Total Maximum Daily Loads for Dioxins in the Houston Ship Channel

Contract No. 582-6-70860
Work Order No. 582-6-70860-02

Quarterly Report No.3

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PREPARED IN COOPERATION WITH THE
TEXAS COMMISSION ON ENVIRONMENTAL QUALITY AND
U.S. ENVIRONMENTAL PROTECTION AGENCY

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UNIT SYMBOLS, ABBREVIATIONS, AND CONVERSIONS

Symbol or abbreviation	Text	Unit Equivalence	Unit Type
^{o}C	degrees Celsius		temperature
kg	kilograms	10^{3} grams	mass
g	grams	454 grams ~ 1 pound	mass
mg	milligrams	10^{-3} grams	mass
µg	micrograms	10^{-6} grams	mass
ng	nanograms	10^{-9} grams	mass
pg	picograms	10^{-12} grams	mass
fg	femtograms	10^{-15} grams	mass
L	liter	3.78 liters ~ 1 gallon	volume
mL	milliliter	10^{-3} liters	volume
mBq	millibecquerel	27 microcuries (mCi)	radioactivity
µg/L	micrograms per liter	~10^{-9}, or 1 ppb	mass/volume concentration
ng/L	nanograms per liter	~10^{-12}, or 1 ppt	mass/volume concentration
pg/L	picograms per liter	~10^{-15}, or 1 ppq	mass/volume concentration
ng/kg	nanograms per kilogram	=10^{-12}, or 1 ppt	mass/mass concentration
mg/g	milligrams per gram	10^{-3}	mass/mass concentrations
g/cm^{2}	gram per square centimeter		cumulative mass
mBq/g	millibecquerel per gram		radioactivity
ppm	parts per million	10^{-6}	unitless concentration
ppb	parts per billion	10^{-9}	unitless concentration
ppt	parts per trillion	10^{-12}	unitless concentration
pq	parts per quadrillion	10^{-15}	unitless concentration

CHAPTER 1

INTRODUCTION

1.1 OVERALL DESCRIPTION OF THE DIOXIN PROJECT

Dioxins, such as polychlorinated dibenzo-*p*-dioxins (PCDDs), dibenzofurans (PCDF), and polychlorinated biphenyls (PCBs), are halogenated aromatic compounds that are extremely persistent in the environment and can affect human health at low concentrations. The PCDDs include 75 congeners, and PCDFs include 135 different congeners. Only 7 out of the 75 congeners of PCDDs are thought to have dioxin-like toxicity. There are 209 PCB congeners out of which 13 are identified as dioxin-like compounds. These dioxin-like compounds are highly toxic and persistent environmental contaminants, and, consequently, they have received a great deal of attention by environmental regulators and researchers.

Dioxins (term used to refer to dioxin-like compounds) have been found likely to present a cancer hazard to humans[1] and can cause health problems even at low doses. Reproductive problems, behavioral abnormalities, and alterations in immune functions are among the health effects caused by exposure to dioxin. As a result of dioxin found in seafood organism tissue, a seafood consumption advisory for catfish and blue crabs was issued by the Texas Department of Health in September 1990 for the upper portion of Galveston Bay and the Houston Ship Channel.

The overall purpose of this project is to develop a Total Maximum Daily Load (TMDL) allocation for dioxin in the Houston Ship Channel System, including upper

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[1] U.S. Environmental Protection Agency (2000). "Dioxin: Scientific Highlights from Draft Reassessment." *Information Sheet 2*, National Center for Environmental Assessment, Office of Research and Development, Washington, DC.

Galveston Bay, and a plan for managing dioxins to correct existing water quality impairments and to maintain good water quality in the future.

There are six main tasks to be completed for this Work Order:

1. Project administration.
2. Amend current Quality Assurance Project Plan (QAPP) to incorporate additional data collection.
3. Conduct dioxin monitoring and data collection in the Houston Ship Channel area.
4. Incorporate collected data into dioxin TMDL models.
5. Participate in stakeholder involvement with the dioxin TMDL project.
6. Estimate TMDL allocations.

1.2 DESCRIPTION OF THE REPORT

This document constitutes the third quarterly report for Work Order No. 582-6-70860-02 (Contract No. 582-6-70860) of the Dioxin TMDL Project and summarizes the activities undertaken by the University of Houston, in conjunction with Parsons during the period March 1, 2006, to May 31, 2006. The report presents all the sampling data gathered in the project to date.

1.3 PROBLEM STATEMENT

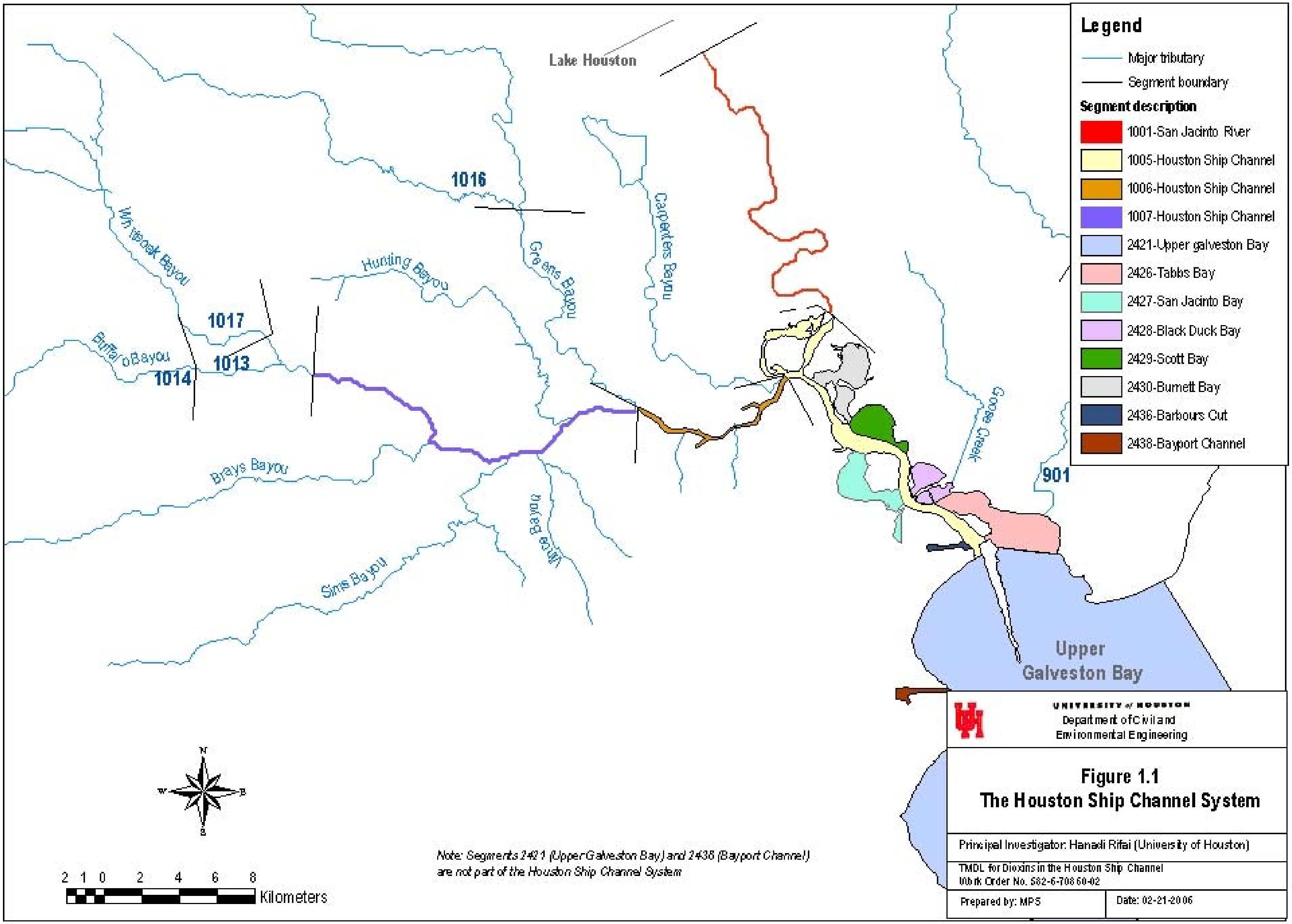
Section 303(d) of the Clean Water Act requires all states to identify waters that do not meet, or are not expected to meet, applicable water quality standards. For each listed water body that does not meet a standard, states must develop a total maximum daily load (TMDL) for each pollutant that has been identified as contributing to the impairment of water quality in that water body. The Texas Commission on Environmental Quality (TCEQ) is responsible for ensuring that TMDLs are developed for impaired surface waters in Texas. The ultimate goal of these TMDLs is to restore the quality of the impaired water bodies.

1.4 PROJECT DESCRIPTION

The dioxin TMDL study has been divided into various phases. Phase I of the TMDL was focused on assessing current conditions and knowledge. Phase II was focused on gathering data in all media to quantify dioxin levels in the channel and their sources. Phase III is focused on model development and load allocation.

1.5 DESCRIPTION OF HOUSTON SHIP CHANNEL SYSTEM

The Houston Ship Channel (HSC) system is a network of bodies of water in the vicinity of Houston, Texas (see Figure 1.1). This system is located in the San Jacinto River Basin. The designated water quality segments that comprise the "enclosed" portion of the HSC include the San Jacinto River Tidal (Segment 1001), HSC (Segments 1005, 1006, and 1007), Buffalo Bayou (Segments 1013 and 1014), Greens Bayou Above Tidal (Segment 1016), Whiteoak Bayou Above Tidal (Segment 1017), Tabbs Bay (Segment 2426), San Jacinto Bay (Segment 2427), Black Duck Bay (Segment 2428), Scott Bay (Segment 2429), Burnett Bay (Segment 2430), and Barbours Cut (Segment 2436). The HSC dioxin-impaired segments listed on the 303(d) list include 1001, 1005, 1006, 1007,



Note: Segments 2421 (Upper Galveston Bay) and 2438 (Bayport Channel) are not part of the Houston Ship Channel System

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Figure 1.1
The Houston Ship Channel System

Principal Investigator: Hanadi Rifai (University of Houston)

TMDL for Dioxins in the Houston Ship Channel
Work Order No. 582-6-70860-02

Prepared by: MPS

Date: 02-21-2006

2426, 2427, 2428, 2429, 2430, and 2436. The system does not include portions of the Ship Channel located in Galveston Bay. However, for the purpose of this TMDL study, the Upper Galveston Bay (Segment 2421) is also included. It is important to note also that Segment 2438 (Bayport Channel) was added to the 303(d) list because of high levels of dioxins after the initiation of this TMDL; therefore, this segment does not form part of this study.

The designated uses assigned to the segments that comprise the HSC system and Upper Galveston Bay, according to the Texas Surface Water Quality Standards, are found in Texas Water Code §26.023.

1.6 DESCRIPTION OF THE SEAFOOD CONSUMPTION ADVISORY AND MOTIVATION FOR THE TMDL STUDY

Because dioxin-like compounds have been proven to bioaccumulate in biological tissue, particularly in animals, the major route of human exposure is through the food chain. Thus, several food advisories have been issued across the United States to prevent people from consuming high doses of these compounds. Section 307.6 of the Texas Surface Water Quality Standards establishes numerical criteria for specific toxic substances. For human health protection, the numerical criteria for dioxins are 1.34×10^{-7}, 1.40×10^{-7}, and 9.33×10^{-8} μg Texas-TEQ/L for water and fish, freshwater fish only, and saltwater fish only, respectively.

A seafood consumption advisory for catfish and blue crabs in the upper portion of Galveston Bay and the Houston Ship Channel (HSC) was issued by the Texas Department of Health in September 1990 as a result of dioxin found in organism tissue.

Due to this, the HSC system was placed on the 303(d) list and a TMDL study was initiated. The overall purpose of this project is to develop a total maximum daily load (TMDL) allocation for dioxin in the Houston Ship Channel System, including upper Galveston Bay, and a plan for managing dioxins to correct existing water quality impairments and maintain good water quality in the future.

