FINAL REPORT

"Nutrient Transport and Water Quality Monitoring in Sabine Lake Bayous"

By

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ACKNOWLEDGEMENT

This study described herein was conducted for the Texas Water Development Board (TWDB) through a contract (No. 2000-483-322) with Lamar University: Nutrient transport and water quality monitoring in Sabine Lake bayous. Mr. Rick McClelland (Technician of the Civil Engineering Department) and three graduate students: Ekapoj Trakarrvanvich, Mohammed Sharifuzzaman, and Jiang Shoudong worked on the project. They involved Datasonde calibration and maintenance, field trips for collecting water samples and data, and data analysis. All work they have done is gratefully appreciated. The great appreciation is towards Dr. Michael E. Warren and the Department of Biology at Lamar University for allow us to use its department boat in all field trips. Without this support the completion of the project is impossible. Dr. David A. Brock of TWDB is the project officer. He provided valuable comments on the report. The TWDB support and Dr. Brock's support and review on the draft final report are gratefully acknowledged.

1. Introduction

This final report covers the ***analysis in determination of nutrient input*** from bayous into Sabine Lake (*section 4*) and normal activities from **September of 1999 to October of 2000** for TWDB Contract (No. 2000-483-322) with Lamar University. The Principle investigator is Dr. Xing Fang in the Department of Civil Engineering at Lamar University.

2. Personnel Activity

There were three graduate students (Ekapoj Trakarrvanvich, Mohammed Sharifuzzaman, Jiang Shoudong) involved the project during the last twelve months. They involved Datasonde calibration and maintenance, field trips for collecting water samples and data, and data analysis. Dr. Fang involved the analysis in determination of nutrient input from bayous into Sabine Lake, advised students, prepared progress and final reports, delivered the data to TWDB, and managed the project.

Mr. Richard McClelland, employed on a part-time basis for boat and equipment maintenance, and field work with graduate students.

3. Major Activities for Water Quality Monitoring

3.1. Total **sixteen** field trips were made to exchange Datasondes from September of 1999 to October of 2000 as shown in the table below. Four hydrolab Datasondes (Recorder™ - water quality multiprobe logger, serial numbers of 31810, 31811, 30609, and 30610) and necessary repairs of the Datasondes were provided by TWDB. Datasondes were activated hourly to measure water level, water temperature, dissolved oxygen, specific conductivity, and salinity. The Datasondes were deployed and maintained at sites (Johnson Bayou and Black Bayou) established by a previous cooperative project between the TWDB and Lamar University. The Datasondes were calibrated according to manufacturers instructions. Information on calibrations of the Datasondes for all installations is stored in an Access database. The raw data recovered from Datasondes were delivered to the TWDB on time by email. The raw data collected by Hydrolab Datasondes are posted on Dr. Fang's web page (http://ceserver.lamar.edu/fang/rawdata.html).

Since there were only two Datasondes in September of 1999, we picked up both Datasondes from Johnson and Black Bayous on September 28, and planned to send them back on September 30 after downloading data and Datasonde calibration. Due to the complication of boat motor repair, the trip to Johnson and Black Bayous were made on October 4. The field trip to Johnson Bayou on October 26 discovered that the Datasonde discontinued data collection on October 22 (missing data for four days). After Datasonde calibration, it found out that the Datasonde still worked well afterwards. No data were recovered from the Datasondes installed in Johnson Bayou from 7/5/2000 to 7/24/200 since the battery on the circuit board was completely dead.

Since there was concern about the Hydrolab's DO performance at low flow conditions, a comparison (see section 3.2) was conducted between the YSI and Hydrolab. Datasondes typically

stay in the field over one month. For the most of time having low flow conditions, it was found that dissolved oxygen concentrations measured by Datasondes at the end of each one-month period were significantly lower than DO values measured by calibrated Datasondes just after installation. This indicates that dissolved oxygen concentrations measured by Hydrolab Datasondes are only reliable within fist or second weeks after installation. In August of 2000, YSI water-quality probe was installed in Black Bayou side by side with Datasonde in order to make necessary comparison about two instruments.

Table 3.1 Information on field trips.

Date of field trips	Bayous
10/26/1999	Johnson Bayou
10/28/1999	Black Bayou
11/16/1999	Johnson Bayou
11/18/1999	Black Bayou
12/13/1999	Johnson & Black Bayou
01/18/2000	Johnson & Black Bayou
02/15/2000	Johnson & Black Bayou
03/16/2000	Johnson & Black Bayou
04/13/2000	Johnson & Black Bayou
05/16/2000	Johnson Bayou
05/18/2000	Black Bayou
06/29/2000	Black Bayou
07/03/2000	Johnson Bayou
07/24/2000	Johnson & Black Bayou
08/25/2000	Johnson & Black Bayou
10/05/2000	Johnson & Black Bayou

3.2 YSI multi-parameter water quality probe (Model YSI 6920-42) from Lamar University was used to collect a set of water quality data to obtain an independent check on the Datasonde record. Data collected by YSI probe were at the same location and depth where Datasonde was installed for each bayou. The clock time of collecting field-check YSI data was occasionally some minutes different from the recording times of the Datasonde. However, this did not affect comparability. In comparison of the data measured by YSI and by Datasonde at the closest last-hour, the data show excellent agreement in water temperature (°C), good agreement in salinity (ppt), and not so good agreement in dissolved oxygen concentration (mg/L) measurements. When we compared DO measured by newly calibrated Hydrolab Datasonde with YSI reading, they were typically in agreement *(highlighted by purple color)*. The following tables are given water quality measurements from YSI and Datasonde at hours before and after YSI was used.

Why did Datasonde probe measure low DO? Hydrolab Datasonde uses a steady state method to measure DO continuously, at the same time (Hydrolab, 1998), DO sensor continuously consume oxygen around it. Therefore it requires a 1-ft/s flow to replenish oxygen to DO sensor, otherwise

Datasonde intends underestimate DO concentration. YSI uses a rapid pulse method to measure DO intermittently (YSI, 1998). DO sensor is automatically turned on for measuring DO, and then turned off for a period which provides sufficient time to allow DO diffusion towards the DO sensor.

Table 3.2 Comparison of reading from Datasonde and YSI 6920 probes.

Location: ***Johnson Bayou***			Date: **09/28/99**	
Probes	Time	Water Temperature (°C)	Salinity (ppt)	Dissolved Oxygen (mg/l)
Datasonde	11:00	No Datasonde installed at that hour		
Datasonde	12:00	26.62	14.20	5.36
YSI 6920	13:08	26.71	15.63	5.07
Location: ***Black Bayou***			Date: **09/28/99**	
Probes	Time	Water Temperature (°C)	Salinity (ppt)	Dissolved Oxygen (mg/l)
Datasonde	14:00	No Datasonde installed at that hour		
Datasonde	15:00	27.34	11.90	0.34
YSI 6920	15:53	27.37	16.75	8.81

Location: ***Johnson Bayou***			Date: **10/26/99**	
Probes	Time	Water Temperature (°C)	Salinity (ppt)	Dissolved Oxygen (mg/l)
Datasonde	15:00	20.00	11.10	9.07
Datasonde	16:00	No data were retrieved due to power loss		
YSI 6920	14:11	20.44	11.38	9.68
Location: ***Black Bayou***			Date: **10/28/99**	
Probes	Time	Water Temperature (°C)	Salinity (ppt)	Dissolved Oxygen (mg/l)
Datasonde	14:00	21.97	12.20	7.03
Datasonde	15:00	22.23	13.30	9.37
YSI 6920	14:12	21.99	13.69	7.90

Table 3.2 Comparison of reading from Datasonde and YSI 6920 probes (continued).

Location: ***Johnson Bayou***			Date: **11/16/99**	
Probes	Time	Water Temperature (°C)	Salinity (ppt)	Dissolved Oxygen (mg/l)
Datasonde	14:00	20.91	13.80	5.74
Datasonde	15:00	No data available		
YSI 6920	14:51	20.82	14.16	8.45
Location: ***Black Bayou***			Date: **11/18/99**	
Probes	Time	Water Temperature (°C)	Salinity (ppt)	Dissolved Oxygen (mg/l)
Datasonde	12:00	20.00	13.80	5.67
Datasonde	13:00	No data available		
YSI 6920	12:51	20.38	14.74	8.25

Location: ***Johnson Bayou***			Date: **12/13/99**	
Probes	Time	Water Temperature (°C)	Salinity (ppt)	Dissolved Oxygen (mg/l)
Datasonde	11:00	No data available		
Datasonde	12:00	15.38	12.50	9.72
YSI 6920	11:06	15.36	12.77	8.55
Location: ***Black Bayou***			Date: **12/13/99**	
Probes	Time	Water Temperature (°C)	Salinity (ppt)	Dissolved Oxygen (mg/l)
Datasonde	13:00	15.15	6.90	3.99
Datasonde	14:00	14.97	11.40	7.69
YSI 6920	13:54	15.01	11.03	8.15

Location: ***Johnson Bayou***			Date: **1/18/00**	
Probes	Time	Water Temperature (°C)	Salinity (ppt)	Dissolved Oxygen (mg/l)
Datasonde	11:00	17.46	11.30	9.10
Datasonde	12:00	18.03	12.40	11.63
YSI 6920	13:00	Loss data for YSI		
Location: ***Black Bayou***			Date: **01/18/00**	
Probes	Time	Water Temperature (°C)	Salinity (ppt)	Dissolved Oxygen (mg/l)
Datasonde	14:00	17.72	11.40	5.20
Datasonde	15:00	18.13	13.40	7.98
YSI 6920	14:34	18.02	12.60	8.20

Table 3.2 Comparison of reading from Datasonde and YSI 6920 probes (continued).

Location: ***Johnson Bayou***			Date: **2/15/00**	
Probes	Time	Water Temperature (°C)	Salinity (ppt)	Dissolved Oxygen (mg/l)
Datasonde	12:00	19.75	15.10	8.21
Datasonde	13:00	19.96	14.00	8.54
YSI 6920	12.08	19.90	14.37	8.54
Location: ***Black Bayou***			Date: **2/15/00**	
Probes	Time	Water Temperature (°C)	Salinity (ppt)	Dissolved Oxygen (mg/l)
Datasonde	14:00	19.74	13.60	3.69
Datasonde	15:00	19.99	14.30	6.89
YSI 6920	14:34	19.84	13.96	7.46

Location: ***Johnson Bayou***			Date: **3/16/00**	
Probes	Time	Water Temperature (°C)	Salinity (ppt)	Dissolved Oxygen (mg/l)
Datasonde	11:00	19.45	12.40	0.61
Datasonde	13:00	20.51	14.4	9.13
YSI 6920	11:40	19.62	13.48	8.30
Location: ***Black Bayou***			Date: **3/16/00**	
Probes	Time	Water Temperature (°C)	Salinity (ppt)	Dissolved Oxygen (mg/l)
Datasonde	14:00	20.56	10.9	3.81
Datasonde	16:00	21.19	13.7	6.34
YSI 6920	15:01	20.93	12.85	7.28

Location: ***Johnson Bayou***			Date: **4/13/00**	
Probes	Time	Water Temperature (°C)	Salinity (ppt)	Dissolved Oxygen (mg/l)
Datasonde	11:00	20.36	11.0	4.45
Datasonde	12:00	20.42	11.70	7.38
YSI 6920	11:33	20.47	11.53	8.20
Location: ***Black Bayou***			Date: **4/13/00**	
Probes	Time	Water Temperature (°C)	Salinity (ppt)	Dissolved Oxygen (mg/l)
Datasonde	14:00	19.96	6.0	4.46
Datasonde	15:00	20.08	6.03	7.07
YSI 6920	14:29	20.03	6.08	7.38

Table 3.2 Comparison of reading from Datasonde and YSI 6920 probes (continued).

Location: ***Johnson Bayou***			Date: **5/16/00**	
Probes	Time	Water Temperature (°C)	Salinity (ppt)	Dissolved Oxygen (mg/l)
Datasonde	10:00	25.19	6.1	1.27
Datasonde	12:00	25.54	7.30	6.80
YSI 6920	10:46	25.50	7.20	7.14
Location: ***Black Bayou***			Date: **5/18/00**	
Probes	Time	Water Temperature (°C)	Salinity (ppt)	Dissolved Oxygen (mg/l)
Datasonde	10:00	26.05	3.2	0.37
Datasonde	12:00	26.16	3.9	7.81
YSI 6920	12:00	26.24	3.74	8.57

Location: ***Johnson Bayou***			Date: **7/3/00**	
Probes	Time	Water Temperature (°C)	Salinity (ppt)	Dissolved Oxygen (mg/l)
Datasonde	11:00	30.48	6.60	1.35
Datasonde	12:00	No data were retrieved due to failure of internal battery		
YSI 6920	11:20	30.70	8.35	8.87
Location: ***Black Bayou***			Date: **6/29/00**	
Probes	Time	Water Temperature (°C)	Salinity (ppt)	Dissolved Oxygen (mg/l)
Datasonde	11:00	29.30	5.00	2.31
Datasonde	12:00	29.58	5.40	6.13
YSI 6920	11:00	29.45	4.26	N/A

Location: ***Johnson Bayou***			Date: **7/24/00**	
Probes	Time	Water Temperature (°C)	Salinity (ppt)	Dissolved Oxygen (mg/l)
Datasonde	12:00	No data were retrieved due to failure of internal battery		
Datasonde	13:00	30.42	8.9	7.28
YSI 6920	12:02	30.04	9.06	6.41
Location: ***Black Bayou***			Date: **7/24/00**	
Probes	Time	Water Temperature (°C)	Salinity (ppt)	Dissolved Oxygen (mg/l)
Datasonde	13:00	29.28	2.90	2.65
Datasonde	15:00	30.54	2.60	5.79
YSI 6920	13:57	30.45	2.70	6.36

Table 3.2 Comparison of reading from Datasonde and YSI 6920 probes (continued).

