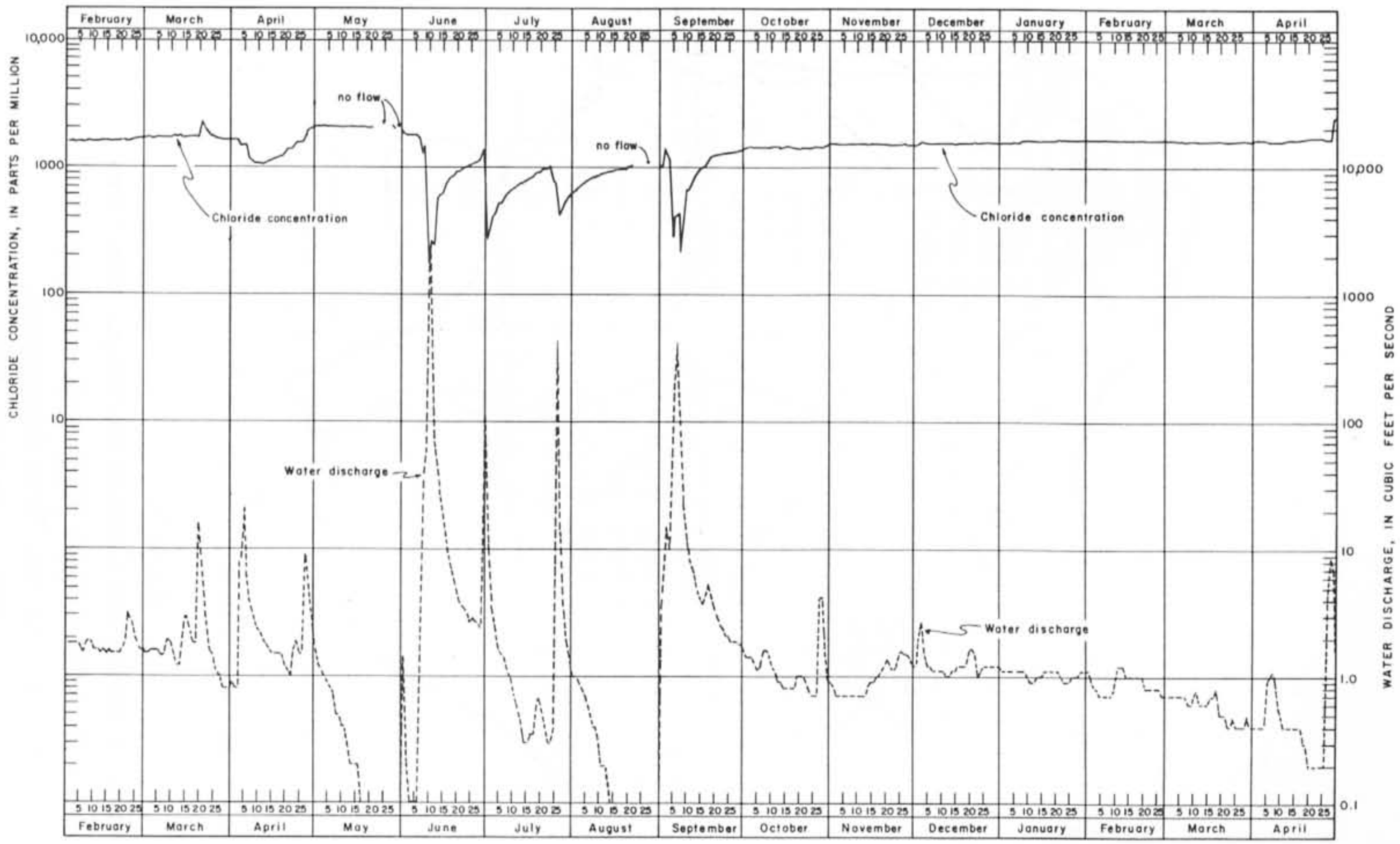

Figure 14

Chloride Concentration and Water Discharge of Salt Prong Hubbard Creek near Albany, February 1, 1962 to April 30, 1963

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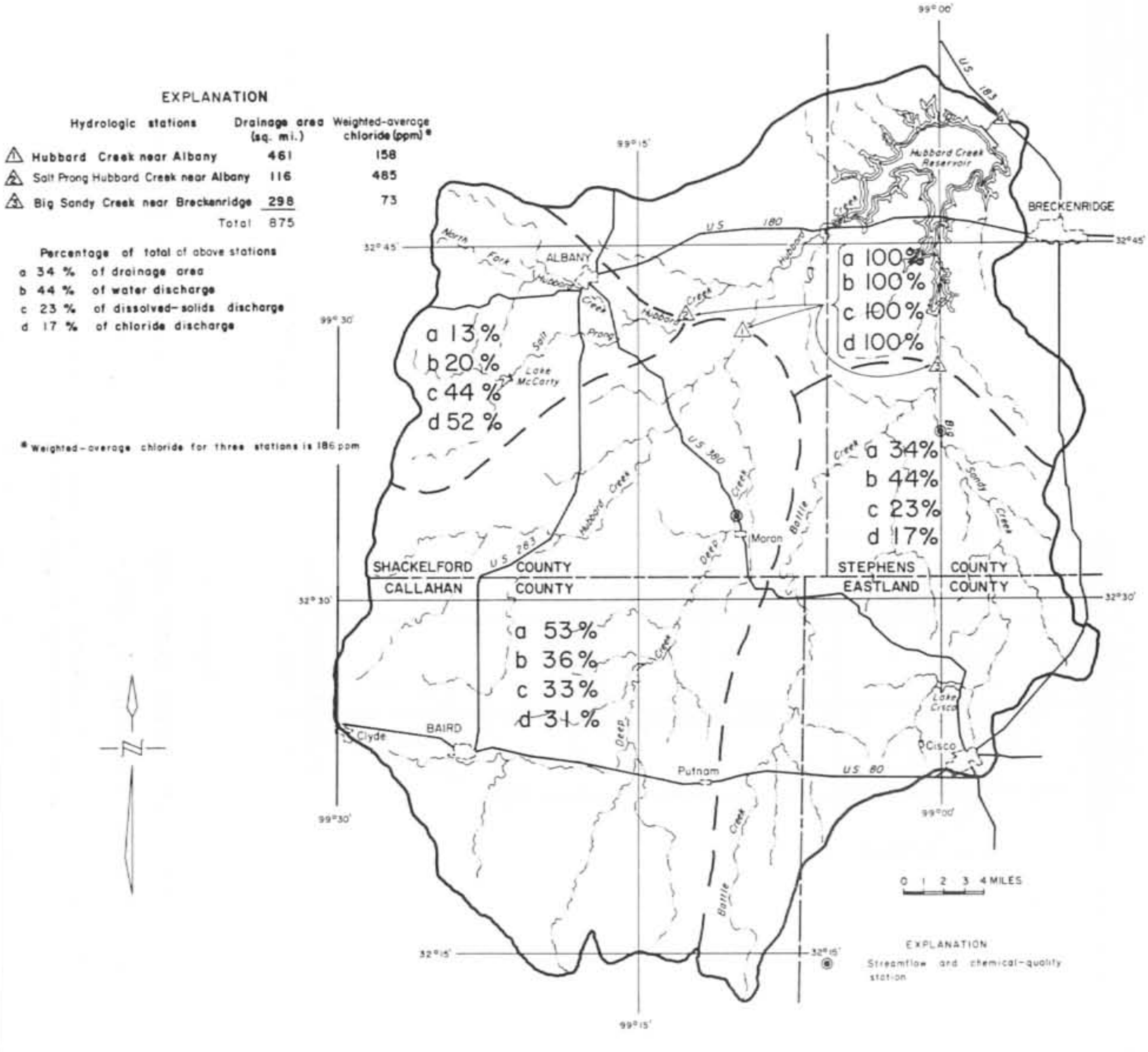