1.7 DESCRIPTION OF THE TEF/TEQ METHODOLOGY

The 31 dioxin-like compounds are often found in complex mixtures. For risk assessment purposes, a toxicity equivalency procedure was developed to describe the cumulative toxicity of these mixtures[2]. This procedure involves assigning individual toxicity equivalency factors (TEFs) to the CDD, CDF, and PCB congeners. Considered most toxic of the dioxin-like congeners is 2,3,7,8-TCDD, assigned a TEF of 1.0. All other congeners have lower TEF values ranging from 0.00001 to 0.5 (Table 1.1), with the exception of 1,2,3,7,8-PeCDF that is assigned a TEF of 1 in the WHO_{98} methodology. To calculate the toxic equivalency (TEQ) of a mixture, the concentration of individual congeners is multiplied by their respective TEF, and the sum of the individual TEQs is the TEQ concentration for the mixture. This is described mathematically as follows:

$$TEQ = \sum_{i=1}^{n} (Congener_i \cdot TEF_i) \qquad (1.1)$$

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[2] Environmental Protection Agency (2000). "Exposure and Human Health Reassessment of 2,3,7,8-Tetrachlorodibenzo-p-Dioxin (TCDD) and Related Compounds. Part I: Estimating Exposure to Dioxin-Like Compounds. Volume: Sources of Dioxin-Like Compounds in the United States." *EPA600/P-00/001Ab*.

Table 1.1 The Toxicity Equivalent Factors (TEF) for Different TEQ Schemes

Compound	I-TEQ$_{DF}$	TEQ$_{DFP}$-WHO$_{94}$	TEQ$_{DFP}$-WHO$_{98}$	Texas TEQ
2,3,7,8-TCDD	1	1	1	1
1,2,3,7,8-PeCDD	0.5	0.5	1	0.5
1,2,3,4,7,8-HxCDD	0.1	0.1	0.1	0.1
1,2,3,6,7,8-HxCDD	0.1	0.1	0.1	0.1
1,2,3,7,8,9-HxCDD	0.1	0.1	0.1	0.1
1,2,3,4,6,7,8-HpCDD	0.01	0.01	0.01	
OCDD	0.001	0.001	0.0001	
2,3,7,8-TCDF	0.1	0.1	0.1	0.1
1,2,3,7,8-PeCDF	0.05	0.05	0.05	0.05
2,3,4,7,8-PeCDF	0.5	0.5	0.5	0.5
1,2,3,4,7,8-HxCDF	0.1	0.1	0.1	0.1
1,2,3,6,7,8-HxCDF	0.1	0.1	0.1	0.1
1,2,3,7,8,9-HxCDF	0.1	0.1	0.1	0.1
2,3,4,6,7,8-HxCDF	0.1	0.1	0.1	0.1
1,2,3,4,6,7,8-HpCDF	0.01	0.01	0.01	
1,2,3,4,7,8,9-HpCDF	0.01	0.01	0.01	
OCDF			0.0001	
PCB-77		0.0005	0.0001	
PCB-81		-	0.0001	
PCB-105		0.0001	0.0001	
PCB-114		0.0005	0.0005	
PCB-118		0.0001	0.0001	
PCB-123		0.0001	0.0001	
PCB-126		0.1	0.1	
PCB-156		0.0005	0.0005	
PCB-157		0.0005	0.0005	
PCB-167		0.00001	0.00001	
PCB-169		0.01	0.01	
PCB-170		0.0001	-	
PCB-180		0.00001	-	
PCB-189		0.0001	0.0001	

Since 1989, three different TEF schemes have been used for evaluating the TEQ of CDDs, CDFs, and dioxin-like PCBs. To differentiate the scheme used to quantify a TEQ, the EPA in its Dioxin Exposure Assessment adopted the following nomenclature:

$I\text{-}TEQ_{DF}$

This abbreviation refers to the International TEF scheme described by the EPA in 1989[3]. This scheme assigns TEF values for the 7 dioxins (CDDs) and 10 furans (CDFs). In the abbreviation, "I" represents "International," TEQ refers to the 2,3,7,8-TCDD Toxic Equivalence of the mixture, and the subscript DF indicates that only dioxins and furans are included in the TEF scheme. This abbreviation is often shortened to I-TEQ, where it is understood that the mixture refers to both dioxins and furans.

$I\text{-}TEQ_{DFP}\text{-}WHO_{94}$

This abbreviation refers to the 1994 World Health Organization (WHO) extension of the TEF scheme to include 13 dioxin-like PCBs[4]. It is noted that the TEFs for dioxins and furans remain as established by EPA in 1989. In this abbreviation, the subscript DFP indicated that dioxins, furans, and PCBs are included in the TEF scheme. If only one or two kinds of compounds are included in a mixture, the subscript should change to reflect the ones that are being considered for evaluating the TEQ. The subscript 94 indicates the year in which the changes to the TEF scheme were made.

$TEQ_{DFP}\text{-}WHO_{98}$

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[3] Environmental Protection Agency (1989).

[4] Ahlborg et al, 1994

This abbreviation refers to the 1998 re-evaluation of the previously established TEFs by the World Health Organization[5]. Again, the subscript DFP indicates the presence of the three dioxin-like groups in the mixture; the absence of one of the groups would be reflected by the omission of the respective subscript. The TEFs for 1,2,3,7,8-PeCDD, OCDD, and PCB-77 were changed, a TEF for PCB-81 was added, and TEFs for PCB-170 and PCB-180 were set to zero. The Texas TEQ excludes 1,2,3,4,6,7,8-HpCDD; OCDD; 1,2,3,4,6,7,8-HpCDF; 1,2,3,4,7,8,9-HpCDF; OCDF; and PCBs. For the remaining congeners it assumes the same values given in the WHO_{94} scheme.

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[5] Van der Berg, 1998

CHAPTER 2

DIOXIN IN AMBIENT WATER OF THE HOUSTON SHIP CHANNEL SYSTEM

2.1 METHODS

2.1.1 Sampling Procedures

Since dioxin concentrations in water are typically lower than the analytical detection limit, water sampling was conducted using the high-volume technique. For this research, a commercially available high-volume sampling system (Infiltrex 300, Axys Environmental Systems, Sydney, BC) was used. Using this technique allows concentrating PCDD/PCDFs from large volumes of water to obtain measurable quantities. The high-volume system uses a four-inch 1μm-glass fiber filter (GFF) cartridge followed by a stainless steel column packed with hydrophobic polymeric resin beads (XAD-2) through which large volumes of water can be passed. Because PCDD/PCDFs are very hydrophobic, they rapidly sorb to the resin, making it possible to completely collect the dissolved PCDD/PCDFs from the sampled water. The PCDD/PCDFs can then be recovered from the GFF and resin by extraction with a nonpolar organic solvent. Water was pumped at a rate of about 1.6 L/min., and the volume of water processed varied between 300 and 750 L. This allowed for reporting limits ranging between 0.013 and 0.033 pg/L for 2378-TCDD. Additional grab water samples were collected and analyzed for total organic carbon (TOC), dissolved organic carbon (DOC), total suspended solids (TSS), and total dissolved solids (TDS). Sampling collection and handling followed the requirements set forth in the approved Quality Assurance project Plans (QAPPs).

2.1.2 Sampling Locations

A total of 47 stations in the Houston Ship Channel (HSC), Upper Galveston Bay, and major tributaries were sampled (1 to 6 times) between Summer 2002 and Fall 2004. Figure 2.1 shows the locations that were sampled to quantify PCDD/PCDFs in water. Three sampling events were undertaken during WO4: Summer 2002 (July 25-September 11), Fall 2002 (October 21-December 10), and Spring 2003 (April 30-June 17), while two events were completed during WO7: Spring 2004 (March 9-April 29) and Fall 2004 (October 20-December 1). In addition, during Summer 2004, water samples were collected from four locations (WO7). Sampling dates were selected to evaluate seasonal differences, if any, in the measured concentrations. Table 2.1 summarizes the total number of dioxin water samples collected in this project.

2.1.3 Analytical Methods

PCDDs and PCDFs in water samples were quantified by high-resolution gas chromatography/high resolution mass spectrometry (HRGC/HRMS) using EPA Method 1613B at PSC/Maxxam Analytical. Resin and filters from water samples were homogenized, spiked with 15 $^{13}C_{12}$-labeled PCDD/PCDF internal standards, and mixed with sodium sulfate, allowing 12-24 hours to dry. Subsequently, the samples were extracted for 18-24 hours using methylene chloride: hexane (1:1) in a Soxhlet extractor

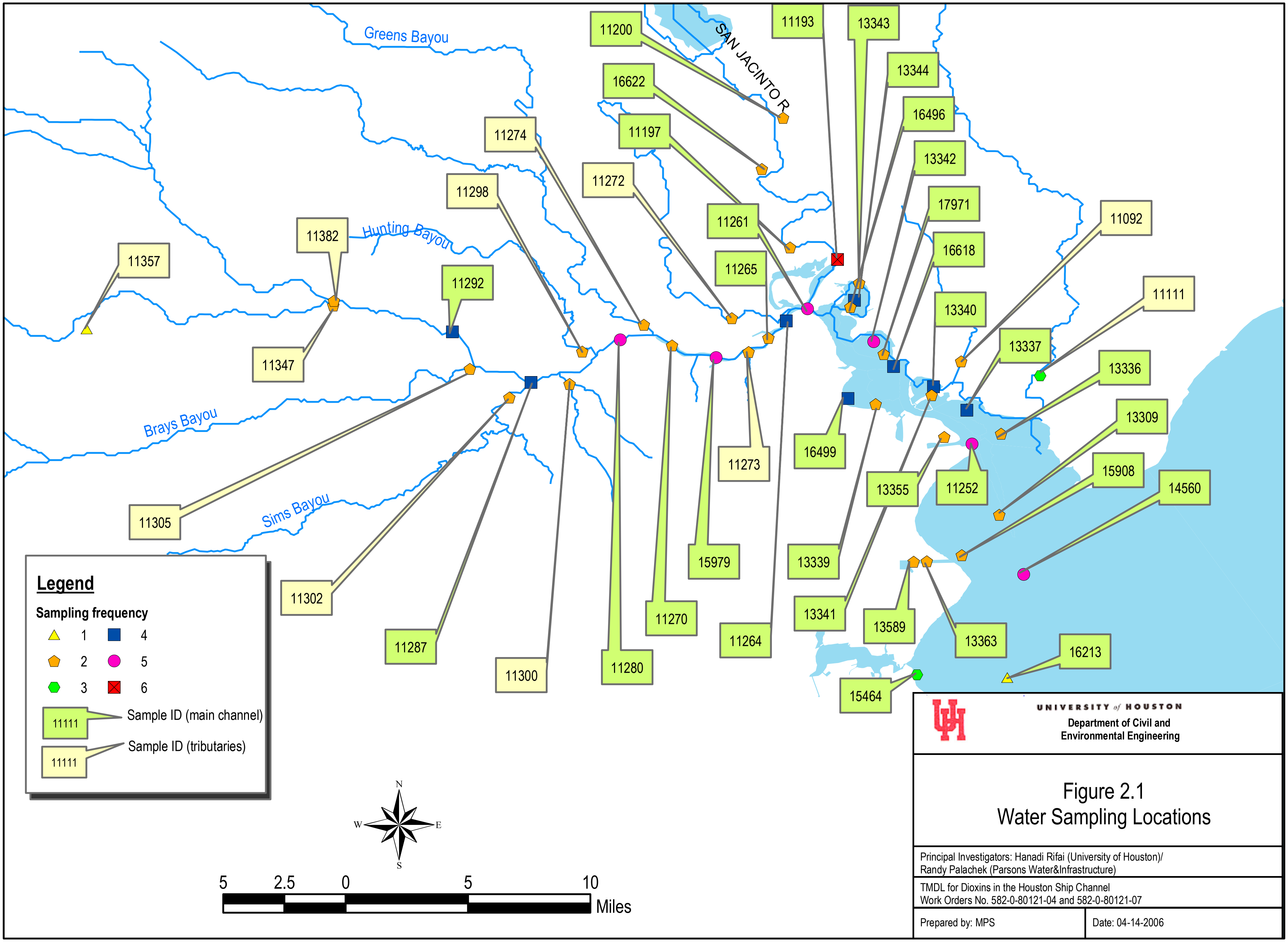

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Figure 2.1
Water Sampling Locations

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TMDL for Dioxins in the Houston Ship Channel
Work Orders No. 582-0-80121-04 and 582-0-80121-07

Prepared by: MPS

Date: 04-14-2006

Table 2.1 Number of Dioxin Water Samples

Sampling Event	**XAD Resin**			**QFF Filter**		
	# sites	**QC samples**[a]	**total # samples**	**# sites**	**QC samples**[a]	**total # samples**
Summer 2002	33	7	40	33	5	38
Fall 2002	18	5	23	18	3	21
Spring 2003	20	3	23	20	2	22
Spring 2004	28	5	33	28	4	32
Summer 2004	2, 2(2)[b]	2	8	2, 2(2)[a]	2	8
Fall 2004	28	3	31	28	3	31
Totals			*158*			*152*

[a] Field duplicates, field blanks and recovery columns specified in the QAPP.