Location: ***Johnson Bayou***			Date: **8/25/00**	
Probes	Time	Water Temperature (°C)	Salinity (ppt)	Dissolved Oxygen (mg/l)
Datasonde	12:00	28.64	10.7	1.31
Datasonde	14:00	29.27	12.20	6.81
YSI 6920	13:08	29.39	12.16	5.70
Location: ***Black Bayou***			Date: **8/25/00**	
Probes	Time	Water Temperature (°C)	Salinity (ppt)	Dissolved Oxygen (mg/l)
Datasonde	14:00	31.18	11.00	2.23
Datasonde	15:00	31.41	12.40	5.57
YSI 6920	14:51	31.54	11.31	4.71

3.3 Three possible methods to estimate flow rates in or out of bayous were investigated by the principle investigator (PI), after consultation with the project manager. First, the PI tried to develop relationships between tidal elevation and flow rate based on flow measurements in 1996, which were provided by TWDB through previous project in the study area. The relationships are very complex and could not be developed with limited available data since unsteady tidal flow is quite different from steady open channel flow. The second method is to measure flow velocities at the center of the cross section passing through the tide station during the field trips. It was found that the flow meter used could not reliably measure them since flows in the bayous were often so slow. Results of flow measurements are documented in this section below. The third method is to estimate flow rates from the previous established rainfall and runoff relationship as discussed in the section 5.3

The first measurement at Johnson Bayou was invalid since the boat motor was still running. The first measurement at Black Bayou could not get velocity at 80% of the maximum depth since flow probe was not long enough. After we exchanged a longer flow probe plus experience in October of 1999, flow measurements were fine after November of 1999. Results were summarized in the following tables. The velocity meter did not function well during the field trips after June of 2000, so no flow velocities were measured in June, July and August of 2000 during the field trips.

Table 3.3 Velocity Measurements in Johnson Bayou and Black Bayou.

Location	**Johnson Bayou**	**Black Bayou**
Date (MM/DD/YY)	**10/26/99**	**10/28/99**
Time (HH:MM)	14:25	14:15
Maximum Depth H_{max} (ft)	8.80	12.00
Velocity at 20% H_{max} (ft/s)	7.00	0.70
Velocity at 80% H_{max} (ft/s)	4.40	N/A
Mean Velocity V_{m28} (ft/s)	5.70	N/A
Velocity at 60% H_{max} (ft/s)	5.50	0.50
Overall Mean Velocity (ft/s)	5.60	N/A
Flow Direction	Into Bayou	Into Bayou
Remark	Motor still running INVALID	Probe cannot reach the 80% maximum elevation

Location	**Johnson Bayou**	**Black Bayou**
Date (MM/DD/YY)	**11/16/99**	**11/18/99**
Time (HH:MM)	15:10	13:00
Maximum Depth H_{max} (ft)	9.80	14.20
Velocity at 20% H_{max} (ft/s)	0.60	0.85
Velocity at 80% H_{max} (ft/s)	0.41	0.47
Mean Velocity V_{m28} (ft/s)	0.51	0.66
Velocity at 60% H_{max} (ft/s)	0.55	0.66
Overall Mean Velocity (ft/s)	0.53	0.66
Flow Direction	Out of Bayou	Out of Bayou
Remark		

Table 3.3 Velocity Measurements in Johnson Bayou and Black Bayou (continued).

Location	**Johnson Bayou**	**Black Bayou**
Date (MM/DD/YY)	***12/13/99***	***12/13/99***
Time (HH:MM)	11:30	13:40
Maximum Depth H_{max} (ft)	9.00	12.00
Velocity at 20% H_{max} (ft/s)	1.35	1.20
Velocity at 80% H_{max} (ft/s)	0.80	0.60
Mean Velocity V_{m28} (ft/s)	1.08	0.90
Velocity at 60% H_{max} (ft/s)	1.17	0.73
Overall Mean Velocity (ft/s)	1.13	0.82
Flow Direction		

Location	**Johnson Bayou**	**Black Bayou**
Date (MM/DD/YY)	***01/18/00***	***01/18/00***
Time (HH:MM)	12:15	15:00
Maximum Depth H_{max} (ft)	9	12
Velocity at 20% H_{max} (ft/s)	1.20	1.10
Velocity at 80% H_{max} (ft/s)	0.50	0.50
Mean Velocity V_{m28} (ft/s)	0.85	0.80
Velocity at 60% H_{max} (ft/s)	0.90	0.80
Overall Mean Velocity (ft/s)	0.87	0.80
Flow Direction	Into Bayou	Out of Bayou
Remarks		

Location	**Johnson Bayou**	**Black Bayou**
Date (MM/DD/YY)	***2/15/00***	***2/15/00***
Time (HH:MM)	12:10	14:40
Maximum Depth H_{max} (ft)	9.20	12.5
Velocity at 20% H_{max} (ft/s)	0.85	0.69
Velocity at 80% H_{max} (ft/s)	0.52	0.31
Mean Velocity V_{m28} (ft/s)	0.685	0.50
Velocity at 60% H_{max} (ft/s)	0.56	0.57
Overall Mean Velocity (ft/s)	0.64	0.52
Flow Direction	Out of Bayou	Out of Bayou
Remarks		

Table 3.3 Velocity Measurements in Johnson Bayou and Black Bayou (continued).

Location	**Johnson Bayou**	**Black Bayou**
Date (MM/DD/YY)	**3/16/00**	**3/16/00**
Time (HH:MM)	11:30	14:30
Maximum Depth H_{max} (ft)	12	15
Velocity at 20% H_{max} (ft/s)	0.28	0.32
Velocity at 80% H_{max} (ft/s)	0.46	0.40
Mean Velocity V_{m28} (ft/s)	0.37	0.36
Velocity at 60% H_{max} (ft/s)	0.43	0.36
Overall Mean Velocity (ft/s)	0.39	0.36
Flow Direction	Out of Bayou	Out of Bayou
Remarks		

Location	**Johnson Bayou**	**Black Bayou**
Date (MM/DD/YY)	**4/13/00**	**4/13/00**
Remarks	Out of order	Out of order

Location	**Johnson Bayou**	**Black Bayou**
Date (MM/DD/YY)	**5/16/00**	**5/18/00**
Time (HH:MM)	11:30	11:15
Maximum Depth H_{max} (ft)	10(4 at site)	14(7.5 at site)
Velocity at 20% H_{max} (ft/s)	0.23	0.97
Velocity at 80% H_{max} (ft/s)	0.40	1.09
Mean Velocity V_{m28} (ft/s)	0.32	1.03
Velocity at 60% H_{max} (ft/s)	0.27	1.24
Overall Mean Velocity (ft/s)	0.30	1.10
Flow direction	Lake to Bayou	Lake to bayou
Remarks		

Table 3.3 Velocity Measurements in Johnson Bayou and Black Bayou (continued).

Location	**Johnson Bayou**	**Black Bayou**
Date (MM/DD/YY)	**7/3/00**	**6/29/00**
Time (HH:MM)	11:24	11:30
Maximum Depth H_{max} (ft)	4.0 (max10.5)	6.0 (max 14)
Velocity at 20% H_{max} (ft/s)	N/A	0.52
Velocity at 80% H_{max} (ft/s)	N/A	0.45
Mean Velocity V_{m28} (ft/s)	N/A	0.485
Velocity at 60% H_{max} (ft/s)	N/A	0.33
Overall Mean Velocity (ft/s)	N/A	0.43
Flow direction	Lake to Bayou	Lake to bayou
Remarks	Out of order	Out of order

4. Major Activities for Nutrients in Sabine Bayous

Water samples were collected at both bayous during each field trip from September of 1999 to August of 2000. Water samples collected were delivered to the Water Quality Laboratory of the Texas Sabine River Authority for analysis. Analytical results are summarized below. Some compounds were analyzed but readings were lower than the detection limits. During the last three months, most of the limits of quantitation have been changed by the Laboratory due to annual re-certification of equipment: TKN from 0.2 to 0.5 mg/l, ammonia from 0.05 to 0.001, nitrate/nitrite from 0.04 to 0.02, and total phosphorus from 0.010 to 0.040.

Table 4.1 Analytical results of nutrient concentrations (mg/l) from water samples collected.

Location	Johnson Bayou			Black bayou			Limit Of Quantitation
Date	**9/28**	**10/26**	**11/16**	**9/28**	**10/28**	**11/18**	
TKN	0.330	0.810	0.360	0.380	ND	0.280	0.200 mg/l
Ammonia N	ND	0.058	ND	ND	ND	ND	0.050 mg/l
TOC	2	8	6	2	2	5	1 mg/l
Nitrate/Nitrite	0.040	0.068	ND	0.040	0.095	0.041	0.030 mg/l
Phosphorus	0.033	0.086	0.031	0.049	0.068	0.035	0.010 mg/l

Location	Johnson Bayou			Black bayou			Limit Of Quantitation
Date	**12/13/99**	**1/18/00**	**2/15/00**	**12/13/99**	**1/18/00**	**2/15/00**	
TKN	0.710	0.460	0.820	0.730	0.770	0.490	0.200 mg/l
Ammonia N	ND	N/A	N/A	0.05	N/A	N/A	0.050 mg/l
TOC	8	<1	<1	9	<1	<1	1 mg/l
Nitrate/Nitrite	0.040	ND	ND	0.080	ND	ND	0.030 mg/l
Phosphorus	0.046	0.056	ND	ND	ND	ND	0.010 mg/l

Table 4.1 Analytical results of nutrient concentrations (mg/l) from water samples collected (continued).

Location	Johnson Bayou			Black bayou			Limit Of Quantitation
Date	**3/16/00**	**4/13/00**	**5/16/00**	**3/16/00**	**4/13/00**	**5/18/00**	
TKN	<0.5	0.58	0.72	<0.5	0.60	0.62	0.500 mg/l
Ammonia N	<0.001	N/A	0.871	<0.001	N/A	2.03	0.001 mg/l
TOC	<1	<1	<1	<1	<1	<1	1 mg/l
Nitrate/Nitrite	0.05	1.5	2.0	0.07	1.4	1.3	0.02 mg/l
Phosphorus	<0.04	0.13	0.2	<0.04	0.04	0.2	0.030 mg/l

Location	Johnson Bayou			Black bayou			Limit Of Quantitation
Date	**7/03/00**	**7/24/00**	**8/25/00**	**6/29/00**	**7/24/00**	**8/25/00**	
TKN	0.60	<0.50	<0.5	0.78	<0.50	<0.5	0.500 mg/l
Ammonia N	0.395	1.97	<0.001	0.955	<0.001	0.905	0.001 mg/l
TOC	<1	10	5	<1	8	<1	1 mg/l
Nitrate/Nitrite	0.27	0.41	0.39	<0.02	0.73	0.31	0.02 mg/l
Phosphorus	0.110	<0.10	0.050	0.040	<0.10	0.050	0.040 mg/l

5. Nutrient Flux Computation

5.1 Introduction

This study is to provide data on movement of saltwater and nutrients moving to Sabine Lake from the marsh lands on the lake's east side. Nutrients into Johnson and Black bayous of Sabine Lake do not come from individual point sources, and do come from nonpoint sources distributed out in the watersheds. Therefore nutrient inputs are closely related to rainfall events which runoff washes nutrient form marshlands into bayous. Fig. 5.1 shows a schematic diagram for typical response curves for hydrograph, pollutograph (concentration changes with time), loading rate and loadograph.

In order to more precisely estimate nutrient loading from rainfall storms, we need a record of flow rate and nutrient concentration during a typical storm in the studying region, and then determine the event mean concentration (EMC).

$$EMC = \overline{C} = \frac{M}{V} = \frac{\sum_{i=1}^{n} V_i C_i}{\sum_{i=1}^{n} V_i} \qquad (5.1)$$

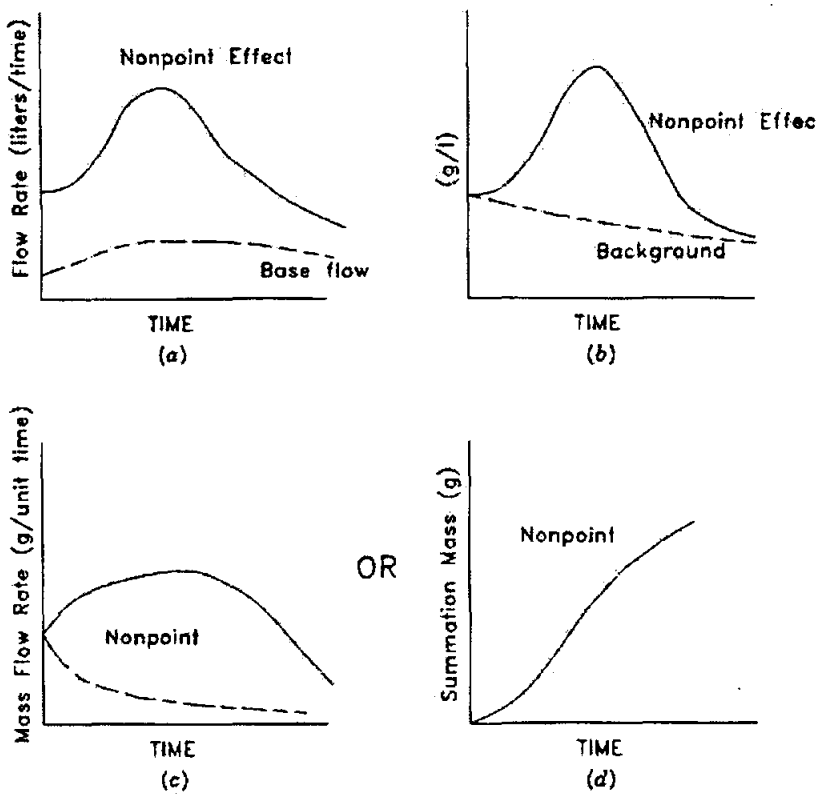


Fig. 5.1 Typical response curves: (a) hydrograph; (b) pollutograph (concentration changes with time); (c) loading rate with time; and (d) loadograph (cumulative mass). (from Wanielista and Yousef, 1992)

where M is the loading per event/storm, mg; V is the total runoff volume per event, L; C_i is the nutrient concentration at time i, and V_i is the runoff volume proportional to flow rate at time i. The arithmetic mean of concentration may not be the EMC. One single measurement of pollutant concentration during rainfall storm may not be the EMC either.