Figure 15

Water, Dissolved-Solids, and Chloride Discharges from Three Subdivisions of Hubbard Creek Watershed, in Percentage of the Total from the Three Subdivisions, February 1, 1962 to April 30, 1963

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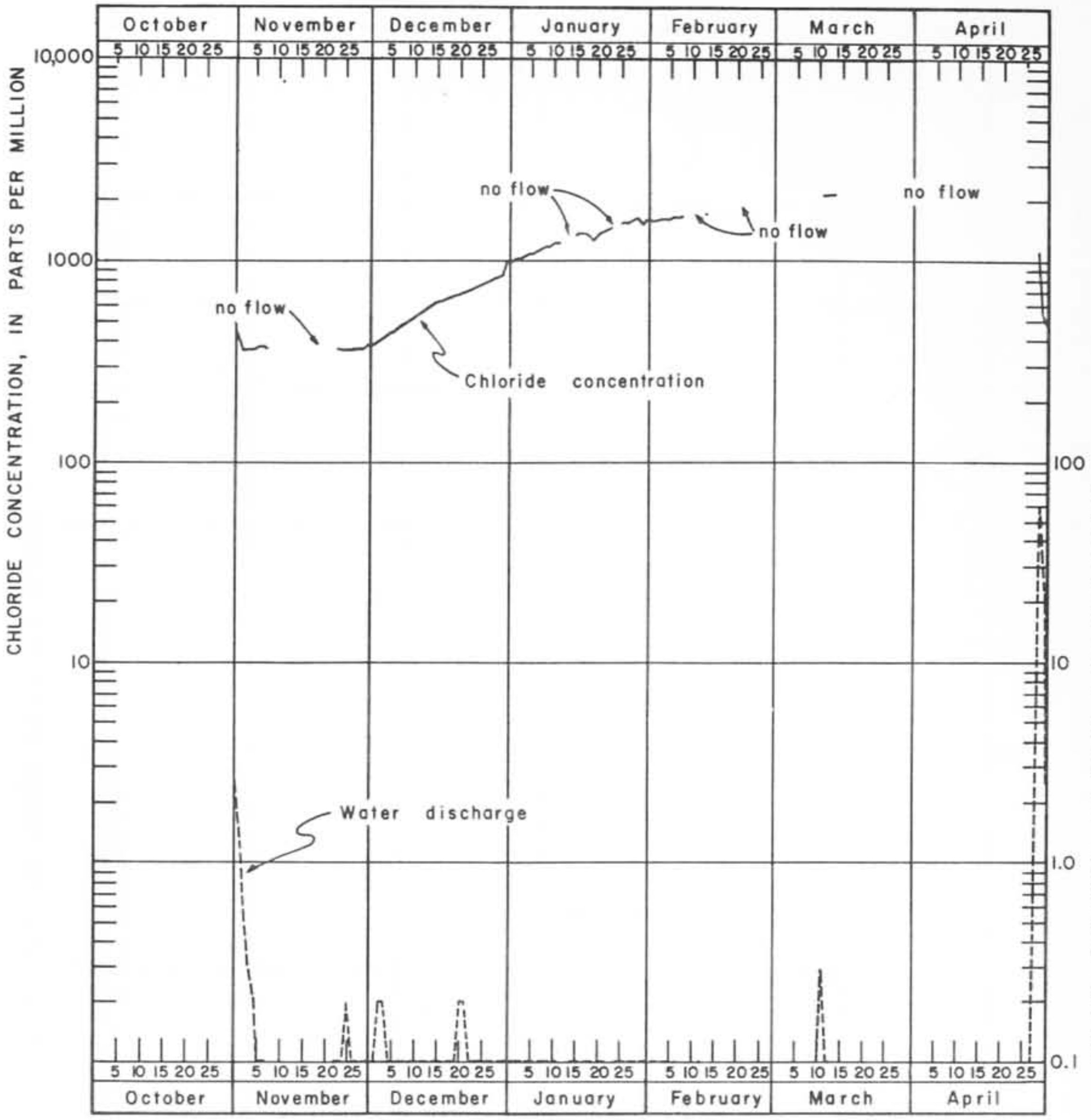

Figure 16

Chloride Concentration and Water Discharge of Deep Creek near Moran, October 31, 1962 to April 30, 1963

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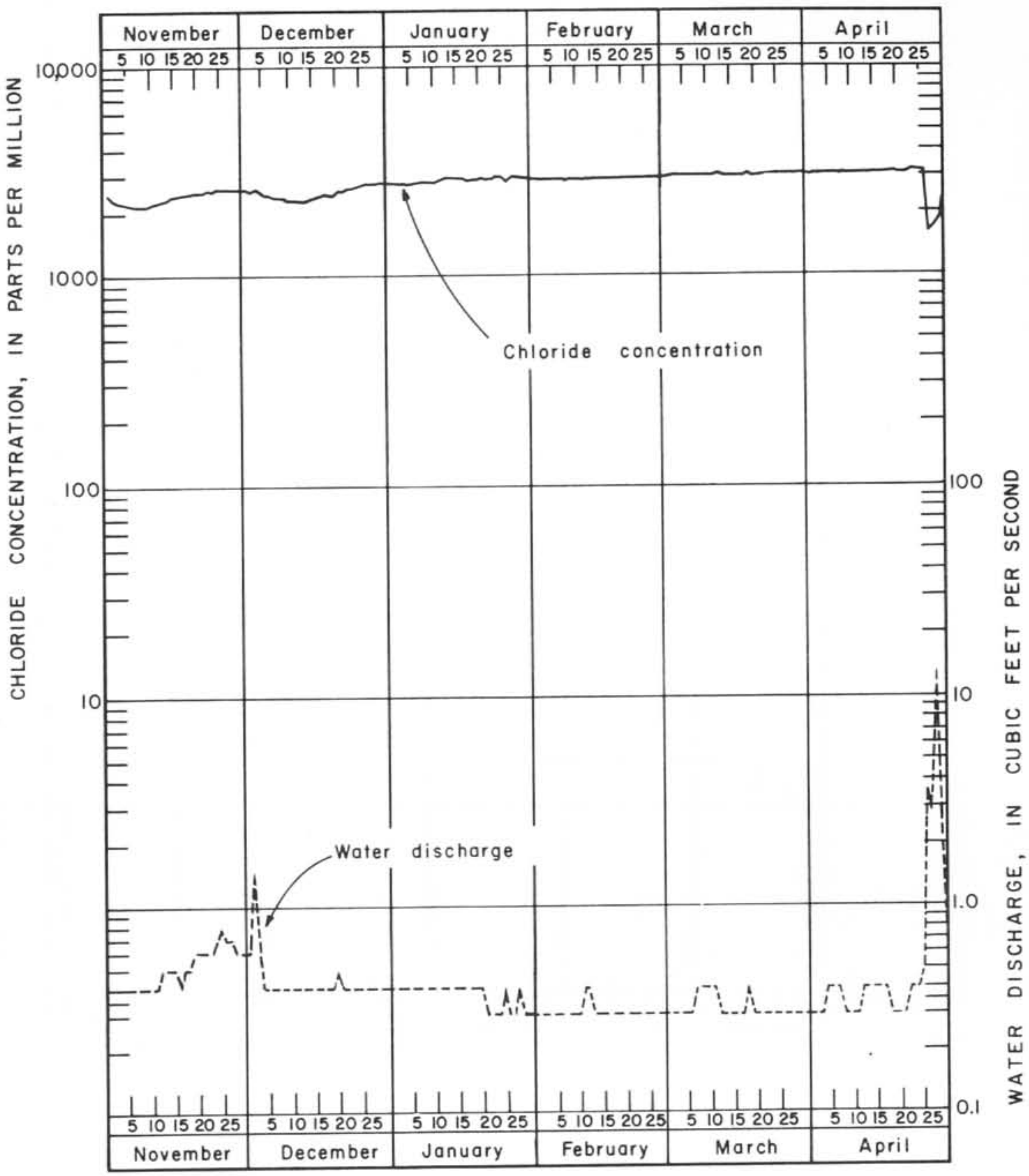

Figure 17

Chloride Concentration and Water Discharge of North Fork Hubbard Creek near Albany, November 1, 1962 to April 30, 1963

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Percentage of water, dissolved solids, and chloride from the area above the North Fork Hubbard Creek station and from the remainder of the area above the station on Salt Prong Hubbard Creek are shown on Figure 18.