[b] 2 sites were sampled at 2 depths (surface and bottom).

and the extract was evaporated to dryness. The extracts were then spiked with 2378-TCDD-$^{37}C_{l4}$ enrichment efficiency standard and subjected to an acid/base wash, and multiplayer silica, alumina and carbon column cleanup procedures to remove interferences from the extracts. After cleanup, the extracts were concentrated to near dryness and spiked with recovery standards (1234-TCDD-$^{13}C_{12}$ and 123789-HxCDD-$^{13}C_{12}$) immediately prior to injection. Chromatographic separation was achieved with a DB-5, capillary chromatography column (60 m, 0.25 mm i.d., 0.25 μm film thickness). A second column DB-225 (30 m, 0.25 mm i.d., 0.25 μm film thickness) was used for confirmation of TCDF identification.

Physical properties of water samples were analyzed at North Water District Laboratory Services (NWDLS) using standard methods (U.S. Environmental Protection Agency, 1983) as follows: TDS EPA 160.1, TSS EPA 160.2, TOC EPA 415.2, and DOC EPA 415.2. Standard field parameters (temperature, pH, salinity, and conductivity) were measured using a YSI multiparameter probe (model 6920 or 600XLM).

2.2 QUALITY CONTROL

Field duplicates and blanks were collected at a frequency of 5% or higher and 4% or higher, respectively, and processed in an identical manner to samples. In addition, laboratory duplicates and blanks were run at a frequency of 5%. Overall, when detected, both field and laboratory blanks showed levels below 5% of the levels in the samples. Results obtained from the duplicate samples were consistent and in agreement with the method requirements for the different congeners. Recoveries for 2,378-substituted congeners ranged from 72% to 92% with an average of 81 %. QC data are included in Appendix A. Non-detects were assumed to be equal to half of the detection limit for total equivalence quotient (TEQ) calculations and summary statistics.

2.3 RESULTS

Table 2.2 provides a summary of the physical properties of water-column samples collected along with the high-volume samples.

A summary of PCDD/PCDF concentrations in water samples collected in this project and the resulting Texas-TEQ levels are provided in Table 2.3. It is noted that PSC/Maxxam Analytical reported dissolved (XAD-resin) and suspended (filter) levels on a mass basis (in picograms); thus, dissolved and suspended concentrations were calculated by dividing those results by the sampled volume and by then adding them up to obtain the total concentration in water presented in Table 2.3. Maps illustrating total TEQ concentrations in water for the sampling events conducted in WO4 and WO7 are shown in Figures 2.2 and 2.3, respectively. Overall, dioxin concentrations in water for Summer 2002 varied between 0.06 and 0.76 pg TEQ/L with an average value of 0.271 pg TEQ/L. Samples for the Fall 2002 sampling varied between 0.07 and 2.67 pg TEQ/L with an average value of 0.572 pg TEQ/L. Dioxin concentrations in water collected during Spring 2003 varied between 0.07 and 3.09 pg TEQ/L with a mean value equal to 0.39 pg TEQ/L. For water samples collected in Spring 2004, dioxin concentrations varied between 0.089 and 1.252 pg TEQ/L with an average value of 0.409 pg TEQ/L. Finally, dioxin concentrations in water samples collected in Fall 2004 varied between 0.075 and 0.877 pg TE/L with an average value of 0.34 pg TEQ/L. It is noted that dioxin levels in water exceeded the water quality standard (0.0933 pg TEQ/L) in 82% of the locations sampled in Summer 2002, 89% of the locations sampled in Fall 2002, 95% of the locations sampled in Spring 2003, 94% of the locations sampled in Spring 2004, and 94% of the locations sampled in Fall 2004. The highest TEQ levels in the Summer 2002

Table 2.2 Physical Characteristics of Water Samples

Station ID	Date	Time	TSS (mg/L)	TDS (mg/L)	TOC (mg/L)	DOC (mg/L)	POC (mg/L)[a]
Summer 2002							
11111	07/31/2002	13:30	413	10418	N/A	N/A	
13341	08/06/2002	18:08	18	11258	N/A	N/A	
11193	08/07/2002	17:44	23.2	6773	N/A	N/A	
13340	08/09/2002	19:17	24.4	13663	N/A	N/A	
13337	08/13/2002	18:30	42	12459	N/A	N/A	
16499	08/14/2002		23	18879	47.4	41.1	
13339	08/16/2002	18:05	16	7715	19.6	12.4	
13339	08/16/2002	18:05	14	7766	18.8	12.1	
13355	08/17/2002	17:00	16	9046	33.7	21.5	
13589	08/18/2002	16:35	20	11511	42.2	37.9	
11261	08/19/2002	16:20	16	3558	33.2	32.5	
13343	08/20/2002	18:20	31	4549	34.9	33.3	
13344	08/21/2002	14:20	6	4498	28.2	26.4	
16496	08/22/2002	15:32	13	4448	27.5	26	
13342	08/23/2002	15:25	15	5113	25.9	25	
13337	08/24/2002	18:30	30	9783	26.4	14.5	
13309	08/25/2002	14:01	25	10091	25.9	14.7	
13338	08/26/2002	15:20	34	8410	28.2	25.8	
16618	08/26/2002	15:45	12	5423	27.5	26.6	
11264	08/27/2002	15:05	21	6564	27.1	26.9	
15979	08/28/2002	13:30	17	4476	25.9	25.9	
11270	08/28/2002	14:56	19	4368	25.1	24.7	
13336	08/29/2002	16:00	88	11187	34.3	30.6	
15908	08/29/2002	15:45	40	13050	17.3	17.2	
11252	08/30/2002	16:15	28	12060	39.2	36	
11252	08/30/2002	16:15	24	12062	33.4	32.3	
11287	08/30/2002	17:10	26	1769	30.7	29	
13363	08/31/2002	15:05	42	14105	N/A	N/A	
17971	08/31/2002	15:20	40	9325	N/A	N/A	
11200	09/02/2002	14:50	21	156	8.97	8.45	
16622	09/02/2002	15:30	22	1085	27	24.8	
11292	09/03/2002	16:10	16	3595	41.1	39.8	
11292	09/03/2002	16:10	17	3786	41.8	39.7	
14560	09/04/2002	15:30	46	16933	41	38.2	
11280	09/04/2002	15:15	19	9312	44.4	43.1	
16213	09/10/2002	16:40	25	15532	24.3	19.9	
15464	09/11/2002	14:30	23	8134	25.3	22.2	
Fall 2002							
11261	10/21/2002	14:15	18	9362	13.7	10.7	
13341	10/24/2002	11:10	16	11934	23.2	21.1	
13342	10/29/2002	16:24	12	1246	N/A	N/A	
16499	10/30/2002	09:40	48	290	N/A	11.5	
13363	10/31/2002	13:55	40	2047	8.98	5	
15979	11/01/2002	13:00	71	191	9.8	9.4	
13336	11/05/2002	16:30	69	315	21.6	21.1	
11280	11/06/2002	14:45	32	172	15.9	N/A	
11292	11/07/2002	14:45	31	171	71.6	N/A	
13344	11/08/2002	14:45	15	822	18.4	17.3	

Table 2.2 Physical Characteristics of Water Samples

Station ID	Date	Time	TSS (mg/L)	TDS (mg/L)	TOC (mg/L)	DOC (mg/L)	POC (mg/L)[a]
13355	11/11/2002	13:00	90	1641	20.3	17.5	
13338	11/12/2002	15:30	42	3546	20.2	19.4	
14560	11/13/2002	16:40	25	3561	22.3	20.2	
14560	11/13/2002	16:40	25	3609	21.2	20.2	
11252	11/14/2002	13:38	19	6638	29.4	25.7	
17971	11/18/2002		22	4592	21.7	19.2	
17971	11/18/2002		22	4459	21.2	18.6	
15464	11/19/2002		17	3041	20.6	18.4	
11193	11/20/2002	12:00	25	619	25.4	23.3	
11200	11/21/2002		35	120	12.9	9.5	
Spring 2003							
13342	05/13/2003	15:00	25	11848	35.8	23.4	
13339	05/14/2003	15:30	21	13579	24.8	24.3	
13343	05/15/2003	16:30	27	11203	23.8	21.4	
13589	05/16/2003	14:15	16	15628	26.4	23.9	
13337	05/19/2003	16:00	45	12752	35.1	30.1	
13340	05/20/2003	15:00	23	13696	24.5	21.3	
16618	05/21/2003	15:00	23	14976	19.8	13.5	
11252	05/22/2003	15:00	17	17579	23.3	23	
11252	05/22/2003	15:00	20	17233	21.7	20.6	
15908	05/27/2003	15:30	22	19682	30.7	26.1	
13309	05/28/2003	15:20	21	20720	27.9	26.8	
11261	05/29/2003	15:10	12	14383	48	30.8	
16496	05/30/2003	16:20	22	14909	29	24.9	
11264	06/02/2003	15:00	12	13582	25.2	24	
16622	06/03/2003	15:00	15	4857	25.6	23.6	
11193	06/04/2003	15:30	23	11994	25.1	22.1	
15464	06/05/2003	14:00	44	17569	26.6	21.1	
14560	06/09/2003	15:00	19	22031	28.2	23.5	
11280	06/11/2003	15:00	7	10676	25	22.6	
11287	06/17/2003	15:00	22	1113	12.4	10.8	
11270	06/18/2003	10:15	13	4580	26	22.9	
Spring 2004							
13340	03/09/2004	15:15	32	5316	29.4	24.2	
11252	03/10/2004	16:35	15	8858	25.8	21.5	
14560	03/11/2004	15:35	25	8777	24.0	21.1	
13342	03/12/2004	16:15	17	4876	24.2	21.5	
16499	03/16/2004	14:50	9	4154	28.3	25.8	
16618	03/17/2004	15:10	14	5752	29.4	25.6	
13338	03/18/2004	13:30	59	6153	27.0	24.6	
13344	03/19/2004	14:00	9	3948	25.6	24.2	
11193	03/23/2004	15:20	20	2503	22.2	20.9	
11193-dup	03/23/2004	15:20	19	2505	23.0	20.8	
11197	03/24/2004	15:10	21	366	15.8	13.7	
11261	03/25/2004	15:10	25	5472	34.0	26.2	
11264	03/26/2004	13:37	22	4557	26.2	24.3	
11265	03/30/2004	15:25	34	4051	25.4	23.6	
15979	03/31/2004	15:30	36	3611	20.8	20.4	
15979-dup	03/31/2004	15:30	35	3586	21.4	20.7	

