

Luce Bayou Background Study
Harris County, Texas

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LUCE BAYOU BACKGROUND STUDY HARRIS COUNTY, TEXAS

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Contents

	Page
List of Figures.....	iii
List of Tables.....	iv
Executive Summary	v
1.0 INTRODUCTION.....	1-1
2.0 DESCRIPTION OF STREAM AND SAMPLING SITE	2-1
3.0 STUDY APPROACH	3-1
4.0 RESULTS.....	4-1
4.1 FLOW CONDITIONS	4-1
4.2 BACTERIA.....	4-1
4.3 DISSOLVED OXYGEN.....	4-2
5.0 DISCUSSION OF RESULTS	5-1
5.1 CURRENT WATER QUALITY CRITERIA.....	5-1
5.2 COMPARING RESULTS WITH WATER QUALITY CRITERIA	5-2
5.2.1 Bacteria	5-2
5.2.2 Dissolved Oxygen.....	5-2
5.3 EC TO FC RATIO.....	5-2
6.0 CONCLUSIONS AND RECOMMENDATIONS	6-1
7.0 REFERENCES.....	7-1

Attachment – Table 3: Sample Size and Number of Exceedances Required to Determine Nonsupport of a Use – Guidance for Assessing Texas Surface and Finished Drinking Water Quality Data, 2004 (Texas Commission on Environmental Quality)

Figures

		Page
1	Luce Bayou Watershed	2-2
2	Flow at USGS Gage 08071280 Luce Bayou above Lake Houston near Huffman.....	4-4

Tables

	Page
1 Harris County Sampling Data.....	4-3

Executive Summary

PBS&J was retained by the Harris County Storm Water Quality Section (HCSWQS) to review and document a study to assess “background” levels of indicator bacteria in a waterway draining a relatively undeveloped watershed and determine if such a stream could meet the criteria for contact recreation. HCSWQS selected Luce Bayou (Texas Commission on Environmental Quality Stream Segment [TCEQ] 1002B) as a reference stream. This stream has the least amount of urbanization of any stream in Harris County; however, the study location is somewhat impacted by discharges from the Texas East Wastewater Treatment Plant of the City of Cleveland. It is also in the backwater of Lake Houston, which should tend to allow settling and produce lower bacteria levels. HCSWQS collected 17 samples from Luce Bayou from November 2005 to March 2006 during low-flow, nonrunoff conditions.

The *E Coli* (EC) data collected meet the geometric mean criterion but not the single sample exceedance criterion for contact recreation. These criteria were developed for full-body swimming. The bacteria concentrations would likely have been more elevated if the sampling had not been restricted to low-flow conditions, because EC concentrations in runoff tend to be much higher than in base flows. The data indicate that a stream in a watershed with relatively little urbanization, sampled only during dry weather conditions and benefiting from a lake backwater effect, cannot meet the contact recreation criteria. There are also a few low dissolved oxygen measurements that may need further investigation.

HCSWQS data are slightly higher than those obtained by the City of Houston at a nearby (downstream) sampling location. The lower results obtained by the City of Houston may be due to greater backwater and settling effects of Lake Houston.

A number of recommendations are provided for further study. With regards to data collection, HCSWQS should consider using the IDEXX method for EC measurements to be consistent with the current norm of EC testing and so that data collected by HCSWQS can be compared on an equal basis with data collected by other entities. The sampling period of 5 months is relatively short. A longer monitoring period at least over two seasons and over two years would provide a more representative data set. The Texas East Wastewater Treatment Plant of the City of Cleveland is located in the upstream part of the watershed. To better understand the anthropomorphic influence at the Luce Bayou sampling site, the effect of the discharge from this plant might be investigated.

1.0 INTRODUCTION

PBS&J was retained under Harris County Purchase Order No. PO83016 to review and document two recent projects by the Harris County Storm Water Quality Section (HCSWQS): the Illicit Discharge Elimination Project (IDEP) and the associated Luce Bayou Background Study. The IDEP was developed and implemented by HCSWQS to investigate whether elimination of illicit discharges to urban waterways would measurably reduce instream indicator bacteria levels. Documentation of the IDEP is in a separate report. The Luce Bayou Background Study was conducted to assess “background” levels of indicator bacteria in a nonurban waterway. PBS&J provided independent professional review and documentation of the study methods and results.