After EMC is determined form a typical storm, monthly or annual nutrient loading can be estimated from the equation 5.2.

$$M_{ik} = V_k \, EMC_{ik} \quad or \quad M_i = \sum_{k=1}^{12} V_k \, EMC_{ik} \tag{5.2}$$

M_i is the annual material loading, e.g. in kg or lb, of nutrient *i* (e.g., total phosphorus, ammonia nitrogen), M_{ik} and V_k are monthly material loading and runoff volume during the month *k*, respectively.

In this study, the difficult we had is that there are **no direct measurements** on flow, and only one measurement per month on nutrient concentrations. An effort was made to measure flow velocities in both bayous at the time to collect water samples, as discussed in the section 3.3. Since the flow in bayous were typically very slow during the last water-year (a very dry year from

September 1, 1999 to August 31, 2000), the flow measurement did not come out what we expected the accuracy for estimating the flow rate from or into the bayous. Estimation of flow (runoff) and average nutrient concentrations will be discussed in the following sections.

5.2 Estimation of Nutrient Concentrations

Five nutrient parameters analyzed from water samples are: (1) Total Kjeldahl nitrogen, TKN; (2) Nitrate plus nitrite, NO2+NO3; (3) Ammonium, NH4; (4) Total phosphorus, TP; and (5) Total organic carbon, TOC. Table 5.1 summarizes the five water quality parameters measured from water samples collected during the study period (one set sample per month). Water samples were analyzed by the Water Quality Laboratory of the Sabine River Authority of Texas and the Seven Trent Laboratory at Houston with necessary EPA quality control.

There are many cases that nutrient concentrations (e.g. NH4) were lower than the detection limits (DL) given by the Laboratories. Lower concentrations were associated with water samples collected after a relative long dry period (e.g. days or weeks). For example, the field trip in April of 2000 was made within 24 hours after the southeast had a heavy rainfall, and nutrient concentrations, especially nitrate/nitrate and total phosphorus, are significantly higher than values measured in any previous months. Low nutrient concentrations during dry periods indicate that nutrients do flow from Sabine Lake through bayous into marshlands, instead of washing nutrients from marshlands into Sabine Lake by runoff.

TKN varies from 0.3 to 0.8 mg/l, and is generally less dependent on rainfall events. High concentrations of TP and NO_2/NO_3 are strongly associated with heavy rainfall events. Ammonia concentrations were typically lower than the detection limit (0.001 mg/l) at both bayous during the study period except May and June of 2000. Obviously (see Table 5.1), there are no multiple records of flow and nutrient concentrations available during a rainfall storm, therefore EMC can not be determined by the standard method. EMCs for five nutrients were estimated as **average** of the available data above DLs in Table 5.1, and given in Table 5.2. These average nutrient concentrations may not accurately represent the event mean concentration of nutrients. Average concentrations associated with rainfall events were determined when concentrations lower than their detection limits were set to be zero (Gleit, 1985) and were not considered in computing averages. It is assumed that those low concentrations were not related to rainfall events.

Table 5.1 Nutrient concentrations determined from water samples collected in Johnson and Black Bayous.

Water Quality Results							Detection Limits (DL)				
DATE	Bayou	TKN	NH4	TOC	NO2/NO3	TP	TKN	NH4	TOC	NO2/NO3	TP
28-Sep-99	Johnson	0.33	<0.05	2	0.040	0.033	0.2	0.05	1.00	0.030	0.01
26-Oct-99	Johnson	0.81	0.058	8	0.068	0.086	0.2	0.05	1.00	0.030	0.01
18-Nov-99	Johnson	0.36	<0.05	6	<0.03	0.031	0.2	0.05	1.00	0.030	0.01
13-Dec-99	Johnson	0.71	<0.05	8	0.040	0.046	0.2	0.05	1.00	0.030	0.01
18-Jan-00	Johnson	0.46	N/A	<1	<0.03	0.056	0.2	0.05	1.00	0.030	0.01
15-Feb-00	Johnson	0.82	N/A	<1	<0.03	<0.01	0.2	0.05	1.00	0.030	0.01
16-Mar-00	Johnson	<0.5	<0.001	<1	0.050	<0.03	0.5	0.001	1.00	0.020	0.03
13-Apr-00	Johnson	0.58	N/A	<1	1.500	0.130	0.5	0.001	1.00	0.020	0.03
16-May-00	Johnson	0.72	0.871	<1	2.000	0.200	0.5	0.001	1.00	0.020	0.03
05-Jul-00	Johnson	0.60	0.395	<1	0.270	0.110	0.5	0.001	1.00	0.020	0.04
24-Jul-00	Johnson	<0.5	1.970	10	0.410	<0.10	0.5	0.001	1.00	0.020	0.10
28-Aug-00	Johnson	<0.5	<0.001	5	0.390	0.050	0.5	0.001	1.00	0.020	0.04
DATE	Bayou	TKN	NH4	TOC	NO2/NO3	TP	TKN	NH4	TOC	NO2/NO3	TP
28-Sep-99	Black	0.38	<0.05	2	0.040	0.049	0.2	0.05	1.00	0.030	0.01
28-Oct-99	Black	<0.2	<0.05	2	0.095	0.068	0.2	0.05	1.00	0.030	0.01
18-Nov-99	Black	0.28	<0.05	5	0.041	0.035	0.2	0.05	1.00	0.030	0.01
13-Dec-99	Black	0.73	0.050	9	0.080	<0.01	0.2	0.05	1.00	0.030	0.01
18-Jan-00	Black	0.77	N/A	<1	<0.03	<0.01	0.2	0.05	1.00	0.030	0.01
15-Feb-00	Black	0.49	N/A	<1	<0.03	<0.01	0.2	0.05	1.00	0.030	0.01
16-Mar-00	Black	<0.5	<0.001	<1	0.070	<0.03	0.5	0.001	1.00	0.020	0.03
13-Apr-00	Black	0.60	N/A	<1	1.400	0.040	0.5	0.001	1.00	0.020	0.03
18-May-00	Black	0.62	2.030	<1	1.300	0.200	0.5	0.001	1.00	0.020	0.03
29-Jun-00	Black	0.78	0.955	<1	<0.02	0.040	0.5	0.001	1.00	0.020	0.04
24-Jul-00	Black	<0.5	<0.001	8	0.730	<0.10	0.5	0.001	1.00	0.020	0.10
28-Aug-00	Black	<0.5	0.905	<1	0.310	0.050	0.5	0.001	1.00	0.020	0.04

Note: DLs were changed due to switching from Houston's laboratory to SRA's lab.
N/A - Samples were miss-handled by the laboratory technician

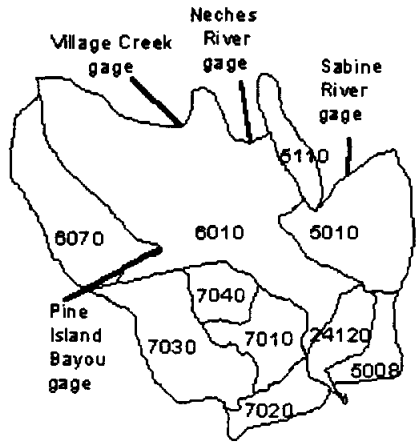
Table 5.2 Estimated average nutrient concentrations in mg/l.

JOHNSON BAYOU		*BLACK BAYOU*	
TKN	0.60 (9)	TKN	0.58 (8)
NH4	0.824 (4)	NH4	0.985 (4)
TOC	6.50 (6)	TOC	5.20 (5)
NO2/NO3	0.530 (9)	NO2/NO3	0.452 (9)
TP	0.082 (9)	TP	0.069 (7)

Note: Number within parentheses is the number of data used to deriver the average concentrations.

5.3 Estimation of Runoff from Bayous to Sabine Lake

The monthly or annual runoff for the 1999-2000 period was based on relationships developed from TWDB 1987-1996 data. Daily surface runoff flow data were provided by TWDB. Basically, total flow from drainage basin runoff is found by summing flows originating in both gaged and ungaged watersheds. Gaged flows are obtained from USGS streamflow records. Ungaged runoff is computed runoff, using a TWDB's rainfall-runoff simulation model, based on precipitation over the watershed. Watersheds used in TWDB's rainfall-runoff simulation model are given below, and Sabine Lake is the watershed 24120.



The **Black Bayou** watershed was defined as 0.25 of the 05010 watershed area. The rest of 05010 was summed with Sabine River. The watershed 05008 was split 50:50 between three bayous and **Johnson bayou**.

In order to estimate runoff volume from Johnson and Black Bayous, rainfall data from September of 1999 to August of 2000 were obtained from the Southern Regional Climate Center at the Louisiana State University. Table 5.3 gives monthly and annual cumulative rainfall in inches. Cumulative rainfall for the last water year was very low (**38.19** in). It is difficult to conclude that the monthly rainfall distribution for the last year is the same or similar to other pervious years (see Figures 5.2 to 5.4). Therefore two methods were developed to estimate monthly or annual runoff volume for the last water year.

Method 1: Based on the annual cumulative rainfall, 1995 to 1996 water year had the lowest annual rainfall (48.25 in) from 1987 to 1996 period, which we have runoff prediction from TWDB rainfall-runoff model. Surface runoff for 1999 to 2000 water year was therefore estimated by proportion from the runoff of 1995 to 1996 water year (Table 5.4).

Table 5.3a. 1987-2000 MONTHLY & YEARLY CUMULATIVE RAINFALL (inches)

MONTH	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Jan	7.76	3.23	6.76	8.78	14.92	11.14	10.04	7.09	4.01	2.45	4.90	8.84	3.09	1.68
Feb	7.68	5.05	0.17	7.80	4.69	6.77	4.09	1.50	2.09	1.28	5.73	5.03	1.13	0.72
Mar	0.94	5.54	3.40	6.54	2.40	3.82	5.51	3.94	5.59	0.45	4.39	5.19	3.44	2.74
Apr	0.26	2.64	2.75	4.25	6.81	5.87	6.46	4.25	4.21	2.08	4.92	1.95	0.74	6.20
May	4.44	0.61	12.69	8.66	13.19	1.42	4.65	9.98	4.61	1.04	2.36	0.08	2.98	6.29
Jun	12.31	4.63	18.90	4.21	7.28	10.67	9.53	8.54	9.21	10.30	3.60	4.50	10.00	4.88
Jul	3.39	3.84	7.74	6.38	3.07	5.39	5.47	6.18	6.66	2.22	7.67	1.56	2.45	1.27
Aug	3.86	5.54	5.03	1.65	3.07	2.24	6.60	4.77	4.61	6.34	2.01	6.70	0.00	2.02
Sep	11.49	10.32	1.20	5.31	7.21	2.09	2.44	5.35	0.67	10.80	5.43	13.20	3.25	
Oct	0.27	1.70	1.17	4.57	3.66	2.91	6.06	12.16	5.51	4.43	1.95	5.34	3.88	
Nov	6.74	1.12	3.14	5.55	3.90	7.09	5.51	0.51	4.80	4.82	2.85	2.92	1.23	
Dec	6.12	5.80	3.14	3.86	11.54	6.30	1.85	6.85	11.10	3.26	6.62	2.79	4.03	
TOTAL	65.26	50.02	66.09	67.57	81.73	65.70	68.21	71.12	63.07	49.47	52.43	58.10	36.22	

Table 5.3b. MONTHLY RAINFALL (inches) IN WATER YEAR (SEPTEMBER TO AUGUST)

MONTH	87-88	88-89	89-90	90-91	91-92	92-93	93-94	94-95	95-96	96-97	97-98	98-99	99-00
Sep	11.49	10.32	1.20	5.31	7.21	2.09	2.44	5.35	0.67	10.80	5.43	13.20	3.25
Oct	0.27	1.70	1.17	4.57	3.66	2.91	6.06	12.16	5.51	4.43	1.95	5.34	3.88
Nov	6.74	1.12	3.14	5.55	3.90	7.09	5.51	0.51	4.80	4.82	2.85	2.92	1.23
Dec	6.12	5.80	3.14	3.86	11.54	6.30	1.85	6.85	11.10	3.26	6.62	2.79	4.03
Jan	3.23	6.76	8.78	14.92	11.14	10.04	7.09	4.01	2.45	4.90	8.84	3.09	1.68
Feb	5.05	0.17	7.80	4.69	6.77	4.09	1.50	2.09	1.28	5.73	5.03	1.13	0.72
Mar	5.54	3.40	6.54	2.40	3.82	5.51	3.94	5.59	0.45	4.39	5.19	3.44	2.74
Apr	2.64	2.75	4.25	6.81	5.87	6.46	4.25	4.21	2.08	4.92	1.95	0.74	6.20
May	0.61	12.69	8.66	13.19	1.42	4.65	9.98	4.61	1.04	2.36	0.08	2.98	6.29
Jun	4.63	18.90	4.21	7.28	10.67	9.53	8.54	9.21	10.30	3.60	4.50	10.00	4.88
Jul	3.84	7.74	6.38	3.07	5.39	5.47	6.18	6.66	2.22	7.67	1.56	2.45	1.27
Aug	5.54	5.03	1.65	3.07	2.24	6.60	4.77	4.61	6.34	2.01	6.70	0.00	2.02
TOTAL	**55.70**	**76.38**	**56.93**	**74.72**	**73.62**	**70.73**	**62.11**	**65.86**	**48.25**	**58.89**	**50.70**	**48.08**	**38.19**

