Intensive Survey of Armand Bayou Segment 1113

March 31 - April 2, 1987

Texas Water Commission

May 1989

INTENSIVE SURVEY OF

ARMAND BAYOU

SEGMENT 1113

March 31 - April 2, 1987

Hydrology, Field Measurements,
Water Chemistry

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ABSTRACT

An intensive survey was conducted on Armand Bayou, Segment 1113, on March 31 - April 2, 1987. Armand Bayou is a small tidal stream which flows into Clear Lake at the southeastern edge of Harris County in southeast Texas. There are no direct discharges of wastewater to the segment; however, five municipal wastewater treatment plants discharge into tributaries to Armand Bayou. The survey included field measurements of dissolved oxygen, pH, temperature and conductivity in the bayou, at the wastewater treatment plants' outfalls, and tributary streams. Water samples for chemical analysis were collected at each sampling point.

The data indicated generally acceptable water quality in the segment. Dissolved oxygen levels were high, although a wide diurnal range of dissolved oxygen at some stations suggested high algal production. Water circulation through the bayou appears to be very slow and accumulated nutrients from the treatment plant discharges are contributing to algae blooms.

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ARMAND BAYOU

SEGMENT 1113

INTRODUCTION

DIRECTIVE

This intensive survey was accomplished in accordance with the Texas Water Code, Section 26.127. The report is to be used for the purpose listed below.

PURPOSE

The purpose of this intensive survey was to provide the Texas Water Commission with a valid information source:

1. to determine quantitative cause and effect relationships of water quality;

2. to obtain data for updating water quality management plans, setting effluent limits, and where appropriate, verifying the classifications of segments;

3. to set priorities for establishing or improving pollution controls; and

4. to determine any additional water quality management actions required.

METHODS

Field and laboratory procedures used during this survey are described in Appendix A. The field measurements, water chemistry, and hydraulic data were collected March 31 - April 2, 1987 by personnel of the Texas Water Commission's Water Quality Monitoring Unit. Laboratory analyses of water samples were conducted by the Texas Department of Health Chemistry Laboratory in Austin, Texas. Parametric coverage, sampling frequencies and spatial relationships of sampling stations were consistent with the objectives of the survey and with known or suspected forms and variabilities of pollutants entering the bayou.

RESULTS AND DISCUSSION

SITE DESCRIPTION

Armand Bayou originates in southeastern Harris County and flows southward into Clear Lake which empties into Galveston Bay. Segment 1113 is the tidal portion of Armand Bayou from the confluence with Clear Lake to a point one-half mile downstream of Genoa-Red Bluff Road, a distance of about 9.0 river miles. A secondary bayou, Horsepen Bayou joins Armand Bayou about 2.7 miles upstream of the Clear Lake confluence and extends about 5.8 miles westward. Horsepen Bayou is not a designated stream segment but it does have a significant impact on water quality in Armand Bayou and was treated as part of the segment on this survey. The reach between the confluence of the two bayous and Clear Lake is called Mud Lake (Figure 1).

The area immediately surrounding Armand Bayou is a nature sanctuary and development is restricted. Fishing and canoeing are permitted on the bayou but motor boats are prohibited. The Harris County Parks Department conducts guided tours through the bayou on electric boats and hiking trails permit access to the area.

Water Quality Standards

The 1985 edition of the Texas Surface Water Quality Standards describes Segment 1113 as a high quality aquatic life habitat, suitable for contact recreation activities. To insure that the segment meets these desired uses, numerical criteria for selected water quality parameters have been established: Minimum dissolved oxygen levels of not less than 4.0 mg/L, pH range of 6.5 to 9.0 standard units, maximum surface water temperature of not greater than 95°F, and fecal coliform density of not greater than 200 organisms/100 mL. The segment is classified as Water Quality Limited, meaning advanced treatment levels are required on wastewater discharges in order for the segment to meet these water quality standards. A summary of water quality data from the past five-year period is presented in Table 2 as it appears in the 8th Edition of the Texas Water Quality Inventory Report.

Wastewater Dischargers

The largest point source of wastewater to the segment is Clear Lake City Water Authority's (CLCWA)'s wastewater treatment plant located on Horsepen Bayou. The City of Houston's Ellington Air Force Base wastewater treatment plant and Gulf Coast Waste Disposal Authority (GCWDA)'s Metro Central wastewater treatment plant both discharge into Horsepen Bayou upstream of CLCWA. The City of LaPorte operates a wastewater treatment plant on Big Island Slough and Bill Fleemer's Spencer Road wastewater treatment plant is on Willow Springs Gully. The permitted discharges for these plants and effluent quality requirements are listed below:

Permit No.	Name	Average Daily Flow (mgd)	BOD_5 (mg/L)	NH_3-N (mg/L)
WQ0010539	CLCWA	6.75	5.0	2.0
WQ0010495	City of Houston	0.99	5.0	5.0
WQ0011851	GCWDA	2.00	5.0	2.0
WQ0010921	City of LaPorte	0.40	5.0	2.0
WQ0012677	Bill Fleemer	0.10	5.0	5.0

INTENSIVE SURVEY DATA

Hydrology

High tide at Station B occurred at 2100 hours on March 31st. Low tide was at 0530 the next morning with another high tide at 1500 hours that afternoon. The tidal range was about 13 inches.