Table 2.2 Physical Characteristics of Water Samples

Station ID	Date	Time	TSS (mg/L)	TDS (mg/L)	TOC (mg/L)	DOC (mg/L)	POC (mg/L)[a]
11280	04/01/2004	15:16	15	2805	20.9	20.0	
11287	04/02/2004	15:42	24	1766	21.6	19.4	
11300	04/08/2004	14:30	16	717	18.2	18.0	
11292	04/09/2004	16:00	21	678	16.8	16.2	
11272	04/13/2004	16:15	87	238	15.3	13.4	
11305	04/15/2004	16:20	15	341	10.7	9.9	
11302	04/16/2004	14:45	17	223	15.8	15.1	
11298	04/20/2004	15:40	23	2637	14.9	12.8	
11274	04/21/2004	15:15	30	2596	16.2	13.8	
11347	04/22/2004	15:10	27	461	11.0	10.4	
11347-dup	04/22/2004	15:10	29	462	11.7	10.8	
11382	04/23/2004	15:30	19	560	11.2	10.1	
11111	04/27/2004	16:08	39	9280	27.8	20.2	
11092	04/28/2004	16:10	66	4020	24.4	20.8	
11273	04/29/2004	16:30	23	5760	23.6	14.7	
Summer 2004							
11193-sh	08/03/2004	12:50	16	9996	38.5	38.0	
11193-de	08/03/2004	13:40	22	12491	28.7	26.4	
11193-sh	08/03/2004	18:00	7	6676	29.8	26.6	
11193-de	08/03/2004	18:00	31	12676	26.8	25.8	
15979-sh	08/05/2004	09:31	35	12554	29.3	27.2	
15979-de	08/05/2004	09:31	36	14141	29.0	28.2	
15979-sh	08/05/2004	15:00	27	12566	32.4	30.4	
15979-de	08/05/2004	15:00	97	14016	71.6	40.0	
11142	08/19/2004	10:00	92	461	9.0	8.2	
11142	08/19/2004	16:10	83	457	9.3	8.1	
11357	08/31/2004	10:30	142	272	10.2	9.3	
11357	08/31/2004	18:00	68.4	273	9.9	9.4	
Fall 2004							
11292	10/19/2004	[b]	5.0	6869	6.36	6.02	29.10
11287	10/20/2004	[b]	4.5	8248	7.75	7.44	23.00
11280	10/21/2004	[b]	4.5	12638	5.55	5.38	21.30
11347	10/22/2004	[b]	40.5	476	5.84	5.75	7.89
15979	10/25/2004	[b]	8.0	9862	6.20	5.81	18.60
15979-dup	10/25/2004	[b]	9.5	9540	5.80	5.75	17.50
11265	10/26/2004	[b]	15.5	13304	5.87	5.68	20.10
11264	10/27/2004	[b]	11.0	14217	5.80	5.54	15.40
11261	10/28/2004	[b]	12.0	14624	5.66	5.66	16.20
11197	10/29/2004	[b]	4.0	10143	7.76	7.36	22.50
11193	11/03/2004	[b]	6.0	8016	7.50	7.35	13.40
11193-dup	11/03/2004	[b]	8.8	8358	7.41	7.38	10.70
11111	11/04/2004	[b]	33.6	6802	6.84	6.62	4.00
13344	11/05/2004	[b]	4.8	8716	6.39	6.35	12.40
11382	11/08/2004	[b]	15.0	434	6.80	6.80	12.10
14560	11/09/2004	[b]	14.5	19607	4.37	4.13	7.20
11302	11/10/2004	[b]	8.5	2617	9.54	9.31	10.70

Table 2.2 Physical Characteristics of Water Samples

Station ID	Date	Time	TSS (mg/L)	TDS (mg/L)	TOC (mg/L)	DOC (mg/L)	POC (mg/L)[a]
11305	11/11/2004	[b]	11.5	1828	6.02	5.75	7.70
11298	11/12/2004	[b]	5.0	6022	6.86	6.79	16.30
16618	11/15/2004	[b]	11.5	18407	4.50	4.46	5.52
16499	11/16/2004	[b]	9.5	19389	4.41	4.38	5.03
13340	11/17/2004	[b]	8.5	18953	4.60	4.41	16.10
13338	11/18/2004	[b]	26.5	13033	5.00	4.96	5.03
11252	11/19/2004	[b]	13.0	8149	5.67	5.51	7.47
11272	11/22/2004	[b]	50.0	1419	11.70	10.70	3.54
11274	11/23/2004	[b]	266.0	151	8.70	7.59	2.36
11274	11/24/2004	[b]	124.0	162	11.70	10.40	2.76
11300	11/29/2004	[b]	5.5	355	7.21	7.18	22.70
11092	11/30/2004	[b]	74.0	547	12.90	12.80	4.93
11273	12/01/2004	[b]	33.0	3842	6.75	6.68	<1
13342	12/02/2004	[b]	9.5	4354	7.42	7.27	9.48

N/A=measurement not available

[a] POC was analyzed to aid in partitioning calculations but was not reported to TRACS

[b] Sample was a composite of equal-size grabs (300 mL) collected every hour throughout the duration of sampling

dup = duplicate sh=shallow de=deep

▨ Tributary

🟨 Sample exceeded holding time (7 days). Value considered an estimate. Data not reported to TRACS

Table 2.3 Total Dioxin Concentrations in Water (pg/L) 1

Station ID	Date	Volume (L)	2,3,7,8-TCDD	1,2,3,7,8-PeCDD	1,2,3,4,7,8-HxCDD	1,2,3,6,7,8-HxCDD	1,2,3,7,8,9-HxCDD	1,2,3,4,6,7,8-HpCDD	OCDD	2,3,7,8-TCDF	1,2,3,7,8-PeCDF	2,3,4,7,8-PeCDF	1,2,3,4,7,8-HxCDF	1,2,3,6,7,8-HxCDF	2,3,4,6,7,8-HxCDF	1,2,3,7,8,9-HxCDF	1,2,3,4,6,7,8-HpCDF	1,2,3,4,7,8,9-HpCDF	OCDF	Total TEQ	Average TEQ[a]
Summer 2002																					
11111	07/31/2002	510	0.1078	< 0.0525	0.1235	0.2000	0.4353	6.941	166.67	0.3216	0.0614	0.0308	< 0.0620	< 0.0863	0.0476	< 0.0112	< 0.6647	0.0480	< 2.765	0.2667	0.2667
13341	08/06/2002	528	0.0506	< 0.0142	< 0.0201	< 0.0381	0.0663	1.307	21.78	0.1364	0.0203	< 0.0170	< 0.1004	< 0.0379	0.0259	0.0119	< 0.1591	< 0.0182	< 0.610	0.0998	0.0998
11193	08/07/2002	455	< 0.3407	< 0.0371	< 0.0451	< 0.0336	< 0.0374	< 1.077	27.47	1.0769	0.0481	< 0.0314	< 0.2308	< 0.0527	< 0.0371	< 0.0411	< 0.1956	0.0681	< 0.925	0.4661	0.4661
13340	08/09/2002	542	< 0.0386	< 0.0247	< 0.0185	0.0959	0.0996	1.125	11.62	0.2915	0.0688	< 0.0620	0.2515	< 0.1358	0.1201	0.0245	< 2.2860	0.0323	< 0.282	0.1510	0.1510
13337	08/13/2002	505	0.1743	< 0.0507	0.0792	< 0.1168	0.2277	5.248	97.03	0.4178	0.0335	< 0.0251	< 0.0851	< 0.0416	< 0.0448	< 0.0475	< 0.5109	0.0598	< 2.495	0.2874	0.2874
16499	08/14/2002	547	0.2413	< 0.0373	0.0448	< 0.0713	< 0.0713	1.810	30.53	0.5466	0.0475	< 0.0512	0.0896	< 0.0399	0.0402	< 0.0287	< 0.5119	0.0258	< 1.645	0.3655	0.3655
13339	08/16/2002	579	0.2884	0.0396	0.0639	0.1002	0.1744	4.093	72.88	0.8981	0.0760	0.0864	0.1468	0.0777	0.0829	0.0415	0.8981	0.0881	5.665	0.5137	0.5137
13355	08/17/2002	688	0.1119	0.0205	0.0538	0.0738	0.1468	3.343	61.48	0.3459	0.0384	0.0407	0.0677	0.0372	0.0424	0.0193	0.4869	0.0349	2.599	0.2231	0.2231
13589	08/18/2002	534	< 0.0124	0.0225	0.0434	0.0506	0.1212	2.331	66.57	0.1049	0.0242	0.0270	0.0303	0.0281	0.0309	0.0142	< 0.2036	0.0169	< 0.753	0.0745	0.0745
11261	08/19/2002	542	0.2269	0.0297	0.0609	0.0923	0.1458	4.077	84.50	0.7380	0.0923	0.0756	0.1273	0.0572	0.0701	0.0389	< 1.0738	0.0738	8.635	0.4173	0.4173
13343	08/20/2002	706	0.1119	0.0251	0.0626	0.0831	0.1510	4.616	171.13	0.3272	0.0477	0.0538	0.0882	0.0501	0.0585	0.0227	< 0.7535	0.0492	3.293	0.2381	0.2381
13344	08/21/2002	709	0.1904	< 0.0202	0.0394	0.0642	0.1100	2.581	67.70	0.4937	0.0451	0.0465	0.0776	0.0492	0.0536	0.0274	0.5275	0.0447	3.498	0.3150	0.3150