Fig. 5.2 MONTHLY RAINFALLFOR 90-91,91-92,92-93 WATER YEARS

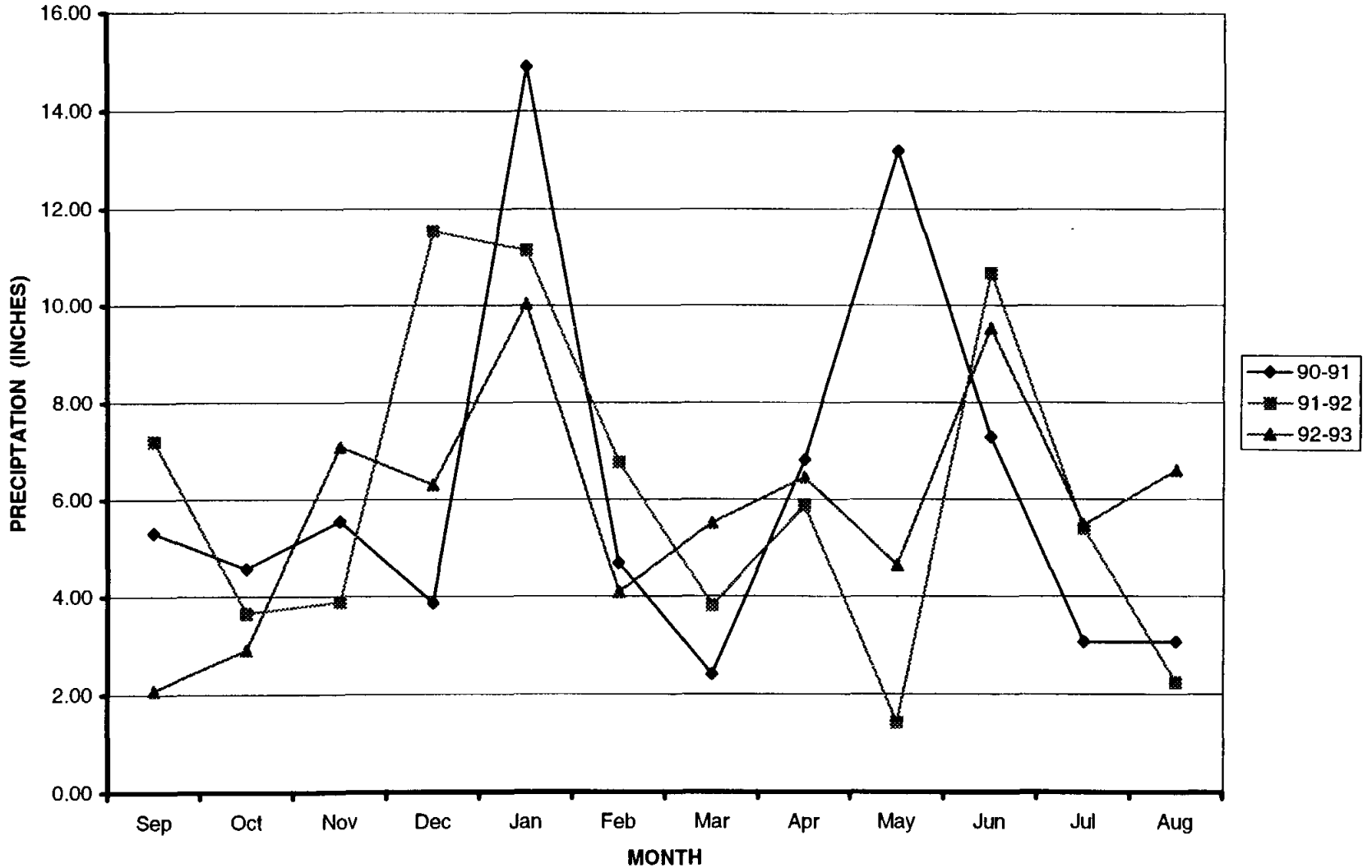


Fig. 5.3 MONTHLY RAINFALL FOR 93-94,94-95,952-96 WATER YEARS

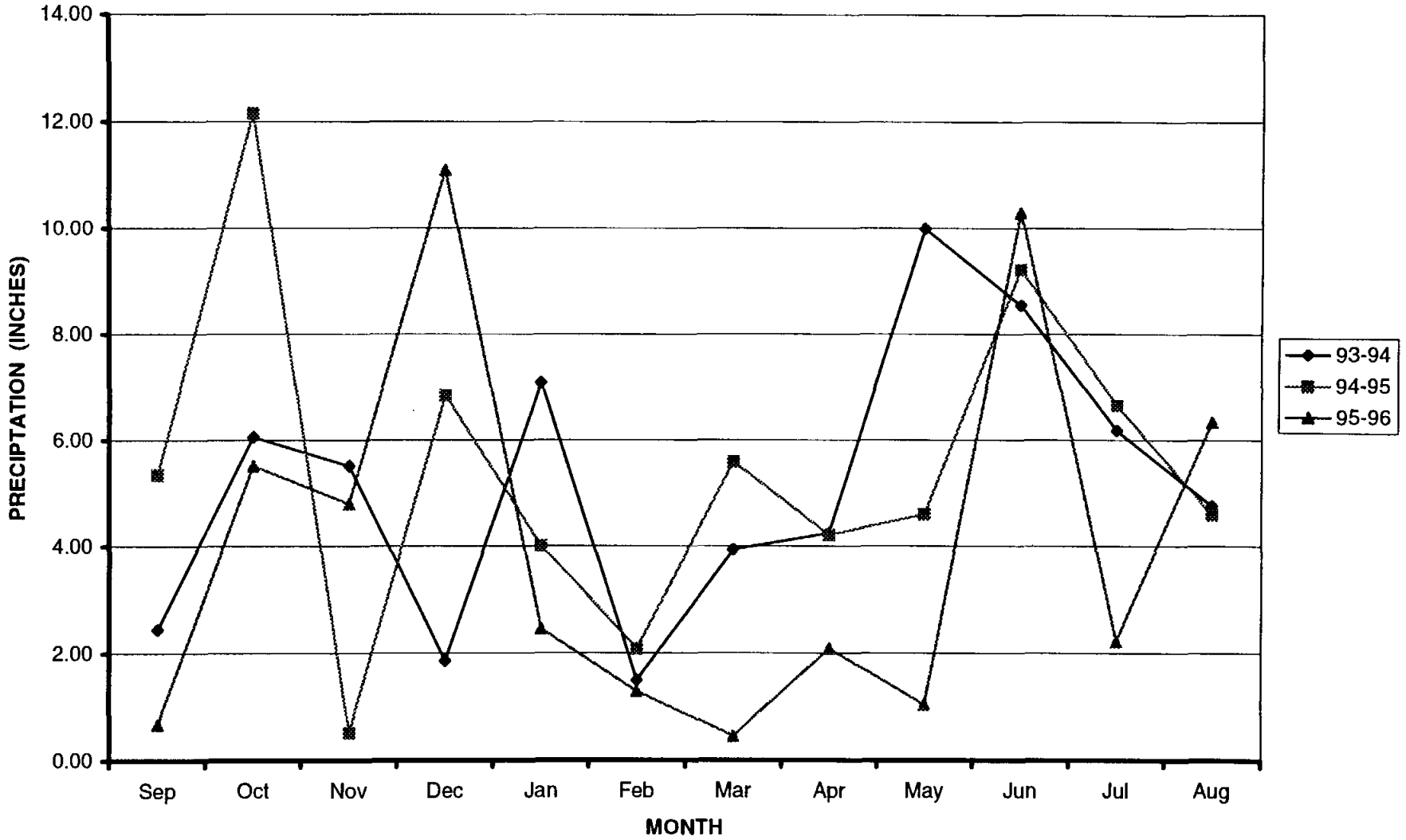


Fig. 5.4 MONTHLY RAINFALL FOR 96-97,97-98,98-99 WATER YEARS

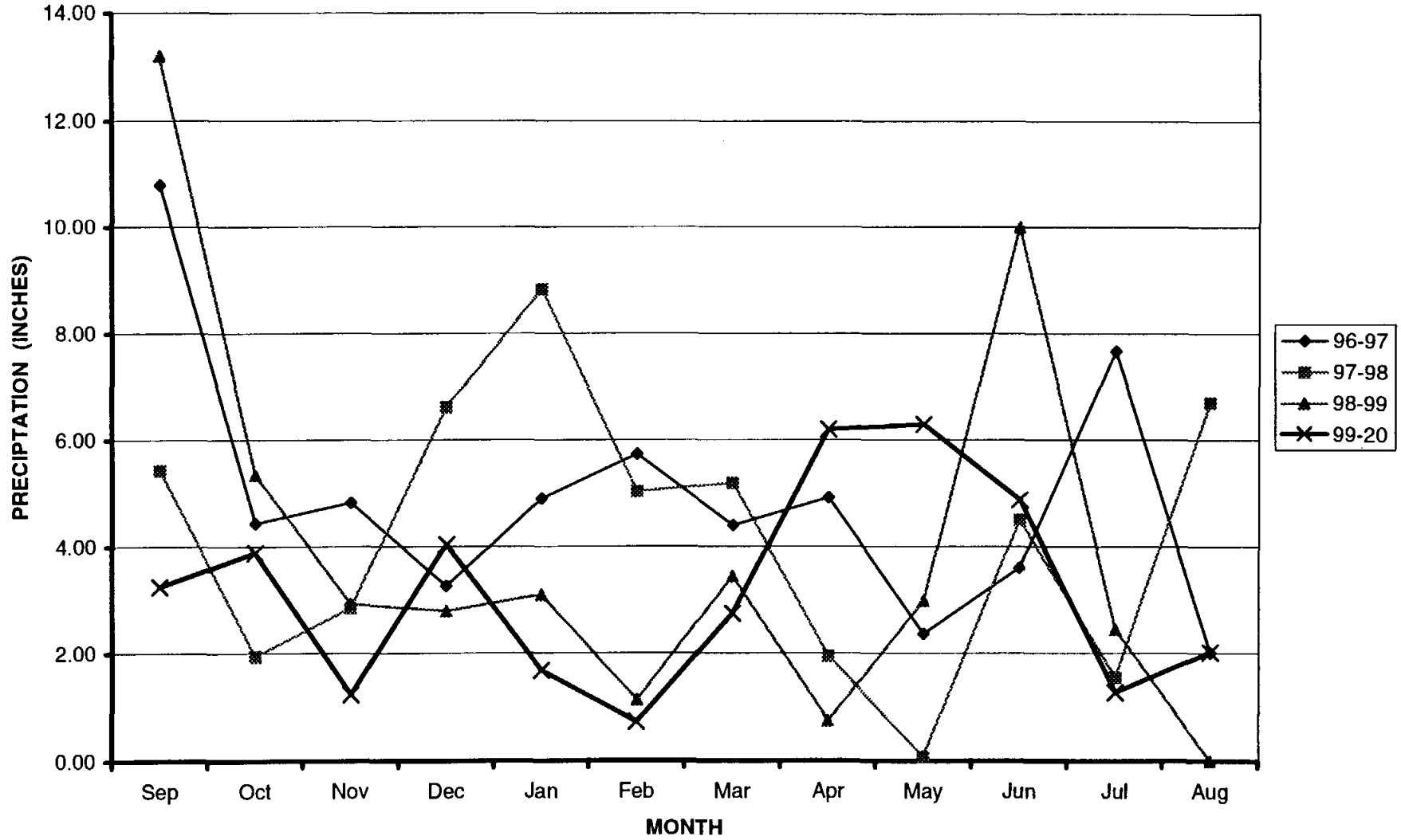


Table 5.4 **Monthly rainfall and flows in Johnson and Black Bayous for 1995 to 1996 water year.**

Year	Month	Rainfall (in)	Flow at Johnson Bayou (cfs)	Flow at Black Bayou (cfs)
1995	September	0.67	327	1723
1995	October	5.51	14641	40699
1995	November	4.80	11479	27109
1995	December	11.10	26369	91055
1996	January	2.45	4663	40630
1996	February	1.28	469	5109
1996	March	0.45	384	1979
1996	April	2.08	631	3230
1996	May	1.04	97	259
1996	June	10.30	3244	9845
1996	July	2.22	707	23137
1996	August	6.34	2496	45707
Annual/Total		48.24	65507	290482

Estimated total (annual) daily flows in Johnson Bayou and Black Bayou in 1999 and 2000 water year are:

$$\textit{Johnson Bayou} \quad V_{99-20} = V_{95-96}\frac{Rain_{99-20}}{Rain_{95-96}} = 65507*\frac{38.19}{48.24} = 51860\ cfs$$

$$\textit{Black Bayou} \quad V_{99-20} = V_{95-96}\frac{Rain_{99-20}}{Rain_{95-96}} = 290482*\frac{38.19}{48.24} = 229965\ cfs$$

Method 2: Some additional efforts were made to match the monthly rainfall in 1999 – 2000 water-year to the monthly rainfall in previous years (1987 to 1996). For example, from Table 5.3, one can identify that the following months: January of 1988, March of 1989, November of 1989, December of 1996, and December of 1996, had the monthly rainfall very close to the monthly rainfall for September of 1999 (3.25 in). Their daily rainfalls and associated daily flows (runoff) in Johnson Bayou were therefore summarized in Table 5.5 (same as Table A.1). The flow in Johnson Bayou during September of 1999 was not simply estimated as the average of the flows from all those months with the same or similar rainfalls. Technical justification (basic rainfall-runoff response concepts) was made to decide which month of rainfall and runoff data will be used. For example, runoff for January of 1988 was too large (7435 cfs) since rainfalls in November and December of 1987 were very large and made soils in the watershed to be completely saturated, while rainfalls before September of 1999 was not a lot. For November of 1989, 0.9 inches rainfall did not cause any increase of surface flow or runoff, which seems impossible. Finally only flows for March of 1989, December 1989 and December of 1996 were used to take average as estimated flow for September of 1999. The similar process was repeated for other months and for Black Bayou. Results of the analysis were documented in the appendix (Tables A.1 to A.24), and summarized below.