HCSWQS conducted this study to characterize water quality in a stream in a relatively undisturbed watershed. Results of this study could help those agencies responsible for implementing future water quality improvement actions to better understand what “baseline” conditions would be and could provide a reference against which to compare streams in more urbanized areas.

2.0 DESCRIPTION OF STREAM AND SAMPLING SITE

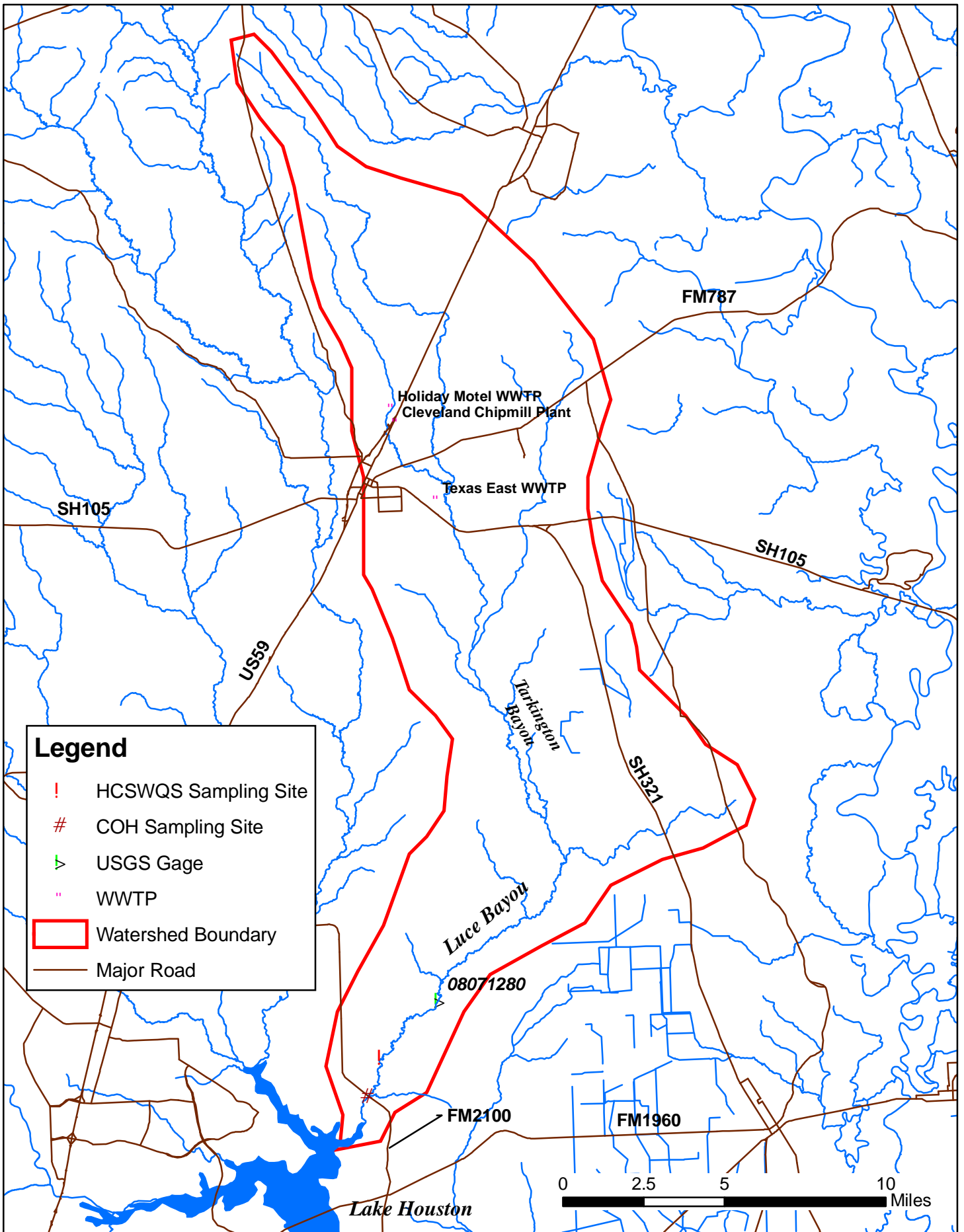
HCSWQS selected Luce Bayou (Texas Commission on Environmental Quality [TCEQ] Stream Segment 1002B) as a reference stream. The Luce Bayou watershed is shown on Figure 1. Luce Bayou is named by Texas Parks and Wildlife Department (TPWD) as an “Ecologically Significant Stream Segment” (TPWD, 2006) and considered to have high biodiversity of fish and macroinvertebrates. The following description of Luce Bayou is largely adopted from the TPWD web site.