Armand Bayou was flowing at a rate of 2.07 ft^3/s at Station O upstream from Segment 1113. Other flowing tributaries included Big Island Slough, 0.15 ft^3/s, and Spring Gully, 0.07 ft^3/s. The flow in Willow Springs Gully was estimated to be less than 0.05 ft^3/s and there was no flow in Horsepen Bayou upstream of tidal (Table 3).

The lower portion of the estuary (Lower Mud Lake) is wide and shallow. The bottom is flat with no features and the depth is about 3 feet and uniform. A defined channel begins to appear in the vicinity of Station B and becomes more pronounced upstream. Subsidence in recent years has caused Mud Lake to spread out and many trees are inudated at normal water levels. Armand Bayou becomes narrower near Station K and the banks are more clearly defined. The channel is u-shaped and extends from bank to bank. Maximum depth is about 10 feet. The bayou becomes narrower and shallower upstream with no large pools or riffle areas within the tidal zone.

Field Measurements

Dissolved oxygen levels were high at all stations, exceeding the minimum criterion of 4.0 mg/L throughout the study period. Diurnal ranges of dissolved oxygen were moderate in the downstream reaches of the segment, with generally less than 4.0 mg/L difference between early morning and mid-afternoon levels. Diurnal dissolved oxygen ranges were somewhat greater in the upstream reaches and tributary streams. Stations where the widest diurnal ranges occurred included Station O (7.1 to 14.8 mg/L), Station L (9.6 to 16.9 mg/L), and Station T (6.5 to 15.3 mg/L) (Table 4). A wide range of dissolved oxygen levels over a diurnal period is often associated with a high rate of algal photosynthesis and respiration.

The pH in Armand Bayou was were generally high with two measurements at Station T slightly exceeding the maximum criterion of 9.0 standard units. High pH levels during afternoon hours are also associated with abundant algal metabolism.

Conductivity levels in the lower portion of the segment, Stations A-C, were generally greater than 14,000 umhos/cm. High conductivity levels extended upstream, especially in bottom waters, to the vicinity of Station K. Upstream of that point conductivity levels decreased to less than 1,000 umhos/cm at some stations. Conductivity levels in treatment plant effluents were less than 1,100 umhos/cm.

Laboratory Analyses

Carbonaceous biochemical oxygen demand ($CBOD_5$) levels were mostly less than 5.0 mg/L at stream stations with slightly higher levels at two of the discharge points, (5.5 mg/L at Station 3 and 8.5 mg/L at Station 5). A $CBOD_5$ level of 5.5 mg/L was also found at Station L.

Nutrient levels were relatively high in the treatment plant effluents, ranging from 1.23 mg/L of nitrate nitrogen at Station 4 to 25.71 mg/L of nitrate nitrogen at Station 2 and 0.51 mg/L of ortho-phosphorus at Station 5 to 7.25 mg/L of ortho-phosphorus at Station 2. Elevated levels of these parameters were also found in Horsepen Bayou, especially at Stations G and I. Nitrate nitrogen levels were 8.87 mg/L and 12.6 mg/L at Stations G and I, respectively and ortho-phosphorus levels at the same stations were 3.77 and 2.55 mg/L, respectively.

Chlorophyll a levels varied greatly from station to station but were generally high, 156 µg/L at Station L, 73 µg/L at Station E and 79 µg/L at Station P indicating a large standing crop of algae. Levels greater than 20 µg/L were present at Stations A, B, C, K, N, and S.

Chloride, sulfate and total dissolved solids (TDS) levels were highest in the more saline waters downstream of Station K. Total suspended solids (TSS) were fairly high at all of the stream stations, (greater than 20 mg/L) except at Station R (7 mg/L) (Table 6).

CONCLUSIONS

Water movement through Segment 1113 is largely a result of tidal action rather than tributary inflow. All tidal exchange however, occurs through a single, relatively small channel at the south end of Mud Lake. During outgoing tides water from Armand Bayou and nutrient laden water from Horsepen Bayou mix freely in the upper reaches of Mud Lake. On incoming tides, some of this enriched water is pushed back into Armand Bayou as well as Horsepen Bayou. Nutrients trapped in this back and forth movement produce prolific algae growth in the area, illustrated by the high chlorophyll a levels in the area bounded by Station E, L and C on the area map. Wind and wave action in Mud Lake provides aeration which helps maintain dissolved oxygen levels, and while wide diurnal ranges of dissolved oxygen occur, no violations of the dissolved oxygen criterion were observed during the survey. Stream monitoring activities at Stations G and L have not recorded any dissolved oxygen violations at these stations during the past four year period.