Table 5.5 ESTIMATED FLOW IN JOHNSON BAYOU FROM FLOWS AND RAINFALLS IN OTHER MONTHS SEPTEMBER, 1999

SEPT.1999	RAINFALL OF	JOHNSON	JAN. 1988		MAR. 1989		NOV. 1989		DEC. 1989		DEC. 1996	
DATE	SEPT. 1999	FLOW	RAINFALL	FLOW	RAINFALL	FLOW	RAINFALL	FLOW	RAINFALL	FLOW	RAINFALL	FLOW
1	0.09		0.5	15	0.03	4	0.96	252	0	3	0	8
2	0.02		0	13	0.74	8	0	355	0	2	0	7
3	0		0	12	0	16	0	98	0	2	0	7
4	0		0	11	0.05	16	0.01	28	0	2	0.2	7
5	0.93		0	11	0	8	0	9	0	2	0.11	19
6	0		0.45	1631	0	5	0	6	0.95	212	0	29
7	0		0.95	2874	0	4	0	5	1.72	389	0	13
8	0		0	802	0	4	0	5	0.05	130	0	8
9	0		0	202	0	4	0	5	0	35	0	7
10	0		0	47	0	4	0	5	0	10	0	6
11	0		0	17	0	4	0	4	0	5	0	6
12	0		0.28	72	0	4	0	4	0	4	0	6
13	0.63		0.02	118	0	3	0	4	0	4	0	6
14	0		0	39	0	3	0.03	4	0	3	0	6
15	0		0	17	0	3	0.27	6	0	3	1.67	5
16	0		0.92	395	0	3	0	8	0	3	0.36	601
17	0		0	694	0	3	0	5	0	3	0	1066
18	0		0	206	0	3	0.23	4	0.07	3	0	310
19	0		0.11	58	0	3	0.59	4	0.06	3	0	81
20	0		0	19	0.12	3	0	4	0	3	0	21
21	0		0	11	1.69	37	0	3	0	3	0	10
22	0		0	10	0.27	63	0.9	3	0	3	0.01	7
23	0		0	9	0	735	0	3	0	3	0	7
24	0		0	9	0	1267	0	3	0	3	0.04	9
25	0		0	9	0	342	0	3	0	2	0	10
26	0		0	8	0	86	0.05	3	0	2	0.07	7
27	0		0	8	0	21	0	3	0	2	0.01	7
28	0.68		0	8	0	8	0.1	3	0.2	2	0	7
29	0.9		0		0.5	131	0	3	0	2	0.21	6
30	0		0	7	0	227	0	3	0	2	0.05	6
31			0	103	0	65			0.09	2	0.53	7
TOTAL	3.25	2135	3.23	7435	3.4	3087	3.14	845	3.14	847	3.26	2302

NOTE: The flow of January1988 was too large since rainfalls in November and December of 1987 were very large.
It could be impossible that 0.9 inches rainfall on NOV 22 1989 did not cause any flow.
So that the average flow of MAR.1989, DEC.1989, and DEC.1996 is the estimated flow for SEPT.1999.

Table 5.6 Estimated daily flows for Johnson and Black Bayou by the Method 2.

Johnson Bayou		Black Bayou	
Month, year	Flow (cfs)	Month, year	Flow (cfs)
September, 1999	2135	September, 1999	19862
October, 1999	3494	October, 1999	17388
November, 1999	469	November, 1999	5109
December, 1999	3494	December, 1999	17388
January, 2000	819	January, 2000	6383
February, 2000	327	February, 2000	1723
March, 2000	1457	March, 2000	6335
April, 2000	5454	April, 2000	28737
May, 2000	2479	May, 2000	22950
June, 2000	318	June, 2000	4271
July, 2000	469	July, 2000	5109
August, 2000	814	August, 2000	14224
Total daily flow (cfs)	21,729	Total flow (cfs)	145,208

Annual inflow from marshland can be derived from the total daily flow (cfs) by the equation: Inflow (m^3) = Total (annual) daily flow (cfs) * 24 hr/day * 3600 s/hr * 0.028317 m^3/ft^3. Results are given below. Flow estimated by the method 2 in Johnson Bayou and Black Bayou is only about 42% and 64% of estimated by the method 1. The last year was very dry, and the method 1 may overestimate the surface runoff from marshland into the lake.

Table 5.7 Estimated flows from the method 1 and the method 2 for Johnson and Black Bayou.

Bayou	Total (annual) daily flow (cfs)[1]	Inflow (10^6 m^3)	Total (annual) daily flow (cfs)[2]	Inflow (10^6 m^3)
Johnson	51860	127	21729	53
Black	229965	563	145208	355

Note: 1, 2 – using estimated flows from the method 1 and the method 2, respectively.

5.4 Estimation of Nutrient Input

Annual nutrient input is estimated as the product of average nutrient concentration and estimated flow from bayou to Sabine Lake due to rainfalls. Results are given in Table 5.8 by using flows estimated by the method 1 and the method 2, respectively. Loading is given as 10^3 kg or tons per year.

6. Discussions and Summary

In this study, it was assumed that nutrients are washed out from marshland into Sabine Lake through bayous by rainfall runoff. Measured nutrient concentrations during the dry period were typically very low. In order to determine annual nutrient loading, surface runoff from marshland and event mean concentrations of nutrient are needed. In this study, surface runoff was estimated from

simulated daily runoff from 1987 to 1996 and rainfall data. Two methods were developed to estimate surface runoff. The method 1 directly gives total (annual) daily flow from marshland from historical (1996) rainfall-runoff relationship without examining difference in rainfall events over time. The method 2 examines rainfall events month by month, and estimates monthly daily flow from historical runoff data with similar monthly rainfall. We believe that the method 2 may provide more accurate estimate in runoff flow rate. There are some differences in estimated nutrient loadings based on two estimated surface runoff volumes. The method 2 for estimating surface runoff could lead more reasonable results on nutrient loading. In order to improve accuracy in estimation of nutrient loading, advanced hydrologic model study and extensive field data collection are needed in the future. All tasks have been completed according to the contract.

Table 5.8 Estimated nutrient loading from Johnson and Black Bayous into Sabine Lake.

Johnson Bayou		***Flow Estimated by Method 1***		***Flow Estimated by Method 2***	
Nutrient Concentration (mg/l)		Inflow (10^6 m^3)	Loading (10^3 kg)	Inflow (10^6 m^3)	Loading (10^3 kg)
TKN	0.600	127	**76**	53	**32**
NH4	0.824	127	**105**	53	**44**
TOC	6.500	127	**826**	53	**345**
NO2/NO3	0.530	127	**67**	53	**28**
TP	0.082	127	**10**	53	**4**
Black Bayou		***Flow Estimated by Method 1***		***Flow Estimated by Method 2***	
Nutrient Concentration (mg/l)		Inflow (10^6 m^3)	Loading (10^3 kg)	Inflow (10^6 m^3)	Loading (10^3 kg)
TKN	0.580	563	**327**	355	**206**
NH4	0.985	563	**555**	355	**350**
TOC	5.200	563	**2928**	355	**1846**
NO2/NO3	0.452	563	**254**	355	**160**
TP	0.069	563	**39**	355	**24**

Note: Loading (kg) = Concentration (mg/l)* inflow (m^3)*1000l/m^3 * 1kg/(1000000 mg)

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APPENDIX A

Estimation of Surface Runoff by the Method 2

Table A.1 ESTIMATED FLOW IN JOHNSON BAYOU FROM FLOWS AND RAINFALLS IN OTHER MONTHS

SEPTEMBER, 1999

SEPT.1999	RAINFALL OF	JOHNSON	JAN. 1988		MAR. 1989		NOV. 1989		DEC. 1989		DEC. 1996	
DATE	SEPT. 1999	FLOW	RAINFALL	FLOW	RAINFALL	FLOW	RAINFALL	FLOW	RAINFALL	FLOW	RAINFALL	FLOW
1	0.09		0.5	15	0.03	4	0.96	252	0	3	0	8
2	0.02		0	13	0.74	8	0	355	0	2	0	7
3	0		0	12	0	16	0	98	0	2	0	7
4	0		0	11	0.05	16	0.01	28	0	2	0.2	7
5	0.93		0	11	0	8	0	9	0	2	0.11	19
6	0		0.45	1631	0	5	0	6	0.95	212	0	29
7	0		0.95	2874	0	4	0	5	1.72	389	0	13
8	0		0	802	0	4	0	5	0.05	130	0	8
9	0		0	202	0	4	0	5	0	35	0	7
10	0		0	47	0	4	0	5	0	10	0	6
11	0		0	17	0	4	0	4	0	5	0	6
12	0		0.28	72	0	4	0	4	0	4	0	6
13	0.63		0.02	118	0	3	0	4	0	4	0	6
14	0		0	39	0	3	0.03	4	0	3	0	6
15	0		0	17	0	3	0.27	6	0	3	1.67	5
16	0		0.92	395	0	3	0	8	0	3	0.36	601
17	0		0	694	0	3	0	5	0	3	0	1066
18	0		0	206	0	3	0.23	4	0.07	3	0	310
19	0		0.11	58	0	3	0.59	4	0.06	3	0	81
20	0		0	19	0.12	3	0	4	0	3	0	21
21	0		0	11	1.69	37	0	3	0	3	0	10
22	0		0	10	0.27	63	0.9	3	0	3	0.01	7
23	0		0	9	0	735	0	3	0	3	0	7
24	0		0	9	0	1267	0	3	0	3	0.04	9
25	0		0	9	0	342	0	3	0	2	0	10
26	0		0	8	0	86	0.05	3	0	2	0.07	7
27	0		0	8	0	21	0	3	0	2	0.01	7
28	0.68		0	8	0	8	0.1	3	0.2	2	0	7
29	0.9		0		0.5	131	0	3	0	2	0.21	6
30	0		0	7	0	227	0	3	0	2	0.05	6
31			0	103	0	65			0.09	2	0.53	7
TOTAL	3.25	2135	3.23	7435	3.4	3087	3.14	845	3.14	847	3.26	2302

NOTE: The flow of January1988 was too large since rainfalls in November and December of 1987 were very large.
It could be impossible that 0.9 inches rainfall on NOV 22 1989 did not cause any flow.
So that the average flow of MAR.1989, DEC.1989, and DEC.1996 is the estimated flow for SEPT.1999.

Table A.2 ESTIMATED FLOW IN BLACK BAYOU FROM FLOWS AND RAINFALLS IN OTHER MONTHS

SEPTEMBER, 1999

SEPT.1999	RAINFALL OF	BLACK	MAR.1989		DEC.1989		DEC.1996	
DATE	SEPT. 1999	FLOW	RAINFALL	FLOW	RAINFAL	FLOW	RAINFALL	FLOW
1	0.09		0.03	18	0	21	0	180
2	0.02		0.74	325	0	16	0	162
3	0		0	1336	0	14	0	88
4	0		0.05	1198	0	13	0.2	55
5	0.93		0	531	0	13	0.11	61
6	0		0	232	0.95	12	0	124
7	0		0	110	1.72	529	0	112
8	0		0	55	0.05	2227	0	65
9	0		0	32	0	1996	0	43
10	0		0	25	0	875	0	34
11	0		0	20	0	370	0	30
12	0		0	18	0	165	0	28
13	0.63		0	18	0	75	0	26
14	0		0	17	0	37	0	25
15	0		0	17	0	25	1.67	24
16	0		0	16	0	17	0.36	960
17	0		0	16	0	16	0	4100
18	0		0	15	0.07	15	0	3920
19	0		0	15	0.06	15	0	1858
20	0		0.12	14	0	14	0	788
21	0		1.69	14	0	14	0	347
22	0		0.27	904	0	14	0.01	156
23	0		0	3895	0	13	0	75
24	0		0	3727	0	13	0.04	48
25	0		0	1764	0	12	0	32
26	0		0	745	0	12	0.07	28
27	0		0	324	0	12	0.01	32
28	0.68		0	142	0.2	11	0	49
29	0.9		0.5	464	0	31	0.21	46
30	0		0	1747	0	100	0.05	47
31			0	1554	0.09	90	0.53	86
TOTAL	3.25	19862	3.4	19308	3.14	6787	3.26	13629

Table A.3 ESTIMATED FLOW IN JOHNSON BAYOU FROM FLOWS AND RAINFALLS IN OTHER MONTHS

OCTOBER, 1999

OCT. 1999	OCT.1999	JOHNSON	NOV. 1991		MAR. 1994		JUL. 1988		MAR. 1992	
DATE	RAINFALL	FLOW	RAINFALL	FLOW	RAINFALL	FLOW	RAINFALL	FLOW	RAINFALL	FLOW
1	0		0	186	0.984	50	0	4	0	9
2	0		0	49	0	83	0	4	0	9
3	0		0	16	0	27	0	4	0	8
4	0		0	8	0	11	0.07	4	0.118	108
5	0		0	7	0	7	0.6	4	0.236	819
6	0		0	7	0	6	0.05	4	0	1172
7	0.19		1.024	185	0	6	0.37	4	0	319
8	2.36		0	321	0.039	496	0.25	58	0	83
9	0.79		0	91	2.126	1170	0	101	0	23
10	0		0	27	0	767	0	30	0	11
11	0		0	11	0	205	0	10	0	8
12	0		0	8	0	53	0	5	0	8
13	0		0	7	0	16	0	4	0	8
14	0		0	7	0	9	0	4	0	8
15	0		0	6	0.591	103	0	3	0	7
16	0		0	6	0	175	0	3	0	7
17	0		1.89	721	0	53	0	3	0	21
18	0		0.197	1266	0	19	0.02	3	0.984	104
19	0.24		0.472	401	0	10	0.28	3	0	143
20	0.09		0.039	185	0	8	0	3	0	47
21	0		0	49	0	7	0.28	8	0.079	69
22	0		0	17	0	7	0	12	0.118	101
23	0		0	10	0	7	0	5	0	32
24	0		0	8	0	7	0	3	0	13
25	0		0	8	0	7	0	3	0	8
26	0		0.039	8	0	6	0	3	0	7
27	0		0	8	0.197	6	0.85	3	0	7
28	0		0	7	0	6	0.5	3	2.283	2350
29	0		0	7	0	6	0.57	2	0	4182
30	0.17		0.236	7	0	6	0	2	0	1210
31	0.04				0	5	0	2	0	300
TOTAL	3.88	3494	3.897	3644	3.937	3344	3.84	304	3.818	11201

NOTE: It could be impossible that 0.85, 0.5, 0.57 inches rainfall on July 27 to 29, 1988 did not cause flow. The flow of March 1992 was too large. We considered the average of flow in November 1991 and March, 1994 as the estimated flow of October, 1999.

