TEXAS WATER DEVELOPMENT BOARD

REPORT 66

LOW-FLOW STUDIES

SABINE AND OLD RIVERS NEAR ORANGE, TEXAS

QUANTITY AND QUALITY, APRIL 12, OCTOBER 31-NOVEMBER 4, 1966

By

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Prepared by the U.S. Geological Survey
in cooperation with the
Texas Water Development Board
and the
Sabine River Authority of Texas

November 1967

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INTRODUCTION

The U.S. Geological Survey made this investigation in cooperation with Texas Water Development Board and the Sabine River Authority of Texas.

Purposes of the investigation were: (1) to determine the distribution of flow in the main stem and anabranches of the Sabine River in the reach between the Geological Survey's stream-gaging station, Sabine River near Ruliff, Texas, and the Sabine River at Interstate Highway 10, near Orange, Texas; (2) to determine quantity and quality of tributary inflow; (3) to devise a method, using discharge records for the station near Ruliff, of estimating fresh-water inflow to downstream sites in the tidal reach; and (4) to define the effects of tide on water quality in the study area.

Because the lower reach of the Sabine River is tidal, sea water from the Gulf of Mexico periodically intrudes through Sabine Lake into the river (Forrest and Cotton, p. 21). Depletion of fresh-water inflow from upstream sources due to increased consumption and reservoir storage would permit salt water to advance farther upstream. Although several private firms have collected some water quality information on the tidal reach of the river (Forrest and Cotton, p. 5), the effects of tide on water quality and the extent of salt water intrusion have not been defined adequately. The lowermost site for which daily streamflow and water-quality records are available is the Geological Survey's stream-gaging and chemical-quality station near Ruliff, which is upstream from the tidal reach of the river. Downstream from this station, the Old River anabranch of the Sabine River diverts part of the flow into Louisiana, where two large privately-owned pumping plants divert water for rice irrigation. Similarly, downstream from the station near Ruliff, the Sabine River Authority diverts water from the main stem Sabine River for industrial and irrigation uses. Sabine and Old Rivers then rejoin in the tide-affected reach upstream from Orange. Neither the quantity of water that flows from the main stem into Old River nor the quantity or quality of tributary inflow to the study reach is known.

Accurate records of streamflow and water quality for the Sabine River near the Orange industrial area are needed for water-quality control. Such records can best be obtained by including in a low-head salt-water barrier dam and navigation lock appropriate weirs and water-stage and water-quality recording instruments. Pending construction of such a facility, Texas Water Development

Board, Sabine River Authority, and others can use the data obtained by this investigation to supplement streamflow and chemical-quality records from the Ruliff station.

DESCRIPTION OF STUDY AREA

The study area extends from the stream-gaging station Sabine River near Ruliff downstream to Interstate Highway 10 near Orange, a reach of about 23 river miles (Figure 1). About 5 miles downstream from the station near Ruliff, part of the Sabine River flows through Cutoff Bayou into Old River, a large anabranch that flows for about 11 miles in Louisiana, then rejoins the main stem. During low-flow periods, the channel of the Sabine River downstream from the Old River divergence is blocked by a sand bar and all of the main stem flow is diverted into Indian Bayou. Farther downstream, flow returns to the main stem through the mouths of Indian Bayou and Swift Lake.

Elevations in the flood plains range from about 15 feet above mean sea level in the upper part of the study area to about sea level in the lower part. Flow in both the Sabine and Old Rivers was restricted to their channels during this study, but both streams overflow frequently. Much of the study area is poorly-drained swampland covered by a profuse growth of pine, cypress, and other large trees. At many sites on both the Sabine and Old Rivers, large trees have fallen across the channels obstructing travel by boat.

The channel of the Sabine River meanders in a series of almost complete loops across its flood plain; Old River is much straighter. Although channel widths differed from site to site, they generally increased in the downstream direction. The channel of the Sabine River near Ruliff was about 150 feet wide, but at Interstate Highway 10 it was more than 500 feet wide. Similarly, the width of the Old River channel increased from about 35 feet in the upper reach to about 175 feet near the mouth. Depths generally increased greatly in the downstream direction. The maximum depth of water observed in the Sabine River near Ruliff was 4.5 feet, but depths of more than 30 feet were noted at Interstate Highway 10. Although the downstream increase in depth of the main stem was usually gradual, an abrupt change was noted near the mouth of Old River where the depth increased from about 8 feet to more than 20 feet. No such abrupt change in depth of the Old River was noted.

In the following discussion, river mileage on the main stem Sabine River (including Indian Bayou) is measured upstream from Interstate Highway 10, which is designated as mile 0.0. Mileage on other streams (including Old River) is measured upstream from the mouths.

METHODS OF INVESTIGATION

Water-Level Measurements

At the beginning of the study, two temporary water-stage recorders were installed to measure fluctuations of water levels caused by the tide and by the pumping of water from Sabine River Authority's diversion canal. (No water was pumped from the other diversion sites during the study.) One of these recorders continuously recorded the water-level fluctuations of the Sabine River at Morgan

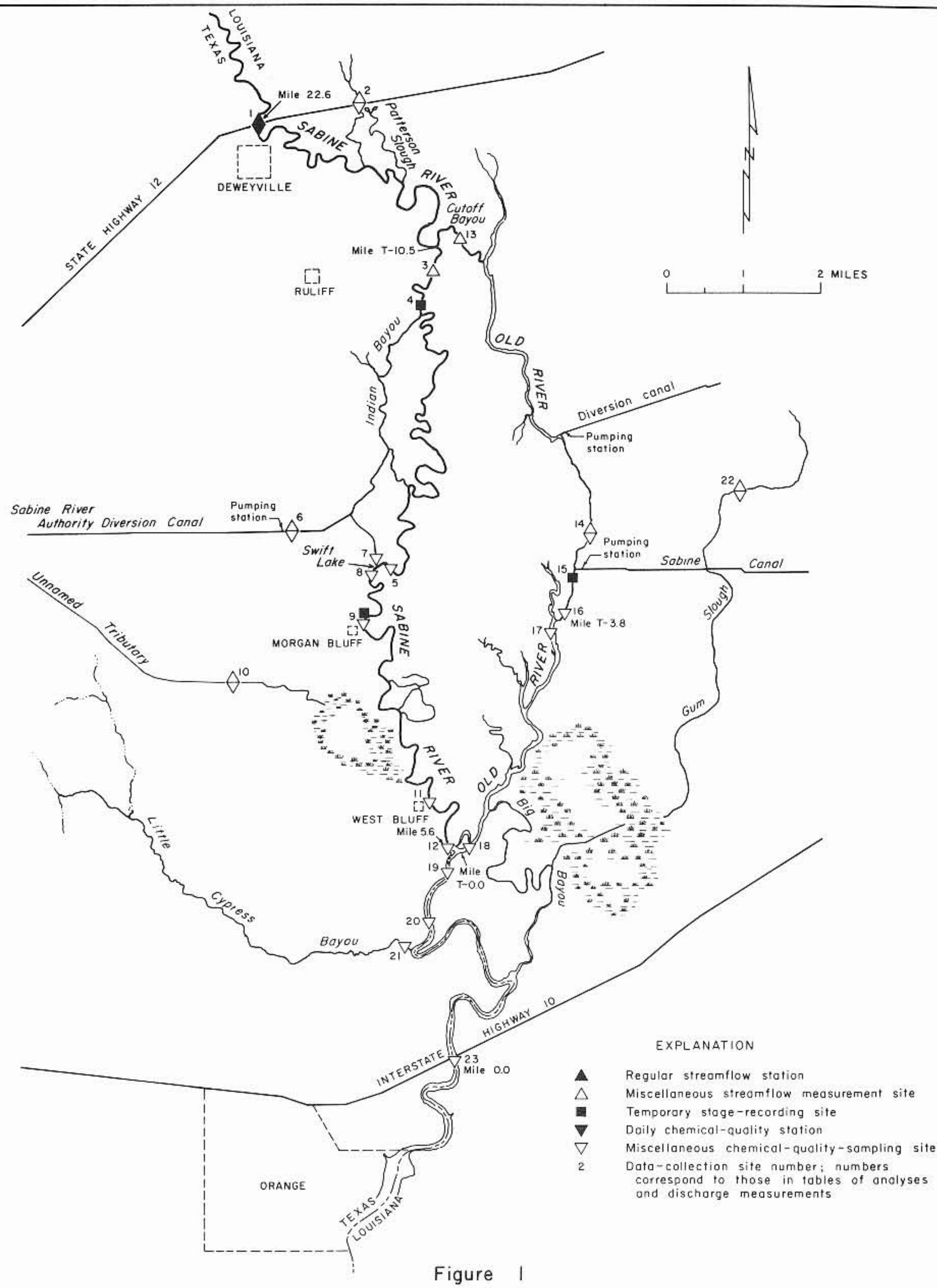


Figure 1

Locations of Streamflow and Chemical - Quality Data - Collection Sites

U.S. Geological Survey in cooperation with the Texas Water Development Board and the Sabine River Authority of Texas

Base from U.S. Geological Survey topographic maps

Bluff (site 9). The other recorder was moved from site to site on Sabine and Old Rivers to determine the approximate distance that flow in the upstream reach was affected by the tide and also whether pumping by the Sabine River Authority affected flow characteristics at upstream sites (Figure 1).

