Appendix F. Water Quality Data

Assessment Methodology

To assess the current state of the watershed, 1998-2003 water quality data were analyzed, primarily from the Texas Commission on Environmental Quality (TCEQ) database, which includes data collected by state agencies, river authorities, county and local governments and volunteer citizen monitors. From the data set, the following key parameters were chosen for this watershed analysis:

- Salinity
- Dissolved oxygen
- Chlorophyll-a
- Nutrients
- Fecal coliform bacteria
- Water clarity (turbidity)
- Sediment chemistry
- Fish kill data

The water quality data were partitioned into seven distinct reaches of Armand Bayou. Four are on the mainstem:

- Mud Lake (the lower tidal reach downstream of the confluence with Horsepen Bayou to the Nasa Parkway bridge)
- Middle Tidal (from the confluence with Horsepen Bayou to the confluence with Big Island Slough, including Bay Area Boulevard and Bay Area Park)
- Upper Tidal (near Oil Field Road)
- Above Tidal (near Genoa-Red Bluff Road)

The other three reaches represent major tributaries:

- Spring Gully
- Big Island Slough
- Horsepen Bayou

Because the data was not consistently collected in all reaches of the bayou or for all parameters of interest, the number of samples available for analysis is indicated for each parameter and reach. The only data available for Spring Gully since 1998 are a few samples from the special study in 1999, so it is not included in the discussions. In addition to this compilation of current data, the entire period of record was analyzed to see if any discernable trends could be identified in the individual reaches for the parameters considered.

Salinity

Salinity is the measure of the amount of dissolved salts in a solution. Salinity is usually determined indirectly by measuring a physical property such as electrical conductivity, which is the ability of a solution to carry an electrical current, and is measured in µmhos/cm. The salt content of freshwater is generally described in terms of its conductivity, which is usually less than 1000 µmhos/cm. Salt water is usually described in terms of its salinity. Salinity is less than 1 part per thousand (ppt) in fresh water and about 35 ppt in the Gulf of Mexico.

The average surface salinity for Mud Lake was 6.7 ppt and it was 2.0 ppt for the Middle Tidal reach. Maximum surface salinities for these two areas reached 20.6 ppt and 12.2 ppt for Mud Lake and Middle Tidal, respectively. Surface waters in the Upper Tidal and above tidal areas had variable conductivity values below 800 µmhos/cm, which is normal for freshwater streams. Big Island Slough and Horsepen Bayou had conductivity values indicating periods of freshwater up to one sample in Horsepen Bayou with a conductivity of 9600 µmhos/cm, which corresponds to a salinity of 5.5 ppt. (Table 1) Essentially, the data show that Armand Bayou is a freshwater to low salinity system.

Dissolved Oxygen

At normal saturation levels, the concentration of dissolved oxygen in Galveston Bay is between 7 and 9 mg/L, depending on water temperature and salinity. Several factors can change the dissolved oxygen levels, however. If excess algal growth occurs, very high dissolved oxygen concentrations (up to 15 or even 20 mg/L) may result. This happens when a great deal of photosynthesis takes place in the water, typically in sunny, warm conditions with high concentrations of nutrients that will allow excess algal growth.

Table 1. Surface (0.3 m depth) conductivity and salinity data from Armand Bayou from 1998 to 2003, where n is the number of measurements

		Specific Conductance (µmhos/cm)				Salinity (ppt)			
	Reach	Avg	n	min	max	Avg	n	min	max
1	Mud Lake	11030	35	372	32800	6.7	34	0.8	20.6
2	Middle Tidal	2669	63	154	20300	2.0	33	0.2	12.2
3	Upper Tidal	424	6	327	544	0.4	5	0.2	1.0
4	Above Tidal	506	27	100	800				
6	Big Island Slough	987	3	503	1940				
7	Horsepen Bayou	1777	79	158	9600				

Conversely, much lower dissolved oxygen levels can occur if there is high oxygen demand (e.g. unusually high numbers of organisms and algae) in the water. If the dissolved oxygen becomes very low (e.g. < 2 mg/L), then many aquatic organisms will not be able to survive. One instance where dissolved oxygen levels may become very low in a water body is at night if an algal bloom occurs, because the algae and the fish that feed on them are still using oxygen at night when no photosynthesis takes place. With their high daytime production and high nighttime oxygen demand, algal blooms cause a large diurnal swing in dissolved oxygen. In some cases these dissolved oxygen swings can be extreme enough to cause large fish kills.

In estuarine tributaries, the water is generally stratified, or layered, meaning that the deeper waters and the shallow waters are not well mixed. Much of this stratification is due to salinity, because high salinity water is heavier than lower salinity water. When possible, dissolved oxygen is measured at the surface (0.3 meters) and at various depths in the water column because significant differences in dissolved oxygen levels may occur at different depths if the layers are not well mixed. If the water is very shallow or if a dissolved oxygen meter with a cable is not available, the dissolved oxygen will just be measured at the 0.3-meter depth. To present this data on Armand Bayou, the surface (0.3 m) samples were compiled separately because they were available for each sampling event and they can be compared directly to one another. The limited data available on the deeper layers of the water column was compiled separately and is shown in the following table in the row below the surface data. The deeper parts of the water column generally had lower dissolved oxygen levels than the surface.