PRESENTATION OF DATA

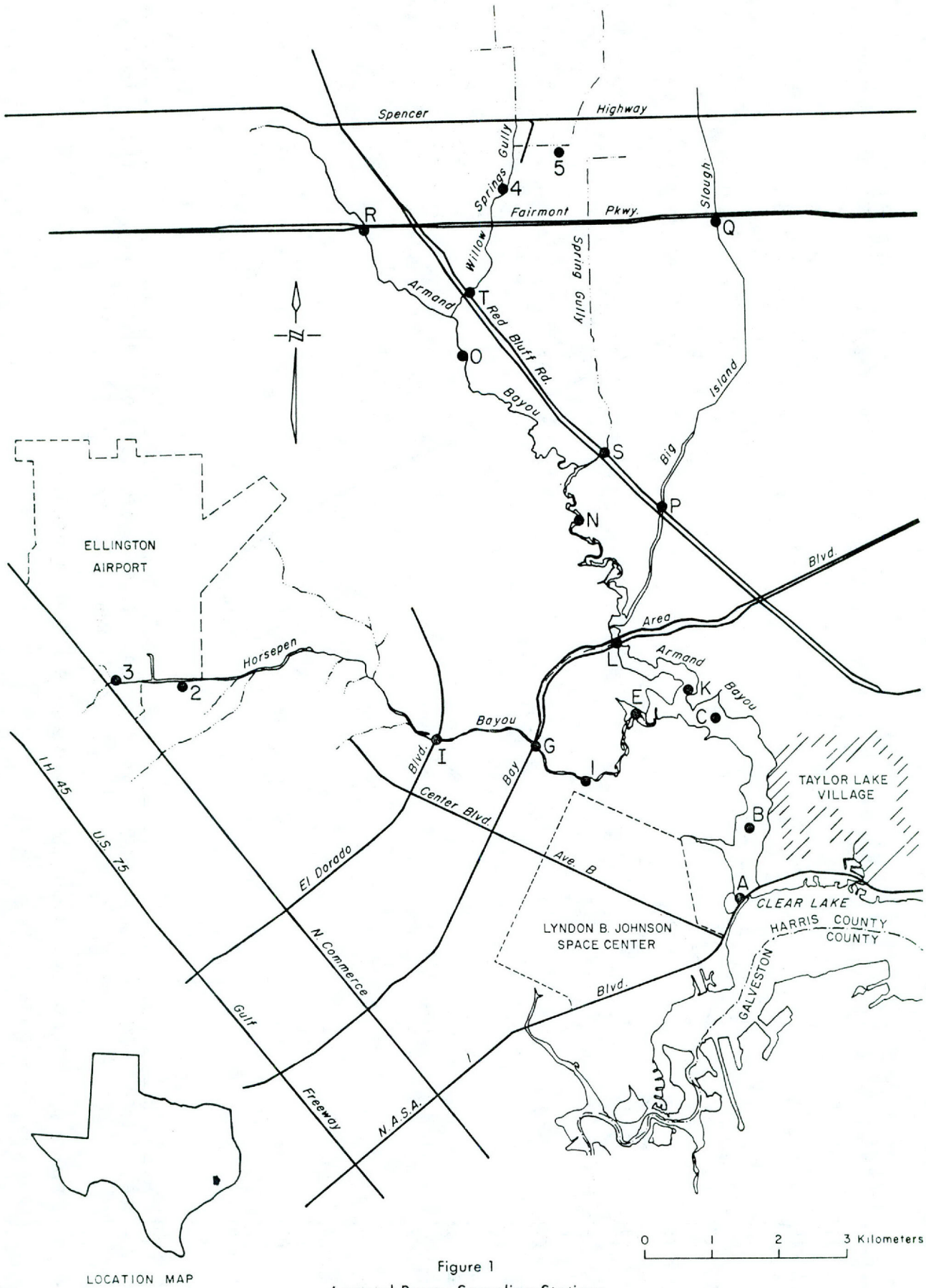

Figure 1
Armand Bayou Sampling Stations

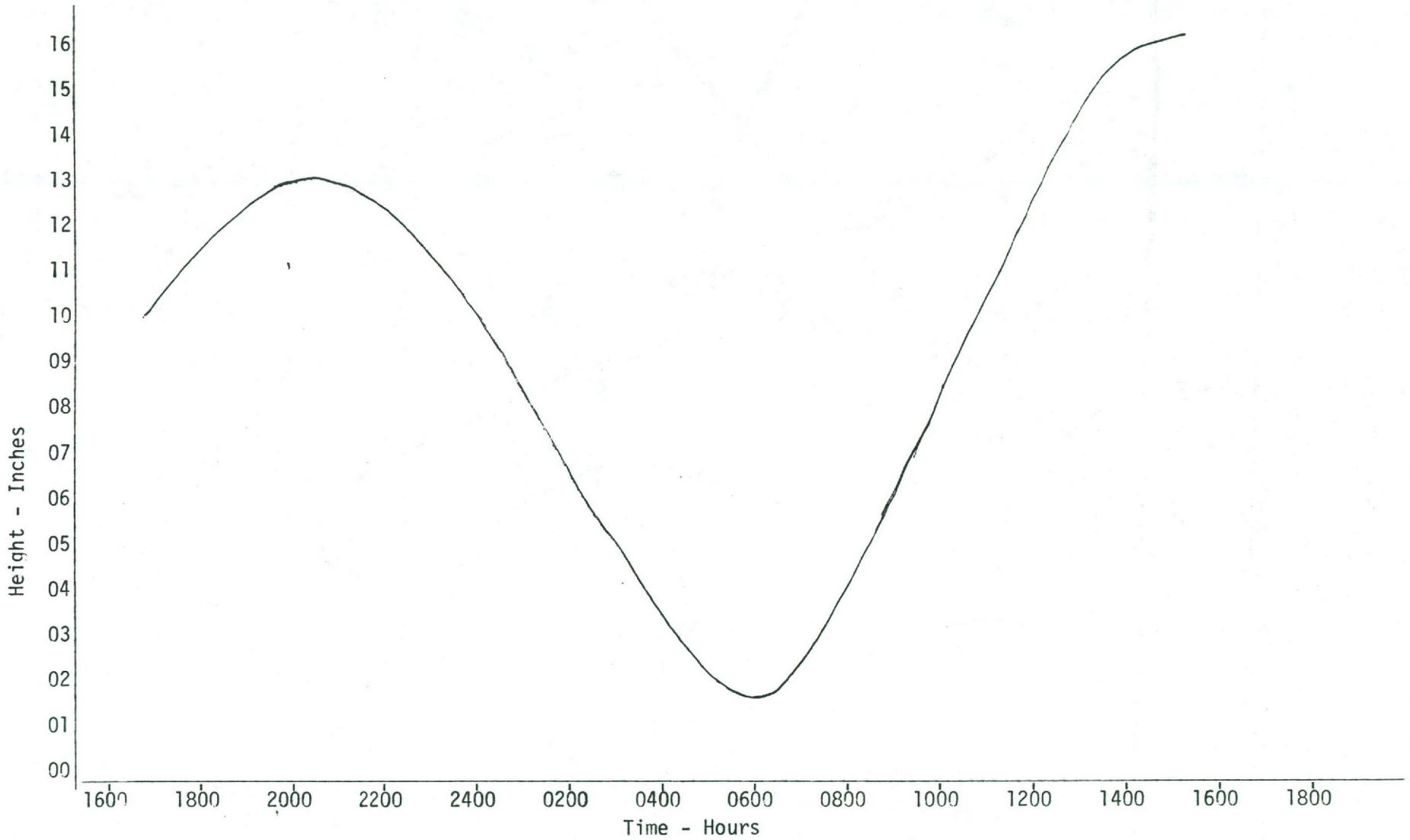

Figure 2. Tidal Range: Lower Mud Lake, March 31 - April 1, 1987

TABLE 1

Armand Bayou Survey Sampling Stations

Map Code	SMN Number	Bayou Mile	Station Description
A	1113.0005		Mud Lake at NASA 1 Bridge
B	1113.0020		Lower Mud Lake 1.4 Km upstream of NASA 1 Bridge
C	1113.0030		Upper Mud Lake 2.8 Km upstream of NASA 1 Bridge
E	1100.0380		Horsepen Bayou 1.0 Km upstream of Armand Bayou
G	1100.0400		Horsepen Bayou at Bay Area Blvd.
I	1100.0450		Horsepen Bayou at El Dorado Blvd.
K	1113.0050		Armand Bayou 0.4 Km upstream of Horsepen Bayou
L	1113.0100		Armand Bayou at Bay Area Blvd.
N	1113.0200		Armand Bayou at unnamed road 1.1 Km downstream of Spring Gully
O	1100.0350		Armand Bayou at Genoa-Red Bluff Road
P	1100.0300		Big Island Slough at Red Bluff Road
Q	1100.0325		Big Island Slough at Fairmont Parkway
R	1100.0355		Armand Bayou at Fairmont Parkway
S	1100.0480		Spring Gully at Red Bluff Road
T	1100.0490		Willow Springs Gully at Red Bluff Road
1	1100.0917		Clear Lake City Water Authority Wastewater Treatment Plant