Streamflow Measurements

During a streamflow reconnaissance on April 12, 1966, discharge at Cutoff Bayou (site 13) was measured to determine both the amount of water that flowed from the main stem into Old River and the optimum flow conditions at which a more comprehensive investigation should be made.

The more detailed investigation was made from October 31 to November 4, when impoundment of water by the upstream Toledo Bend Reservoir had reduced flow of the Sabine River near Ruliff to about 500 cfs (cubic feet per second). During this period, discharge of the Sabine and Old Rivers downstream from their divergence was measured repeatedly to determine distribution of the flow that passed the Ruliff station. Flow passing the Ruliff station during these measurements was determined from gaging-station records. Discharge was measured also in the Sabine River Authority's diversion canal, and all accessible tributaries were inspected for flow.

Water-Quality Sampling Program

Four basic techniques have been used for the collection of quality-of-water data from tidal streams (Pyatt, p. F4): (1) a series of fixed stations along the streams for the duration of a tidal cycle; (2) the utilization of a high speed craft capable of moving as rapidly as the tide so that water samples can be collected from many sites in the stream during approximately the same tidal phase; (3) continuous recorders; and (4) random sampling. The first of these techniques requires many personnel and considerable funds. The second requires a high speed craft and an easily navigable channel. The third technique requires expensive equipment capable of recording continuously the desired water-quality data. Because not all these requirements could be met, the fourth, or random sampling technique, was used to select sampling sites and time sequence for this study.

Specific conductance increases as salinity increases, and field measurement of specific conductance is a simple, rapid, and reliable method for detecting variations of salinity in a tidal stream. Therefore, conductance was measured at 10 sites on the Sabine River and at 5 sites on the Old River (Figure 1) to detect longitudinal variations of salinity. At most of these sites specific conductance, temperature, pH, and dissolved oxygen were measured at the surface and bottom in one or more verticals to detect vertical and transversal variations of water quality. When such variations were detected, the water-quality measurements were made at several intermediate depths. If no change in conductance from surface to bottom occurred, a single water sample was collected for chemical analysis. If a sharp change was found, samples were collected from the surface, bottom, and intermediate depths. In the laboratory, specific conductance and chloride content of each sample were determined and were used to select a number of representative samples for more complete chemical analysis. From the relation of conductance to the concentrations of chloride and dissolved solids in these samples, the chloride and dissolved-solids content were calculated for water at all other points where field conductance was measured.

Specific conductance, temperature, dissolved oxygen content, and pH of tributary inflow also were determined, and water samples were collected for chemical analysis.

ANALYSIS OF DATA

Water-Stage Records

Locations at which temporary water-stage recorders were installed are shown in Figure 1; variations of river stage are shown in Figure 2. Because the recording gages were not adjusted to mean sea level, only the fluctuations of water levels, rather than actual elevations, can be determined from Figure 2. The hydrograph of river stage for the Sabine River at Morgan Bluff (site 9) shows generally that the tide which affected the study area was the daily type. (Only one high tide and one low tide occurred daily.) The hydrograph also shows that at Morgan Bluff the range between high and low tides was about 2.1 feet during the second day of the investigation. It increased to about 2.7 feet during the third day, then decreased to about 0.7 feet on the fourth day. A strong north wind accompanied by light rain occurred during the second day of the investigation. The unusually low tide and large range in stage that occurred during the third day apparently was caused by the strong north wind.

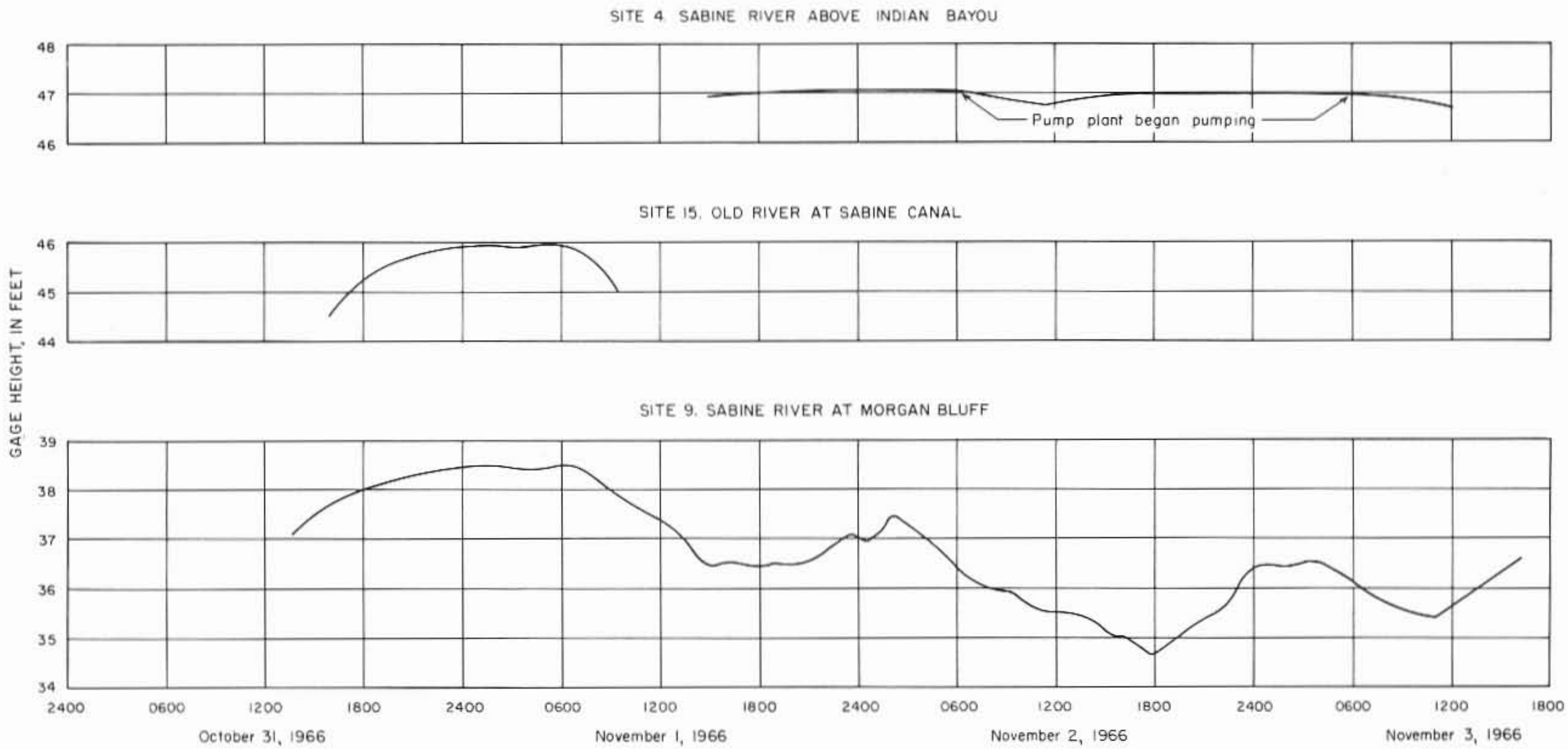
Field observations and records of stage indicated that the river stage, and thus the discharge, of the Sabine River were affected by tide as far upstream as the divergence of Indian Bayou (Figure 1). Similarly, records of stage (Figure 2) and field observations indicated that the Old River was affected by tide as far upstream as site 14 (mile T-4.8). Tide-affected reaches of the Sabine and Old Rivers are shown graphically in Figure 3.

Streamflow Distribution

Results of discharge measurements are given in Table 1; locations of measuring sites are shown in Figure 1. Distribution of flow between the Sabine and Old Rivers is shown on the flow-analysis diagrams in Figure 4.

Data in Figure 4 show that during the streamflow reconnaissance of April 12, when streamflow at the Ruliff station averaged about 1,680 cfs, 838 cfs (about 50 percent of the main stem flow) entered Old River. Streamflow data collected on October 31 at 1715 hours, when none of the pumping stations in the area was operating, show that 277 cfs (about 53 percent of the 525 cfs that passed the Ruliff station) flowed into Old River (Figure 4).