Luce Bayou begins in Northwest Liberty County and flows southwesterly to Lake Houston. The bayou is narrow and shallow in its upper reaches, but widens and deepens downstream as it enters the backwater of Lake Houston. The sediment is mixed mud and sand, and the banks are lined with hardwood forest that provides habitat for a variety of wildlife. The bayou provides habitat for a diverse biological community of fish including perch, bluegill, and catfish.

At the sampling site this stream is wide and sluggish. HCSWQS selected this site because of its intact riparian corridor and the relative lack of anthropomorphic disturbance in the contributing drainage area. Besides the City of Cleveland (Population 7,605, 2000 Census) in the northern part of the watershed, the watershed is largely undeveloped. In the vicinity of the City of Cleveland, there are three permitted wastewater dischargers. Based on the self-reporting data in the Permit Compliance System (PCS) database (U.S. Environmental Protection Agency [EPA], 2006), one has no discharge, one has only a discharge of about 0.001 to 0.002 million gallons per day (MGD). The remaining one is the Texas East Wastewater Treatment Plant of the City of Cleveland. It has a permitted discharge of 0.95 MGD and the average discharge during the sampling period was about 0.38 MGD (0.59 cubic feet per second [cfs]). Luce Bayou has the least amount of urbanization of any stream in Harris County. HCSWQS observed that the drainage area above the sampling site is predominately timberland and rice fields. The site selected was upstream of any subdivisions in Harris County. The geographic coordinates for the HCSWQS sampling site are 30°05'4.26" north and -95°05' 23.79" east.

In addition to the site selected by HCSWQS, there is a monitoring station used by the City of Houston located at FM 2100 and a U.S. Geological Survey (USGS) flow gaging station 08071280 (Luce Bayou above Lake Houston near Huffman). The locations of these stations are also shown on Figure 1.

**FIGURE 1
LUCE BAYOU WATERSHED**



3.0 STUDY APPROACH

Water samples were planned to be taken at base flow, with a minimum of 3 days antecedent dry period. Field parameters measured included pH, dissolved oxygen (DO), temperature, and conductivity. Lab analysis was performed for fecal coliform (FC), *Escherichia coli* (EC), total suspended solids (TSS), total dissolved solids (TDS), ammonia, and sulfates. HCSWQS collected 17 samples from Luce Bayou from November 2005 to March 2006. Frequency of sampling averaged once per week.

Field sampling for all lab-tested parameters and chain-of-custody handling were conducted according to procedures documented in the TNRCC Water Quality Sampling and Shipping Procedures (2002). Analyses of parameters of interest for instream sampling followed EPA Standard Methods (40CFR Part 136). Quality control and quality assurance followed those procedures outlined in TNRCC Surface Water Quality Monitoring Procedures Manual (1999). Laboratory analysis of samples was conducted by an outside contract lab, A & B Laboratories.