Relation to Base Flow

During the winter of 1961-62 personnel of the U. S. Geological Survey made two field investigations in the Hubbard Creek watershed. Samples were collected at 62 sites. Locations of the sites and the data obtained are shown in Figure 19 and Tables 2 and 3.

The first field investigation was made in December 1961. Potential sources of contamination and evidence of contamination were observed. The December survey was made during a low-flow period and most of the sampling sites had discharges of less than 1 cfs. The water samples varied from brines collected west of Albany that contained more than 20,000 ppm chloride to water of excellent quality (16 ppm chloride) in Lake Cisco.

Another low-flow investigation was made in January 1962. A water sample was collected at each streamflow station, at some of the December sampling sites, and at new sampling sites. At most of the sites chloride concentrations were higher than in December. Results of the low-flow investigation are given in Figure 20.

Relation to Geology

Chloride contamination of the streams in the watershed is so widespread that the quality of water of most of the streams has only a minor relation to the types of rocks cropping out at the surface. However, the quality of water in many small streams and in the numerous stockponds scattered throughout the area reflect the effect of these rocks.

As a part of the study of salt-water contamination of the Hubbard Creek watershed, Conselman, Jenke, and Tice (written communication, May 1962) collected and analyzed water samples from many small streams and stock tanks. At the time the samples were collected, no appreciable runoff had occurred for several months. Consequently, the quality of water in the small streams and stockponds was probably of poorer quality than the average for runoff from these virtually uncontaminated areas. Although the chloride values may not be representative of the average runoff, we can assume, with confidence, that they approximate the maximum chloride concentration of the average annual runoff. Chloride concentrations shown on Figure 21 strongly indicate that the concentration of chloride in the natural runoff of the watershed would not be more than 35 ppm and probably would be less.

Only one natural spring containing a high concentration of chloride is known to occur in the watershed. The site of this spring, near the head of one of the tributaries of Salt Prong, is known as the "Old Albany Salt Works." The exact date of its first use as a local source of salt is unknown, but earliest records mention its use.

Samples of water collected at different places in the seepage area near the salt works by U. S. Geological Survey personnel on July 13, 1940, contained

EXPLANATION

Hydrologic stations	Drainage area (sq. mi.)	Weighted-average chloride (ppm)
△1 North Fork Hubbard Creek near Albany	38.4	2520
△2 Salt Prong Hubbard Creek near Albany	116	1610
Intervening area	77.6	643

Percentage of total for sub-basin

- a 33 % of drainage area
- b 52 % of water discharge
- c 74 % of dissolved-solids discharge
- d 81 % of chloride discharge

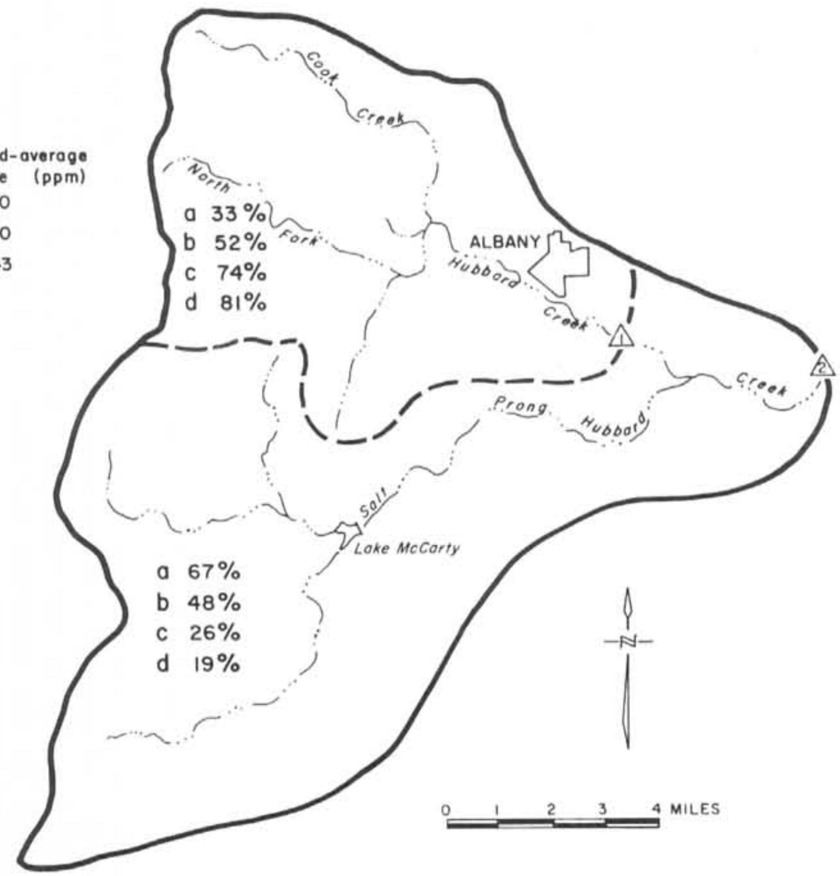

Figure 18

Water, Dissolved-Solids, and Chloride Discharges from Areas Above Station on Salt Prong Hubbard Creek, in Percentage of Total from Sub-Basin, November 1, 1962 to April 30, 1963

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Table 2.--Water and chloride discharge at chemical-quality sampling sites in the Hubbard Creek watershed