On November 1 at 1120 hours, when the Sabine River Authority's pumping plant was diverting about 145 cfs from the main stem, the flow entering Old River decreased to 214 cfs (about 43 percent of the 495 cfs that passed the Ruliff station). This flow of 214 cfs was obtained by subtracting the measured flow of 281 cfs in the main stem (site 3) from the flow of 495 cfs at the Ruliff station. Records of river stage for the Sabine River near the mouth of



EXPLANATION

Gage heights not to sea level; arbitrary scale used as aid for determining range in stage

Figure 2

River Stage at Three Sites on the Sabine and Old Rivers

U. S. Geological Survey in cooperation with the Texas Water Development Board and the Sabine River Authority of Texas

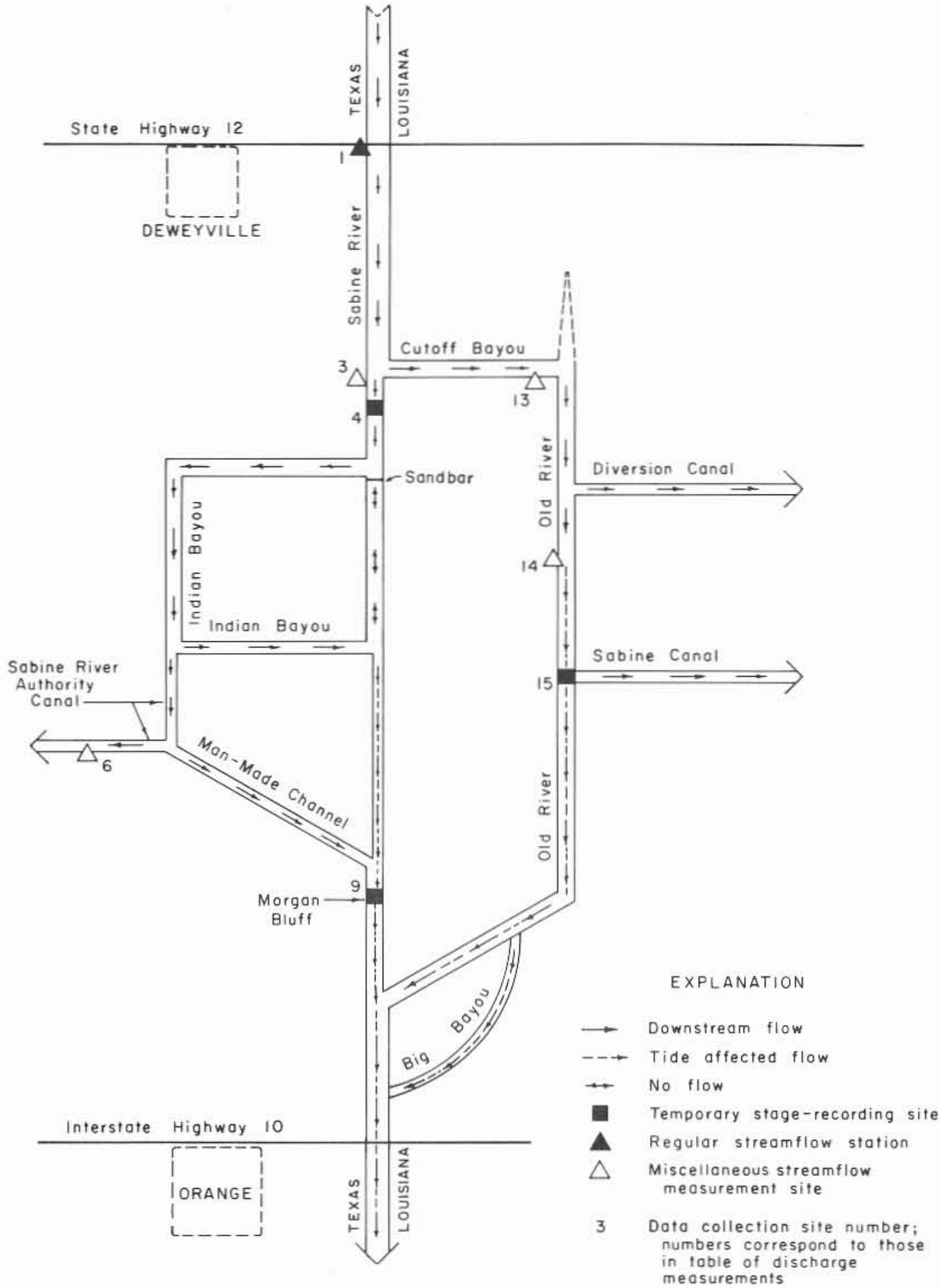


Figure 3

Tide-Affected Reaches of the Sabine and Old Rivers

U.S. Geological Survey in cooperation with the Texas Water Development Board and the Sabine River Authority of Texas

Table 1.--Summary of discharge measurements, Sabine and Old Rivers and tributaries near Orange, Texas.

Site No.	Date 1966 (hour)	Stream	Location	River Miles	Discharge in cfs			
					Main Stream	Old River	Tributary	Diversion
1	Apr. 12	Sabine River	Lat 30°18'13", long 93°44'37", at gaging station Sabine River near Ruliff, Texas	22.6	1,720			
1	do	do	do	do	1,650			
1	Oct. 31	do	do	do	521			
2	Nov. 2	Patterson Slough	Lat 30°18'29", long 93°43'15", at Louisiana State Highway 12	T-1.2			10	
3	Nov. 1 (1120)	Sabine River	Lat 30°16'30", long 93°42'21", 0.5 mile downstream from Cutoff Bayou	17.3	a281			
3	Nov. 2 (2110)	do	do	do	237			
6	do	Sabine River Authority Diversional Canal	Lat 30°13'42", long 93°44'13", about 1.4 miles upstream from Swift Lake					130
10	do	Unnamed tributary to Sabine River	Lat 30°11'53", long 93°45'00", at Old Texas State Highway 87	T-1.4			.5	
13	Apr. 12	Cutoff Bayou (Old River)	Lat 30°16'51", long 93°41'57", 0.8 mile downstream from Sabine River	T-9.8		838		
13	Oct. 31 (1715)	do	do	do		277		
13	Nov. 2 (2110)	do	do	do		261		
14	do (1430)	Old River	Lat 30°13'36", long 93°40'17", 0.4 mile upstream from Sabine Canal	T-4.8		b252		
22	do	Gum Slough	Lat 30°14'03", long 98°38'21", at Louisiana State Highway 109	T-6.7			.8	

a Affected by pumping from Sabine River Authority Canal
b May be affected by tide

Indian Bayou (Figure 2) show that pumping from the Sabine River Authority's diversion canal caused a drawdown of the water surface in the main stem. This drawdown caused the slope of the water surface to increase. In response to this increase in slope, the proportion of flow that entered Old River decreased (Figure 4).

Streamflow data collected on November 2 at 2110 hours (Figure 4), after the Sabine River Authority had stopped pumping, show that about 52 percent of the flow of the Sabine River entered Old River.

Pumping plants on Old River were not operating during the study. Operation of these plants can be expected to cause an increase in slope of the water surface of Old River and thus cause some change in the distribution of flow between the Sabine and Old Rivers. Changes in channel conditions, such as those that might occur during floods, also may alter flow distribution.

Only two flowing tributaries, an unnamed tributary (site 10) and Gum Slough (site 22), were located during the study. Each of these streams, which discharge into the lower reach of the study area, was flowing less than 1 cfs. Patterson Slough (site 2), an overflow channel of the Sabine River near Ruliff, was flowing about 10 cfs. Flow measured in Patterson Slough is included in streamflow records of the Sabine River near Ruliff (site 1).

Variations in Water Quality

Locations of chemical-quality sampling sites are shown in Figure 1; results of chemical analyses are given in Table 2. Profiles of the weighted-average chloride concentrations for the Sabine and Old Rivers are shown in Figure 5. Because samples were not collected from all sampling sites at the same tidal phase, the chloride profiles in Figure 5 do not represent conditions that actually existed at any given time. Instead, the profiles show the average chloride concentration of each cross-section at the time of sampling and the approximate extent of salt-water intrusion.

In the following discussion, the chloride profiles and other chemical-quality data were used to subdivide the study area into three reaches.