This study employed Standard Method 9222G for EC analysis. In this procedure, EC data are enumerated using a nutrient agar substrate containing 4-methylumbelliferyl- β -D-glucuronide (MUG) following the FC test (APHA, 1998). In this procedure, EC are a subset of the FC rather than an independent test. In the Quality Assurance Project Plans (QAPPs) of both the Houston-Galveston Area Council's Clean Rivers Program and the Bacteria Total Maximum Daily Load (TMDL) Study for Buffalo and White Oak Bayous, the IDEXX method for EC enumeration is specified. Moreover, in the current Surface Water Quality Monitoring Procedures published by TCEQ (TCEQ, 2003), only the IDEXX method is mentioned for the analysis of EC data. Nevertheless, EC data analyzed by the MUG test is still accepted by TCEQ. More discussion will follow in Section 5.

4.0 RESULTS

4.1 FLOW CONDITIONS

The field and laboratory test results are presented in Table 1. The data show low conductivity, TDS, ammonia and sulfates, as expected for an east Texas stream with little anthropomorphic influences. The TSS levels are also relatively low since the sampling has been focused on avoiding runoff conditions. Figure 2 shows the flow recorded at the USGS gage 08071280. The gage has a drainage area of 218 square miles and is located about 3 miles upstream of the HCSWQS sampling site. Since there is no flow measurement at the HCSWQS site, the USGS gage flow was used to evaluate the flow conditions at the sampling site, and flows on the day of sampling are included in Table 1. The sampling dates are also shown on Figure 2. Twelve of the 17 samples were taken when the gaged flow was below 10 cfs. The highest flow of the sampling events was 46 cfs on December 21, 2005 and appears to be on the falling limb of a runoff event. Most of the data were collected at low flow conditions as intended. However the data collected on December 21, 2005 may have been affected by runoff conditions. It should also be noted that when the stream flow is very low, the discharge from the Texas East Wastewater Treatment Plant of the City of Cleveland (about 0.6 cfs) becomes more significant.

The average daily flow at the USGS gage for 2001–2005 is 205 cfs. The average flow for the days in which data were collected is 11 cfs, markedly lower than the long-term average.

4.2 BACTERIA

The geometric means for FC and EC are 108 cfu/100mL and 98 cfu/100mL, respectively. Note that for results below detection limit, 50% of the reporting limit is used in the calculation (TCEQ, 2004).

The City of Houston Department of Health and Human Services has also sampled Luce Bayou at a location somewhat downstream of the site HCSWQS selected (Figure 1). HCSWQS selected a more upstream location to reduce possible effects from Lake Houston and to eliminate possible influences due to several subdivisions and a golf course. The City of Houston's data used for this study were collected from June 2001 to October 2005. The IDEXX method was used for EC testing. The EC geometric mean was 75 cfu/100mL which compares very favorably to HCSWQS's data. The following table summarizes the results of the EC data from the City of Houston.

	Data Period	Number of Data	Geometric Mean (MPN/dL)	Number >394 MPN/dL
City of Houston	June 19, 2001– October 25, 2005	56	75	8

4.3 DISSOLVED OXYGEN

During November and December 2005, DO was surprisingly low. The lowest reading measured 2.21 mg/L, below the stream criterion of 5.0 mg/L. HCSWQS verified that the instrument had been properly calibrated. The City of Houston's water quality data show a higher minimum reading of 3.3 mg/L.