2	1100.9018		Gulf Coast Waste Disposal Metro Central Wastewater Treatment Plant
3	1100.9019		City of Houston Ellington Air Force Base Wastewater Treatment Plant
4	1100.9020		City of LaPorte Wastewater Treatment Plant
5	1100.9021		Bill Fleemer Spencer Road Wastewater Treatment Plant

TABLE 2

Historical Water Quality Data
October 1, 1981 through September 30, 1985

Parameter	Criterion	Number of Samples	Minimum	Maximum	Mean	Number of Violations	Mean of Violations
Dissolved Oxygen (mg/L)	4.0	17	3.7	12.3	7.1	1	3.7
Temperature (F)	95.0	17	48.0	86.5	70.1	0	0
pH	6.5-9.0	9	7.1	9.2	8.2	2	9.2
Chloride (mg/L)	N/A	16	18	6115	1511	0	0
Sulfate (mg/L)	N/A	15	10	788	181	0	0
TDS (mg/L)	N/A	9	201	10150	2436	0	0
Fecal Coliforms (#/100 mL)	200	15	20	9400	222	8	792

TABLE 3

Armand Bayou Flow Data

Station	Date	Time	Ft^3/sec	Method
O	04/01/87	1410	2.068	Portable Meter
Q	04/01/87	1716	0.146	Portable Meter
R	04/01/87	1741	0.330	Portable Meter
S	04/02/87	0900	0.05	Estimate
1	04/01/87	24-hr. average	2.327	Totalizer
2	04/01/87	24-hr. average	0.637	Totalizer
3	04/01/87	24-hr. average	0.459	Totalizer
4	04/01/87	24-hr. average	0.104	Totalizer
5	04/01/87	24-hr. average	0.008	Self-reporting records