Sabine River--Mile 22.6 to Mile 5.6

Data in Table 2 and Figure 6 show that water in this 17-mile reach was fresh and well mixed. Dissolved-solids and chloride concentrations ranged from 78-85 ppm (parts per million) and 15-20 ppm, respectively. Dissolved-oxygen concentrations ranged from 8.2 ppm at site 1 to 7.1 ppm at sites 11 and 12. Among the more significant factors that affect the dissolved-oxygen content of any stream are the amounts and nature of organic material present, the temperature and dissolved-mineral content of the water, bacterial activity, photosynthesis, and aeration from exposure to the atmosphere. Aeration is influenced greatly by the dissolved-oxygen deficiency; the character of the streambed; and the depth, volume, and velocity of flow. Undoubtedly, the downstream decrease of dissolved oxygen between sites 1 and 12 resulted from a combination of several of these factors. As the water moves downstream through the profuse vegetation, it picks up considerable organic debris, and dissolved oxygen is utilized in the oxidation of this debris. In the downstream direction, stream

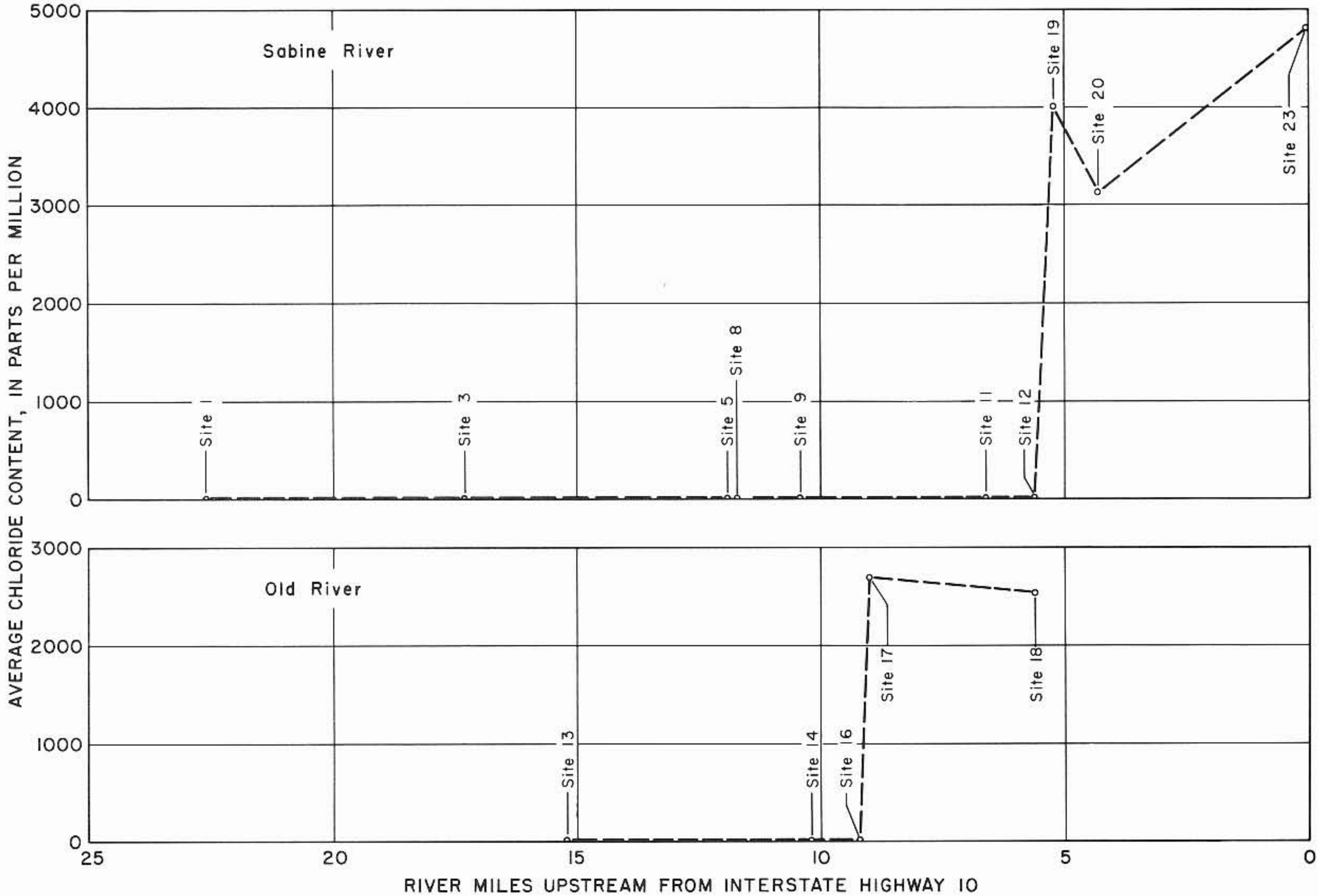


Figure 5

Profiles of Chloride in the Sabine and Old Rivers

U.S. Geological Survey in cooperation with the Texas Water Development Board and the Sabine River Authority of Texas

Table 2.--Chemical analyses of streams in the Sabine River basin near Orange, Texas.

(Results in parts per million except as indicated)

Date (1966)	Hour	Sampling Point: Distance from right edge of water (feet)	Sampling Point: Depth below water surface (feet)	Water Temp. (°C)	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Dissolved oxygen (DO): ppm	Dissolved oxygen (DO): Percent of saturation	Dissolved solids (Calculated)	Hardness as $CaCO_3$: Calcium, Magnesium	Hardness as $CaCO_3$: Noncarbonate	Sodium adsorption ratio	Specific conductance (micromhos at 25°C)	pH: Field	pH: Laboratory	Density (gm/ml at 20°C)
SITE 1. SABINE RIVER NEAR RULIFF (MILE 22.6)																							
Oct. 31	1400	25	0	19.0	--	--	--	--	--	--	--	a15	--	8.2	87	78	--	--	--	125	7.1	--	--
do.	1400	25	4.5	19.0	--	--	--	--	--	--	--	a15	--	8.2	87	78	--	--	--	125	7.1	--	--
do.	1430	75	0	19.0	17	7.2	1.8	13	1.7	34	5.6	15	0.2	8.2	87	78	26	0	1.1	125	7.1	6.9	--
do.	1430	75	3.4	19.0	--	--	--	--	--	--	--	a15	--	8.2	87	78	--	--	--	125	7.1	--	--
do.	1500	135	0	19.0	--	--	--	--	--	--	--	a15	--	8.2	87	78	--	--	--	125	7.1	--	--
do.	1500	135	3.6	19.0	--	--	--	--	--	--	--	a15	--	8.2	87	78	--	--	--	125	7.1	--	--
SITE 2. PATTERSON SLOUGH AT LOUISIANA STATE HIGHWAY 12 (MILE T-1.2)																							
Nov. 4	0935	5	0	10.0	16	7.5	2.4	14	2.2	33	9.8	18	0.2	8.7	77	86	29	2	1.1	141	6.1	6.8	--
SITE 3. SABINE RIVER 0.5 MILE DOWNSTREAM FROM CUTOFF BAYOU (MILE 17.3)																							
Nov. 1	1110	10	0	17.5	--	--	--	--	--	--	--	a16	--	8.2	85	80	--	--	--	128	7.1	--	--
do.	1110	10	1.8	17.5	--	--	--	--	--	--	--	a16	--	8.2	85	80	--	--	--	128	7.1	--	--
do.	1120	60	0	17.5	--	--	--	--	--	--	--	a16	--	8.2	85	80	--	--	--	128	7.1	--	--
do.	1120	60	2.3	17.5	--	--	--	--	--	--	--	16	--	8.2	85	80	--	--	--	128	7.1	--	--
do.	1130	110	0	17.5	--	--	--	--	--	--	--	a16	--	8.2	85	80	--	--	--	128	7.1	--	--
do.	1130	110	2.0	17.5	--	--	--	--	--	--	--	a16	--	8.2	85	80	--	--	--	128	7.1	--	--
SITE 5. SABINE RIVER 200 YARDS UPSTREAM FROM SWIFT LAKE (MILE 11.9)																							
Nov. 3	1540	50	0	15.0	--	--	--	--	--	--	--	17	--	7.4	73	82	--	--	--	133	6.8	--	--
do.	1540	50	4	15.0	--	--	--	--	--	--	--	a17	--	7.4	73	82	--	--	--	133	6.9	--	--
SITE 6. SABINE RIVER AUTHORITY DIVERSION CANAL, 1.8 MILES UPSTREAM FROM SWIFT LAKE																							
Nov. 2	0920	20	0	15.5	--	--	--	--	--	--	--	16	--	--	--	82	--	--	--	136	--	--	--
SITE 7. SWIFT LAKE, 0.2 MILE UPSTREAM FROM MOUTH																							
Nov. 3	1530	20	0	14.0	--	--	--	--	--	--	--	a15	--	9.2	88	80	--	--	--	127	6.9	--	--
do.	1530	20	4	14.0	--	--	--	--	--	--	--	15	--	9.2	88	80	--	--	--	127	6.9	--	--
SITE 8. SABINE RIVER 450 FEET DOWNSTREAM FROM MOUTH OF SWIFT LAKE (MILE 11.7)																							
Nov. 3	1500	40	0	14.5	--	--	--	--	--	--	--	a16	--	8.3	81	81	--	--	--	130	6.8	--	--
do.	1500	40	10	14.5	--	--	--	--	--	--	--	a16	--	8.3	81	81	--	--	--	130	6.8	--	--
do.	1510	100	0	15.0	--	--	--	--	--	--	--	a16	--	7.4	73	81	--	--	--	130	6.8	--	--
do.	1510	100	10	14.5	--	--	--	--	--	--	--	16	--	7.5	73	81	--	--	--	130	6.8	--	--
SITE 9. SABINE RIVER AT MORGAN BLUFF (MILE 10.4)																							
Nov. 1	1545	10	0	16.5	--	--	--	--	--	--	--	a17	--	7.2	73	83	--	--	--	134	6.6	--	--
do.	1545	10	4	16.5	--	--	--	--	--	--	--	a17	--	7.2	73	83	--	--	--	134	6.6	--	--
do.	1550	25	0	16.5	--	--	--	--	--	--	--	a17	--	7.2	73	83	--	--	--	134	6.6	--	--
do.	1550	25	19	16.5	--	--	--	--	--	--	--	a17	--	7.2	73	83	--	--	--	134	6.6	--	--
do.	1555	75	0	17.0	--	--	--	--	--	--	--	a17	--	7.2	73	83	--	--	--	134	6.6	--	--
do.	1555	75	9	17.0	16	7.8	1.9	14	1.8	36	6.4	17	0.2	7.2	73	83	27	0	1.2	134	6.6	6.7	--
do.	1600	100	0	17.0	--	--	--	--	--	--	--	a17	--	7.2	73	83	--	--	--	134	6.6	--	--
do.	1600	100	8	17.0	--	--	--	--	--	--	--	a17	--	7.2	73	83	--	--	--	134	6.6	--	--