16496	08/22/2002	731	0.2134	0.0230	< 0.0436	0.0715	0.1245	2.866	76.33	0.5609	0.0465	0.0451	0.0895	0.0520	0.0602	0.0264	0.5540	0.0518	3.707	0.3520	0.3520
13342	08/23/2002	536	0.2537	0.0306	0.0591	0.0961	0.1847	4.254	67.72	0.7090	0.0597	0.0597	0.1006	0.0647	0.0623	0.0317	0.8004	0.0688	4.631	0.4327	0.4327
13337A	08/24/2002	534	0.1966	0.0384	0.0787	0.1253	0.2790	5.993	144.01	0.5768	0.0625	0.0524	0.1176	0.0689	0.0524	0.0311	< 0.8652	0.0727	8.146	0.3781	0.3781
13309	08/25/2002	548	0.0974	< 0.0204	< 0.0580	0.0922	0.1757	2.807	81.04	0.2609	0.0367	< 0.0341	0.0440	< 0.0670	< 0.0505	0.0246	< 0.4465	0.0454	2.411	0.1976	0.1976
16618	08/26/2002	515	0.1981	< 0.0192	< 0.0367	0.0699	0.1283	2.709	63.69	0.6019	0.0454	0.0489	0.0672	0.0454	< 0.0517	0.0221	< 0.5631	0.0462	< 3.340	0.3347	0.3347
13338	08/26/2002	548	0.1569	0.0292	0.0591	0.1215	0.2445	4.982	108.58	0.4453	0.0474	0.0423	0.0887	0.0642	0.0637	0.0259	< 0.6624	0.0453	3.942	0.3064	0.3064
11264	08/27/2002	296	0.2703	< 0.0274	< 0.0338	0.0845	0.1186	2.635	61.49	0.8108	0.1057	0.0669	0.1970	0.0740	0.0655	0.0507	< 1.0203	0.0777	10.946	0.4639	0.4639
15979	08/28/2002	538	0.5019	0.0229	0.0357	0.0948	0.0948	3.086	58.55	1.5985	0.0781	0.0632	0.1375	0.0781	0.0743	0.0405	< 1.2454	0.0762	< 14.126	0.7642	0.7642
11270	08/28/2002	512	0.2051	< 0.0191	0.0289	< 0.0789	0.0877	3.008	71.09	0.7031	0.0482	0.0486	0.1131	0.0545	0.0539	0.0307	< 0.6641	0.0406	2.949	0.3548	0.3548
13336	08/29/2002	515	0.2621	0.0425	0.0812	0.1883	0.4117	6.738	173.01	0.7126	0.0654	0.0604	0.1229	0.0845	< 0.0744	0.0406	1.0330	0.0806	6.757	0.4881	0.4881
15908	08/29/2002	509	< 0.0862	< 0.0161	< 0.0320	0.0674	0.1558	3.018	73.65	0.2358	0.0251	0.0218	0.0525	0.0385	0.0312	0.0165	0.3829	< 0.0326	< 2.403	0.1618	0.1618
11252	08/30/2002	722	< 0.1163	0.0215	0.0343	0.0698	0.1537	2.812	73.96	0.3296	0.0337	0.0360	0.0546	0.0398	0.0332	0.0183	0.4515	0.0375	3.047	0.2056	0.2056
11287	08/30/2002	530	< 0.0172	0.0149	< 0.0209	0.0636	< 0.0760	1.979	29.26	0.1019	0.0266	< 0.0277	0.0519	< 0.0479	< 0.0517	< 0.0279	< 0.5894	< 0.0315	< 1.549	0.0706	0.0706
17971	08/31/2002	506	0.1660	0.0123	0.0190	0.0453	0.0751	1.700	43.87	0.4565	0.0338	0.0348	0.0583	0.0350	0.0364	0.0182	0.4150	0.0375	3.128	0.2656	0.2656
13363	08/31/2002	555	< 0.0539	< 0.0123	< 0.0263	0.0528	0.1209	2.243	69.96	0.1423	0.0187	0.0193	0.0281	0.0261	< 0.0220	< 0.0124	< 0.2661	0.0245	< 1.541	0.1074	0.1074
11200	09/02/2002	507	< 0.0101	0.0136	0.0286	0.0694	0.1233	3.144	129.98	0.0418	0.0122	0.0146	0.0223	0.0207	0.0233	0.0225	< 0.2387	0.0418	< 0.586	0.0572	0.0572
16622	09/02/2002	527	< 0.0161	< 0.0133	< 0.0281	0.0689	0.0860	3.226	126.57	0.0588	0.0152	< 0.0156	< 0.0298	< 0.0194	< 0.0201	< 0.0125	< 0.2112	< 0.0093	< 0.552	0.0580	0.0580
11292	09/03/2002	716	< 0.0324	0.0226	0.0246	0.0648	0.0613	1.936	35.34	< 0.1285	0.0372	0.0503	0.0437	0.0359	< 0.0475	< 0.0169	< 0.0147	< 0.0169	< 0.957	0.0974	0.0888
11292-dup	09/03/2002	610	< 0.0223	0.0238	0.0269	0.0608	< 0.0634	1.854	34.89	0.1098	0.0302	< 0.0387	0.0449	< 0.0277	0.0515	0.0180	< 0.4092	0.0230	< 0.941	0.0803	
11280	09/04/2002	509	0.2259	< 0.0183	< 0.0202	0.0472	< 0.0511	1.690	30.26	0.5894	0.0489	0.0375	0.0713	0.0287	< 0.0314	< 0.0145	< 0.3395	< 0.0299	< 1.690	0.3395	0.3395
14560	09/04/2002	603	0.0501	0.0158	0.0340	0.0735	0.1405	2.970	81.09	0.1111	0.0199	0.0163	0.0347	0.0260	0.0226	0.0104	0.2504	0.0199	1.489	0.1124	0.1124
16213	09/10/2002	638	0.0815	0.0333	0.0771	0.1534	0.2888	5.887	127.10	0.1737	0.0246	0.0276	0.0519	0.0350	0.0321	0.0051	< 0.5530	0.0407	2.702	0.1949	0.1949
16213-dup	09/10/2002	697	0.0637	< 0.0222	< 0.0565	0.0977	< 0.2215	4.416	106.74	0.1435	0.0255	0.0189	0.0489	0.0428	0.0366	0.0133	< 0.4428	< 0.0329	< 1.762	0.1506	0.1506
15464	09/11/2002	660	< 0.0214	0.0177	0.0309	0.0682	0.1152	2.955	63.94	0.0485	0.0223	< 0.0185	0.0392	0.0515	0.0430	0.0136	< 0.4470	0.0311	1.091	0.0715	0.0859
15464-dup	09/11/2002	702	0.0291	0.0256	0.0432	0.1095	0.1731	3.756	72.38	0.0660	0.0029	< 0.0229	0.0406	0.0376	0.0380	0.0042	< 0.5368	0.0432	1.514	0.1002	
Fall 2002																					
11261	10/21/2002	424	< 0.2241	< 0.0151	< 0.0238	< 0.0427	0.0693	1.979	56.84	0.5472	0.0274	< 0.0283	0.0653	< 0.0245	< 0.0153	< 0.0083	< 0.3892	< 0.0335	< 4.080	0.2988	0.2988
13341	10/24/2002	715	< 0.0685	0.0161	0.0376	0.0635	0.1147	2.783	67.27	0.1650	0.0165	0.0236	0.0466	0.0215	0.0190	0.0062	< 0.3455	< 0.0250	1.692	0.1268	0.1268
13342	10/29/2002	708	0.1723	< 0.0208	0.0346	0.1299	0.1299	4.831	179.38	0.3672	0.0264	< 0.0273	0.1441	< 0.0395	< 0.0466	< 0.0339	< 0.6469	0.0565	3.291	0.2803	0.2803
16499	10/30/2002	720	0.8194	0.0336	0.0542	0.1347	0.1556	5.694	251.39	1.9722	0.0917	0.0750	0.1667	< 0.0736	0.0569	0.0353	< 0.7639	< 0.0639	3.264	1.1405	1.1405
13363	10/31/2002	704	0.2784	0.0192	0.0291	0.0739	0.1023	3.352	171.88	0.6676	0.0322	0.0287	< 0.0710	< 0.0320	< 0.0277	< 0.0158	< 0.3793	< 0.0268	< 1.577	0.4009	0.4009
15979	11/01/2002	658	1.2310	< 0.0441	0.0638	0.1565	0.1535	5.319	147.42	2.7356	0.0821	< 0.0851	0.1672	0.0702	0.0699	0.0401	< 1.7173	0.0736	< 28.116	1.6328	1.6328
13336	11/05/2002	531	0.3164	0.0220	0.0507	0.1092	0.1544	5.574	263.65	0.9360	0.0397	< 0.0441	0.2034	< 0.0395	0.0275	< 0.0096	< 0.7100	< 0.0612	4.200	0.4992	0.4992
11280	11/06/2002	708	0.1045	0.0184	0.0347	0.0876	0.0847	3.729	60.31	0.3814	0.0233	0.0452	0.0833	< 0.0312	0.0287	0.0071	< 0.6723	< 0.0386	1.751	0.2110	0.2110
11292	11/07/2002	693	< 0.0089	0.0170	0.0271	0.0765	0.0662	2.973	48.63	0.0794	0.0149	0.0404	0.0885	< 0.0302	0.0368	0.0074	< 0.6465	< 0.0315	< 1.342	0.0755	0.0755
13344	11/08/2002	710	0.1761	< 0.0121	0.0228	0.0563	0.0690	2.648	136.20	0.5070	0.0245	< 0.0234	0.1141	< 0.0194	0.0117	< 0.0062	< 0.3521	< 0.0238	1.676	0.2709	0.2709