Map number	Sampling site	Date	Water discharge (cfs)	Chloride		Specific conductance (micromhos at 25°C)
				Ppm	Tons per day	
1	Hubbard Creek 8.5 miles west of Moran	Jan. 23, 1962	0	880	--	3,000
2	Jenkins Creek 9 miles west of Moran	do.	a .15	110	0.04	722
3	Hubbard Creek 8 miles west of Moran	do.	a1.0	208	.56	1,130
4	Hubbard Creek 3 miles west of Sedwick	Jan. 26, 1962	a .8	280	.60	1,420
5	Hubbard Creek 2.5 miles north of Sedwick	do.	1.06	700	2.00	2,640
6	Mexia Creek 4.5 miles west of Putnam	Dec. 10, 1961	a .15	146	.06	907
7	Deep Creek 6 miles northwest of Putnam	Jan. 23, 1962	a .1	305	.08	1,570
8	Tributary to Deep Creek 6 miles northwest of Putnam	do.	a .01	4,480	b .12	13,300
9	Deep Creek 7 miles northwest of Putnam	Jan. 26, 1962	a .2	680	.37	2,590
10	Tributary to Deep Creek 4 miles north of Putnam	Jan. 23, 1962	a .05	3,960	b .54	11,200
11	Tributary to Deep Creek 7 miles northwest of Putnam	Jan. 26, 1962	0	4,110	--	11,700
12	Deep Creek 0.5 mile west of Moran	do.	a .5	1,650	2.23	5,840
13	Tributary to Deep Creek 1.8 miles west of Moran	do.	a .01	13,600	b .37	32,900
14	Deep Creek 0.5 mile north of Moran	Dec. 10, 1961	a .8	630	1.36	2,460
15	Deep Creek 3 miles north of Moran	Jan. 22, 1962	--	1,580	--	5,460
16	Deep Creek 9.4 miles southeast of Albany	Jan. 26, 1962	.32	730	.63	2,800
17	Hubbard Creek near Albany	Dec. 10, 1961	a2.0	268	1.45	1,200
17	do.	Jan. 26, 1962	1.62	600	2.62	2,280
18	Salt Prong Hubbard Creek 5 miles southwest of Albany	Jan. 23, 1962	a .25	120	.08	887
19	Salt Prong Hubbard Creek 4.5 miles southwest of Albany	do.	a .1	120	.03	918
20	Salt Prong Hubbard Creek 4.3 miles southwest of Albany	do.	a .1	322	.09	1,500
21	Salt Prong Hubbard Creek 4 miles southwest of Albany	do.	a .3	365	.30	1,660
22	Salt Prong Hubbard Creek 2 miles south of Albany	do.	a .2	435	.23	1,850
23	Salt Prong Hubbard Creek 3.5 miles southeast of Albany	Dec. 10, 1961	a .4	510	.55	2,040
23	do.	Jan. 25, 1962	.74	560	1.12	2,240
24	North Fork Hubbard Creek 3 miles west of Albany	Dec. 10, 1961	a .15	880	.36	3,060
25	Tributary to North Fork Hubbard Creek 3 miles west of Albany	do.	a .01	23,500	b .65	51,700
26	Tributary to North Fork Hubbard Creek 3 miles northwest of Albany	do.	a .05	3,150	.43	9,250
27	North Fork Hubbard Creek 2.5 miles northwest of Albany	do.	a .5	3,780	5.10	10,900
27	do.	Jan. 26, 1962	a .15	4,880	b1.98	13,400
28	Cook Creek 6 miles northwest of Albany	Dec. 10, 1961	a .1	2,120	.57	6,630
29	Cook Creek 5.7 miles northwest of Albany	do.	a .1	2,550	.69	7,780
30	Cook Creek 5 miles northwest of Albany	do.	a .4	3,700	4.00	10,900
30	do.	Jan. 26, 1962	a .15	9,290	b3.81	23,500
31	Cook Creek 3 miles northwest of Albany	Dec. 10, 1961	a .5	6,360	b8.64	17,000
31	do.	Jan. 26, 1962	a .2	5,860	b3.19	15,700
32	North Fork Hubbard Creek 2 miles west of Albany	do.	a .2	3,320	1.79	9,710
33	North Fork Hubbard Creek at Albany	do.	a .6	3,120	5.05	9,110
34	North Fork Hubbard Creek 1.6 miles southeast of Albany	Dec. 10, 1961	a1.5	2,090	8.46	6,480
34	do.	Jan. 25, 1962	.55	2,750	4.08	8,200
35	Salt Prong Hubbard Creek near Albany	Dec. 10, 1961	a2.5	1,720	11.6	5,520
35	do.	Jan. 25, 1962	1.62	1,650	7.22	5,250
36	Snailum Creek 3 miles northeast of Albany	Dec. 10, 1961	a .01	92	.00	501
37	Snailum Creek 6.7 miles east of Albany	Jan. 25, 1962	.06	2,080	.34	6,380
38	Salt Prong Hubbard Creek 8 miles east of Albany	do.	1.58	1,540	6.57	4,970
39	Hubbard Creek 9 miles east of Albany	Jan. 25, 1962	2.93	1,250	9.89	4,190
40	Dry Branch 1.2 miles southeast of Ibex	Dec. 10, 1961	a .05	196	.03	994
41	Hubbard Creek 12 miles east of Albany	do.	a2.5	660	4.46	2,380
41	do.	Jan. 26, 1962	3.13	1,280	10.8	4,300
42	Hubbard Creek 6 miles northwest of Breckenridge	Dec. 10, 1961	a .8	305	.66	1,240
42	do.	Jan. 26, 1962	6.14	770	12.8	2,900
43	Sink Creek 8 miles northwest of Breckenridge	Dec. 10, 1961	a .05	21	.00	390
44	Lake Cisco 2.5 miles north of Cisco	do.	--	16	--	272
45	Big Sandy Creek 3 miles north of Cisco	Jan. 22, 1962	a .8	70	.15	838
46	Big Sandy Creek 13 miles north of Cisco	Dec. 10, 1961	a .05	44	.01	356
46	do.	Jan. 22, 1962	0	45	--	410
47	Big Sandy Creek 9.5 miles southwest of Breckenridge	Jan. 25, 1962	.02	10,200	b .56	24,000
48	Battle Creek 2 miles east of Putnam	Dec. 10, 1961	a .05	88	.01	1,020
49	Battle Creek 6 miles northeast of Putnam	Jan. 26, 1962	0	39	--	398
50	Battle Creek 8 miles northeast of Moran	Jan. 22, 1962	--	42	--	433
51	Battle Creek 8.5 miles northeast of Moran	Dec. 10, 1961	0	27	--	352
52	Tributary to Battle Creek 7 miles southeast of Moran	Jan. 22, 1962	a .02	10,500	b .58	26,100
53	Tributary to Battle Creek 8.5 miles northeast of Moran	Dec. 10, 1961	a .3	1,120	.91	3,640
54	Battle Creek 9.5 miles southwest of Breckenridge	do.	a .01	1,340	.04	4,430
55	Battle Creek 9.3 miles southwest of Breckenridge	Jan. 25, 1962	a .002	980	.00	3,430
56	Big Sandy Creek near Breckenridge	Dec. 10, 1961	a .3	520	.42	2,020
56	do.	Jan. 25, 1962	.03	1,260	.10	4,470
57	Big Sandy Creek 6.3 miles southwest of Breckenridge	do.	a .002	1,520	.01	5,070
58	Big Sandy Creek 5.7 miles west of Breckenridge	Dec. 10, 1961	a .5	130	.18	613
58	do.	Jan. 25, 1962	a .002	129	.00	633
59	Big Sandy Creek 6 miles northwest of Breckenridge	do.	a .01	500	.01	1,930
60	Unnamed creek 2.5 miles west of Breckenridge	Dec. 10, 1961	a .05	77	.01	667
61	Unnamed creek 2.8 miles west of Breckenridge	do.	a .01	42	.00	586
62	Hubbard Creek near Breckenridge	Jan. 26, 1962	5.93	720	11.5	2,630

a Estimated.

b Density correction applied.

Table 3.--Analyses of surface water at chemical-quality sampling sites in the Hubbard Creek watershed