See footnote at end of table.

Table 2.--Chemical analyses of streams in the Sabine River basin near Orange, Texas--Continued

(Results in parts per million except as indicated)

Date (1966)	Hour	Sampling Point: Distance from right edge of water (feet)	Sampling Point: Depth below water surface (feet)	Water Temp. (°C)	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Dissolved oxygen (DO): ppm	Dissolved oxygen (DO): Percent of saturation	Dissolved solids (Calculated)	Hardness as $CaCO_3$: Calcium, Magnesium	Hardness as $CaCO_3$: Noncarbonate	Sodium adsorption ratio	Specific conductance (micromhos at 25°C)	pH: Field	pH: Laboratory	Density (gm/ml at 20°C)
SITE 10. UNNAMED TRIBUTARY TO SABINE RIVER AT OLD TEXAS STATE HIGHWAY 87 (MILE T-1.4)																							
Nov. 4	1000	1	0	9.0	12	8.0	3.4	40	2.4	19	11	68	0.2	9.1	78	154	34	18	3.0	297	7.0	6.3	--
SITE 11. SABINE RIVER AT WEST BLUFF (MILE 6.6)																							
Nov. 1	1700	20	0	16.0	--	--	--	--	--	--	--	a18	--	7.1	71	83	--	--	--	133	6.7	--	--
do.	1700	20	7	16.0	--	--	--	--	--	--	--	a18	--	7.1	71	83	--	--	--	133	6.7	--	--
do.	1710	60	0	16.0	--	--	--	--	--	--	--	a18	--	7.1	71	83	--	--	--	133	6.6	--	--
do.	1710	60	7	16.0	--	--	--	--	--	--	--	18	--	7.1	71	83	--	--	--	133	6.7	--	--
do.	1730	100	0	16.0	--	--	--	--	--	--	--	a18	--	7.1	71	83	--	--	--	133	6.6	--	--
do.	1730	100	5	16.0	--	--	--	--	--	--	--	a18	--	7.1	71	83	--	--	--	133	6.6	--	--
SITE 12. SABINE RIVER 100 YARDS UPSTREAM FROM MOUTH OF OLD RIVER (MILE 5.6)																							
Nov. 2	1100	20	0	16.0	--	--	--	--	--	--	--	a20	--	7.2	72	85	--	--	--	140	6.5	--	--
do.	1100	20	8	16.0	--	--	--	--	--	--	--	20	--	7.1	71	85	--	--	--	140	6.5	--	--
do.	1105	80	0	16.0	--	--	--	--	--	--	--	a20	--	7.2	72	85	--	--	--	140	6.5	--	--
do.	1105	80	8	16.0	--	--	--	--	--	--	--	a20	--	7.1	71	85	--	--	--	140	6.5	--	--
do.	1110	150	0	16.0	--	--	--	--	--	--	--	a20	--	7.1	71	85	--	--	--	140	6.5	--	--
do.	1110	150	5	16.0	--	--	--	--	--	--	--	a20	--	7.1	71	85	--	--	--	140	6.5	--	--
SITE 13. CUTOFF BAYOU 0.8 MILE DOWNSTREAM FROM SABINE RIVER (MILE T-9.8)																							
Oct. 31	1650	12	0	19.0	--	--	--	--	--	--	--	a16	--	8.2	87	79	--	--	--	130	7.1	--	--
do.	1650	12	5.5	19.0	--	--	--	--	--	--	--	a16	--	8.2	87	79	--	--	--	130	7.1	--	--
do.	1715	47	0	19.0	--	--	--	--	--	--	--	a16	--	8.2	87	79	--	--	--	130	7.1	--	--
do.	1715	47	7.0	19.0	--	--	--	--	--	--	--	16	--	8.2	87	79	--	--	--	130	7.1	--	--
do.	1740	82	0	19.0	--	--	--	--	--	--	--	a16	--	8.2	87	79	--	--	--	130	7.1	--	--
do.	1740	82	5.0	19.0	--	--	--	--	--	--	--	a16	--	8.2	87	79	--	--	--	130	7.1	--	--
SITE 14. OLD RIVER 0.4 MILE UPSTREAM FROM SABINE CANAL (Mile T-4.8)																							
Nov. 2	--	--	--	17.0	--	--	--	--	--	--	--	17	--	--	--	79	--	--	--	131	--	--	--
SITE 16. OLD RIVER 0.6 MILE DOWNSTREAM FROM SABINE CANAL (MILE T-3.8)																							
Nov. 2	1500	15	0	16.0	16	7.8	2.1	16	1.7	34	6.4	22	0.2	7.7	77	89	28	0	1.3	149	7.0	7.0	--
do.	1500	15	13	16.0	--	--	--	--	--	--	--	a22	--	7.6	76	89	--	--	--	149	7.0	--	--
do.	1510	40	0	16.0	--	--	--	--	--	--	--	a22	--	7.7	77	89	--	--	--	149	7.0	--	--
do.	1510	40	6	16.0	--	--	--	--	--	--	--	a22	--	7.7	77	89	--	--	--	149	7.0	--	--
do.	1515	60	0	16.0	--	--	--	--	--	--	--	a22	--	7.7	77	89	--	--	--	149	7.0	--	--
do.	1515	60	3	16.0	--	--	--	--	--	--	--	a22	--	7.7	77	89	--	--	--	149	7.0	--	--
SITE 17. OLD RIVER 0.8 MILE DOWNSTREAM FROM SABINE CANAL (MILE T-3.6)																							
Nov. 2	1530	20	0	16.0	--	--	--	--	--	--	--	44	--	7.8	78	130	--	--	--	228	6.9	--	--
do.	1530	20	5	17.0	--	--	--	--	--	--	--	a44	--	7.3	74	130	--	--	--	235	6.9	--	--
do.	1535	20	9	17.0	10	102	278	2,310	83	72	577	4,230	--	4.5	48	7,620	1,400	1,340	--	13,100	6.9	7.3	1.005
do.	1535	20	10	19.5	--	--	--	--	--	--	--	a6,150	--	.7	8	11,200	--	--	--	18,500	6.9	--	--
do.	1535	20	15	17.0	--	--	--	--	--	--	--	6,150	--	.3	3	11,200	--	--	--	18,500	6.6	--	--

See footnote at end of table.