Table 2.3 Total Dioxin Concentrations in Water (pg/L) 1

Station ID	Date	Volume (L)	2,3,7,8-TCDD	1,2,3,7,8-PeCDD	1,2,3,4,7,8-HxCDD	1,2,3,6,7,8-HxCDD	1,2,3,7,8,9-HxCDD	1,2,3,4,6,7,8-HpCDD	OCDD	2,3,7,8-TCDF	1,2,3,7,8-PeCDF	2,3,4,7,8-PeCDF	1,2,3,4,7,8-HxCDF	1,2,3,6,7,8-HxCDF	2,3,4,6,7,8-HxCDF	1,2,3,7,8,9-HxCDF	1,2,3,4,6,7,8-HpCDF	1,2,3,4,7,8,9-HpCDF	OCDF	Total TEQ	Average TEQ^a
13355	11/11/2002	505	0.6356	0.0380	0.0958	0.1743	0.3010	9.069	419.80	2.0000	0.0665	< 0.0572	0.2139	< 0.0513	0.0279	0.0129	< 0.9129	< 0.0717	4.851	0.9683	0.9683
13338	11/12/2002	715	0.5021	< 0.0241	0.0513	0.1007	< 0.1301	4.937	198.60	1.7762	0.0568	0.0508	< 0.2238	< 0.0508	0.0238	< 0.0140	< 0.6601	< 0.0586	< 4.196	0.7711	0.7846
13338-dup	11/12/2002	712	0.5154	< 0.0277	< 0.0654	0.1180	0.1587	5.913	247.19	1.7837	0.0640	< 0.0539	0.2486	< 0.0593	0.0265	< 0.0156	< 0.7346	< 0.0688	< 4.986	0.7982	
14560	11/13/2002	554	0.1282	< 0.0208	< 0.0426	0.0686	< 0.1029	2.978	149.82	0.4007	0.0264	< 0.0244	< 0.1300	< 0.0310	< 0.0271	< 0.0264	< 0.3051	< 0.0614	< 1.498	0.2226	0.1997
14560-dup	11/13/2002	712	0.1011	< 0.0126	< 0.0265	< 0.0421	0.0913	2.149	102.53	0.3371	0.0233	0.0171	< 0.1166	< 0.0250	0.0188	< 0.0150	< 0.2514	< 0.0365	< 1.110	0.1768	
11252	11/14/2002	721	0.1456	< 0.0155	< 0.0362	< 0.0624	< 0.0888	3.273	159.50	0.4854	0.0212	< 0.0248	0.1137	< 0.0269	0.0176	< 0.0191	< 0.3467	< 0.0513	< 1.761	0.2427	0.2427
17971	11/18/2002	720	0.2222	< 0.0157	< 0.0317	0.0482	0.0728	1.861	82.08	0.6250	0.0300	0.0303	0.0667	< 0.0246	0.0149	< 0.0213	< 0.3069	< 0.0431	< 2.069	0.3315	0.3315
15464	11/19/2002	703	< 0.0448	< 0.0162	< 0.0398	< 0.0612	< 0.0925	2.546	79.23	0.1408	0.0169	< 0.0211	0.0683	< 0.0304	< 0.0404	< 0.0267	< 0.4154	< 0.0455	< 1.209	0.0953	0.0953
11193	11/20/2002	706	1.9065	< 0.0275	0.0242	0.0508	0.0779	2.620	134.56	6.2323	0.1649	0.1143	0.3824	< 0.0854	0.0171	< 0.0101	< 0.3654	0.0698	1.197	2.6720	2.6720
11200	11/21/2002	728	< 0.0257	0.0100	0.0265	0.0618	0.0824	3.420	178.57	0.0824	0.0118	< 0.0099	< 0.0893	< 0.0184	0.0098	0.0063	< 0.2514	0.0261	0.893	0.0669	0.0669
Spring 2003																					
13342	05/13/2003	700	0.2314	< 0.0254	< 0.0487	< 0.1497	< 0.1770	4.314	115.57	0.6000	< 0.0373	0.0389	< 0.0807	< 0.0270	< 0.0207	< 0.0077	< 0.5343	< 0.0440	3.679	0.3737	0.3737
13339	05/14/2003	674	0.1884	< 0.0243	< 0.0501	0.1435	< 0.1911	4.214	110.68	0.4896	< 0.0269	0.0300	< 0.0688	< 0.0223	< 0.0178	< 0.0083	< 0.4822	< 0.0349	2.552	0.3130	0.3130
13343	05/15/2003	710	< 0.1592	0.0294	0.0789	0.1972	0.2563	9.056	385.92	0.4042	< 0.0415	0.0506	< 0.1535	0.0518	0.0448	< 0.0108	< 1.1268	0.0721	4.944	0.3049	0.3049
13589	05/16/2003	702	< 0.0330	< 0.0110	< 0.0264	0.0551	< 0.0843	2.236	87.46	0.0883	< 0.0135	< 0.0229	< 0.0335	< 0.0141	< 0.0125	< 0.0070	< 0.2920	< 0.0207	0.969	0.0741	0.0741
13337	05/19/2003	702	0.1396	0.0329	0.0956	0.1781	0.3504	7.066	159.54	0.3832	0.0325	0.0376	0.0940	0.0399	0.0271	< 0.0073	< 0.6140	< 0.0456	2.977	0.2938	0.2938
13340	05/20/2003	702	< 0.0527	0.0148	0.0369	0.0684	0.1154	2.920	69.52	0.1396	0.0131	0.0245	< 0.0402	0.0167	0.0148	< 0.0060	< 0.3234	< 0.0204	1.282	0.1075	0.1075
16618	05/21/2003	701	0.2126	< 0.0233	0.0471	0.1284	0.2111	4.294	115.12	0.5706	0.0321	0.0362	0.0776	0.0331	0.0194	< 0.0076	< 0.4893	< 0.0341	3.709	0.3518	0.3518
11252	05/22/2003	702	0.1011	0.0174	0.0399	0.0940	0.1595	3.348	80.20	0.2550	< 0.0185	< 0.0385	0.0417	< 0.0202	< 0.0162	< 0.0093	< 0.3675	0.0228	1.852	0.1828	0.1879
11252-dup	05/22/2003	701	0.0999	0.0180	0.0392	0.1058	0.1598	3.352	79.46	0.2454	0.0171	0.0399	0.0448	0.0217	< 0.0148	< 0.0049	< 0.3909	< 0.0230	1.883	0.1930	
15908	05/27/2003	702	< 0.0798	0.0167	0.0444	0.1011	0.1966	4.145	135.19	0.1994	< 0.0170	0.0427	0.0489	0.0222	< 0.0170	< 0.0073	< 0.4131	0.0291	1.937	0.1663	0.1663
13309	05/28/2003	710	< 0.0606	< 0.0135	0.0342	0.0789	0.1465	2.958	83.10	0.1620	< 0.0132	< 0.0662	0.0306	0.0152	< 0.0101	< 0.0066	< 0.2648	0.0189	1.324	0.1238	0.1238
11261	05/29/2003	701	0.3281	< 0.0183	0.0387	0.1060	0.1529	3.581	89.87	0.8987	0.0495	0.0999	0.1163	0.0399	< 0.0245	< 0.0081	< 0.8160	0.0551	7.832	0.5268	0.5268
16496	05/30/2003	546	< 0.2070	< 0.0181	< 0.0436	0.1013	0.1515	4.207	140.29	0.4689	< 0.0328	< 0.1026	0.0799	< 0.0337	< 0.0253	< 0.0081	< 0.6703	< 0.0385	4.385	0.3345	0.3345
11264	06/02/2003	702	< 0.3034	< 0.0262	0.0541	< 0.1097	0.1439	3.191	78.92	0.7123	0.0598	0.0726	0.1538	0.0556	0.0484	< 0.0238	< 0.8761	0.0826	13.789	0.3716	0.4050
11264-dup	06/02/2003	701	0.2853	< 0.0181	< 0.0341	0.0897	< 0.1110	2.882	68.19	0.6990	< 0.0501	0.0599	0.1379	< 0.0387	< 0.0284	< 0.0140	< 0.7019	< 0.0556	9.173	0.4384	
16622	06/03/2003	702	< 0.0275	0.0160	< 0.0413	0.1040	0.1481	5.057	179.49	0.1011	0.0138	0.0353	< 0.0566	0.0205	0.0197	< 0.0060	< 0.3946	< 0.0298	1.093	0.0987	0.0987
11193	06/04/2003	703	2.1622	< 0.0447	< 0.0336	0.0825	0.1181	2.831	101.00	7.5533	0.2034	< 0.1421	0.4182	< 0.0991	0.0344	< 0.0112	0.4993	0.0599	2.817	3.0948	3.0948
15464	06/05/2003	462	< 0.0429	< 0.0316	0.0742	0.1768	0.3141	7.229	124.24	0.1180	< 0.0294	0.0446	0.1024	< 0.0530	< 0.0496	< 0.0134	< 0.9567	0.0610	2.519	0.1686	0.1686
14560	06/09/2003	702	< 0.0346	< 0.0158	0.0403	0.0940	0.1681	3.162	72.93	0.0883	< 0.0113	< 0.0309	0.0293	0.0128	< 0.0113	< 0.0061	< 0.2137	< 0.0151	0.883	0.0945	0.0945
11280	06/11/2003	700	0.2200	< 0.0176	< 0.0311	< 0.0607	< 0.0671	1.556	30.14	0.6143	< 0.0466	< 0.0401	< 0.1070	< 0.0331	< 0.0293	< 0.0220	< 0.3800	< 0.0586	1.923	0.3342	0.3342
11287	06/17/2003	702	< 0.0256	< 0.0355	0.0764	< 0.1667	0.1809	5.840	86.89	0.1282	0.0470	0.0499	< 0.1467	< 0.0456	0.0541	< 0.0182	1.2536	< 0.0698	2.550	0.1300	0.1300
11270	06/18/2003	710	0.2296	< 0.0254	0.0442	0.1028	0.1127	3.549	104.23	0.7042	< 0.0482	0.0648	< 0.1620	0.0377	< 0.0320	< 0.0123	< 0.6085	0.0425	2.592	0.3933	0.3933
Spring 2004																					
13340	03/09/2004	705	< 0.0440	0.0129	0.0299	0.0553	0.0965	2.000	57.73	0.1220	0.0142	0.0217	< 0.0278	< 0.0163	0.0150	< 0.0045	< 0.2638	< 0.0197	0.979	0.0893	0.0893
11252	03/10/2004	709	< 0.0677	0.0175	0.0385	0.0804	0.1523	3.061	112.83	0.1834	0.0188	0.0199	0.0358	0.0188	0.0147	< 0.0071	< 0.3004	< 0.0261	1.551	0.1274	0.1274
14560	03/11/2004	702	< 0.0513	0.0208	0.0570	0.1083	0.2436	4.459	142.45	0.1296	0.0160	0.0199	0.0407	0.0229	0.0194	< 0.0077	< 0.3504	< 0.0298	1.543	0.1272	0.1272
13342	03/12/2004	702	0.1681	0.0175	0.0422	0.0840	0.1368	3.348	118.38	0.4416	0.0255	0.0281	< 0.0588	< 0.0268	0.0204	< 0.0080	< 0.4416	< 0.0370	2.892	0.2728	0.2728
16499	03/16/2004	706	< 0.1941	0.0201	0.0401	0.0737	0.1374	3.116	117.56	0.5099	0.0288	0.0248	0.0659	0.0262	0.0197	0.0059	< 0.4660	< 0.0326	3.074	0.2662	0.2662
16618	03/17/2004	712	0.1952	0.0202	0.0382	0.0787	0.1306	3.188	139.04	0.5056	0.0337	0.0251	0.0640	0.0289	0.0219	< 0.0052	< 0.4185	< 0.0407	3.202	0.3068	0.3068
13338	03/18/2004	701	< 0.2168	< 0.0347	0.1013	0.1797	0.4023	6.819	206.85	0.5392	0.0350	< 0.0277	0.0932	0.0456	0.0268	< 0.0076	< 0.6990	< 0.0585	4.051	0.3596	0.3596
13344	03/19/2004	704	< 0.0909	0.0089	< 0.0216	0.0423	0.0847	1.918	62.78	0.2401	0.0143	0.0156	0.0330	< 0.0143	0.0118	< 0.0055	< 0.2401	< 0.0214	1.436	0.1309	0.1309
11193	03/23/2004	700	1.1000	< 0.0279	0.0410	0.0929	0.1486	4.086	181.43	3.2857	0.1033	0.0836	0.2214	0.0644	0.0230	< 0.0101	< 0.5171	0.0526	2.786	1.5475	1.2524
11193-dup	03/23/2004	702	0.6781	0.0185	0.0283	0.0598	0.0926	2.550	106.84	2.0228	0.0641	0.0510	0.1410	0.0447	0.0168	< 0.0080	< 0.3205	< 0.0340	1.738	0.9573	
11197	03/24/2004	702	< 0.0477	< 0.0124	0.0303	0.0684	0.0969	3.148	148.15	0.1453	0.0137	0.0135	0.0246	< 0.0470	0.0114	< 0.0081	< 0.2350	< 0.0221	0.621	0.0957	0.0957
11261	03/25/2004	712	0.3722	0.0215	0.0448	0.0997	0.1601	3.989	148.88	1.0112	0.0435	0.0406	0.1070	0.0417	0.0247	< 0.0083	< 0.6096	0.0476	4.888	0.5548	0.5548
11264	03/26/2004	701	0.4394	< 0.0207	0.0395	0.0927	0.1441	3.566	129.81	1.2268	0.0506	0.0425	0.1155	0.0439	0.0230	< 0.0090	< 0.5949	0.0502	5.407	0.6413	0.6413
11265	03/30/2004	702	0.4288	0.0283	0.0527	0.1154	0.1838	4.459	155.27	1.1966	0.0687	0.0541	0.1624	0.0615	0.0312	0.0090	< 0.9630	< 0.0688	11.111	0.6547	0.6547
15979	03/31/2004	701	0.8417	0.0338	0.0588	0.1669	0.1912	5.464	169.76	2.3110	0.0799	0.0785	0.2397	0.0813	0.0484	< 0.0104	< 1.6120	< 0.1013	17.546	1.2124	1.1782