TABLE 4

Armand Bayou Field Measurements

Map Code and Station Number	Date	Time	Depth (ft)	Water Temperature (°C)	Conductivity (µmhos/cm)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% Sat.)	pH
A 1113.0005	04/01/87	0645	1.0	14.1	15700	10.7	104.3	8.2
	04/01/87	0645	4.0	14.3	16280	10.0	97.9	8.2
	04/01/87	1030	1.0	15.0	15630	13.1	130.3	8.6
	04/01/87	1030	7.0	14.5	15800	11.5	113.1	8.4
	04/01/87	1430	1.0	16.9	15690	14.4	149.1	8.6
	04/01/87	1430	7.0	16.8	15670	14.1	145.7	8.6
	04/01/87	1735	1.0	18.0	16000	13.9	147.3	8.7
	04/01/87	1735	8.0	17.9	16080	13.9	147.0	8.6
		DIEL MEAN		15.9	15917	12.4	126.8	8.5
B 1113.0020	04/01/87	0700	1.0	13.7	13380	11.0	106.3	8.5
	04/01/87	1035	1.0	15.2	14100	12.7	126.8	8.6
	04/01/87	1035	4.0	15.2	15380	11.8	117.8	8.5
	04/01/87	1445	1.0	17.4	15890	14.0	146.5	8.6
	04/01/87	1445	5.0	16.9	15930	13.8	142.9	8.6
	04/01/87	1745	1.0	17.6	15890	13.5	141.9	8.7
	04/01/87	1745	5.0	17.4	15900	14.2	148.6	8.7
		DIEL MEAN		15.7	14829	12.6	127.8	8.6
C 1113.0030	04/01/87	0715	1.0	14.3	11150	11.4	111.6	8.5
	04/01/87	0715	4.0	14.3	11890	10.0	97.9	8.5
	04/01/87	1045	1.0	15.6	13200	13.1	132.0	8.7
	04/01/87	1045	5.0	15.2	13170	12.4	123.8	8.7
	04/01/87	1500	1.0	18.4	14530	14.8	158.1	8.8
	04/01/87	1500	5.0	18.4	14730	14.7	157.0	8.7
	04/01/87	1750	1.0	18.3	15480	13.6	145.0	8.8
	04/01/87	1750	4.0	18.2	15000	13.7	145.8	8.7
		DIEL MEAN		16.4	13507	12.6	130.0	8.7

TABLE 4 CONTINUED

Map Code and Station Number	Date	Time	Depth (ft)	Water Temperature (°C)	Conductivity (µmhos/cm)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% Sat.)	pH
E 1100.0380	04/01/87	0730	1.0	14.6	3080	8.4	82.8	8.2
	04/01/87	0730	4.0	15.0	4860	8.6	85.5	8.2
	04/01/87	1055	1.0	16.9	6700	10.2	105.6	8.4
	04/01/87	1055	5.0	15.1	9000	11.6	115.6	8.6
	04/01/87	1530	1.0	22.1	6200	13.1	150.6	8.7
	04/01/87	1530	7.0	18.7	11680	15.4	165.5	8.8
	04/01/87	1800	1.0	20.4	7250	14.6	162.4	8.8
	04/01/87	1800	7.0	19.0	12190	15.3	165.5	8.8
		DIEL MEAN		17.5	7267	11.9	126.1	8.5
G 1100.0400	04/01/87	0615	1.0	14.2	1095	11.4	111.4	8.4
	04/01/87	1025	1.0	16.5	1056	8.3	85.2	8.3
	04/01/87	1410	1.0	20.5	1166	8.5	94.7	8.1
	04/01/87	1810	1.0	18.5	1281	8.9	95.3	8.1
		DIEL MEAN		17.0	1162	9.6	99.0	8.2
I 1100.0450	04/01/87	0715	1.0	14.6	1174	7.8	76.9	7.9
	04/01/87	1100	1.0	16.0	1170	9.5	96.5	8.4
	04/01/87	1440	1.0	19.4	1137	12.9	140.6	8.4
	04/01/87	1840	1.0	17.9	1125	14.4	152.3	8.5
		DIEL MEAN		16.7	1151	11.2	116.1	8.3
K 1113.0050	04/01/87	0750	1.0	13.9	7460	11.0	106.8	8.6
	04/01/87	0750	5.0	15.1	10020	10.1	100.6	8.8
	04/01/87	1105	1.0	15.8	10380	13.5	136.6	8.7
	04/01/87	1105	5.0	15.6	10530	13.3	134.0	8.7
	04/01/87	1510	1.0	18.2	12510	15.6	166.0	8.9
	04/01/87	1510	6.0	18.0	12730	15.2	161.1	8.8
	04/01/87	1815	1.0	18.6	12650	16.1	172.7	9.0
	04/01/87	1815	6.0	18.3	13150	15.0	159.9	8.9
		DIEL MEAN		16.6	11026	13.4	139.2	8.8