Table 2.--Chemical analyses of streams in the Sabine River basin near Orange, Texas--Continued

(Results in parts per million except as indicated)

Date (1966)	Hour	Sampling Point: Distance from right edge of water (feet)	Sampling Point: Depth below water surface (feet)	Water Temp. (°C)	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Dissolved oxygen (DO): ppm	Dissolved oxygen (DO): Percent of saturation	Dissolved solids (Calculated)	Hardness as $CaCO_3$: Calcium, Magnesium	Hardness as $CaCO_3$: Noncarbonate	Sodium adsorption ratio	Specific conductance (micromhos at 25°C)	pH: Field	pH: Laboratory	Density (gm/ml at 20°C)
SITE 17. OLD RIVER 0.8 MILE DOWNSTREAM FROM SABINE CANAL (Mile T-3.6)--Continued																							
Nov. 2	1540	50	0	16.0	16	8.2	3.2	27	2.1	34	9.0	41	0.2	7.7	77	124	34	1	2.0	221	6.8	6.8	--
do.	1540	50	5	16.0	--	--	--	--	--	--	--	a95	--	7.7	77	230	--	--	--	430	6.7	--	--
do.	1545	50	8	16.0	--	--	--	--	--	--	--	428	--	7.1	72	850	--	--	--	1,600	6.7	--	--
do.	1545	50	10	17.5	--	--	--	--	--	--	--	a6,200	--	.2	2	11,200	--	--	--	18,600	6.6	--	--
do.	1550	50	16	20.0	8.3	150	391	3,430	113	93	849	6,200	--	.4	5	11,200	1,980	1,910	--	18,600	6.5	7.1	1.008
do.	1555	80	0	16.5	--	--	--	--	--	--	--	76	--	7.6	77	180	--	--	--	339	6.8	--	--
do.	1555	80	5	16.5	--	--	--	--	--	--	--	a95	--	7.6	77	230	--	--	--	430	6.8	--	--
do.	1555	80	7	19.5	--	--	--	--	--	--	--	205	--	6.3	68	430	--	--	--	811	6.6	--	--
do.	1600	80	10	21.0	--	--	--	--	--	--	--	a6,210	--	.2	2	11,200	--	--	--	18,700	6.6	--	--
do.	1600	80	16	20.5	--	--	--	--	--	--	--	6,210	--	.4	5	11,200	--	--	--	18,700	6.5	--	--
SITE 18. OLD RIVER 300 YARDS UPSTREAM FROM MOUTH (MILE T-0.2)																							
Nov. 2	1335	25	0	16.5	--	--	--	--	--	--	--	170	--	7.6	77	360	--	--	--	679	6.7	--	--
do.	1335	25	5	16.5	--	--	--	--	--	--	--	a180	--	7.2	73	395	--	--	--	750	6.4	--	--
do.	1340	25	10	23.0	--	--	--	--	--	--	--	2,380	--	4.6	54	4,270	--	--	--	7,660	6.4	--	--
do.	1340	25	14	22.0	--	--	--	--	--	--	--	6,590	--	.4	5	12,100	--	--	--	19,900	6.5	--	--
do.	1345	100	0	16.0	--	--	--	--	--	--	--	172	--	7.7	77	365	--	--	--	689	6.6	--	--
do.	1345	100	5	16.0	--	--	--	--	--	--	--	a180	--	7.7	77	385	--	--	--	730	6.6	--	--
do.	1350	100	10	17.0	--	--	--	--	--	--	--	540	--	6.9	71	990	--	--	--	1,910	6.5	--	--
do.	1350	100	12	23.0	--	--	--	--	--	--	--	a6,100	--	.2	2	11,000	--	--	--	18,200	6.5	--	--
do.	1355	100	15	23.0	--	--	--	--	--	--	--	a6,770	--	.2	2	12,300	--	--	--	20,300	6.5	--	--
do.	1355	100	17	23.0	--		--	--	--	--	--	6,770	--	.2	2	12,300	--	--	--	20,300	6.5	--	--
do.	1400	150	0	16.0	--	--	--	--	--	--	--	170	--	7.7	77	360	--	--	--	680	6.7	--	--
do.	1400	150	5	17.0	--	--	--	--	--	--	--	a170	--	7.1	72	380	--	--	--	720	6.4	--	--
do.	1405	150	10	22.0	--	--	--	--	--	--	--	2,400	--	4.6	53	4,470	--	--	--	7,800	6.5	--	--
do.	1405	150	12	22.5	--	--	--	--	--	--	--	a6,800	--	.2	2	12,400	--	--	--	20,400	6.5	--	--
do	1410	150	15	23.5	--	--	--	--	--	--	--	a6,800	--	.2	2	12,400	--	--	--	20,400	6.5	--	--
do	1415	150	23	23.5	--	--	--	--	--	--	--	6,800	--	.2	2	12,400	--	--	--	20,400	6.4	--	--
SITE 19. SABINE RIVER 0.2 MILE DOWNSTREAM FROM MOUTH OF OLD RIVER (MILE 5.2)																							
Nov. 2	1130	20	0	16.0	--	--	--	--	--	--	--	106	--	7.5	75	240	--	--	--	453	6.7	--	--
do.	1130	20	4	16.0	--	--	--	--	--	--	--	a115	--	7.4	74	260	--	--	--	485	6.6	--	--
do.	1135	20	6	16.5	--	--	--	--	--	--	--	a155	--	7.0	71	350	--	--	--	655	6.6	--	--
do.	1135	20	8	16.5	--	--	--	--	--	--	--	a160	--	7.0	71	360	--	--	--	670	6.6	--	--
do.	1140	20	10	20.0	--	--	--	--	--	--	--	a4,300	--	1.5	17	7,550	--	--	--	13,000	6.4	--	--
do.	1140	20	11	20.5	--	--	--	--	--	--	--	6,500	--	.6	7	11,900	--	--	--	19,700	6.4	--	--
do.	1145	20	12	22.0	--	--	--	--	--	--	--	a6,850	--	.2	2	12,400	--	--	--	20,400	6.4	--	--
do.	1145	20	13	22.0	--	--	--	--	--	--	--	a6,850	--	.2	2	12,400	--	--	--	20,400	6.4	--	--
do.	1150	20	14	22.0	--	--	--	--	--	--	--	a6,850	--	.2	2	12,400	--	--	--	20,400	6.5	--	--
do.	1150	20	15	23.5	--	--	--	--	--	--	--	a6,850	--	.2	2	12,400	--	--	--	20,400	6.4	--	--
do.	1155	20	20	23.5	--	--	--	--	--	--	--	a6,850	--	.2	2	12,400	--	--	--	20,400	6.4	--	--
do.	1155	20	24	22.0	--	--	--	--	--	--	--	6,850	--	.6	7	12,400	--	--	--	20,400	6.4	--	--
do.	1210	100	0	16.0	16	9.5	6.2	50	3.2	34	15	86	0.2	7.4	74	203	49	21	3.1	377	6.7	6.8	--
do.	1210	100	5	16.0	--	--	--	--	--	--	--	a120	--	7.4	74	270	--	--	--	500	6.6	--	--
do.	1215	100	9	18.0	11	68	169	1,460	51	53	370	2,650	--	1.3	14	4,800	864	821	22	8,370	6.5	7.2	--
do.	1215	100	10	21.0	--	--	--	--	--	--	--	a6,850	--	.2	2	12,400	--	--	--	20,400	6.5	--	--
do.	1220	100	13	23.0	--	--	--	--	--	--	--	a6,850	--	.2	2	12,400	--	--	--	20,400	6.5	--	--
do.	1220	100	18	23.5	--	--	--	--	--	--	--	a6,850	--	.2	2	12,400	--	--	--	20,400	6.5	--	--
do.	1225	100	23	23.0	6.5	163	425	3,790	133	91	937	6,850	3.5	.4	5	12,400	2,150	2,080	--	20,400	6.5	7.1	1.008

See footnote at end of table.

Table 2.--Chemical analyses of streams in the Sabine River basin near Orange, Texas--Continued

(Results in parts per million except as indicated)