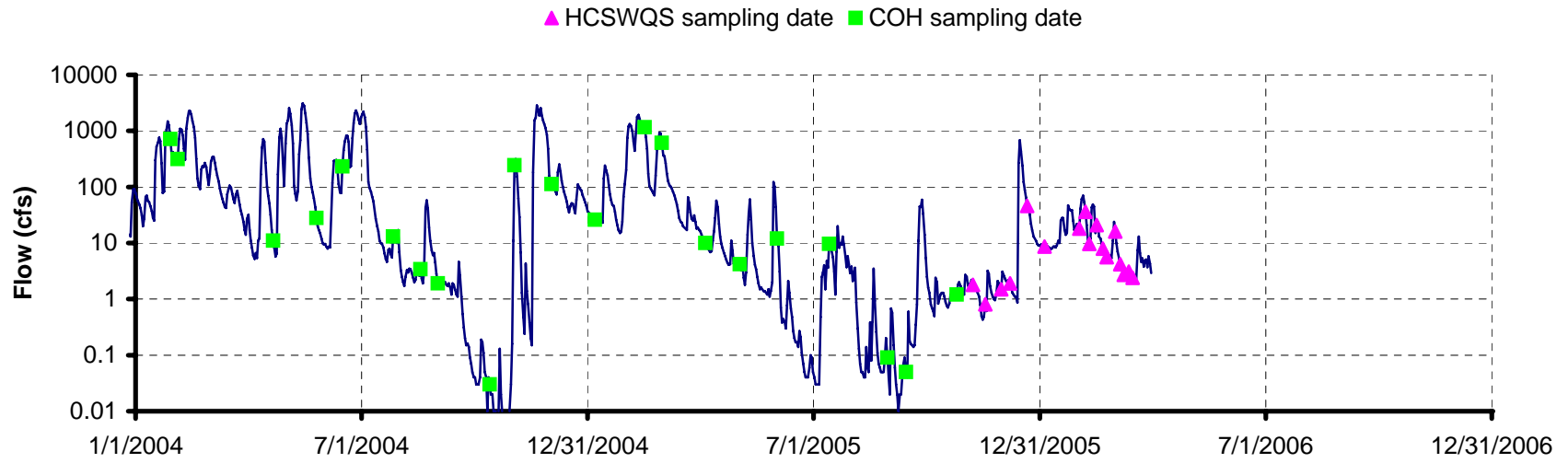
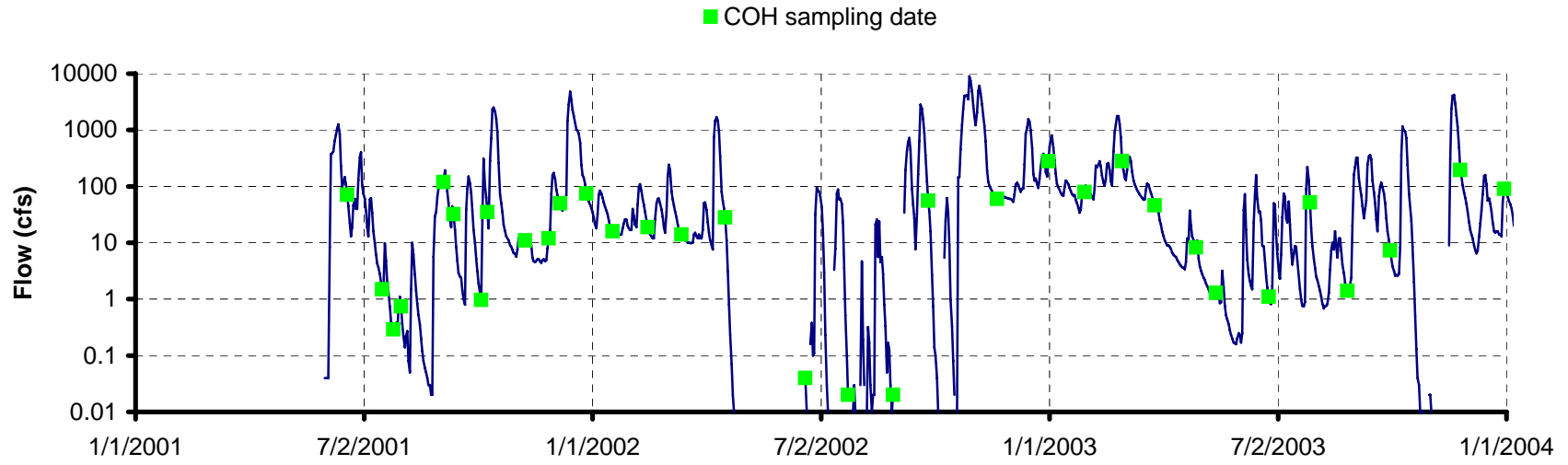
TABLE 1
HARRIS COUNTY SAMPLING DATA