Table A.4 ESTIMATED FLOW IN BLACK BAYOU FROM FLOWS AND RAINFALLS IN OTHER MONTHS

OCTOBER, 1999

OCT. 1999	OCT.1999	BLACK	NOV. 1991		MAR. 1994	
DATE	RAINFALL	FLOW	RAINFALL	FLOW	RAINFALL	FLOW
1	0		0	3489	0.984	59
2	0		0	1538	0	570
3	0		0	653	0	2065
4	0		0	287	0	1817
5	0		0	127	0	803
6	0		0	60	0	347
7	0.19		1.024	38	0	161
8	2.36		0	137	0.039	80
9	0.79		0	508	2.126	655
10	0		0	457	0	2652
11	0		0	212	0	2404
12	0		0	101	0	1076
13	0		0	56	0	461
14	0		0	35	0	210
15	0		0	27	0.591	100
16	0		0	23	0	214
17	0		1.89	21	0	724
18	0		0.197	738	0	643
19	0.24		0.472	3091	0	295
20	0.09		0.039	2946	0	138
21	0		0	1967	0	74
22	0		0	1188	0	46
23	0		0	524	0	33
24	0		0	229	0	29
25	0		0	107	0	26
26	0		0.039	60	0	25
27	0		0	37	0.197	24
28	0		0	34	0	42
29	0		0	30	0	105
30	0.17		0.236	27	0	96
31	0.04				0	54
TOTAL	3.88	17387.5	3.897	18747	3.937	16028

Table A.5 ESTIMATED FLOW IN JOHNSON BAYOU FROM FLOWS AND RAINFALLS IN OTHER MONTHS NOVEMBER, 1999

NOV.1999 DATE	NOV.1999 RAINFALL	JOHN FLOW	NOV. 1988		SEPT. 1989		FEB. 1996	
			RAINFALL	FLOW	RAINFALL	FLOW	RAINFALL	FLOW
1	0		0	5	0	109	0.35	47
2	0		0	5	0	28	0.09	88
3	0		0	5	0	13	0	53
4	0		0	5	0	9	0	19
5	0		0	5	0.27	9	0	10
6	0		0	4	0.15	9	0	8
7	0		0	4	0	9	0	7
8	0		0	4	0.05	8	0	7
9	0		0	4	0	8	0.02	7
10	0		0.04	4	0.13	8	0	7
11	0		0.01	4	0	8	0	7
12	0		0.54	4	0	7	0	6
13	0		0	4	0.6	7	0	6
14	0		0	3	0	7	0	6
15	0		0	3	0	7	0	6
16	0		0.4	3	0	7	0	6
17	0		0	3	0	6	0	5
18	0		0	3	0	6	0	5
19	0		0.08	3	0	6	0.01	5
20	0		0	3	0	6	0	5
21	0		0	3	0	6	0	5
22	0		0	3	0	5	0	5
23	0.93		0	3	0	5	0	5
24	0		0	3	0	5	0	4
25	0.3		0.01	2	0	5	0	4
26	0		0.03	2	0	5	0	4
27	0		0	2	0	5	0	4
28	0		0	2	0	5	0.2	4
29	0		0	2	0		0.61	124
30	0		0.01	2	0			
TOTAL	1.23	469	1.12	102	1.2	318	1.28	469

NOTE: It could be impossible that 0.54 inch rainfall did not cause any flow on NOV.12,1988. The distribution of rainfall is different from NOV.1999. We cosidered the flow of FEB. 1996 as the flow of NOV. 1999.

Table A.6 ESTIMATED FLOW IN BLACK BAYOU FROM FLOWS AND RAINFALLS IN OTHER MONTHS

NOVEMBER, 1999

NOV.1999 DATE	NOV.1999 RAINFALL	BLACK FLOW	FEB. 1996	
			RAINFALL	FLOW
1	0		0.35	410
2	0		0.09	477
3	0		0	1370
4	0		0	1244
5	0		0	573
6	0		0	255
7	0		0	125
8	0		0	68
9	0		0.02	44
10	0		0	35
11	0		0	30
12	0		0	28
13	0		0	27
14	0		0	27
15	0		0	26
16	0		0	25
17	0		0	24
18	0		0	24
19	0		0.01	23
20	0		0	22
21	0		0	21
22	0		0	21
23	0.93		0	20
24	0		0	20
25	0.3		0	19
26	0		0	18
27	0		0	18
28	0		0.2	21
29	0		0.61	94
30	0			
TOTAL	1.23	**5109**	1.28	5109

Table A.7 ESTIMATED FLOW IN JOHNSON BAYOU FROM FLOWS AND RAINFALLS IN OTHER MONTHS

DECEMBER, 1999

DEC.1999	DEC.1999	JOHNSON	NOV. 1991		MAR. 1994		FEB. 1993		JAN. 1995	
DATE	RAINFALL	FLOW	RAINFALL	FLOW	RAINFALL	FLOW	RAINFALL	FLOW	RAINFALL	FLOW
1	0		0	186	0.984	50	0	97	0	1020
2	0.57		0	49	0	83	0	31	0	278
3	0		0	16	0	27	0	14	0.236	80
4	0.61		0	8	0	11	0	10	0	34
5	0		0	7	0	7	0.315	13	0	14
6	0		0	7	0	6	0	90	0.118	9
7	0		1.024	185	0	6	0	141	0	8
8	0		0	321	0.039	496	0	44	0	8
9	0.01		0	91	2.12	1170	0	17	0	8
10	0		0	27	0	767	1.299	58	0	8
11	0.01		0	11	0	205	0	1168	0	7
12	0.4		0	8	0	53	0	1921	0.748	7
13	0		0	7	0	16	0	520	0.669	987
14	0		0	7	0	9	0	132	0	1731
15	0		0	6	0.59	103	0.433	32	0	469
16	0		0	6	0	175	0.236	596	0	119
17	0.14		1.89	721	0	53	0	1033	0	29
18	1.06		0.197	1266	0	19	0	283	0.157	12
19	0		0.472	401	0	10	0	75	0	83
20	1.22		0.039	185	0	8	0.039	21	0	141
21	0.01		0	49	0	7	0	11	0	44
22	0		0	17	0	7	0	9	0.787	17
23	0		0	10	0	7	0	8	0	339
24	0		0	8	0	7	0	8	0	588
25	0		0	8	0	7	1.77	8	0	164
26	0		0.039	8	0	6	0	1340	0.827	46
27	0		0	8	0.197	6	0	2348	0.472	794
28	0		0	7	0	6	0	634	0	2433
29	0		0	7	0	6			0	2229
30	0		0.236	7	0	6			0	594
31	0				0	5			0	146
TOTAL	4.03	3494	3.897	3644	3.93	3344	4.092	10662	4.014	12446

NOTE: The flows in FEB. 1993 and JAN. 1995 were too large since there are large rainfalls before those months. We used the average flow of NOV. 1991 and MAR. 1994 as the estimated flow of DEC. 1999

Table A.8 ESTIMATED FLOW IN BLACK BAYOU FROM FLOWS AND RAINFALLS IN OTHER MONTHS DECEMBER, 1999

DEC.1999 DATE	DEC.1999 RAINFALL	BLACK FLOW	NOV. 1991		MAR. 1994	
			RAINFALL	FLOW	RAINFALL	FLOW
1	0		0	3489	0.984	59
2	0.57		0	1538	0	570
3	0		0	653	0	2065
4	0.61		0	287	0	1817
5	0		0	127	0	803
6	0		0	60	0	347
7	0		1.024	38	0	161
8	0		0	137	0.039	80
9	0.01		0	508	2.12	655
10	0		0	457	0	2652
11	0.01		0	212	0	2404
12	0.4		0	101	0	1076
13	0		0	56	0	461
14	0		0	35	0	210
15	0		0	27	0.59	100
16	0		0	23	0	214
17	0.14		1.89	21	0	724
18	1.06		0.197	738	0	643
19	0		0.472	3091	0	295
20	1.22		0.039	2946	0	138
21	0.01		0	1967	0	74
22	0		0	1188	0	46
23	0		0	524	0	33
24	0		0	229	0	29
25	0		0	107	0	26
26	0		0.039	60	0	25
27	0		0	37	0.197	24
28	0		0	34	0	42
29	0		0	30	0	105
30	0		0.236	27	0	96
31	0				0	54
TOTAL	4.03	17388	3.897	18747	3.93	16028

Table A.9 ESTIMATED FLOW IN JOHNSON BAYOU FROM FLOWS AND RAINFALLS IN OTHER MONTHS JANUARY, 2000

JAN.2000 DATE	JAN.2000 RAINFALL	JONSON FLOW	OCT. 1988		AUG. 1990		DEC. 1993	
			RAINFALL	FLOW	RAINFALL	FLOW	RAINFALL	FLOW
1	0		0	2135	0.984	10	0	9
2	0		0.75	963	0	10	0	8
3	0.2		0	251	0.079	9	0	8
4	0		0	61	0	9	0.433	8
5	0		0	19	0.236	9	0	8
6	0		0	10	0	9	0	7
7	0		0	9	0	8	0	7
8	0.39		0	9	0	8	0	7
9	0		0	8	0	8	0	7
10	0		0	8	0	8	0.512	7
11	0		0	8	0	7	0	6
12	0		0	8	0	7	0	6
13	0		0	7	0	7	0.157	6
14	0		0	7	0	7	0	6
15	0		0	7	0	6	0	6
16	0		0	7	0	6	0	6
17	0		0	7	0	6	0	5
18	0		0	6	0	6	0.118	5
19	0		0	6	0	6	0	5
20	0		0	6	0	11	0	5
21	0		0	6	0	15	0	5
22	0		0	6	0.079	8	0.236	5
23	0		0.6	60	0.039	23	0	4
24	0		0	102	0	39	0	4
25	0		0	32	0	19	0	4
26	0		0.11	12	0	9	0	4
27	1.09		0	9	0	6	0	4
28	0		0.24	10	0	53	0.394	195
29	0		0	7	0	89	0	340
30	0		0	6	0.236	28	0	95
31	0		0	5	0	11	0	27
TOTAL	1.68	819	1.7	3797	1.653	457	1.85	819

NOTE: At the beginning of OCT.1988, there was a large flow caused by a large rainfall in the last month. It could be impossible 0.984 inches rainfall in AUG.1990 did not cause a large flow. We considered the flow of DEC.1993 as the estimated flow of JAN.2000.

Table A.10 ESTIMATED FLOW IN BLACK BAYOU FROM FLOWS AND RAINFALLS IN OTHER MONTHS

JANUARY, 2000

Jan-00	RAINFALL	BLACK	DEC, 1993	
DATE	Jan-00	FLOW	RAINFALL	FLOW
1	0		0	35
2	0		0	34
3	0.2		0	33
4	0		0.433	326
5	0		0	1295
6	0		0	1163
7	0		0	523
8	0.39		0	234
9	0		0	116
10	0		0.512	185
11	0		0	561
12	0		0	499
13	0		0.157	234
14	0		0	119
15	0		0	70
16	0		0	46
17	0		0	35
18	0		0.118	31
19	0		0	35
20	0		0	58
21	0		0	54
22	0		0.236	39
23	0		0	36
24	0		0	34
25	0		0	30
26	0		0	26
27	1.09		0	24
28	0		0.394	23
29	0		0	68
30	0		0	219
31	0		0	198
TOTAL	1.68	6383	1.85	6383

Table A.11 ESTIMATED FLOW IN JOHNSON BAYOU FROM FLOWS AND RAINFALLS IN OTHER MONTHS

FEBRUARY, 2000

FEB.2000	FEB.2000	JOHNSON	MAY, 1988		SEPT. 1995	
DATE	RAINFALL	FLOW	RAINFALL	FLOW	RAINFALL	FLOW
1	0		0	1273	0	10
2	0		0	313	0	10
3	0		0	66	0	10
4	0		0	18	0	10
5	0		0	8	0	9
6	0		0	8	0	9
7	0.49		0	7	0	9
8	0		0	7	0	8
9	0		0	7	0	8
10	0		0	7	0	8
11	0		0	7	0	8
12	0		0.23	6	0	7
13	0		0	13	0.276	7
14	0		0	18	0	7
15	0		0	9	0	7
16	0		0	7	0.079	7
17	0.1		0	6	0	6
18	0		0	6	0	6
19	0		0	5	0	6
20	0		0	5	0.039	6
21	0		0.38	5	0.239	39
22	0		0	5	0.039	66
23	0.05		0	5	0	22
24	0		0	5	0	10
25	0		0	5	0	6
26	0.08		0	4	0	6
27	0		0	4	0	5
28	0		0	4	0	5
29	0		0	4	0	5
30			0	4	0	5
31			0	4		
TOTAL	0.72	327	0.61	1845	0.672	327

NOTE: At the beginning of MAY 1988, there was a large flow caused by a large rainfall in the last month, so we used the flow of SEPT.1995 as the estimated flow of FEB.2000