Date (1966)	Hour	Sampling Point: Distance from right edge of water (feet)	Sampling Point: Depth below water surface (feet)	Water Temp. (°C)	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Dissolved oxygen (DO): ppm	Dissolved oxygen (DO): Percent of saturation	Dissolved solids (Calculated)	Hardness as $CaCO_3$: Calcium, Magnesium	Hardness as $CaCO_3$: Non-carbonate	Sodium adsorption ratio	Specific conductance (micromhos at 25°C)	pH: Field	pH: Laboratory	Density (gm/ml at 20°C)
SITE 19. SABINE RIVER 0.2 MILE DOWNSTREAM FROM MOUTH OF OLD RIVER (MILE 5.2)--Continued																							
Nov. 2	1235	200	0	16.0	--	--	--	--	--	--	--	89	--	7.5	75	205	--	--	--	384	6.6	--	--
do.	1235	200	5	16.0	--	--	--	--	--	--	--	a210	--	7.1	71	410	--	--	--	780	6.5	--	--
do.	1240	200	8	16.0	--	--	--	--	--	--	--	348	--	7.0	70	680	--	--	--	1,300	6.5	--	--
do.	1240	200	10	22.0	--	--	--	--	--	--	--	a6,110	--	.8	10	11,100	--	--	--	18,400	6.5	--	--
do.	1245	200	12	22.0	--	--	--	--	--	--	--	6,110	--	.5	6	11,100	--	--	--	18,400	6.6	--	--
SITE 20. SABINE RIVER AT SOUTHERN PACIFIC RAILROAD CROSSING (MILE 4.3)																							
Nov. 3	1345	50	0	16.0	--	--	--	--	--	--	--	292	--	7.8	78	585	--	--		1,110	6.9	--	--
do.	1345	50	5	16.5	--	--	--	--	--	--	--	460	--	7.0	72	875	--	--		1,690	6.8	--	--
do.	1350	50	10	20.0	--	--	--	--	--	--	--	4,030	--	2.7	30	7,440	--	--		12,800	6.6	--	--
do.	1350	50	15	23.0	--	--	--	--	--	--	--	a6,570	--	.2	2	12,000	--	--		19,800	6.6	--	--
do.	1355	50	20	22.5	--	--	--	--	--	--	--	a6,570	--	.2	2	12,000	--	--		19,800	6.6	--	--
do.	1355	50	25	22.5	--	--	--	--	--	--	--	6,570	--	.6	7	12,000	--	--		19,800	6.6	--	--
do.	1400	125	0	16.0	--	--	--	--	--	--	--	288	--	7.7	77	595	--	--		1,130	6.9	--	--
do.	1400	125	5	16.5	--	--	--	--	--	--	--	460	--	6.9	70	980	--	--		1,890	6.8	--	--
do.	1405	125	10	21.0	--	--	--	--	--	--	--	4,660	--	1.8	21	8,400	--	--		14,500	6.6	--	--
do.	1405	125	15	23.0	--	--	--	--	--	--	--	a6,530	--	.2	2	11,800	--	--		19,500	6.6	--	--
do.	1405	125	20	23.0	--	--	--	--	--	--	--	6,530	--	.5	6	11,800	--	--		19,500	6.6	--	--
do.	1410	240	0	16.5	--	--	--	--	--	--	--	275	--	7.6	77	555	--	--		1,050	6.9	--	--
do.	1410	240	5	16.5	--	--	--	--	--	--	--	a330	--	7.5	76	660	--	--		1,250	6.8	--	--
do.	1415	240	8	17.5	--	--	--	--	--	--	--	a1,010	--	6.0	62	1,830	--	--		3,450	6.7	--	--
do.	1415	240	10	19.5	--	--	--	--	--	--	--	3,420	--	3.2	36	6,290	--	--		10,900	6.6	--	--
do.	1415	240	13	21.0	--	--	--	--	--	--	--	6,080	--	.6	7	11,100	--	--		18,500	6.6	--	--
SITE 21. LITTLE CYPRESS BAYOU 100 YARDS UPSTREAM FROM MOUTH (MILE T-0.1)																							
Nov. 3	1325	50	0	16.5	15	18	31	270	9.8	36	67	480	0.2	8.2	84	909	172	143	9.0	1,750	6.9	6.9	--
do.	1325	50	2	16.0	--	--	--	--	--	--	--	a550	--	7.4	75	1,050	--	--	--	2,020	6.9	--	--
do.	1330	50	4	15.5	--	--	--	--	--	--	--	a610	--	7.6	76	1,140	--	--	--	2,200	6.9	--	--
do.	1330	50	6	15.5	--	--	--	--	--	--	--	a750	--	6.5	65	1,370	--	--	--	2,640	6.9	--	--
do.	1335	50	8	14.0	--	--	--	--	--	--	--	1,040	--	1.9	18	1,870	--	--	--	3,610	6.9	--	--
do.	1335	50	10	14.0	12	56	139	1,140	38	49	288	2,080	22	1.9	19	3,800	711	671	19	6,790	6.7	7.2	--
SITE 22. GUM SLOUGH AT LOUISIANA STATE HIGHWAY 109 (MILE T-6.7)																							
Nov. 4	0830	--	0	8.5	11	16	4.2	98	2.1	31	53	140	0.2	10.0	86	340	58	32	5.6	644	6.5	6.8	--

See footnote at end of table.

Table 2.--Chemical analyses of streams in the Sabine River basin near Orange, Texas--Continued

(Results in parts per million except as indicated)

Date (1966)	Hour	Sampling Point: Distance from right edge of water (feet)	Sampling Point: Depth below water surface (feet)	Water Temp. (°C)	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Dissolved oxygen (DO): ppm	Dissolved oxygen (DO): Percent of saturation	Dissolved solids (Calculated)	Hardness as $CaCO_3$: Calcium, Magnesium	Hardness as $CaCO_3$: Noncarbonate	Sodium adsorption ratio	Specific conductance (micromhos at 25°C)	pH: Field	pH: Laboratory	Density (gm/ml at 20°C)
SITE 23. SABINE RIVER AT INTERSTATE HIGHWAY 10 (MILE 0.0)																							
Nov. 3	1115	5	0	16.5	--	--	--	--	--	--	--	1,470	--	6.9	70	2,670	--	--		4,940	6.7	--	--
do.	1115	5	2	17.0	--	--	--	--	--	--	--	a1,570	--	6.8	71	2,810	--	--		5,200	6.7	--	--
do.	1120	5	4	17.0	--	--	--	--	--	--	--	a1,970	--	6.1	64	3,560	--	--		6,400	6.6	--	--
do.	1120	5	6	18.5	--	--	--	--	--	--	--	3,080	--	4.4	48	5,520	--	--		9,570	6.5	--	--
do.	1125	5	8	18.0	--	--	--	--	--	--	--	a4,100	--	3.5	38	7,260	--	--		12,500	6.5	--	--
do.	1125	5	10	18.0	--	--	--	--	--	--	--	4,530	--	3.2	35	7,870	--	--		13,900	6.5	--	--
do.	1130	160	0	16.5	12	46	112	926	35	44	236	1,700	0.2	6.9	71	3,090	576	540	17	5,710	6.7	6.9	1.004
do.	1130	160	5	18.0	--	--	--	--	--	--	--	a2,250	--	5.2	55	4,040	--	--		7,200	6.7	--	--
do.	1135	160	10	21.0	7.0	110	267	2,470	86	66	598	4,430	--	2.4	28	8,000	1,370	1,320		14,500	6.6	--	--
do.	1135	160	15	22.0	--	--	--	--	--	--	--	a5,800	--	.7	8	10,600	--	--		17,600	6.6	--	--
do.	1140	160	20	22.0	--	--	--	--	--	--	--	a7,600	--	.2	2	13,800	--	--		22,700	6.6	--	--
do.	1140	160	25	22.0	--	--	--	--	--	--	--	a7,980	--	.2	2	14,500	--	--		23,700	6.6	--	--
do.	1145	160	33	21.0	4.8	186	500	4,490	153	97	1,090	7,980	3.0	.2	2	14,500	2,520	2,440		23,700	6.6	6.1	1.009
do.	1155	360	0	17.0	--	--	--	--	--	--	--	1,500	--	6.8	71	2,720	--	--		5,020	6.8	--	--
do.	1155	360	5	17.0	--	--	--	--	--	--	--	2,300	--	5.4	56	4,110	--	--		7,380	6.7	--	--
do.	1200	360	10	19.5	--	--	--	--	--	--	--	a4,600	--	2.8	31	8,130	--	--		14,000	6.7	--	--
do.	1200	360	15	21.0	--	--	--	--	--	--	--	a6,100	--	.5	6	11,000	--	--		18,200	6.7	--	--
do.	1205	360	20	22.0	--	--	--	--	--	--	--	a7,600	--	.2	2	13,600	--	--		22,400	6.7	--	--
do.	1205	360	26	21.0	--	--	--	--	--	--	--	7,890	--	.7	8	13,900	--	--		22,800	6.6	--	--
do.	1210	520	0	17.5	--	--	--	--	--	--	--	1,490	--	6.8	71	2,700	--	--		4,990	6.8	--	--
do.	1210	520	2	17.5	--	--	--	--	--	--	--	a1,550	--	6.5	68	2,810	--	--		5,200	6.8	--	--
do.	1215	520	5	17.5	--	--	--	--	--	--	--	a1,750	--	5.9	62	3,140	--	--		5,800	6.7	--	--
do.	1215	520	8	19.0	--	--	--	--	--	--	--	3,740	--	3.5	39	6,750	--	--		11,700	6.6	--	--

a Calculated from specific conductance.

gradients decrease, the channel widens, and velocity and turbulence decrease. The velocity periodically is decreased still further by the rising tide. Therefore, the rate of aeration is decreased. Also, because dissolved oxygen measurements at different sites were made at different times of the day, differences in photosynthetic activity and water temperature probably caused some variation in the observed concentrations of dissolved oxygen.

Tributary inflow in this reach totaled about 0.5 cfs, from an unnamed tributary that joins the main stem downstream from Morgan Bluff. The flow in Patterson Slough, an overflow channel of the Sabine River, was about 10 cfs. Water in Patterson Slough (site 2) contained 86 ppm dissolved solids, 18 ppm chloride, and 8.7 ppm dissolved oxygen. Water in the unnamed tributary (site 10) contained 154 ppm dissolved solids, 68 ppm chloride, and 9.1 ppm dissolved oxygen.