Date	Time	Flow (cfs)	Temp (deg F)	DO (mg/L)	FC (cfu/dL)	EC (cfu/dL)	pH (SU)	TSS (mg/L)	TDS (mg/L)	NH3-N (mg/L)	SO4 (mg/L)	Cond (mS/cm)	Number of days since last precip
7-Nov-05	13:34	1.8	77.5	7.70	> 200	78	7.30	5.2	120	< 0.1	4.6	0.20	7
17-Nov-05	11:26	0.81	65.2	2.66	64	72	7.02	3.7	108	< 0.1	4.0	0.20	1.5
30-Nov-05	12:32	1.5	61.5	2.85	16	16	6.91	2.5	126	< 0.1	4.5	0.20	2.5
7-Dec-05	11:11	1.9	55.2	2.21	3,600	3,600	6.91	3.8	76	0.1	3.1	0.20	4
21-Dec-05	12:35	46	51.5	9.46	212	200	6.61	14.4	100	0.2	7.6	0.10	
21-Dec-05	12:35	SPLIT					20						
4-Jan-06	13:43	8.6	64.1	5.76	56	52	7.01	10.1	96	0.1	8.6	0.10	>2
1-Feb-06	9:02	18	59.5	5.02	648	580	7.00	7.80	110	< 0.1	7.6	0.20	4
6-Feb-06	13:05	36	66.4	8.11	< 4	< 4	3.55	12.2	102	0.2	5.3	0.20	>2
9-Feb-06	13:51	9.6	63.9	7.51	< 4	< 4	7.13	7.4	136	0.1	7.1	0.10	2
15-Feb-06	10:56	21	57.6	8.35	660	488	7.01	5.5	128	0.2	4.9	0.10	5
20-Feb-06	12:21	7.9	53.2	5.19	< 4	< 4	6.98	< 2.5	140	0.2	6.0	0.10	>5
23-Feb-06	10:05	5.6	59.3	5.20	4,800	4,800	7.20	20.6	116	< 0.1	5.7	0.10	>8
2-Mar-06	12:31	16	69.1	6.83	416	416	7.28	6.5	120	< 0.1	6.1	0.20	5
6-Mar-06	12:40	4.2	73.9	7.58	< 4	< 4	7.38	4.2	202	< 0.1	5.7	0.20	9
9-Mar-06	10:50	2.7	69.0	6.34	1,600	1,600	7.34	5.6	78.0	< 0.1	6.5	0.20	12
13-Mar-06	10:13	3.1	69.8	6.29	72	52	7.34	9.6	112	< 0.1	5.9	0.20	12
16-Mar-06	10:45	2.4	69.5	4.36	2,700	2,700	7.17	2.8	120	< 0.1	5.9	0.20	>2
Mean		11.0	63.9	6.0	885	862	6.89	7.2	117	0.094	5.8	0.16	
Geometric Mean					108	98							
Number of single sample exceedance					7	7							

Notes:

1. For results below detection limit, 50% of the reporting limit is used in the calculation.
2. Single sample criteria for FC and EC are 400 cfu/dL and 394 cfu/dL respectively.
3. Flow data for day of data collection are from USGS gage 08071280 about 3 miles upstream of the sampling site.

FIGURE 2
FLOW AT USGS GAGE 08071280 LUCE BAYOU ABOVE LAKE HOUSTON NEAR HUFFMAN



5.0 DISCUSSION OF RESULTS

5.1 CURRENT WATER QUALITY CRITERIA

The technical basis for the contact recreation criteria is the epidemiological studies of disease risk associated with full body contact recreation. The EPA criteria documents in both 1976 and 1986 produce recommended numerical criteria, which were developed from studies of diseases, such as gastroenteritis reported by swimmers in public lakefront swimming areas (EPA, 1976, 1986). For many years Texas employed the FC criteria recommended in the 1976 EPA document—FC geometric mean of 200 colony forming units (cfu) per 100 mL or deciliter (dL) based on at least 5 samples collected evenly within 30 days, with not more than 10% of samples exceeding 400 cfu/dL.

In 2000 Texas adopted new contact recreation criteria that were based on the 1986 EPA criteria document. The EPA criteria were developed from epidemiological studies conducted in the late 1970s of swimmers at public swimming areas that had nearby wastewater discharges.