Overall, dissolved oxygen was lowest in the Upper Tidal reach, averaging 4.4 mg/L at the surface and 3.5 mg/L in the profile measurements (Table 2). Three of the six surface readings and nine of the 14 profile readings were below 4 mg/L, which is the TCEQ water quality standard for this segment. (Two of those nine profile readings would have been excluded from assessment based on temperature stratification.) The limited 24-hour monitoring (from continuously recording meters deployed overnight) also shows that this area has chronically low dissolved oxygen in the warmer months.

Oxygen levels in Mud Lake, Horsepen Bayou, and the Middle Tidal reaches were generally high, with only a few surface readings that fell below 4 mg/L (4% in Horsepen and Middle Tidal). The 24-hour monitoring also shows this pattern in the middle and lower tidal reaches.

Chlorophyll-a

Chlorophyll-a is typically used to measure the relative levels of phytoplankton in the water. Pheophytin-a is also sometimes measured, as it is "recently dead" chlorophyll. Sometimes the combination of these values is a better measure of the overall trophic condition (ability to support the food web) of a water body.

Average chlorophyll values were highest in Mud Lake, Middle Tidal, and Horsepen Bayou reaches, where the dissolved oxygen levels were also very high (Table 3). In the trend analysis, it appears that overall chlorophyll-a is decreasing, while pheophytin-a is increasing, however in the Mud Lake reach both chlorophyll and pheophytin may be increasing. Declines in chlorophyll-a are observed in many other areas of the Galveston Bay system as well. Effects of the declining chlorophyll-a concentrations on higher levels of the food chain are not yet known. Increases in chlorophyll-a appear to occur only in areas identified as eutrophic.

Table 2. Dissolved oxygen readings from Armand Bayou from 1998 – 2003, where n is the number of measurements

Reach		Dissolved Oxygen (mg/L)							
(depth of samples)		Avg	n	min	max	Below 4 mg/L		Above 10 mg/L	
1	Mud Lake (0.3 m)	8.6	35	5.1	14.8	0	0%	7	20%
	Mud Lake (0.6 - 2.1 m)	7.2	16	4.9	10.0	0	0%		
2	Middle Tidal	8.8	82	3.0	21.6	3	4%	23	28%
	Bay Area Blvd (1.1 - 2.7 m)	6.1	33	0.2	13.1	7	21%	0	0%
3	Upper Tidal	4.4	6	2.5	7.9	3	50%	0	0%
	Upper Tidal (0.6 - 3.0 m)	3.5	14	0.9	7.6	9	64%		
4	Above Tidal	6.2	38	3.3	9.1	7	18%	0	0%
6	Big Island Slough	8.1	3	7.2	8.6	0	0%	0	0%
	Big Island Slough (0.6 - 1.5 m)	6.1	3	4.9	7.1	0	0%	0	0%
7	Horsepen Bayou	7.8	99	2.5	15.0	4	4%	20	20%
	Horsepen Bayou (0.9 - 2.7 m)	6.0	9	0.5	12.2	3	33%	0	0%

Nutrients

Total phosphorus and ammonia values tended to be highest in Horsepen Bayou, while Mud Lake and Middle Tidal had relatively high phosphorus concentrations (Table 4). Average ammonia was generally low in the other reaches.

Fecal Coliform Bacteria

Based upon the screening level, fecal coliform bacteria counts were high in about 20% of the samples considered here, with no obvious differences between the reaches (Table 5). Table 5 presents fecal coliform data from Armand Bayou (1998 - 2003) compared to the TCEQ water quality screening level. The current assessment guidance lists a waterbody as impaired for bacteria if >25% of the samples exceed the screening level.

Water Clarity (Turbidity)

Water clarity averaged a little lower in the Mud Lake and Middle Tidal reaches than the other reaches (Table 6). Total suspended solids were also highest in Mud Lake and Middle Tidal. The trend analysis indicated that water clarity (secchi depth) in Horsepen Bayou appears to have shown some improvement from 1990 to the present.

Sediment Contaminants

Sediment was sampled for metals only twice in 2002 by the TCEQ. Copper, cadmium, mercury, zinc, lead and arsenic did not exceed any state screening levels. However, chromium and nickel slightly exceeded the state 85th percentile at the Middle Tidal station in one of the two samples. Barium exceeded the state 85th percentile at the Upper Tidal station in both of the samples. The 85th percentile is a value computed from the TCEQ database that is higher than 85% of the samples collected from tidal streams. A sample that exceeds the this number is relatively high but will not necessarily cause adverse effects. While nickel, chromium and barium exceeded the 85th percentile, they did not exceed any effects-based screening levels.