Date of collection	Discharge (cfs)	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Dissolved solids (sum): Parts per million	Dissolved solids (sum): Tons per acre-foot	Dissolved solids (sum): Tons per day	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Non-carbonate	Percent sodium	Specific conductance (micromhos at 25°C)	pH	Sodium adsorption ratio
6. MEXIA CREEK 4.5 MILES WEST OF PUTNAM																			
Dec. 10, 1961--------	a0.15		83	30					146	0.2				330			907		
14. DEEP CREEK 0.5 MILE NORTH OF MORAN																			
Dec. 10, 1961--------	a0.8	3.6	143	43		290	157	137	630	4.2	1,330	1.81	2.87	534	406	54	2,460	7.2	5.5
17. HUBBARD CREEK NEAR ALBANY																			
Dec. 10, 1961--------	a2.0	5.6	84	24		121	149	66	268	0.8	663	0.87	3.47	308	186	46	1,200	7.1	3.0
23. SALT PRONG HUBBARD CREEK 3.5 MILES SOUTHEAST OF ALBANY																			
Dec. 10, 1961--------	a0.4	9.8	116	43		242	260	57	510	0.2	1,110	1.51	1.20	466	254	53	2,040	7.3	4.9
24. NORTH FORK HUBBARD CREEK 3 MILES WEST OF ALBANY																			
Dec. 10, 1961--------	a0.15	8.8	215	51		334	199	64	880	1.8	1,650	2.24	0.67	746	584	49	3,060	7.3	5.3
25. TRIBUTARY TO NORTH FORK HUBBARD CREEK 3 MILES WEST OF ALBANY																			
Dec. 10, 1961--------	a0.01	12	3,010	978		10,000	141	94	23,500		37,700	b52.5	1.02	11,500	11,400	65	51,700	6.8	41
26. TRIBUTARY TO NORTH FORK HUBBARD CREEK 3 MILES NORTHWEST OF ALBANY																			
Dec. 10, 1961--------	a0.05	5.3	530	227		1,110	227	38	3,150		5,170	7.03	0.70	2,260	2,070	52	9,250	7.4	10
27. NORTH FORK HUBBARD CREEK 2.5 MILES NORTHWEST OF ALBANY																			
Dec. 10, 1961--------	a0.5	2.6	620	178		1,490	136	65	3,780		6,200	8.43	8.37	2,280	2,170	59	10,900	7.2	14
28. COOK CREEK 6 MILES NORTHWEST OF ALBANY																			
Dec. 10, 1961--------	a0.1	6.0	400	76		880	172	88	2,120		3,660	4.98	.99	1,310	1,170	59	6,630	7.2	11
29. COOK CREEK 5.7 MILES NORTHWEST OF ALBANY																			
Dec. 10, 1961--------	a0.1	5.5	455	89		1,080	177	98	2,550		4,360	5.93	1.18	1,500	1,360	61	7,780	7.3	12
30. COOK CREEK 5 MILES NORTHWEST OF ALBANY																			
Dec. 10, 1961--------	a0.4	6.0	650	134		1,530	169	132	3,700		6,240	8.49	6.74	2,170	2,030	60	10,900	7.1	14
31. COOK CREEK 3 MILES NORTHWEST OF ALBANY																			
Dec. 10, 1961--------	a0.5	4.3	1,070	225		2,590	121	152	6,360		10,500	b14.4	14.2	3,600	3,500	61	17,000	7.1	19
34. NORTH FORK HUBBARD CREEK 1.6 MILES SOUTHEAST OF ALBANY																			
Dec. 10, 1961--------	a1.5	2.6	428	113		741	156	66	2,090		3,520	4.79	14.3	1,530	1,400	51	6,480	7.2	8.2
35. SALT PRONG HUBBARD CREEK NEAR ALBANY																			
Dec. 10, 1961--------	a2.5	4.2	335	105		631	156	82	1,720	0.2	2,950	4.01	19.9	1,270	1,140	52	5,520	7.1	7.7

a Estimated.
b Density correction applied.

Table 3.--Analyses of surface water at chemical-quality sampling sites in the Hubbard Creek watershed--Continued

Date of collection	Discharge (cfs)	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Dissolved solids (sum)			Hardness as $CaCO_3$		Percent sodium	Specific conductance (micromhos at 25°C)	pH	Sodium adsorption ratio
											Parts per million	Tons per acre-foot	Tons per day	Calcium, magnesium	Non-carbonate				
40. DRY BRANCH 1.2 MILES SOUTHEAST OF IBEX																			
Dec. 10, 1961--------	a0.05	5.2	83	18		90	149	74	196	0.5	540	0.73	0.07	281	159	41	994	7.6	2.3
41. HUBBARD CREEK 12 MILES EAST OF ALBANY																			
Dec. 10, 1961--------	a2.5	5.1	149	38		273	151	64	660	0.8	1,260	1.71	8.50	528	405	53	2,380	7.0	5.2
42. HUBBARD CREEK 6 MILES NORTHWEST OF BRECKENRIDGE																			
Dec. 10, 1961--------	a0.8	4.4	82	24		125	114	48	305	0.8	646	0.88	1.40	303	210	47	1,240	7.0	3.1
53. TRIBUTARY TO BATTLE CREEK 8.5 MILES NORTHEAST OF MORAN																			
Dec. 10, 1961--------	a0.3	2.7	180	42		483	78	26	1,120		1,890	2.57	1.53	622	558	63	3,640	7.2	8.4
54. BATTLE CREEK 9.5 MILES SOUTHWEST OF BRECKENRIDGE																			
Dec. 10, 1961--------	a0.01	5.2	240	36		616	172	54	1,340	0.0	2,380	3.24	0.06	747	606	64	4,430	7.0	9.8
56. BIG SANDY CREEK NEAR BRECKENRIDGE																			
Dec. 10, 1961--------	a0.3	5.5	126	30		222	127	79	520	0.5	1,050	1.43	0.85	438	334	52	2,020	6.6	4.6
58. BIG SANDY CREEK 5.7 MILES WEST OF BRECKENRIDGE																			
Dec. 10, 1961--------	a0.5	4.6	43	7.3		63	88	17	130	0.2	c334	0.45	0.45	138	66	50	613	6.5	2.3
60. UNNAMED CREEK 2.5 MILES WEST OF BRECKENRIDGE																			
Dec. 10, 1961--------	a0.05	8.3	64	13		55	162	86	77	0.2	c400	0.54	0.05	213	80	36	667	6.8	1.6
61. UNNAMED CREEK 2.8 MILES WEST OF BRECKENRIDGE																			
Dec. 10, 1961--------	a0.01	14	61	14		41	257	23	42	0.0	c328	0.45	0.01	210	0	30	586	7.0	1.2

a Estimated.
c Residue on evaporation at 180°C.

4,150 and 17,050 ppm of chloride. A sample analyzed by Conselman, Jenke, and Tice on March 13, 1962, contained 1,075 ppm chloride.

In his study of the salt area in 1940, W. H. White of the U. S. Geological Survey (written communication) concluded that the source of the salt was not extensive and that the salt water originated by slow movement of ground water through limestones which crop out to the east and dip beneath the site.

In 1962, Conselman, Jenke, and Tice (written communication) independently arrived at essentially the same conclusion. They conclude that "The apparently unique character of this salt spring, and the unmeasurably low volume of the seepage indicate that this salt deposit results from leaching of a small area of capped Valera [not shown on Figure 2] within which a saline pocket apparently is located. Such pockets are rare. The combination of structure and topography necessary to permit seepage is also rare. It is therefore highly unlikely that salt springs would be either numerous or qualitatively important in this area."

An additional indication of the low level of natural contamination in the Hubbard Creek watershed is the low sodium-chloride ratio of water from Hubbard Creek near Breckenridge. Figure 22 shows the relation of the sodium-chloride ratio to the chloride concentration for a stream affected by natural-salt contamination, and for Hubbard Creek near Breckenridge. In 1958, Burdge Irelan (written communication) stated that the characteristics and concentrations of individual ions were different in water from saline springs and in oil-field brines. A study by Leonard and Ward (1962, p. 126-127) of the sodium-chloride ratio, in parts per million, in brines from springs in Oklahoma showed a uniform ratio of 0.64. The combining ratio of sodium and chloride, in parts per million, is 0.65. Chemical analyses of 30 oil-field brines from the same general area consistently showed sodium-chloride ratios of less than 0.60 and the average of the ratios for the 30 samples of oil-field brine was 0.50. In Figure 22 the sodium-chloride ratio of the Salt Fork Brazos River near Aspermont, which is affected strongly by brine inflow from springs (Baker, R. C., Hughes, L. S., and Yost, I. D., 1964, p. 1), agrees well with the natural brine ratio of 0.64 found by Leonard and Ward, except for the dilute waters of high flow. The ratio of sodium to chloride for Hubbard Creek near Breckenridge was substantially less than 0.60, except for dilute waters containing less than 80 ppm chloride. The contrast between the sodium-chloride ratio of water from Hubbard Creek and from Salt Fork of Brazos River probably would be greater if the flow of Hubbard Creek near Breckenridge was not diluted by inflow from relatively uncontaminated tributaries.

WATER QUALITY AND USE

The chemical quality of the water of Hubbard Creek Reservoir is a major factor in determining the value of the water supply to the consumer. The water in the streams is of fair to poor quality and may be undesirable or only marginal for some uses. However, most of the water to be used will be withdrawn from the reservoir, where mixing will improve the quality.