Old River--Mile T-10.5 to Mile T-3.8

Water in the upper 6.7-mile reach of the Old River was fresh, well mixed, and similar in chemical character to water in the upstream reach of the main stem (Figure 6). Dissolved-solids concentrations ranged from 79 ppm at site 13 to 89 ppm at site 16; chloride concentrations ranged from 16 ppm at site 13 to 22 ppm at site 16. As was noted on the upstream reach of the Sabine River, dissolved-oxygen concentrations in the Old River decreased in the downstream direction--from 8.2 ppm at site 13 to 7.7 ppm at site 16.

Sabine River--Mile 5.6 to Mile 0.0 and Old River--Mile T-3.8 to Mile T-0.0

The farthest distance that salt water advanced upstream in the main stem Sabine River was at site 19 (mile 5.2) near the mouth of Old River. Although erosion of the salt-water wedge by fresh-water current and turbulence caused some mixing, the interface between fresh and salt water was fairly sharp at site 19 (Figure 7). Water at the surface contained less than 250 ppm dissolved solids and 110 ppm chloride, whereas water below depths of 12 feet contained 12,400 ppm dissolved solids and 6,850 ppm chloride. Lateral variations of salinity were insignificant. The dissolved-oxygen content of the water generally decreased greatly with depth. Water at the surface contained as much as 7.5 ppm, but below depths of 10 feet the water contained as little as 0.2 ppm. Although the decrease of dissolved oxygen roughly coincided with the increase of salinity, neither the increase in salinity nor the increase of temperature (Table 2) caused the large decrease of dissolved oxygen. The solubility of oxygen in water decreases as the salinity increases; however, the amount of oxygen dissolved by sea water in equilibrium with air is about 80 percent of that dissolved by fresh water. At site 19, water at the surface was about 75 percent saturated with dissolved oxygen, whereas water below 10 feet was only 2-7 percent saturated. According to Forrest and Cotton (p. 12-13), the dissolved oxygen content of water in the lower reaches of the Sabine River has been depleted by pollution. Therefore, much of the dissolved-oxygen deficit at site 19 probably resulted from oxidation of organic pollution. The source of the organic material is not known; however, the fact that water which was deficient in dissolved oxygen was also more saline indicates that the organic material was from downstream sources--probably from sewage and industrial effluents.

According to Keighton (p. 39), pollution entering a tidal river may, under some conditions, be carried considerable distances upstream from the point of introduction.

Figure 5 shows that the salt front advanced farther upstream in the Old River than in the main stem. Salt water was detected in the Old River at site 17 (mile T-3.6). At this site, mixing was poor and considerable horizontal stratification of fresh and salt waters occurred (Figure 7). Water at the surface contained 124-180 ppm dissolved solids and 41-76 ppm chloride. Below depths of 9 feet, the water contained about 11,200 ppm dissolved solids and 6,200 ppm chloride. The dissolved-oxygen content also varied greatly with depth. Water at the surface contained as much as 7.8 ppm dissolved oxygen (78 percent of saturation), but water below depths of 10 feet contained as little as 0.2 ppm (2 percent of saturation).

The different distances to which salt water advanced upstream in the Sabine and Old Rivers cannot be attributed to differences of fresh-water discharge. The streamflow study showed that when none of the pumping plants was operating, about half the water that passed the stream-gaging station near Ruliff flowed into Old River. According to Keighton (p. 4), two connecting river channels may not undergo the same tidal conditions because the shape of the waterway, its depth and width, and irregularities or obstructions in the river bed or shoreline all affect the tidal behavior. In the main stem Sabine River upstream from the mouth of Old River, depths decreased abruptly (from more than 20 feet at site 19 to less than 10 feet at site 12). This abrupt decrease in depth was the major factor in preventing the advance of salt water farther upstream in the main stem. There was no such abrupt decrease of depth in the Old River, however; therefore, the salt water advanced farther upstream to site 17.

Although salt water was not detected in the Old River upstream from site 17, a low-head barrier dam has been built at mile T-4.4 to prevent salt water being pumped into Sabine Canal.

Downstream from Old River, some mixing of salt and fresh water occurred. At site 20 (mile 4.3), the dissolved-solids and chloride content of water at the surface increased to more than 550 ppm and 250 ppm, respectively. Nevertheless, the salinity gradient from surface to bottom remained large. Water at the bottom of the deepest part of the channel contained 12,000 ppm dissolved solids and 6,570 ppm chloride. Dissolved-oxygen concentrations also varied greatly with depth; water at the surface contained as much as 7.8 ppm (78 percent of saturation), whereas water below depths of 15 feet contained as little as 0.2 ppm (2 percent of saturation).

The chloride profile (Figure 5) indicates that the average chloride content (and thus the average salinity) decreased between sites 19 and 20. Similarly, the maximum chloride content at site 20 (6,570 ppm) was less than the maximum chloride content at site 19 (6,850 ppm). Part of this apparent downstream decrease in salinity probably was caused by the difference in tidal stage. Data for site 19 were collected on November 2 during the very low tide that resulted from a strong north wind, whereas data for site 20 were collected during the rising tide on November 3. The incoming tide probably caused temporary storage of fresh water upstream from the head of the tide, and the apparent decrease in average chloride content of water at site 20.

Although mixing of fresh and salt water in the tidal reach generally increased in the downstream direction, complete mixing was not attained. At site 23, the lowermost site in the study area, dissolved-solids and chloride concentrations of water at the surface increased to more than 2,600 ppm and 1,400 ppm, respectively. Water at the bottom of the deepest part of the channel contained 14,500 ppm dissolved solids and 7,980 ppm chloride (Figure 7). The dissolved-oxygen content also varied greatly--from a maximum of 6.9 ppm at the surface to a minimum of 0.2 ppm below depths of 15 feet.

Tributary inflow in this reach was only about 0.8 cfs from Gum Slough. Water in Gum Slough (site 22) contained 340 ppm dissolved solids, 140 ppm chloride, and 10.0 ppm dissolved oxygen.

SUMMARY OF CONCLUSIONS

During the low-flow period October 31-November 4, 1966, measured tributary inflow to the Sabine and Old Rivers between the Sabine River stream-gaging station near Ruliff and the Sabine River at Interstate Highway 10 totaled only about 1.3 cfs. Streamflow at the station near Ruliff averaged about 500 cfs, or almost 100 percent of the total fresh-water inflow to the tide-affected reaches of the Sabine River and Old River, a large Sabine River anabranch. About 50 percent of this flow left the main stem and passed through Old River. Similarly, on April 12, 1966, when flow at the Ruliff station averaged about 1,680 cfs, the flow was distributed equally between the two streams. Therefore, daily fresh-water inflow to the tide-affected reach of the main stem Sabine River downstream from the divergence of Old River can be estimated for other periods with similar discharges by subtracting the amount of water diverted by the Sabine River Authority from 50 percent of the mean daily discharge of the Sabine River near Ruliff. Large changes in discharge or channel conditions, such as those that might occur during floods, may alter flow distribution, however.

Although fresh-water inflow to the tide-affected reaches of the Sabine and Old Rivers was about equal during the period of study, sea water advanced about 3.6 miles farther upstream in the Old River than in the Sabine River. The different distances to which salt water advanced in the two streams is attributed to differences in channel characteristics, principally the greater depth in Old River.

Upstream from the salt front in both the Sabine and Old Rivers, dissolved-solids and chloride concentrations were low (generally less than 90 ppm and 25 ppm, respectively). Dissolved-oxygen concentrations upstream from the salt front ranged from 8.2 ppm to 7.1 ppm in the main stem and from 8.2 ppm to 7.7 ppm in Old River. In both streams, the dissolved oxygen decreased in the downstream direction. Much of this decrease probably resulted from the oxidation of natural organic debris.

At the uppermost site affected by salt water intrusion, the salt and fresh waters were sharply stratified. Water at the surface was fresh and very similar in chemical composition to water at upstream sites, whereas water near the bottom contained more than 12,000 ppm dissolved solids and 6,500 ppm chloride. Although mixing of salt and fresh waters increased seaward, the salinity gradient from surface to bottom was large throughout the remainder of the tidal reach. Average chloride content and salinity generally increased seaward.

Dissolved-oxygen concentrations in the reach affected by salt-water intrusion generally decreased greatly with increase in depth. Although the decrease of dissolved oxygen coincided roughly with the increase of salinity, only a small part of the dissolved-oxygen deficit resulted from the increase in salinity. Much of the deficit probably resulted from the oxidation of organic pollution pushed upstream by the periodic rise of the tide.

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