Table 2.3 Total Dioxin Concentrations in Water (pg/L) 1

Station ID	Date	Volume (L)	2,3,7,8-TCDD	1,2,3,7,8-PeCDD	1,2,3,4,7,8-HxCDD	1,2,3,6,7,8-HxCDD	1,2,3,7,8,9-HxCDD	1,2,3,4,6,7,8-HpCDD	OCDD	2,3,7,8-TCDF	1,2,3,7,8-PeCDF	2,3,4,7,8-PeCDF	1,2,3,4,7,8-HxCDF	1,2,3,6,7,8-HxCDF	2,3,4,6,7,8-HxCDF	1,2,3,7,8,9-HxCDF	1,2,3,4,6,7,8-HpCDF	1,2,3,4,7,8,9-HpCDF	OCDF	Total TEQ	Average TEQ[a]
15979-dup	03/31/2004	701	0.7989	< 0.0342	0.0603	0.1612	0.1669	5.078	158.35	2.1398	0.0785	0.0785	0.2126	< 0.0813	0.0452	< 0.0103	< 1.3124	< 0.0873	12.967	1.1441	
11280	04/01/2004	706	0.4108	0.0239	0.0374	0.1020	0.1034	3.244	68.41	1.1756	0.0657	0.0567	0.1643	< 0.0643	0.0330	0.0082	< 0.6983	< 0.0525	2.465	0.6227	0.6227
11287	04/02/2004	703	< 0.0711	< 0.0186	< 0.0349	0.0916	0.0900	2.774	36.42	0.2304	< 0.0193	0.0260	0.0597	< 0.0351	0.0272	< 0.0073	< 0.6543	< 0.0387	1.661	0.1416	0.1416
11300	04/08/2004	700	< 0.0596	< 0.0284	0.0363	0.0951	0.1049	2.500	29.00	0.3300	0.1871	0.0851	0.4471	0.1311	0.0456	< 0.0111	< 0.6114	< 0.0680	0.926	0.2370	0.2370
11292	04/09/2004	708	< 0.0297	0.0275	0.0492	0.1299	0.1370	4.181	64.83	0.2062	0.0246	0.0508	0.0763	< 0.0537	0.0438	< 0.0103	< 0.7486	< 0.0387	1.483	0.1324	0.1324
11272	04/13/2004	706	0.4207	0.0694	0.1445	0.3414	0.4207	11.756	548.16	1.0340	0.1275	0.0878	0.3244	< 0.1586	0.0754	0.0177	< 1.5581	< 0.1076	9.377	0.7536	0.7536
11305	04/15/2004	708	< 0.0167	0.0274	0.0500	0.1116	0.1257	3.192	39.83	0.1059	0.0267	0.0410	0.0597	< 0.1653	0.0379	< 0.0092	< 0.5551	< 0.0312	0.901	0.1021	0.1021
11302	04/16/2004	734	< 0.0341	0.0450	0.0845	0.2030	0.1757	4.918	45.78	0.1580	0.0463	0.0599	0.0940	0.0627	0.0790	0.0399	< 1.1308	< 0.0967	2.411	0.1703	0.1703
11298	04/20/2004	703	0.2475	< 0.0256	0.0546	0.1536	0.1579	5.121	93.88	0.7966	< 0.0464	0.0546	0.0939	< 0.0640	0.0403	< 0.0065	< 0.8435	0.0451	1.636	0.4232	0.4232
11274	04/21/2004	710	< 0.0732	0.0206	0.0379	0.1042	0.1155	3.887	214.08	0.3211	0.0283	0.0394	0.0817	< 0.0859	0.0239	< 0.0056	< 0.4268	< 0.0320	1.169	0.1603	0.1603
11347	04/22/2004	703	< 0.0115	0.0284	0.0324	0.3841	0.1536	8.250	69.70	0.0555	0.0176	0.0248	0.0415	< 0.0498	0.0326	< 0.0088	< 0.5064	< 0.0257	0.765	0.1072	0.0907
11347-dup	04/22/2004	705	< 0.0105	0.0218	0.0250	0.2426	0.1021	5.957	52.48	0.0553	< 0.0121	< 0.0196	0.0360	0.0213	0.0233	< 0.0054	< 0.3716	0.0180	0.583	0.0743	
11382	04/23/2004	707	< 0.0050	< 0.0129	0.0181	0.0533	0.0512	1.711	26.17	0.0636	< 0.0095	0.0219	0.0243	< 0.0216	0.0140	< 0.0050	< 0.2772	< 0.0182	0.692	0.0439	0.0439
11111	04/27/2004	708	< 0.0975	0.0397	0.1186	0.1963	0.4181	8.220	224.58	0.2684	0.0381	0.0323	0.0691	< 0.0480	0.0284	< 0.0114	< 0.5692	< 0.0359	2.218	0.2406	0.2406
11092	04/28/2004	707	< 0.0519	0.0554	0.1405	0.2928	0.4102	10.141	301.27	0.1669	0.0444	0.0505	0.1277	< 0.0764	0.0699	< 0.0119	< 1.5120	< 0.0751	3.833	0.2306	0.2306
11273	04/29/2004	702	< 0.6026	< 0.0984	< 0.1866	0.5470	0.5584	15.655	216.52	3.1624	1.9088	0.8732	3.2336	< 0.9544	0.4843	0.6325	< 21.1538	1.5057	478.632	1.8235	1.8235
Summer 2004																					
11193-de	08/03/2004	678	1.6077	< 0.0413	0.0624	0.1475	0.2507	5.826	162.24	5.5752	0.1503	0.1069	0.2743	0.0883	0.0320	< 0.0114	0.7006	< 0.0416	7.094	2.3318	2.3318
11193-sh	08/03/2004	723	0.9986	< 0.0243	0.0372	0.0730	0.1268	3.416	119.23	3.4163	< 0.0920	0.0802	0.2102	< 0.0542	< 0.0196	< 0.0077	< 0.3582	< 0.0397	2.490	1.4482	1.4482
15979-de	08/05/2004	659	0.9105	0.0569	0.1024	0.1775	0.3187	4.734	91.05	2.3976	< 0.0812	0.0653	0.1517	0.0534	0.0328	< 0.0118	< 0.8346	< 0.0640	8.801	1.2993	1.2993
15979-sh	08/05/2004	661	0.5204	< 0.0257	< 0.0384	0.0968	0.1289	3.132	65.81	1.4221	< 0.0525	0.0578	0.1183	< 0.0452	< 0.0322	< 0.0092	0.6278	< 0.0384	5.123	0.7512	0.7512
11142	08/18/2004	707	< 0.0106	< 0.0228	< 0.0371	< 0.0880	0.1150	3.041	93.07	0.0383	< 0.0136	< 0.0137	0.0215	< 0.0197	< 0.0273	< 0.0146	< 0.4342	< 0.0252	0.762	0.0550	0.0551
11142-dup	08/18/2004	707	< 0.0093	< 0.0192	< 0.0378	< 0.0921	0.1141	3.041	92.93	0.0348	< 0.0163	0.0147	0.0218	< 0.0199	< 0.0262	< 0.0141	< 0.3762	< 0.0221	0.779	0.0552	
11357	08/31/2004	326	< 0.0178	< 0.0322	< 0.0531	< 0.1080	0.1393	3.491	66.38	< 0.0491	< 0.0193	< 0.0199	< 0.0322	< 0.0334	< 0.0380	< 0.0156	0.4794	< 0.0242	1.029	0.0722	0.0745
11357-dup	08/31/2004	326	< 0.0172	< 0.0291	< 0.0466	< 0.1077	< 0.1291	3.196	66.44	< 0.0485	< 0.0221	< 0.0184	< 0.0313	< 0.0371	< 0.0374	< 0.0169	0.4773	< 0.0316	1.004	0.0768	
Fall 2004																					
11292	10/19/2004	705	< 0.0255	< 0.0397	< 0.0383	< 0.0851	< 0.0750	2.000	29.62	0.2298	< 0.0411	< 0.0525	< 0.0559	< 0.0999	< 0.0356	< 0.0369	< 0.3670	< 0.0325	0.870	0.1004	0.1004
11287	10/20/2004	704	< 0.0838	< 0.0246	< 0.0293	< 0.0604	< 0.0631	1.737	28.64	0.2770	< 0.0384	< 0.0351	< 0.0501	< 0.0558	< 0.0253	< 0.0261	< 0.3824	< 0.0364	1.412	0.1351	0.1351
11280	10/21/2004	701	0.3566	< 0.0237	< 0.0359	< 0.0743	< 0.0854	1.997	47.22	1.0699	< 0.0670	< 0.0514	< 0.0917	< 0.0803	< 0.0300	< 0.0341	< 0.4151	< 0.0452	4.094	0.5263	0.5263
11347	10/22/2004	701	< 0.0251	< 0.0294	< 0.0454	0.1268	0.1284	3.809	77.46	0.0999	< 0.0471	< 0.0428	< 0.0628	< 0.2197	< 0.0579	< 0.0318	< 0.7618	< 0.0285	1.897	0.0951	0.0951
15979	10/25/2004	712	0.6025	< 0.0247	< 0.0331	< 0.1045	< 0.1129	2.937	58.29	1.8961	< 0.0823	< 0.0756	0.1788	< 0.2107	< 0.0539	< 0.0295	< 1.6096	< 0.0854	20.295	0.9002	0.8708
15979-dup	10/25/2004	708	0.5621	< 0.0328	< 0.0692	< 0.1243	< 0.1370	2.839	55.93	1.8503	< 0.1017	< 0.0791	< 0.1552	< 0.2117	< 0.0579	< 0.0551	< 1.4986	< 0.1299	20.452	0.8415	
11265	10/26/2004	703	0.3215	< 0.0336	< 0.0351	< 0.0829	< 0.1233	2.461	58.75	0.9246	< 0.0795	< 0.0578	0.1593	< 0.1437	0.0475	< 0.0293	< 0.8663	< 0.1108	14.794	0.5030	0.5030
11264	10/27/2004	706	0.3513	< 0.0572	< 0.0618	< 0.1252	< 0.1521	2.762	72.38	0.9490	< 0.1119	< 0.0977	< 0.2323	< 0.1742	0.0663	< 0.0538	< 1.4178	0.1841	25.113	0.5582	0.5582
11261	10/28/2004	708	0.6031	< 0.0308	< 0.0516	0.1134	< 0.1879	4.040	106.78	1.6525	< 0.0989	< 0.0658	0.1893	< 0.1653	0.0410	< 0.0243	< 1.1709	< 0.1144	22.740	0.8774	0.8774
11197	10/29/2004	703	< 0.0967	< 0.0206	< 0.0427	< 0.0597	< 0.0853	< 1.619	83.70	0.2532	< 0.0388	< 0.0347	< 0.0459	< 0.0474	< 0.0283	< 0.0307	< 0.2475	< 0.0541	1.755	0.1555	0.1555
11193	11/03/2004	705	< 0.2142	< 0.0211	< 0.0482	< 0.0837	< 0.1163	2.540	128.23	0.6582	< 0.0610	< 0.0496	< 0.0715	< 0.0949	< 0.0257	< 0.0200	< 0.3603	< 0.0624	3.560	0.3277	0.3372
11193-dup	11/03/2004	720	0.2319	< 0.0251	< 0.0360	< 0.0693	< 0.1025	2.653	126.67	0.6639	< 0.0458	< 0.0333	< 0.0608	< 0.0874	< 0.0226	< 0.0250	< 0.3556	< 0.0431	3.639	0.3468	
11111	11/04/2004	702	< 0.0726	< 0.0641	< 0.1439	0.2279	< 0.4103	8.761	316.24	0.2279	< 0.0670	< 0.0598	< 0.0897	< 0.1311	< 0.0541	< 0.0484	< 0.6410	< 0.0912	2.521	0.2323	0.2323
13344	11/05/2004	700	< 0.2243	< 0.0951	< 0.1809	< 0.1809	< 0.1806	2.671	82.29	0.6429	< 0.1414	< 0.1257	< 0.1339	< 0.1316	< 0.1457	< 0.1669	< 0.4543	< 0.2516	4.800	0.3703	0.3703
11382	11/08/2004	704	< 0.0337	< 0.0334	< 0.0405	< 0.0817	< 0.0984	2.855	75.43	< 0.0653	< 0.0440	< 0.0412	< 0.0253	< 0.1477	< 0.0334	< 0.0303	< 0.4574	< 0.0322	1.443	0.0745	0.0745
14560	11/09/2004	703	< 0.0417	< 0.0183	< 0.0428	0.0972	0.2105	3.186	81.37	0.1380	< 0.0253	< 0.0201	< 0.0398	< 0.0324	< 0.0174	< 0.0114	< 0.2333	< 0.0277	1.410	0.0948	0.0948
11302	11/10/2004	702	< 0.0150	< 0.0221	< 0.0321	0.0880	0.0812	2.836	45.33	< 0.1225	< 0.0236	< 0.0272	< 0.0379	< 0.0922	< 0.0298	< 0.0157	< 0.6453	< 0.0178	1.742	0.0695	0.0695
11305	11/11/2004	702	< 0.0178	< 0.0142	0.0283	0.0806	< 0.0620	2.806	44.02	0.1026	< 0.0328	< 0.0389	< 0.0544	< 0.2194	< 0.0322	< 0.0175	< 0.5043	< 0.0353	1.101	0.0727	0.0727
11298	11/12/2004	707	< 0.0934	< 0.0212	0.0521	0.1260	0.1372	4.221	99.15	0.3904	< 0.0474	< 0.0508	0.1007	< 0.1491	< 0.0373	< 0.0264	< 0.7001	< 0.0666	2.014	0.2058	0.2058
16618	11/15/2004	701	< 0.1398	< 0.0205	< 0.0344	< 0.0586	< 0.1424	2.710	73.61	0.3894	< 0.0267	< 0.0314	< 0.0526	< 0.0298	< 0.0201	< 0.0228	< 0.2910	< 0.0352	3.310	0.2112	0.2112
16499	11/16/2004	703	< 0.1735	< 0.0228	< 0.0313	< 0.0752	< 0.1078	2.589	76.10	0.4694	< 0.0351	< 0.0324	< 0.0548	< 0.0277	< 0.0188	< 0.0205	< 0.3997	< 0.0553	3.798	0.2474	0.2474
13340	11/17/2004	702	< 0.0393	< 0.0137	< 0.0330	< 0.0501	< 0.0897	1.597	44.66	0.1140	< 0.0188	< 0.0170	< 0.0256	< 0.0161	< 0.0147	< 0.0134	< 0.1936	< 0.0353	0.916	0.0752	0.0752
13338	11/18/2004	709	< 0.2525	< 0.0265	0.0673	0.1347	< 0.2172	5.021	150.63	0.8039	< 0.0522	< 0.0450	0.1016	< 0.0621	< 0.0288	< 0.0226	< 0.6841	< 0.0901	8.618	0.3979	0.3979