Domestic

Water to be used in the home should be clear, pleasant to the taste, and free from pathogenic organisms. The recommended limits for most substances

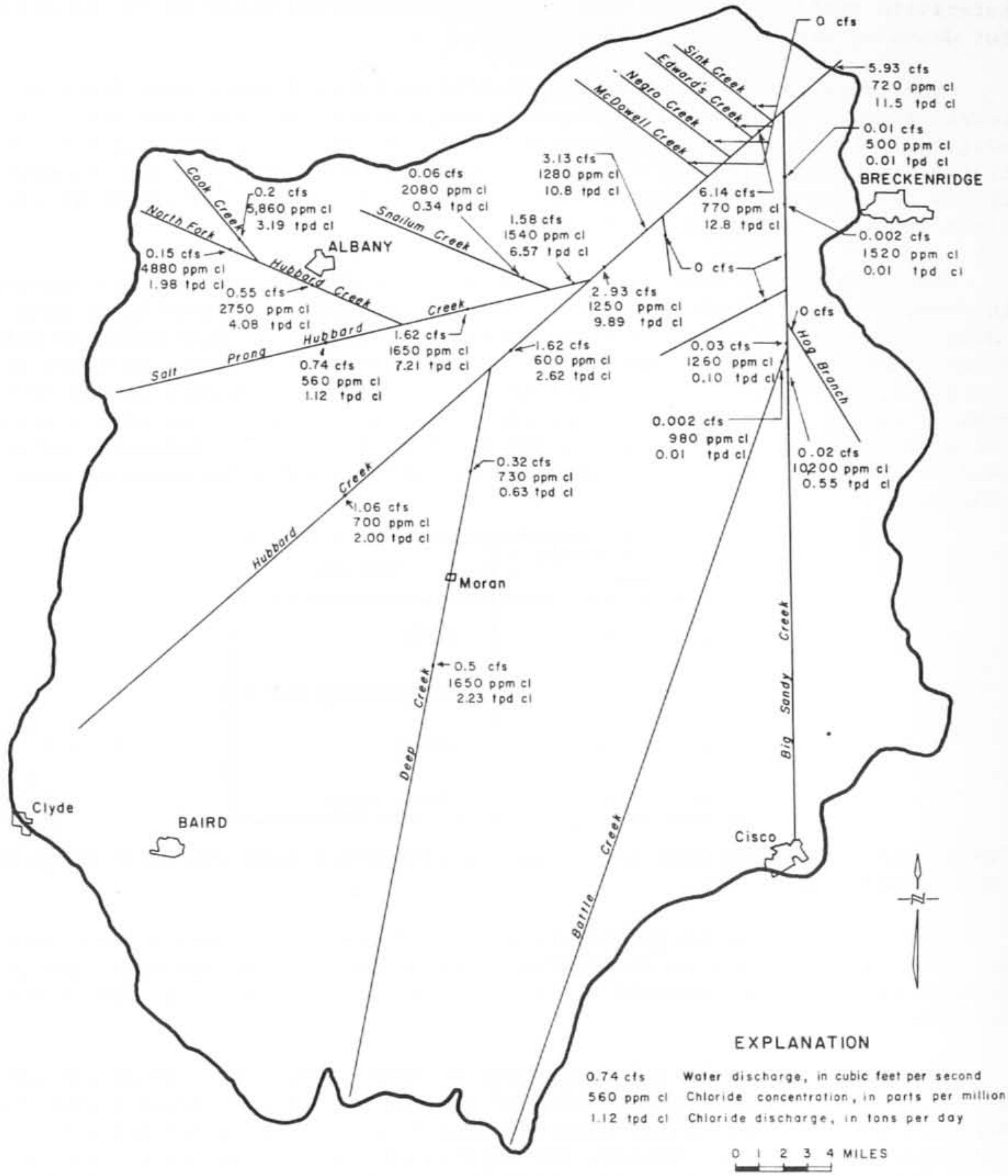

Figure 20

Base Flow, Chloride Concentration, and Chloride Discharge at Selected Sites in the Hubbard Creek Watershed, January 25-26, 1962

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found in water are listed in the Public Health Service Drinking Water Standards (1962, p. 7). These standards apply only to waters used on common carriers in interstate traffic, but the limits given are normally accepted as the standard for drinking water in the United States.

Some 7 years of record at the station on Hubbard Creek near Breckenridge reveal that concentrations of fluoride and nitrate are less than the accepted maximums. The nitrate concentration rarely exceeds 5 ppm and fluoride concentration averages less than 0.5 ppm for the period of record. The recommended limits for nitrate and fluoride are 44 ppm and 1.2 ppm (fluoride limit applicable only to this area), respectively.

Hardness is the characteristic of water that receives the most attention in domestic use. As the hardness of water increases the quantity of soap required to produce a lather also increases. The use of hard water is also objectionable because it contributes to the formation of scale in water heaters, radiators, and pipes. Calcium and magnesium are the principal causes of hardness of water. Several other elements also cause hardness but rarely occur in sufficient quantities to have any appreciable effect. The following table is used by the U. S. Geological Survey in classifying water hardness by numerical ranges.

Hardness range (ppm)	Rating
60 or less	Soft
61 to 120	Moderately hard
121 to 180	Hard
More than 180	Very hard

Present data indicate that water from Hubbard Creek Reservoir will range from hard to very hard.

Water containing large quantities of sulfate usually has a laxative effect. Sulfate, however, will be no problem in the Hubbard Creek Reservoir and should be well below the recommended limit of 250 ppm set by the U. S. Public Health Service.

For most people the chloride-taste threshhold occurs at about 250 ppm and water with a chloride concentration of 500 ppm has an unmistakable and characteristic salty taste. Also, chloride concentrations below 500 ppm may cause corrosion in home water heaters and appliances. The recommended limit by the U. S. Public Health Service for chloride is 250 ppm and water in Hubbard Creek Reservoir may equal or exceed this limit, especially during drought periods and if pollution by oil-field brine is not reduced.

Annual weighted-average concentrations and extremes for the period of record at Hubbard Creek station near Breckenridge are given in Table 1.