TABLE 4 CONTINUED

Map Code and Station Number	Date	Time	Depth (ft)	Water Temperature (°C)	Conductivity (µmhos/cm)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% Sat.)	pH
L 1113.0100	04/01/87	0805	1.0	14.0	4600	10.0	97.3	8.5
	04/01/87	0805	4.0	14.0	4600	9.6	93.4	8.5
	04/01/87	1115	1.0	16.2	6200	13.3	135.7	8.7
	04/01/87	1115	5.0	15.4	6980	12.7	127.4	8.7
	04/01/87	1515	1.0	19.1	9310	16.9	183.1	8.9
	04/01/87	1515	7.0	17.4	9710	14.5	151.7	8.8
	04/01/87	1825	1.0	18.7	9620	16.7	179.5	9.0
	04/01/87	1825	5.0	18.4	9660	16.0	170.9	8.9
		DIEL MEAN		16.5	7398	13.5	139.5	8.7
N 1113.0200	04/01/87	0820	1.0	14.5	754	6.8	66.9	8.1
	04/01/87	1201	1.0	16.8	990	7.2	74.4	8.2
	04/01/87	1550	1.0	19.2	1148	9.5	103.2	8.4
	04/01/87	1935	1.0	17.8	1254	10.2	107.6	8.4
		DIEL MEAN		16.7	1025	8.5	87.8	8.3
O 1100.0350	04/01/87	0853	1.0	13.8	965	7.1	68.8	---
	04/01/87	1300	1.0	19.4	968	12.5	136.3	8.0
	04/01/87	1632	1.0	21.3	967	14.8	167.6	8.2
	04/01/87	1939	1.0	19.6	955	9.0	98.5	8.3
		DIEL MEAN		17.7	962	9.7	103.3	8.2
P 1100.0300	04/01/87	0845	1.0	13.8	1678	7.6	73.6	8.2
	04/01/87	1215	1.0	16.3	2340	9.5	97.1	8.4
	04/01/87	1640	1.0	18.2	2850	13.0	138.3	8.7
	04/01/87	1955	1.0	17.4	3090	13.0	136.0	8.7
		DIEL MEAN		16.1	2447	10.6	108.7	8.5

TABLE 4 CONTINUED

Map Code and Station Number	Date	Time	Depth (ft)	Water Temperature (°C)	Conductivity (µmhos/cm)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% Sat.)	pH
Q 1100.0325	04/01/87	0830	1.0	13.1	1827	9.8	93.4	---
	04/01/87	1238	1.0	19.1	1841	11.3	122.5	8.0
	04/01/87	1604	1.0	22.9	1842	12.5	146.0	8.1
	04/01/87	1910	1.0	20.2	1851	10.7	118.5	8.3
		DIEL MEAN		17.8	1839	10.7	113.8	8.1
R 1100.0355	04/01/87	0700	1.0	11.9	891	8.8	81.6	---
	04/01/87	1115	1.0	16.5	881	10.1	103.7	7.8
	04/01/87	1620	1.0	23.7	866	13.4	158.9	8.5
	04/01/87	1925	1.0	20.7	855	12.0	134.3	8.7
		DIEL MEAN		17.5	874	10.8	115.2	8.3
S 1100.0480	04/01/87	0600	1.0	11.7	1159	7.7	71.1	---
	04/01/87	1039	1.0	16.6	1218	9.3	95.7	8.2
	04/01/87	1440	1.0	23.1	1129	11.7	137.2	8.1
	04/01/87	1814	1.0	21.0	1084	11.4	128.3	8.2
		DIEL MEAN		17.4	1141	9.8	104.3	8.2
T 1100.0490	04/01/87	0630	1.0	9.7	1005	6.5	57.3	---
	04/01/87	1055	1.0	16.5	1012	11.3	116.0	7.9
	04/01/87	1454	1.0	27.4	977	15.3	194.1	9.1
	04/01/87	1833	1.0	25.3	975	12.0	146.6	9.3
		DIEL MEAN		18.8	992	10.5	118.3	8.7

TABLE 4 CONTINUED

Map Code and Station Number	Date	Time	Depth (ft)	Water Temperature (°C)	Conductivity (µmhos/cm)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% Sat.)	pH
1 1100.9017	04/01/87	0640	1.0	20.8	785	7.9	88.6	6.9
	04/01/87	1040	1.0	21.7	758	7.4	84.4	6.9
	04/01/87	1430	1.0	22.7	759	7.9	91.9	6.9
	04/01/87	1825	1.0	22.4	776	8.1	93.7	7.1
		DIEL MEAN		21.8	773	7.9	90.2	7.0
2 1100.9018	04/01/87	0735	1.0	19.5	1015	7.2	78.7	7.0
	04/01/87	1115	1.0	20.6	1002	6.7	74.8	7.0
	04/01/87	1500	1.0	21.8	1004	7.1	81.2	6.8
	04/01/87	1855	1.0	21.0	1002	7.4	83.3	7.0
		DIEL MEAN		20.6	1007	7.2	80.1	7.0
3 1100.9019	04/01/87	0740	1.0	11.3	865	9.7	88.8	8.2
	04/01/87	1130	1.0	13.7	860	10.0	96.6	8.1
	04/01/87	1520	1.0	14.3	851	10.7	104.8	8.5
	04/01/87	1910	1.0	14.4	855	9.7	95.2	8.3
		DIEL MEAN		13.2	859	9.9	94.8	8.3
4 1100.9020	04/01/87	0729	1.0	18.5	998	8.2	87.8	---
	04/01/87	1135	1.0	20.1	1090	8.6	95.1	7.4
	04/01/87	1516	1.0	20.4	1021	8.3	92.3	7.9
	04/01/87	1846	1.0	20.4	1016	8.3	92.3	7.9
		DIEL MEAN		19.7	1022	8.3	91.2	7.7
5 1100.9021	04/01/87	0800	1.0	16.2	856	7.4	75.5	---
	04/01/87	1206	1.0	18.1	856	7.0	74.3	7.4
	04/01/87	1538	1.0	19.0	858	7.4	80.0	7.2
		DIEL MEAN		17.7	857	7.3	77.2	7.3