Table A.12 ESTIMATED FLOW IN BLACK BAYOU FROM FLOWS AND RAINFALLS IN OTHER MONTHS FEBRUARY, 2000

Feb-00 DATE	RAINFALL Feb-00	BLACK FLOW	SEP. 1995 RAINFALL	FLOW
1	0		0	311
2	0		0	155
3	0		0	86
4	0		0	57
5	0		0	47
6	0		0	40
7	0.49		0	38
8	0		0	37
9	0		0	36
10	0		0	35
11	0		0	34
12	0		0	33
13	0		0.276	32
14	0		0	31
15	0		0	30
16	0		0.079	29
17	0.1		0	28
18	0		0	30
19	0		0	50
20	0		0.039	101
21	0		0.239	128
22	0		0.039	95
23	0.05		0	61
24	0		0	43
25	0		0	33
26	0.08		0	28
27	0		0	26
28	0		0	24
29	0		0	23
30			0	22
31				
TOTAL	0.72	1723	0.672	1723

Table A.13 ESTIMATED FLOW IN JOHNSON BAYOU FROM FLOWS AND RAINFALLS IN OTHER MONTHS MARCH, 2000

MAR.2000 DATE	MAR.2000 RAINFALL	JOHNSON FLOW	APR. 1988		APR. 1989	
			RAINFALL	FLOW	RAINFALL	FLOW
1	0		0.06	873	0	20
2	0		0	227	0	9
3	0		0	56	0	6
4	0		0	18	0.05	6
5	0		0	10	0	5
6	0		0.05	9	0	5
7	0		0	9	0	5
8	0		0	8	0	5
9	0		0	8	0.02	5
10	0		0	8	0.05	5
11	0.77		0	8	0	5
12	0		0	7	0.31	4
13	0		0	7	0.1	4
14	1.18		0	7	1.09	360
15	0.04		0	7	0	631
16	0.01		0.11	7	0	173
17	0		0	7	0	46
18	0		0	6	0	13
19	0.25		0	6	0	7
20	0		0	6	0	5
21	0		0	6	0	5
22	0		0	6	0	5
23	0		0	5	0	5
24	0		0	5	0	5
25	0		0	5	0	5
26	0.49		0	5	0	4
27	0		0	5	0	4
28	0		0	5	0	4
29	0		2.31	2607	0	38
30	0		0.11	4603	1.13	63
31	0					
TOTAL	2.74	1457	2.64	8546	2.75	1457

NOTE: The flow in APRIL 1988 was too large, we considered the flow of APRIL 1989 as the estimated flow of MAR. 2000.

Table A.14 ESTIMATED FLOW IN BLACK BAYOU FROM FLOWS AND RAINFALLS IN OTHER MONTHS MARCH, 2000

MAR.2000 DATE	MAR.2000 RAINFALL	BLACK FLOW	APR. 1989 RAINFALL	APR. 1989 FLOW
1	0		0	687
2	0		0	298
3	0		0	139
4	0		0.05	70
5	0		0	41
6	0		0	31
7	0		0	24
8	0		0	23
9	0		0.02	22
10	0		0.05	22
11	0.77		0	21
12	0		0.31	20
13	0		0.1	20
14	1.18		1.09	19
15	0.04		0	376
16	0.01		0	1553
17	0		0	1393
18	0		0	616
19	0.25		0	266
20	0		0	124
21	0		0	62
22	0		0	35
23	0		0	26
24	0		0	21
25	0		0	19
26	0.49		0	19
27	0		0	18
28	0		0	18
29	0		0	69
30	0		1.13	283
31	0			
TOTAL	2.74	6335	2.75	6335

Table A.15 ESTIMATED FLOW IN JOHNSON BAYOU FROM FLOWS AND RAINFALLS IN OTHER MONTHS APRIL, 2000

APR.2000	APR. 2000	JOHNSON	DEC. 1987		DEC. 1992		JUL. 1994		AUG. 1996	
DATE	RAINFALL	FLOW	RAINFALL	FLOW	RAINFALL	FLOW	RAINFALL	FLOW	RAINFALL	FLOW
1	0		0	58	0	10	0	12	0.16	6
2	0		0	20	0	9	0	90	0	5
3	0.01		0	13	0	9	0	150	0	5
4	0.47		0	11	1.417	140	0	49	0	4
5	0		0	11	0	240	0.709	20	0	4
6	0		2.33	919	0.039	71	0	13	0	4
7	0		0	3195	0.039	24	0	11	1.19	4
8	0		0	3227	0.039	12	0.906	191	0	4
9	0		0	860	1.85	858	1.26	466	0	4
10	0		0	211	0	1516	0.157	1119	0.32	4
11	0		0	49	0	434	0	1471	0.38	4
12	0		0	18	0	113	0	399	0.21	24
13	5.75		0.05	12	0	30	2.717	106	0.39	40
14	0		0	12	0.236	109	0	32	0	14
15	0		0	11	1.536	291	0	327	0	6
16	0		0	11	0.276	266	0	559	0.06	4
17	0.02		0	11	0	94	0	165	0	4
18	0.01		0	10	0	31	0	58	0	3
19	0		0.69	117	0	15	0	22	0	3
20	0		0.22	368	0.394	102	0	199	0	3
21	0		1.26	1112	0	171	0.039	338	0.44	3
22	0		0	1503	0	54	0	99	1.54	5
23	0.01		0	526	0.236	31	0.394	78	0.1	586
24	0.01		0	138	0	31	0	96	0	1026
25	0		0	37	0.236	16	0	34	0	280
26	0		1	357	0	11	0	17	0.01	71
27	0.01		0.57	901	0	10	0	12	0.01	17
28	0		0	741	0	9	0	11	0	7
29	0		0	294	0	9	0	11	1.49	5
30	0		0	81	0	9	0	10	0.03	127
31				26	0	9	0	10	0.01	220
TOTAL	6.29	5454.5	6.12	14860	6.298	4734	6.182	6175	6.34	2496

NOTE: The flow of DEC.1987 was too large since Novermber of 1987 was wet month and the flow in AUG.1996 was too small. We considered the average of the flow of DEC. 1992 and JULY. 1994 as the estimated flow of APRIL 2000.

Table A.16 ESTIMATED FLOW IN BLACK BAYOU FROM FLOWS AND RAINFALLS IN OTHER MONTHS APRIL, 2000

APR.2000	APR. 2000	BLACK	DEC. 1992		JUL. 1994	
DATE	RAINFALL	FLOW	RAINFALL	FLOW	RAINFALL	FLOW
1	0		0	32	0	54
2	0		0	31	0	45
3	0.01		0	30	0	42
4	0.47		1.417	29	0	40
5	0		0	744	0.709	54
6	0		0.039	3093	0	220
7	0		0.039	2773	0	592
8	0		0.039	1219	0.906	517
9	0		1.85	525	1.26	972
10	0		0	1525	0.157	3154
11	0		0	5547	0	3073
12	0		0	4918	0	1899
13	5.75		0	2150	2.717	1712
14	0		0.236	902	0	2357
15	0		1.536	772	0	1930
16	0		0.276	1966	0	1337
17	0.02		0	2408	0	827
18	0.01		0	1790	0	377
19	0		0	963	0	179
20	0		0.394	563	0	98
21	0		0	822	0.039	70
22	0		0	823	0	69
23	0.01		0.236	473	0.394	63
24	0.01		0	260	0	50
25	0		0.236	280	0	44
26	0		0	413	0	41
27	0.01		0	953	0	39
28	0		0	820	0	37
29	0		0	377	0	36
30	0		0	178	0	35
31			0	97	0	34
TOTAL	6.29	28737	6.298	37476	6.182	19997

Table A.17 ESTIMATED FLOW IN JOHNSON BAYOU FROM FLOWS AND RAINFALLS IN OTHER MONTHS
MAY, 2000

May-00	RAINFALL	JOHNSON	NOV. 1995		NOV. 1996		APR. 1997	
DATE	May-00	FLOW	RAINFALL	FLOW	RAINFALL	FLOW	RAINFALL	FLOW
1	0.02		0.315	44	0.08	35	0	15
2	0.65		2.205	15	0	53	0	10
3	3.06		0.197	2801	0	22	0.23	9
4	1		0	4915	0	13	0.22	74
5	0		0.197	1320	0	10	0.44	132
6	0		0	330	0	9	0	53
7	0		0	104	1.17	227	0	19
8	0		0	67	0	393	0.02	11
9	0		0	22	0	112	0	8
10	0		0.039	12	0	34	0	8
11	0		0.433	32	0	14	0.52	8
12	0		0	48	0	10	0.01	189
13	0.14		0	19	0	9	0	327
14	0		0	11	0	9	0	93
15	0		0	9	0	37	0	28
16	0		0	8	2.4	407	0	12
17	0		0.394	8	0.18	643	0	8
18	0		0.079	52	0	191	0	7
19	0		0.433	85	0	53	0.04	7
20	0.01		0	161	0	18	0	7
21	0		0	247	0	11	0	8
22	0		0	72	0	9	0	7
23	0		0	24	0	9	0	6
24	0		0	11	0.58	38	0.04	6
25	0		0	9	0	61	3.35	6
26	0		0	8	0	23	0	3143
27	0		0.079	8	0	12	0.04	5516
28	0		0.433	321	0	9	0.01	1480
29	0		0	560	0.41	8	0	362
30	0		0	156	0		0	75
31	0							
TOTAL	4.88	2479	4.804	11479	4.82	2479	4.92	11634

NOT At the edn of OCT. 1995, therer was rain amounted of 0.67 inches. This caused a very large flow in the beginning of NOV.1995.
On April 25,there was 3.35 inches rain which did not cause flow in Johson Bayou. This could be impossible.
We used the flow of NOV., 1996 as the estimated flow of MAY 2000.

Table A.18 ESTIMATED FLOW IN BLACK BAYOU FROM FLOWS AND RAINFALLS IN OTHER MONTHS MAY, 2000

May-00 DATE	RAINFALL May-00	JOHNSON FLOW	NOV. 1996 RAINFALL	FLOW
1	0.02		0.08	228
2	0.65		0	280
3	3.06		0	787
4	1		0	692
5	0		0	321
6	0		0	155
7	0		1.17	87
8	0		0	802
9	0		0	3233
10	0		0	2895
11	0		0	1275
12	0		0	546
13	0.14		0	250
14	0		0	121
15	0		0	66
16	0		2.4	48
17	0		0.18	479
18	0		0	2341
19	0		0	3487
20	0.01		0	2343
21	0		0	1021
22	0		0	444
23	0		0	205
24	0		0.58	101
25	0		0	100
26	0		0	214
27	0		0	188
28	0		0	101
29	0		0.41	62
30	0		0	78
31	0			
TOTAL	4.88	22950	4.82	22950

Table A.19 ESTIMATED FLOW IN JOHNSON BAYOU FROM FLOWS AND RAINFALLS IN OTHER MONTHS JUNE, 2000

Jun-00	RAINFALL	JOHNSON	FEB. 1989		OCT. 1987	
DATE	Jun-00	FLOW	RAINFALL	FLOW	RAINFALL	FLOW
1	0		0	109	0	212
2	0		0	28	0	53
3	0		0.01	13	0	20
4	0		0	9	0	13
5	0		0.03	9	0	12
6	0		0	9	0	12
7	0		0	9	0	12
8	0		0	8	0	11
9	0.03		0	8	0	11
10	0		0	8	0	11
11	0		0	8	0	10
12	0		0.03	7	0	10
13	0		0	7	0	10
14	0		0	7	0	9
15	0		0	7	0	9
16	0		0	7	0	9
17	0		0	6	0	9
18	0.02		0.06	6	0	8
19	0		0	6	0	8
20	0		0.02	6	0.09	8
21	0		0	6	0	8
22	0		0	5	0	7
23	0.01		0	5	0.03	7
24	0		0	5	0.12	7
25	0.01		0	5	0	7
26	0.01		0	5	0.03	6
27	0		0.02	5	0	6
28	0		0	5	0	6
29	0				0	6
30	0.04				0	6
					0	6
TOTAL	0.12	318	0.17	318	0.27	529

NOTE: The rainfall in OCT.1987 was two times of that in JUN. 2000

Table A.20 ESTIMATED FLOW IN BLACK BAYOU FROM FLOWS AND RAINFALLS IN OTHER MONTHS
JUNE, 2000

Jun-00	RAINFALL	BLACK	FEB. 1989	
DATE	Jun-00	FLOW	RAINFALL	FLOW
1	0		0	1968
2	0		0	873
3	0		0.01	388
4	0		0	215
5	0		0.03	123
6	0		0	72
7	0		0	65
8	0		0	52
9	0.03		0	40
10	0		0	34
11	0		0	32
12	0		0.03	30
13	0		0	29
14	0		0	28
15	0		0	27
16	0		0	26
17	0		0	25
18	0.02		0.06	25
19	0		0	24
20	0		0.02	23
21	0		0	23
22	0		0	25
23	0.01		0	24
24	0		0	22
25	0.01		0	21
26	0.01		0	20
27	0		0.02	19
28	0		0	18
29	0			
30	0.04			
TOTAL	0.12	4271	0.17	4271

Table A.21 ESTIMATED FLOW IN JOHNSON BAYOU FROM FLOWS AND RAINFALLS IN OTHER MONTHS
JULY, 2000

Jul-00	Jul-00	JOHNSON	**FEB.1996**		**SEP.1989**		**OCT.1989**	
DATE	RAINFALL	FLOW	RAINFALL	FLOW	RAINFALL	FLOW	RAINFALL	FLOW
1	0		0.35	47	0	121	0	9
2	0		0.09	88	0	36	0	8
3	0		0	53	0	14	0	8
4	0		0	19	0	10	0	8
5	0		0	10	0.27	664	0	8
6	0		0	8	0.15	1174	0	7
7	0.01		0	7	0	341	0	20
8	0		0	7	0.05	92	0.03	29
9	0		0.02	7	0	26	0	13
10	0		0	7	0.13	124	0	8
11	0.03		0	7	0	877	0	7
12	0		0	6	0	1242	0	7
13	0		0	6	0.6	1069	0	6
14	0		0	6	0	1372	0	6
15	0		0	6	0	370	0.03	6
16	0		0	6	0	98	0	6
17	0.01		0	5	0	28	0	6
18	0		0	5	0	15	0	5
19	0		0.01	5	0	12	0	5
20	0		0	5	0	12	0	5
21	0		0	5	0	12	0	5
22	0		0	5	0	11	0	5
23	0.98		0	5	0	11	0	5
24	0		0	4	0	11	0	5
25	0.01		0	4	0	10	0	4
26	0		0	4	0	10	0	4
27	0		0	4	0	10	0	4
28	0		0.2	4	0	9	0	4
29	0		0.61	124	0	9	0.06	4
30	0				0	9	1.05	4
31	0.23						0	37
TOTAL	1.27	**469**	1.28	469	1.2	7799	1.17	258