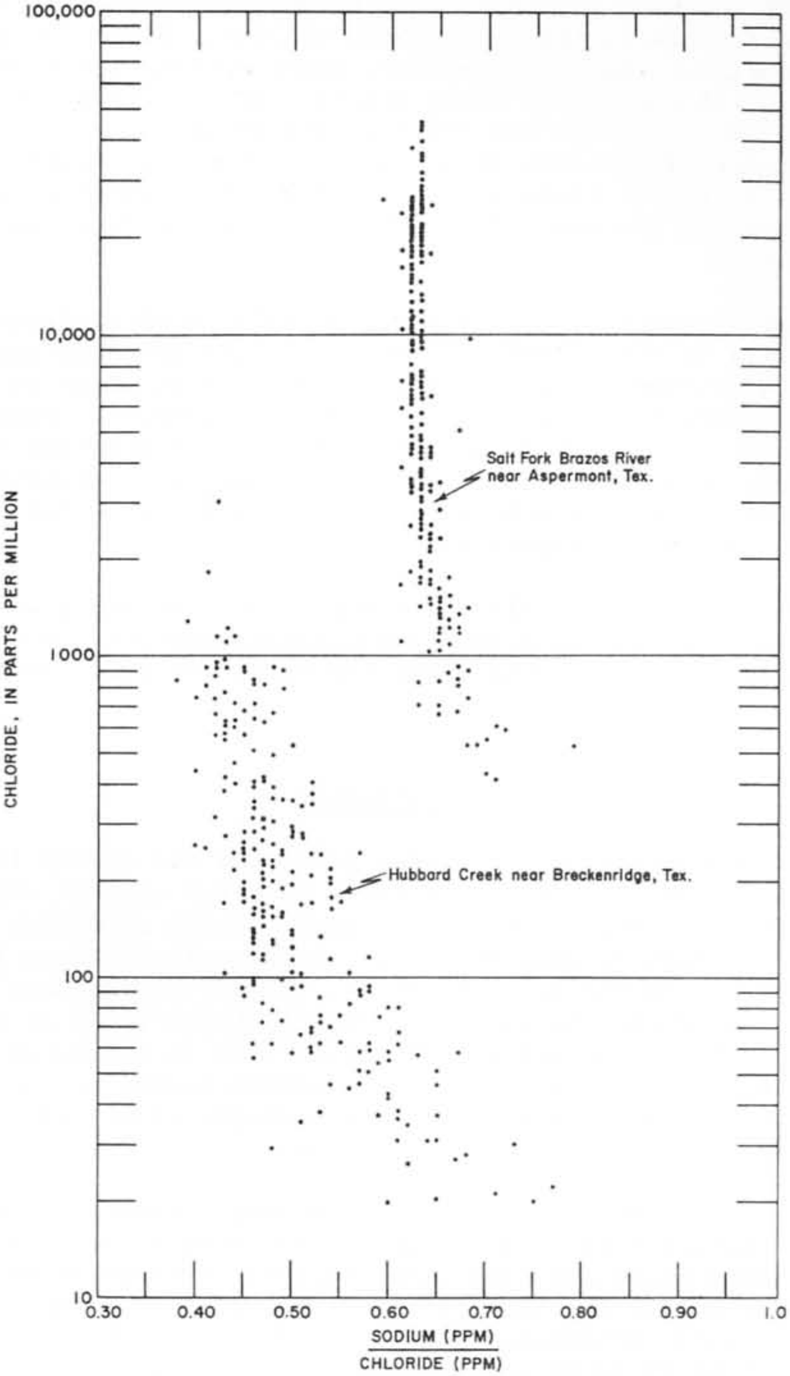

Figure 22

Relation of Sodium-Chloride Ratio to Chloride Concentration for a Stream Affected by Natural Contamination and for Hubbard Creek near Breckenridge

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Industry

Because of the many different uses of water by industry, there are many different requirements in regard to water quality. Often the quality of water is of more importance than the quantity; water treatment may be more costly than development of sources of water supply. An individual element or characteristic may determine the value of the water supply for one application, while water of uniform quality is necessary to another. Uniformity of water quality may be difficult to maintain in the water supplied by the Hubbard Creek Reservoir because of the sporadic rainfall on the watershed and the probability of long droughts.

The primary concern of most industries using Hubbard Creek Reservoir as a water supply will be the hardness of water and the chloride concentration. Hardness is objectionable because of the formation of scale in pipes, boilers, and other containers where water is heated or evaporated. Formation of the calcium carbonate scale causes loss of heat transfer and loss of flow. However, this scale is also a protective coating against corrosive properties of the water. A high chloride concentration in industrial water is objectionable because of its corrosive properties.

The Hubbard Creek Reservoir water supply will probably be suitable for many industrial purposes, with or without minor treatment, but the chloride concentration and hardness could limit the water for some industrial applications.

Irrigation

The total concentration of soluble salts and the sodium ion and its relation to other ions are the characteristics of water of most concern in irrigation water. High concentrations of dissolved solids or sodium ions in water may reduce crop yields by decreasing the ability of plants to take water and by adversely affecting the soil structure. The U. S. Salinity Laboratory Staff (1954, p. 80) introduced the sodium-adsorption ratio (SAR) as a measure of the sodium hazard in water for irrigation. Figure 23 is a diagram for classifying water with respect to salinity hazard and sodium hazard on the basis of specific conductance and SAR. Annual weighted averages (1956-62) for Hubbard Creek near Breckenridge are plotted on the diagram.

The water in Hubbard Creek Reservoir probably would be classified as medium to high salinity and low sodium. This classification should be used only as a guide because there are many other factors involved in determining the value of a water supply for irrigation. A few of the factors to be considered are the type of soil, drainage, rainfall, and salt tolerance. With the annual average rainfall of 25 to 26 inches, the Hubbard Creek Reservoir water should be satisfactory for irrigation of crops with moderate salt tolerance. During droughts, when the rate of evaporation from the reservoir equals or exceeds the inflow, the water supply may be marginal for irrigation of most plants.