The Texas version of these criteria for freshwater include the geometric mean EC level of 126 cfu/dL. Texas also chose a single sample “not to exceed” criterion of 394 cfu/dL. The new Texas criteria dropped the “5 samples in 30 days” requirement. If the IDEXX test procedure is employed, results are expressed as Most Probable Number (MPN/dL). The standard allows FC as an alternative indicator until sufficient data are available for EC. The geometric mean and single sample criteria for FC are 200 and 400 cfu/dL, respectively. The Texas standards also dropped the “not more than 10% >400” provision in the earlier standards.

A key point with these criteria is that they were developed from risk assessments using epidemiological data obtained under specific water quality conditions (good weather when people were engaged in recreational swimming at designated swimming beaches) while the criteria are being applied to a much wider range of waters, some of which are very different from those originally considered.

To minimize non-attainment problems, the single sample not to exceed criterion is considered violated only when individual samples exceed the criterion more than 25% of the time (TCEQ, 2004). Note that the number of exceedances required to indicate non-support for a given sample size is determined by probability theory and is not simply 25% of the number of samples (see Table 3 of TCEQ 2004 attached to this report).

The 24-hour average DO criterion for Luce Bayou is 5 mg/L, with an absolute minimum criterion of 3 mg/L. The pH range specified is 6.5–9, the maximum temperature is 90°F, the sulfate and TDS criteria are 50 and 400 mg/L, respectively.

5.2 COMPARING RESULTS WITH WATER QUALITY CRITERIA

5.2.1 Bacteria

The EC geometric mean of the data at HCSWQS site is below the geometric mean criterion. The number of single sample exceedances (7 out of 17) is at the threshold, and therefore indicates that the contact recreation use is not supported. Even if the sample collected on December 21, 2005, which might have been affected by runoff conditions were excluded, the data set would still violate the single sample exceedance criterion. The FC data also meet the geometric mean criterion but not the single sample criterion.

The site was selected as a background site, to show what might be achieved if all human caused (or urban) bacteria discharges were eliminated. It would appear that even a very undeveloped site will not meet the contact recreation criteria. Moreover, a sampling plan not targeted towards low flow during the same period would likely result in a higher geometric mean and more single sample exceedances. On the other hand, it needs to be recognized that the sampling duration is only about 5 months and does not meet TCEQ's requirements for a representative data set suitable for water quality assessment. TCEQ requires at a minimum samples distributed over at least two seasons and over 2 years (TCEQ 2004). Furthermore, it is noted that the stream is not entirely free of the influence of wastewater effluent. Another factor that needs further consideration is that the site is affected by the backwater of Lake Houston, which should tend to allow settling and produce lower bacteria observations.

The city has a longer term data set that is not targeted towards low flow conditions (sampling dates shown on Figure 2), and the site might have influences from nearby subdivisions and a golf course. With these factors, the bacteria level might be expected to be higher than that at the HCSWQS site. However, the EC geometric mean is below criterion and the number of single sample exceedances (8 out of 56) is also below the threshold for nonsupport. A probable explanation is that the city's site is further downstream, and thus has more of a lake backwater effect that promotes settling and results in lower bacteria levels.

5.2.2 Dissolved Oxygen

The 2002 Texas Water Quality Inventory documents the most recent assessment of DO level of Luce Bayou by the state. The stream was cited as having an Aquatic Life Use concern for depressed DO. In the 2006 Basin Summary Report prepared (Houston-Galveston Area Council [H-GAC], 2006), the assessment by H-GAC with instantaneous DO measurements indicates compliance with the water quality standard. Occasional low DO measurements are not uncommon in shaded, low velocity streams in east Texas (TCEQ, 2005).

5.3 EC TO FC RATIO

The older FC criterion had a geometric mean 200 cfu/dL; for EC the geometric mean criterion is 126 cfu/dL. In some cases, such as the work done at the Buffalo Bayou and White Oak Bayou TMDLs

(UH, 2005), all FC data obtained before 2001 was simply converted to EC based on the 126:200 ratio, i.e., 0.63. The ratio of EC geometric mean to FC geometric mean was found to be 0.91 in this study.