TABLE 5

Armand Bayou Laboratory Analyses

Map Code and Station Number	Date	Time	Depth ft	5day CBOD mg/L	Filt. 5day CBOD mg/L	20day CBOD mg/L	Filt. 20day CBOD mg/L	Filt. TOC mg/L	TKN mg/L	NH_3-N mg/L	NO_2-N mg/L	NO_3-N mg/L	Ortho P mg/L	Total P mg/L	Chl. a µg/L	Pheo. a µg/L	Cl^- mg/L	$SO_4^=$ mg/L	TSS mg/L	VSS mg/L	TDS mg/L	Total Alk. mg/L	Cond. µmhos/cm	pH
1 1100.9017	04/01/87	COMP	1.0	2.0	1.5	4.5	3.5	10	2.50	0.17	<0.01	18.58	6.89	7.35	---	---	89	97	7	2	490	----	852	6.8
2 1100.9018	04/01/87	COMP	1.0	1.5	1.5	3.5	3.5	7	1.40	<0.02	<0.01	25.71	7.25	9.66	---	---	146	77	<5	<5	600	----	1112	7.1
3 1100.9019	04/01/87	COMP	1.0	5.5	4.5	15.0	13.0	10	1.90	0.03	0.02	7.52	1.89	2.37	---	---	85	19	6	2	506	----	952	8.1
4 1100.9020	04/01/87	COMP	1.0	4.5	3.0	10.0	5.5	8	2.80	0.87	0.05	1.23	5.21	5.73	---	---	103	43	18	10	592	----	1080	8.0
5 1100.9021	04/01/87	COMP	1.0	8.5	6.5	21.0	13.0	12	2.90	0.57	0.67	2.52	0.51	1.00	---	---	82	36	7	5	516	----	906	7.7
A 1113.0005	04/01/87	COMP	COMP	4.0	2.0	7.5	3.5	8	2.20	0.03	0.01	0.03	0.24	0.44	24	15	5191	702	69	15	9580	----	20720	8.6
B 1113.0020	04/01/87	COMP	COMP	4.0	1.0	15.0	2.0	7	1.70	<0.02	<0.01	0.02	0.24	0.47	40	17	4929	657	85	22	9130	----	18816	8.7
C 1113.0030	04/01/87	COMP	COMP	4.5	1.0	10.0	2.0	8	1.70	<0.02	<0.01	0.02	0.25	0.55	59	13	4422	587	64	13	8220	----	17360	8.6
E 1100.0380	04/01/87	COMP	COMP	4.5	1.0	10.0	2.5	8	1.60	<0.02	0.03	3.20	1.57	1.87	73	4	2334	322	55	13	4450	----	9352	8.6
G 1100.0400	04/01/87	COMP	1.0	2.0	1.5	5.0	3.0	7	1.60	0.22	0.08	8.87	3.77	4.07	9	6	196	57	24	5	678	----	1305	8.2
I 1100.0450	04/01/87	COMP	1.0	2.5	1.0	4.5	2.0	5	1.40	0.06	0.04	12.60	2.55	4.76	19	<2	179	49	27	5	682	----	1314	8.2
K 1113.0050	04/01/87	COMP	COMP	4.5	1.0	11.0	2.0	8	1.70	<0.02	0.01	0.13	0.40	0.72	54	45	4416	489	59	14	8520	----	17360	8.8
L 1113.0100	04/01/87	COMP	COMP	5.5	1.0	13.0	2.5	8	1.60	<0.02	0.02	0.54	0.53	0.82	156	11	2384	316	58	14	4590	----	9324	8.7
N 1113.0200	04/01/87	COMP	1.0	3.5	1.0	6.5	2.0	7	1.20	0.02	0.01	0.06	0.16	0.31	37	12	198	50	29	6	616	----	1232	8.3
O 1100.0350	04/01/87	COMP	1.0	1.5	1.0	3.0	2.5	5	0.90	0.09	0.02	0.15	0.32	0.44	2	4	101	28	26	1	544	----	1078	8.4
P 1100.0300	04/01/87	COMP	1.0	5.0	1.0	9.0	2.0	7	1.80	0.02	0.02	0.41	0.33	0.59	79	4	629	104	49	14	1370	----	2835	8.6
Q 1100.0325	04/01/87	COMP	1.0	1.5	1.0	3.0	2.0	4	0.90	<0.02	<0.01	0.01	<0.01	0.09	2	<2	346	102	37	4	1046	----	2144	8.5
R 1100.0355	04/01/87	COMP	1.0	1.5	1.0	2.5	2.5	5	0.50	<0.02	<0.01	0.01	0.02	0.10	2	2	83	39	7	3	494	----	960	8.6
S 1100.0480	04/01/87	COMP	1.0	3.0	1.0	5.5	2.5	7	1.10	<0.02	0.01	<0.01	0.06	0.21	25	6	157	53	40	6	646	----	1248	8.5
T 1100.0490	04/01/87	COMP	1.0	3.0	1.5	6.5	3.0	5	1.40	0.15	0.02	0.09	0.75	1.02	8	6	107	32	83	10	572	----	1112	8.9