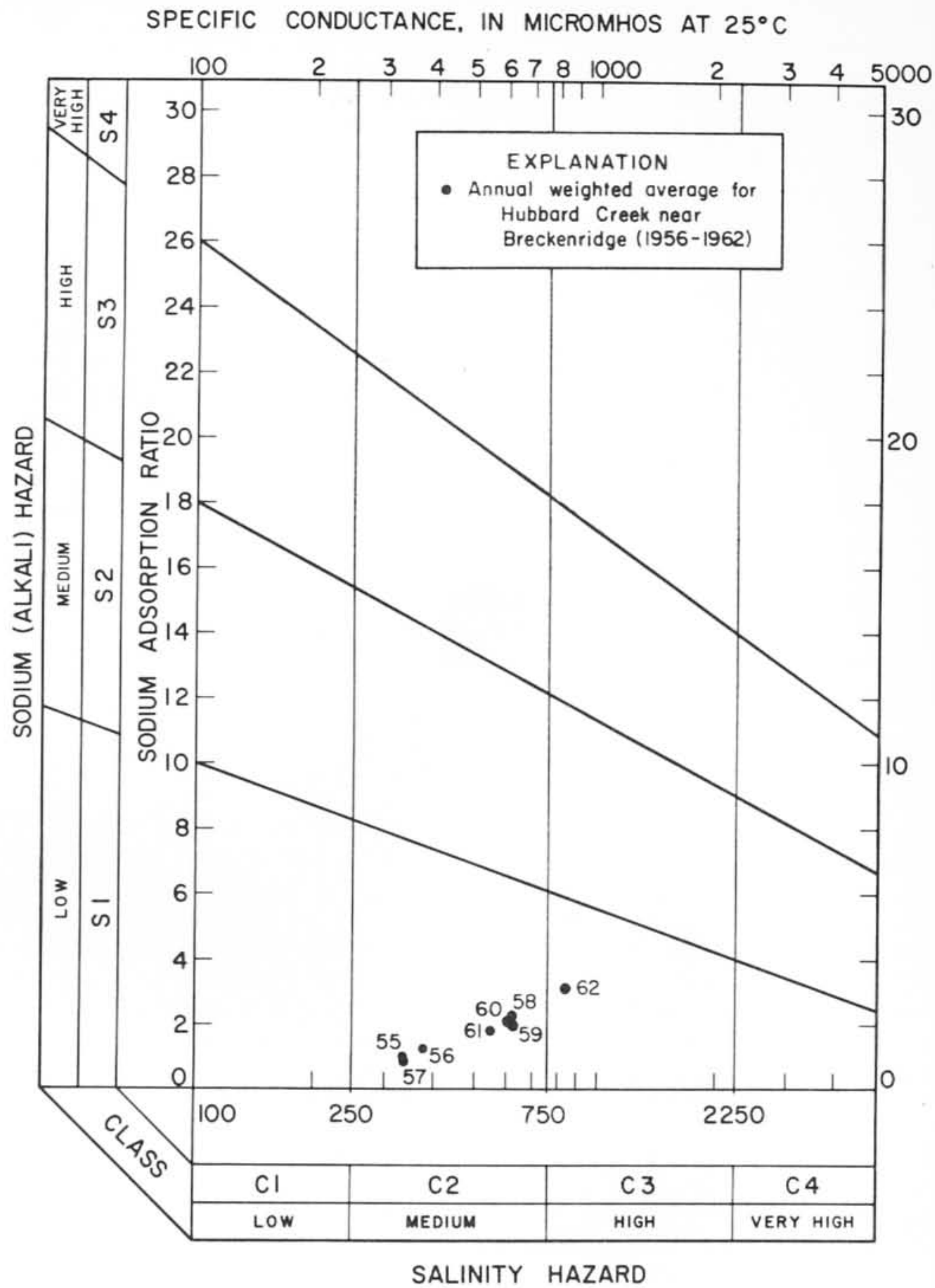

Figure 23

Classification of Water from Hubbard Creek Watershed for Irrigation Use

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

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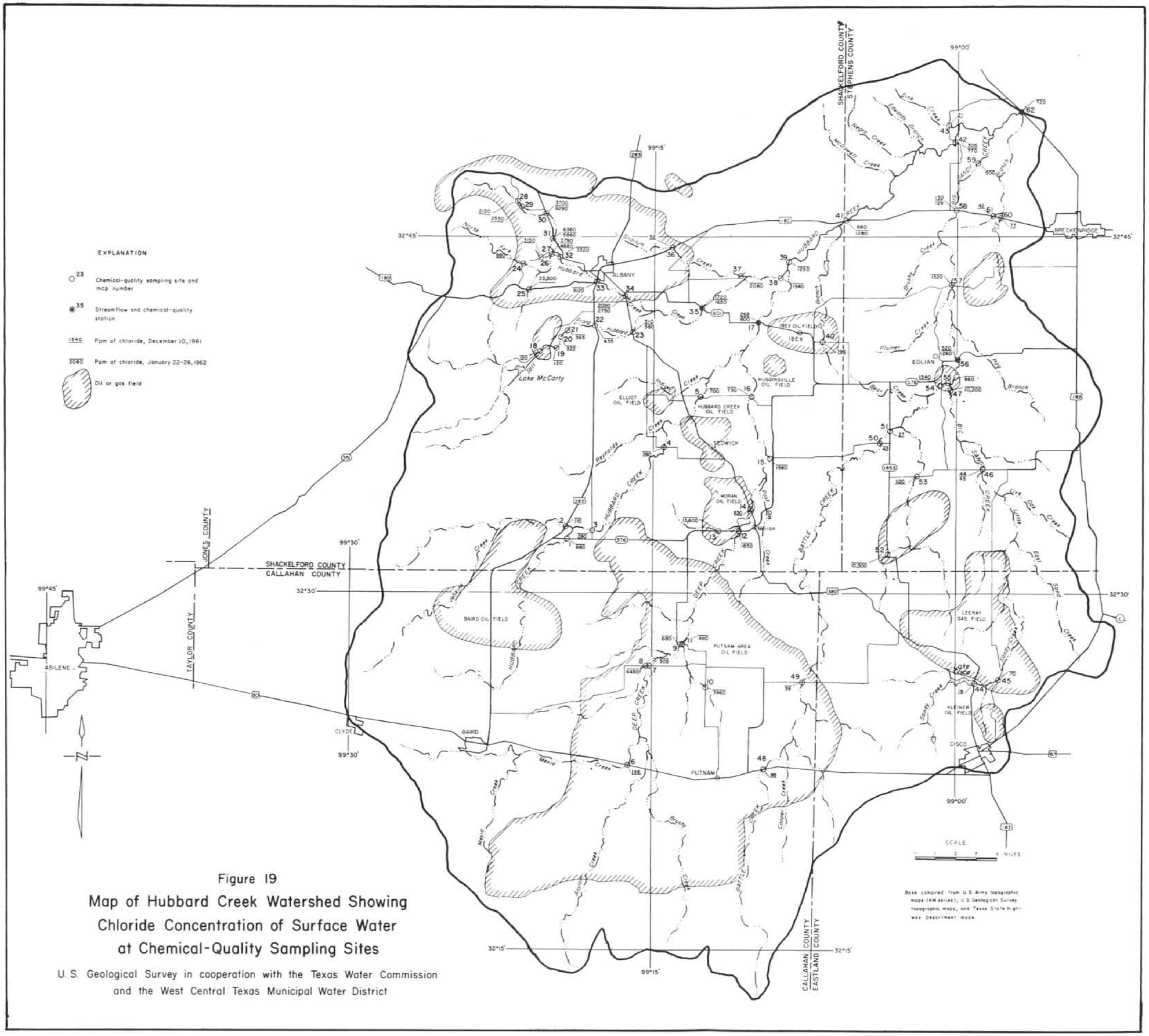

Figure 19

Map of Hubbard Creek Watershed Showing Chloride Concentration of Surface Water at Chemical-Quality Sampling Sites

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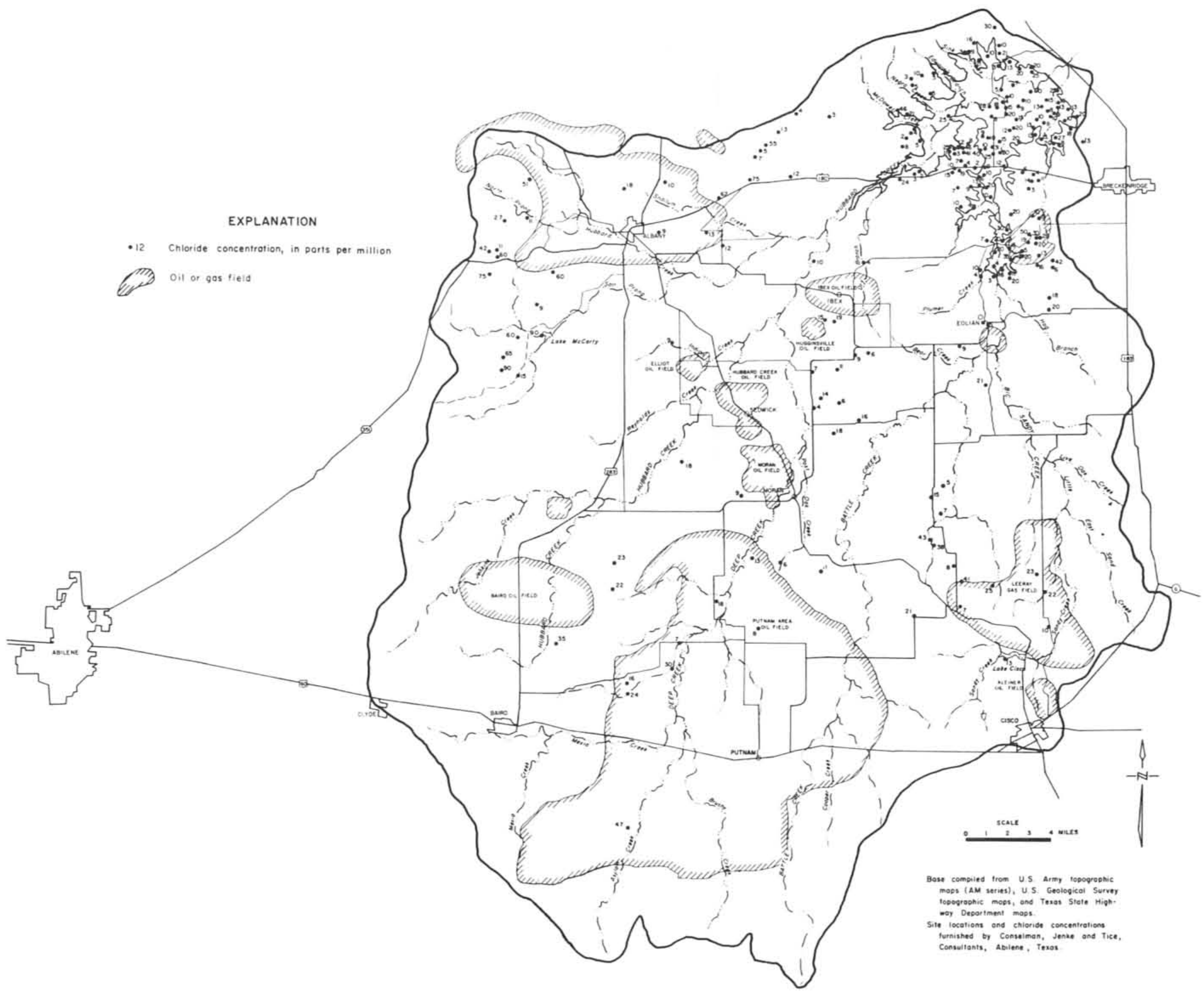

Figure 21

Map of Hubbard Creek Watershed Showing Natural Chloride Concentration of Surface-Water Runoff

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