Fish Kill Data

TPWD maintains an inventory of fish kills and pollution complaints in its Pollution Response Inventory and Species Mortality (PRISM), with records existing as early as the 1970's. (Records from the 1970's and early 1980's may be incomplete.) Fish Kill and pollution events in the Armand Bayou watershed are investigated by staff from TPWD's Dickinson office, often in collaboration with TCEQ staff.

TPWD records indicated that seven fish kills have been recorded in the Armand Bayou watershed since 1971.

Table 3. Chlorophyll-a and pheophytin a values from Armand Bayou (1998-2003), where n is the number of measurements.

		Chlorophyll-a (µg/L)				Chlorophyll-a + Pheophytin a			
	Reach	Avg	n	min	max	Avg	n	min	max
1	Mud Lake	38.3	24	1	135	77.7	24	8.4	344.0
2	Middle Tidal	27.3	28	1	69.4	58.0	28	6.9	189.4
3	Upper Tidal	10.5	7	1	26	33.7	7	13.1	57.4
4	Above Tidal		0						
6	Big Island Slough	9.2	5	1	25.8	33.8	5	5.0	94.8
7	Horsepen Bayou	23.7	12	1	79.2	46.8	12	4.2	101.5

Table 4. Ammonia and phosphorus concentrations in Armand Bayou (1998 - 2003), where n is the number of measurements.

		Ammonia (mg/L)				Phosphorus (mg/L)			
	Reach	Avg	n	min	max	Avg	n	Min	max
1	Mud Lake	0.08	23	0.05	0.26	0.43	23	0.21	0.78
2	Middle Tidal	0.11	55	0.01	0.64	0.42	33	0.15	0.90
3	Upper Tidal	0.09	11	0.01	0.17	0.18	11	0.07	0.35
4	Above Tidal	0.12	11	0.01	0.35	0.19	5	0.10	0.40
5	Spring Gully	0.11	5	0.01	0.19	0.05	5	0.01	0.11
6	Big Island Slough	0.07	5	0.05	0.15	0.24	5	0.21	0.30
7	Horsepen Bayou	0.26	74	0.01	2.28	1.37	19	0.24	4.20

Table 5. Fecal Coliform values in Armand Bayou (1998 - 2003)

		Fecal Coliform, cfu/100ml				(Screening Level 400 cfu/100mL)	
	Reach	Average	N	Minimum	Maximum	# Exceeds	% Exceeds
1	Mud Lake	1167	32	10	30500	5	16%
2	Middle Tidal	1162	42	9	34000	9	21%
3	Upper Tidal	226	4	18	490	1	25%
4	Above Tidal	4023	2	45	8000	1	50%
6	Big Island Slough	50	2	27	72	0	0%
7	Horsepen Bayou	995	40	10	12000	10	25%

Table 6. Secchi and total suspended solids (TSS) data for Armand Bayou (1998 - 2003)

		Secchi (meters)				TSS (mg/L)			
	Reach	Avg	n	min	max	Avg	n	min	max
1	Mud Lake	0.34	31	0.15	0.7	45	24	19	99
2	Middle Tidal	0.32	50	0.15	3.5	36	42	4	90
3	Upper Tidal	0.55	4	0.2	1.02	21	6	12	35
4	Above Tidal	0.52	32	0.2	0.8	11	7	4	22
6	Big Island Slough	0.48	3	0.4	0.52				
7	Horsepen Bayou	0.54	29	0.2	1.15	16	81	1	62

Table 7. Historical fish kills in the Armand Bayou watershed

Start Date	Exact Location Name	Est. Total Killed	Cause	Event Description
4-20-71	Middle Bayou (Armand Bayou) from Bay Area Blvd. to Spring Gully.	500	Low Dissolved Oxygen	Approximately 500 fish were found dead in Middle Bayou (Armand Bayou).
7-30-79	Big Island Slough - One half mile East and one-half mile West of Red Bluff	352	Low Dissolved Oxygen	Fish kill in Big Island Slough, Harris County.
10-16-81	Drainage ditch in Brookforest subdivision — where ditch enters Horsepen Bayou	204	Low Dissolved Oxygen	Two hundred and four fish were killed in a drainage ditch in Brookforest subdivision.
01-25-97	Armand Bayou between Bay Area (above) and the golf course (below).	210	Cold front / freeze	An estimated 200 gar, less than 10 catfish, and some sunfish were observed dead in Armand Bayou, Harris County, Texas.
02-06-97	Drainage ditch that goes into Horsepen Bayou at Brook Forest Subdivision.	157	Unknown	
12-12-97	Spencer Highway and Big Island Slough	19,568	Gasoline	A spill of unleaded gasoline into Big Island Slough caused a fish kill of sunfish, largemouth bass, bullhead catfish, striped mullet, blue crab, crayfish, and minnows.
05-20-99	Willow Spring Creek downstream of Pasadena Blvd. to Canada Street.	182	Low Dissolved Oxygen	A fish kill occurred in Willow Spring creek due to low dissolved oxygen.