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APPENDIX A

FIELD AND LABORATORY PROCEDURES

The following methods are used for field and laboratory determinations of specified physical and chemical parameters. Unless otherwise indicated, composite water samples are collected at each sampling site and stored in polyethylene containers on ice until delivery to the laboratory. Laboratory chemical analyses are conducted by the Water Chemistry Laboratory of the Texas Department of Health unless otherwise noted. Field measurements are conducted *in situ* where possible.

WATER ANALYSES

Field Measurements

Parameter	Unit of Measure	Method
Temperature	^{o}C	Hand Mercury thermometer, Hydrolab Surveyor II, or Hydrolab 4041
Dissolved Oxygen	mg/L	Azide modification of Winkler titration method, Hydrolab Surveyor II, or Hydrolab 4041
pH	Standard Units	Hydrolab Surveyor II or Hydrolab 4041
Conductivity	umhos/cm	Hydrolab Surveyor II or Hydrolab 4041
Total Alkalinity	mg/L as $CaCO_3$	Titration with sulfuric acid using methyl red/bromcresol green indicator(1)
Chlorine Residual	mg/L	N,N-diethyl-p-phenylene-diamine (DPD) ferrous titrimetric method(1)
Transparency	in, ft or cm	Secchi disc

Laboratory Analyses

Parameter	Unit of Measure	Method
Five Day, 20°C, Nitrogen Suppressed Biochemical Oxygen Demand	mg/L	Membrane electrode method(1), Nitrogen Suppression using 2-chloro-6-(trichloromethyl)-pyridine (TCMP) method(2)
Five Day, 20°C, Filtered, Nitrogen Suppressed, Biochemical Oxygen Demand	mg/L	Samples filtered with glass fiber filter; Analysis conducted on filtrate; Membrane electrode method(1), Nitrogen Suppression using TCMP method(2)
Twenty Day, 20°C, Nitrogen Suppressed, Biochemical Oxygen Demand	mg/L	Membrane electrode method(1), Nitrogen Suppression using TCMP method(2)
Twenty Day, 20°C, Filtered, Nitrogen Suppressed, Biochemical Oxygen Demand	mg/L	Samples filtered with glass fiber filter; Analyses conducted on filtrate; Membrane electrode method(1), Nitrogen Suppression using TCMP method(2)
Total Suspended Solids	mg/L	Gooch crucibles and glass fiber disc(1)
Volatile Suspended Solids	mg/L	Gooch crucibles and glass fiber disc(1)
Kjeldahl Nitrogen colorimetric phenate method(3)	mg/L as N	Block digestor and automated
Ammonia Nitrogen	mg/L as N	Automated colorimetric phenate method(3)
Nitrite Nitrogen	mg/L as N	Colorimetric method(1)
Nitrate Nitrogen	mg/L as N	Automated cadmium reduction method(1)
Total Phosphorus	mg/L as P	Persulfate digestion followed by automated ascorbic acid method(1)
Orthophosphorus	mg/L as P	Automated ascorbic acid method(1)

Laboratory Analyses Continued

Parameter	Unit of Measure	Method
Sulfate	mg/L	Automated Methylthymol Blue(3)
Chloride	mg/L	Automated Ferricyanide method(3)
Total Filterable Residue (Total Dissolved Solids)	mg/L	Evaporation at 180°C(3)
Total Organic Carbon	mg/L	O/I TOC analyzer, combustion-infrared method(1)
Conductivity	umhos/cm	Wheatstone bridge utilizing 0.01 cell constant(1)
Chlorophyll a	ug/L	Spectrophotometric method(1)
Pheophytin a	ug/L	Spectrophotometric pheophytin correction method(1)

FECAL COLIFORMS

Fecal coliform samples are collected in sterile plastic bags. If the sample has residual chlorine, bags containing sodium thiosulfate are used for dechlorination of the sample. Following collection, the samples are stored on ice until delivery to a laboratory or until cultures are set up by survey personnel (within six hours of collection). Fecal coliform analyses are conducted utilizing the membrane filter method(1).

HYDROLOGICAL

Parameter	Unit of Measure	Method
Flow Measurement	m^3/s, ft^3/s	Marsh-McBirney Model 201 electronic flow meter, or gage height readings at USGS gaging stations(4)
Time-of-Travel	m/s, ft/s	Tracing of Rhodamine WT dye using a Turner Model 110 or 111 fluorometer(5)

HYDROLOGICAL CONTINUED

Parameter	Unit of Measure	Method
Waterbody Width	m or ft	Optical range finder or tape measure
Water Depth	m or ft	Raytheon Marine Model DE-719 B recording fathometer or manual measurement
Tidal Period	hours	Level recorder or staff gage measurements
Tidal Amplitude	m or ft	Level recorder or staff gage measurements
Changes in Water Surface Level	m or ft	Level recorder or staff gage measurements

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