Table A.22 ESTIMATED FLOW IN BLACK BAYOU FROM FLOWS AND RAINFALLS IN OTHER MONTHS JULY,2000

Jul-00	Jul-00	BLACK	FEB.1996	
DATE	RAINFALL	FLOW	RAINFALL	FLOW
1	0		0.35	410
2	0		0.09	477
3	0		0	1370
4	0		0	1244
5	0		0	573
6	0		0	255
7	0.01		0	125
8	0		0	68
9	0		0.02	44
10	0		0	35
11	0.03		0	30
12	0		0	28
13	0		0	27
14	0		0	27
15	0		0	26
16	0		0	25
17	0.01		0	24
18	0		0	24
19	0		0.01	23
20	0		0	22
21	0		0	21
22	0		0	21
23	0.98		0	20
24	0		0	20
25	0.01		0	19
26	0		0	18
27	0		0	18
28	0		0.2	21
29	0		0.61	94
30	0			
31	0.23			
TOTAL	1.27	**5109**	1.28	**5109**

Table A.23 ESTIMATED FLOW IN JOHNSON BAYOU FROM FLOWS AND RAINFALLS IN OTHER MONTHS
AUGUST, 2000

Aug-00	Aug-00	JOHNSON	MAY.1997		SEP.1992		OCT.1997		DEC.1993	
DATE	RAINFALL	FLOW	RAINFALL	FLOW	RAINFALL	FLOW	RAINFALL	FLOW	RAINFALL	FLOW
1	1.1		0	20	0.118	6	0	9	0	9
2	0		0.06	9	0	6	0	8	0	8
3	0		0	8	0.551	110	0	8	0	8
4	0		0	8	0.039	189	0	8	0.433	8
5	0		0	8	0	55	0	8	0	8
6	0		0	8	0	18	0	7	0	7
7	0		0	7	0	8	0.12	31	0	7
8	0.46		0	7	0	6	0.13	50	0	7
9	0		0.35	7	0	6	0.04	82	0	7
10	0.01		0.03	31	0	6	0.01	130	0.512	7
11	0.04		0	49	0.472	7	0	53	0	6
12	0		0.01	18	0	9	0	19	0	6
13	0		0	9	0	6	1.00	10	0.157	6
14	0		0	7	0.236	11	0	8	0	6
15	0		0.03	6	0	15	0	7	0	6
16	0		0	398	0	8	0	7	0	6
17	0		0.05	762	0.354	21	0	7	0	5
18	0.01		0	308	0	73	0	7	0.118	5
19	0		0	83	0	85	0	6	0	5
20	0		0.02	24	0	27	0	6	0	5
21	0		0	11	0	11	0	6	0	5
22	0		0.42	9	0.236	31	0	6	0.236	5
23	0		0.14	324	0	49	0.1	6	0	4
24	0.37		0.73	568	0	17	0	6	0	4
25	0.01		0	264	0.079	8	0.44	5	0	4
26	0		0	224	0	6	0	81	0	4
27	0.01		0	64	0	5	0	140	0	4
28	0		0	22	0	5	0	42	0.394	195
29	0.01		0	21	0	5	0.11	14	0	340
30	0		0.22	148	0	5	0	7	0	95
31	0		0.3	925			0	6	0	27
Total	2.02	**814**	2.36	4357	2.085	814	1.95	790	1.85	819

Table A.24 ESTIMATED FLOW IN BLACK BAYOU FROM FLOWS AND RAIFALLS IN OTHER MONTHS AUGUST,2000

Aug-00	Aug-00	BLACK	**SEP.1992**	
DATE	RAINFALL	FLOW	RAINFALL	FLOW
1	1.1		0.12	30
2	0		0	69
3	0		0.55	208
4	0		0.04	276
5	0		0	815
6	0		0	1860
7	0		0	1501
8	0.46		0	666
9	0		0	293
10	0.01		0	141
11	0.04		0.47	76
12	0		0	55
13	0		0	45
14	0		0.24	34
15	0		0	83
16	0		0	255
17	0		0.35	231
18	0.01		0	708
19	0		0	2596
20	0		0	2311
21	0		0	1020
22	0		0.24	438
23	0		0	202
24	0.37		0	99
25	0.01		0.08	55
26	0		0	41
27	0.01		0	31
28	0		0	29
29	0.01		0	28
30	0		0	28
31	0			
Total	2.02	**14224**	2.09	14224

APPENDIX B

Reply to review comments of the draft final report

LAMAR UNIVERSITY
A Member of The Texas State University System

MEMO

To: Dr. Tommy Knowles, Deputy Executive Administrator of TWDB.
Dr. David Brock, Project Manager of TWDB contract 2000-483-322.

From: Dr. Xing Fang, Principal Investigator of TWDB contract 2000-483-322.

Date: November 28, 2000.

Subject: Reply of review comments on the draft final report.

All comments from TWDB reviewers have been considered in the revision of the final report. First, several tables with various data have been added in the final report in order to include activities from September of 1999 to August of 2000. These tables and data were in the progress reports 1 to 3 submitted to TWDB before. Other comments are addressed one by one in the followings:

(1). The contract number 200-483-322 has been added underneath "Texas Water Development Board" in the cover page.

(2). The following statements have been added in Section 3.1: "Four hydrolab Datasondes (Recorder™ - water quality multiprobe logger, serial numbers of 31810, 31811, 30609, and 30610) and necessary repairs of the Datasondes were provided by TWDB. Datasondes were activated hourly to measure water level, water temperature, dissolved oxygen, specific conductivity, and salinity. The Datasondes were deployed and maintained at sites (Johnson Bayou and Black Bayou) established by a previous cooperative project between the TWDB and Lamar University. The Datasondes were calibrated according to manufacturers instructions. Information on calibrations of the Datasondes for all installations is stored in an Access database."

(3). The following statements haven been added in the second paragraph of Section 3.1: "Since there was concern about the Hydrolab's DO performance at low flow conditions, a comparison (see section 3.2) was conducted between the YSI and Hydrolab. Datasondes typically stay in the field over one month. ...."

(4). Sentences in the introduction of Section 5 have been changed as suggested: "This study is to provide data on movement of saltwater and nutrients moving to Sabine Lake from the marsh lands on the lake's east side. Nutrients into Johnson and Black bayous of

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Sabine Lake do not come from individual point sources, and do come from nonpoint sources distributed out in the watersheds."

(5). Tables 5.1 and 5.2 have been removed. General discussion on EMC determination was rearranged.

(6). The following statements have been added to address question: "**3.3** Three possible methods to estimate flow rates in or out of bayous were investigated by the principle investigator (PI), after consultation with the project manager. First, the PI tried to develop relationships between tidal elevation and flow rate based on flow measurements in 1996, which were provided by TWDB through previous project in the study area. The relationships are very complex and could not be developed with limited available data since unsteady tidal flow is quite different from steady open channel flow. The second method is to measure flow velocities at the center of the cross section passing through the tide station during the field trips. It was found out that the flow meter used could not reliably measure them since flows in the bayous were often so slow. Results of flow measurements are documented in this section below. The third method is to estimate flow rates from the previous established rainfall and runoff relationship as discussed in the section 5.3."

(7). The sentence in the first paragraph of Section 5.3 has been changed as suggested: "The monthly or annual runoff for the 1999-2000 period was based on relationships developed from TWDB 1987-1996 data. Daily surface runoff flow data were provided by TWDB."

(8). The first sentence of Section 5.4 has been changed as suggested: "Annual nutrient input is estimated as the product of average nutrient concentration and estimated flow from bayou to Sabine Lake due to rainfalls."

(9). The sentences in the first paragraph of Section 6 have been changed as suggested: "In this study, it was assumed that nutrients are washed out from marshland into Sabine Lake through bayous by rainfall runoff. Measured nutrient concentrations during the dry period were typically very low. In order to determine annual nutrient loading, surface runoff from marshland and event mean concentrations of nutrient are needed."

Comments from the second reviewer have been considered. The following changes have been made in the final report.

(1). The following sentences have been added in Section 3.2: "Data collected by YSI probe were at the same location and depth where Datasonde was installed for each bayou." "Why did Datasonde probe measure low DO? Hydrolab Datasonde uses a steady state method to measure DO continuously, at the same time, DO sensor continuously consume oxygen around it. Therefore it requires a 1-ft/s flow to replenish oxygen to DO sensor, otherwise Datasonde intends underestimate DO concentration. YSI uses a rapid pulse method to measure DO intermittently (YSI, 1998). DO sensor is

automatically turned on for measuring DO, and then turned off for a period which provides sufficient time to allow DO diffusion towards the DO sensor."

(2). The reply for the comment (6) above answers this comment (2) too.

(3). Duplication of page numbering has been fixed.

(4). The reply for the comment (6) above answers this comment (4) too.

(5). In the Section 3.3, tables and data have been added for velocity measurements during field trips.

(6). Table number and title have been added. Tables afterwards have been renumbered.

(7). Both methods 1 and 2 were discussed clearly in Section 5.4. Section 6 "Discussion and Summary" provides further explanation on methods and difference in nutrient loading computation. "Two methods were developed to estimate surface runoff. The method 1 directly gives total (annual) daily flow from marshland from historical (1996) rainfall-runoff relationship without examining difference in rainfall events over time. The method 2 examines rainfall events month by month, and estimates monthly daily flow from historical runoff data with similar monthly rainfall. We believe that the method 2 may provide more accurate estimate in runoff flow rate. There are some differences in estimated nutrient loadings based on two estimated surface runoff volumes. The method 2 for estimating surface runoff could lead more reasonable results on nutrient loading. In order to improve accuracy in estimation of nutrient loading, advanced hydrologic model study and extensive field data collection are needed in the future."

ATTACHMENT 1
TEXAS WATER DEVELOPMENT BOARD
Review of the Draft Final Report: Contract No. 2000-483-322
"Nutrient Transport and Water Quality Monitoring in Sabine Lake Bayous"
by Dr. Xing Fang, Lamar University

There is one major topic for revision, which is needed for this report to be accepted. The final report needs to cover the entire project, not just the period since the interim report. Addressing this problem will largely mean expanding a couple of data tables, and should serve to answer some of the other reviewer's concerns, below. Detailed reviewer comments follow.

1. The cover page should give the contract number 2000-483-322 underneath "Texas Water Development Board".

2. Section 3, "Major Activities for Water Quality Monitoring" should include a statement identifying the models of instruments used and saying that the sondes and YSI meters were calibrated according to manufacturers instructions. We should also say that the Datasondes were deployed and maintained at sites established by a previous cooperative project between the TWDB and Lamar University.

3. The second paragraph of Section 3 might state that the reason the comparison was conducted between the YSI and Hydrolab was because there was concern about the Hydrolab's DO performance at low flow conditions.

4. The introduction to Section 5 should say "....nutrients moving to Sabine Lake from the marsh lands...", and "...from nonpoint sources distributed out in the watersheds...".

5. Table 5.1 and 5.2 appear to provide an example of a calculation method with data not related to the study. Because the data relate to another situation, they are a little distracting and could confuse some readers. The author might consider just removing that portion of the text.

6. The paragraph beginning on the bottom of page 6 discusses problems with flow measurements. I know that an instrument was used to try to collect flows. It appeared to me that the problem was that flows in the bayou were often so slow that the flow meter could not reliably measure them. Some indication of velocities could be given, for times when the instrument could accurately show flow. The paragraph could also report that the PI investigated the possibility of using differences between tidal elevations to estimate flow. The paragraph should state that the PI, in consultation with the project manager, decided it would be necessary to use other methods to estimate flow data.

7. The first paragraph of section 5.3 is a little misleading. It should indicate the runoff for the 1999-2000 period was based on relationships developed from TWDB 1987-1996 data.

8. The first sentence of 5.4 should read "....is estimated as the product of average nutrient....."

9. The first paragraph of Section 6 is a little unclear. I think you are saying that the source of nutrients may not be from the marshlands. Do you mean to say that often the flow of nutrients may be from Sabine Lake into the marsh, instead of from the marsh to Sabine Lake? That would be hard to be sure about, from this study, but could be stated as a possible explanation.

The following comments are based on the assumption that this report is the only report for this particular project.

1. Page 5, section 3.2: It is not clear if the Datasonde and YSI probes were used at one location or at three different locations within each bayou. If they were used at one site, an explanation of why one probe measured low DO is necessary. If they were used at separate sites, a discussion of possible causal factors for the DO would improve the report.

2. Page 6, section 3.3: One of the objectives of this study (from the scope of work) was "to collect data on nutrient transport in two bayous". It is not clear how the PI accomplished this objective without velocity measurements. Although equipment failure is sometimes a problem in field studies, there are alternative methods of estimating velocity. For example, weight change of pre-weighed lifesavers (candy) is a common boot-strap method for estimating velocity.

3. Page numbering is duplicated after the first page 6.

4. Second Page 6 (bottom line): The report states "...the difficult we had is that there **are no direct measurements** on flow, and only one measurement per month on nutrient concentrations." This appears to be a significant problem that could have been remedied during project planning.

5. Page 7 (top line): "Effort" to measure flow velocities is not evident in the report.

6. Page 13 (mid page): There is a small table in the middle of the page that requires a title and method headings.

7. Page 14: The basis for comparison between the two methods is not clear. The methods estimate significantly different inflows and loadings, but no explanation is provided to account for these differences.