Jensen and Lee (2005) compared parallel FC and EC data collected in different parts of the state for different reasons. The data include both freshwater, saline water, and waters with varying degrees of wastewater input. The EC data are results of the IDEXX method. One of their findings is that the EC/FC ratio tends to be close to the ratio of the criteria values (126/200 or 0.63) when there is little wastewater present. When there is a high degree of wastewater influence, the ratio tends to be on the order of 3 or more. However, EC data from the MUG test should always give EC/FC ratio less than one. It appears that the more wastewater influence a waterbody is subjected to, the more likely the two EC test methods would give different results.

6.0 CONCLUSIONS AND RECOMMENDATIONS

Luce Bayou was selected by HCSWQS as a reference stream against which to compare additional cleanup efforts for streams in more urbanized areas. HCSWQS collected a set of data during a 5-month period targeted towards low flow (nonrunoff) conditions. The EC data collected in this manner meet the geometric mean criterion but not the single sample exceedance criterion. The bacteria concentrations would likely have been more elevated if the sampling had not been restricted to low-flow conditions and if the site was not in the backwater of Lake Houston. The data indicate that even a stream in a watershed with relatively little urbanization still cannot meet the contact recreation criteria. There are also a few low DO measurements that may need further investigation. Recommendations for further study are as follows.

With regards to data collection, HCSWQS should consider using the IDEXX method to be consistent with the current norm of EC testing so that data collected by HCSWQS can be compared on an equal basis with data collected by other entities. It is not expected that the change would have a large effect on this watershed since the wastewater contribution appears to be small, but it would likely raise the EC values and make demonstration of criteria attainment less likely. The instrument reading scale should be adjusted for conductivity data to provide more resolution. The reporting limit for ammonia data should be lowered for the results to be useful for nutrient analysis.

The sampling period of 5 months is relatively short. A longer monitoring period, at least over two seasons and over two years, would provide a more representative data set.

To verify the relative lack of anthropomorphic influence in Luce Bayou, the effect of the discharge from the Texas East Wastewater Treatment Plant of the City of Cleveland might be investigated in more detail. It is not expected that this would change the results, but if a longer term study were planned, this effort should be considered.

7.0 REFERENCES

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Attachment – Table 3

**Sample Size and Number of Exceedances
Required to Determine Nonsupport of a Use –
Guidance for Assessing Texas Surface and Finished
Drinking Water Quality Data, 2004 (Texas Commission
on Environmental Quality)**

Table 3. Sample Size and Number of Exceedances Required to Determine Nonsupport of a Use

(Error rates for sample sizes greater than 20 are provided in Appendix B.)

Minimum number of exceedances chosen to give a less than 20% probability of falsely classifying water body as not supporting when actually fully supporting.			
Sample Size (n)	Minimum Number of Exceedances Required (e)	Exact Binomial Type I Error Rate Assuming 25% Actual Exceedance Rate	Exact Binomial Type II Error Rate Assuming 26% Actual Exceedance Rate
20	8	10.2	41.6
19	7	17.5	41.6
18	7	13.9	41.1
17	7	10.7	40.8
16	6	18.9	40.7
15	6	14.8	40.3
14	6	11.2	40.1
13	6	8	39.5
12	5	15.8	39.1
11	5	11.5	38.7
10	5	7.8	37.7

Flow Conditions

Streams are routinely monitored under highly variable flow conditions—from extreme low flows that typically occur in late summer months following extended dry periods, to high flows that follow seasonal storm events. Water quality criteria and screening levels generally apply to flowing streams as long as flow exceeds the seven-day, two-year low flow (7Q2). *Low-flow criteria* (7Q2) are calculated from historical USGS stream flow records and are available for most classified streams in Appendix B of the TSWQS. In places where low-flow criteria are not available, they may be approximated from a downstream gaged site, or from one located in a nearby watershed of similar size.

Many small, unclassified streams in Texas develop intermittent stream flow in summer months and eventually become completely dry, while others maintain perennial pools when flow is interrupted. The decision matrix that follows (page 13) was developed for this guidance to explain which dissolved oxygen, toxic substances in water, and bacteria criteria apply under different flow conditions.