Table 2.3 Total Dioxin Concentrations in Water (pg/L) 1

Station ID	Date	Volume (L)	2,3,7,8-TCDD	1,2,3,7,8-PeCDD	1,2,3,4,7,8-HxCDD	1,2,3,6,7,8-HxCDD	1,2,3,7,8,9-HxCDD	1,2,3,4,6,7,8-HpCDD	OCDD	2,3,7,8-TCDF	1,2,3,7,8-PeCDF	2,3,4,7,8-PeCDF	1,2,3,4,7,8-HxCDF	1,2,3,6,7,8-HxCDF	2,3,4,6,7,8-HxCDF	1,2,3,7,8,9-HxCDF	1,2,3,4,6,7,8-HpCDF	1,2,3,4,7,8,9-HpCDF	OCDF	Total TEQ	Average TEQ[a]
11252	11/19/2004	704	0.0881	< 0.0207	< 0.0175	< 0.0398	0.0682	1.690	73.86	0.2543	< 0.0230	< 0.0209	0.0243	< 0.0195	< 0.0182	< 0.0206	< 0.1776	< 0.0273	1.264	0.1413	0.1413
11272	11/22/2004	701	< 0.0442	< 0.0310	< 0.0613	< 0.1041	< 0.1526	4.736	469.33	0.1255	< 0.0399	< 0.0442	< 0.0606	< 0.1441	< 0.0321	< 0.0184	< 0.4322	< 0.0185	2.040	0.1236	0.1236
11274	11/24/2004	720	< 0.0681	< 0.0529	0.1335	0.3403	0.4069	14.625	1305.56	0.4597	< 0.0981	0.1164	0.3006	< 0.5306	< 0.1006	< 0.0363	< 1.8458	< 0.3514	6.051	0.3545	0.3545
11300	11/29/2004	708	< 0.0763	< 0.0268	< 0.0510	0.1271	< 0.1256	4.266	66.38	1.1723	1.2147	< 0.3828	2.5226	0.7218	< 0.0905	< 0.0547	< 1.3008	< 0.3404	2.049	0.7975	0.7975
11092	11/30/2004	702	< 0.0265	0.0429	< 0.1293	< 0.2688	0.3276	9.302	351.14	0.1154	< 0.0490	< 0.0410	< 0.1115	< 0.2721	0.0652	< 0.0132	< 1.3704	< 0.0761	3.058	0.1953	0.1953
11273	12/01/2004	701	0.4265	< 0.0670	< 0.1241	0.3281	0.3666	10.913	208.27	2.0685	1.2553	0.5193	2.0542	< 2.2539	0.3324	0.3081	< 19.9287	1.4180	637.660	1.4304	1.4304
13342	12/02/2004	712	0.1124	< 0.0249	< 0.0324	< 0.0348	< 0.0560	1.489	71.07	0.3301	< 0.0341	< 0.0298	< 0.0251	< 0.0534	< 0.0288	< 0.0308	< 0.2008	< 0.0504	2.907	0.1757	0.1757

[a] Average of duplicate samples, otherwise concentration of a single sample

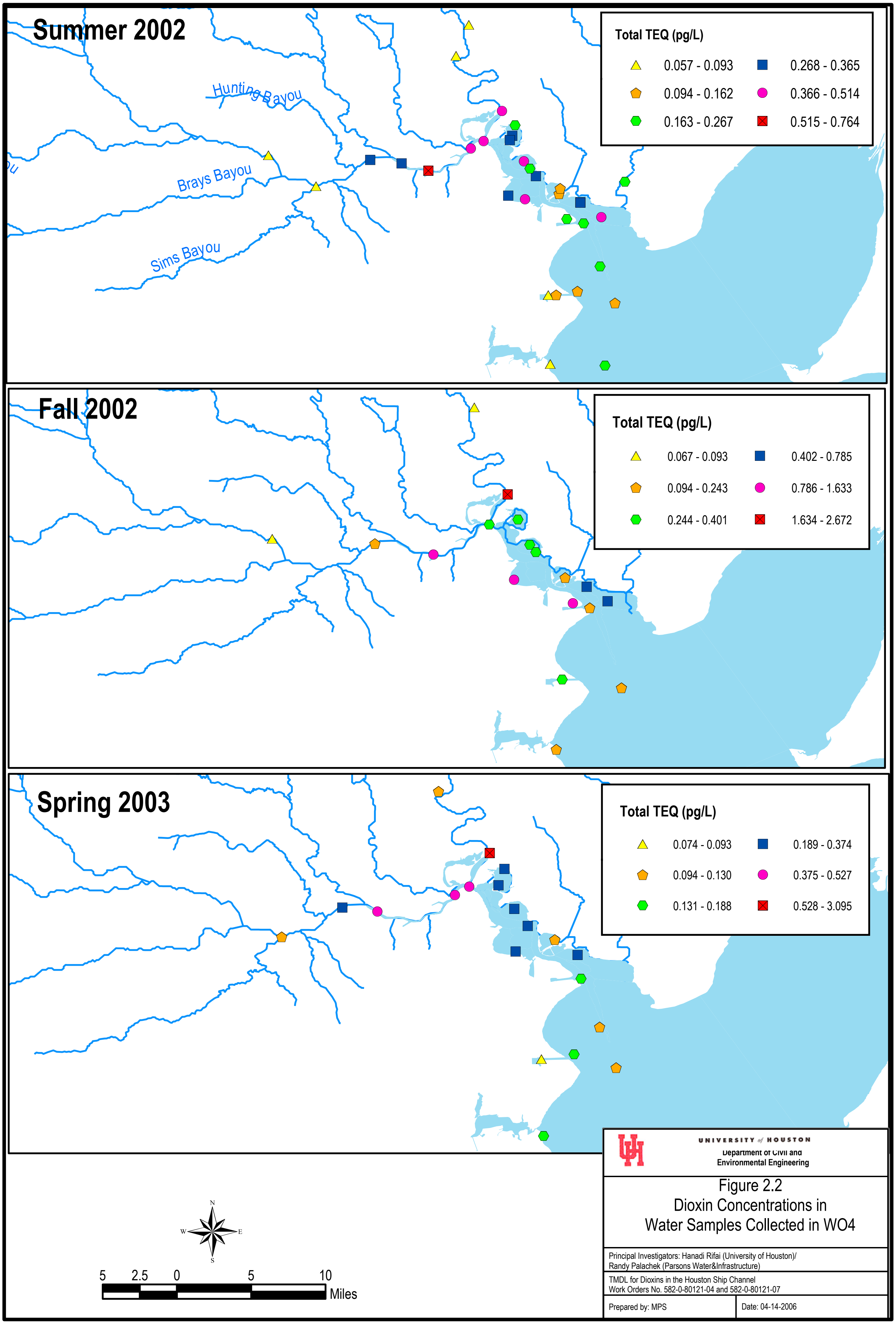
dup = duplicate de= deep sh=shallow

Values reported to the detection limit

If either the dissolved or suspended concentration was non-detect, the total concentration in water was reported here as less than the sum of the detected concentration and the MDL for the non-detected phase. If a congener was non-detected in both phases, the total concentration in water was reported as less than the sum of the MDL for both phases

Total TEQ was calculated as the sum of the dissolved TEQ plus the suspended TEQ. Non-detects were assumed to be 1/2 detection limit

▨	Tributary
🟦	Value for one or both phases is between the detection and the reporting limits
🟨	Value for one or both phases is an estimate due to blank contamination (concentration < 20 times lowest concentration)
🟥	Value for one or both phases is an estimate due to QC issues (interference, signal to noise ratio)
🟩	Exceeds the Texas WQS (0.0933 pg/L)



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Environmental Engineering

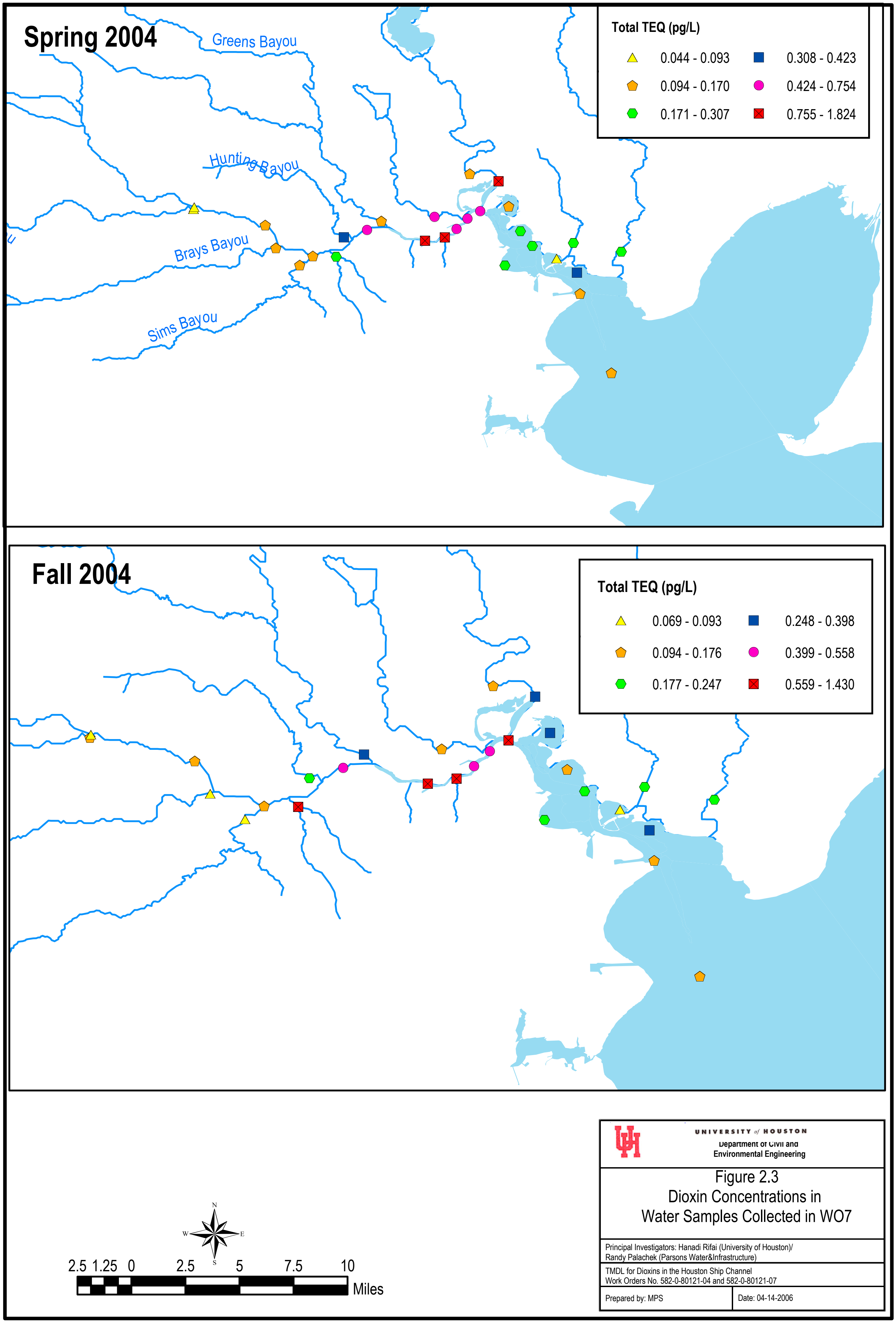
Figure 2.2
Dioxin Concentrations in
Water Samples Collected in WO4

Principal Investigators: Hanadi Rifai (University of Houston)/
Randy Palachek (Parsons Water&Infrastructure)

TMDL for Dioxins in the Houston Ship Channel
Work Orders No. 582-0-80121-04 and 582-0-80121-07

Prepared by: MPS

Date: 04-14-2006



UNIVERSITY of HOUSTON
Department of Civil and
Environmental Engineering

Figure 2.3
Dioxin Concentrations in
Water Samples Collected in WO7

Principal Investigators: Hanadi Rifai (University of Houston)/
Randy Palachek (Parsons Water&Infrastructure)

TMDL for Dioxins in the Houston Ship Channel
Work Orders No. 582-0-80121-04 and 582-0-80121-07

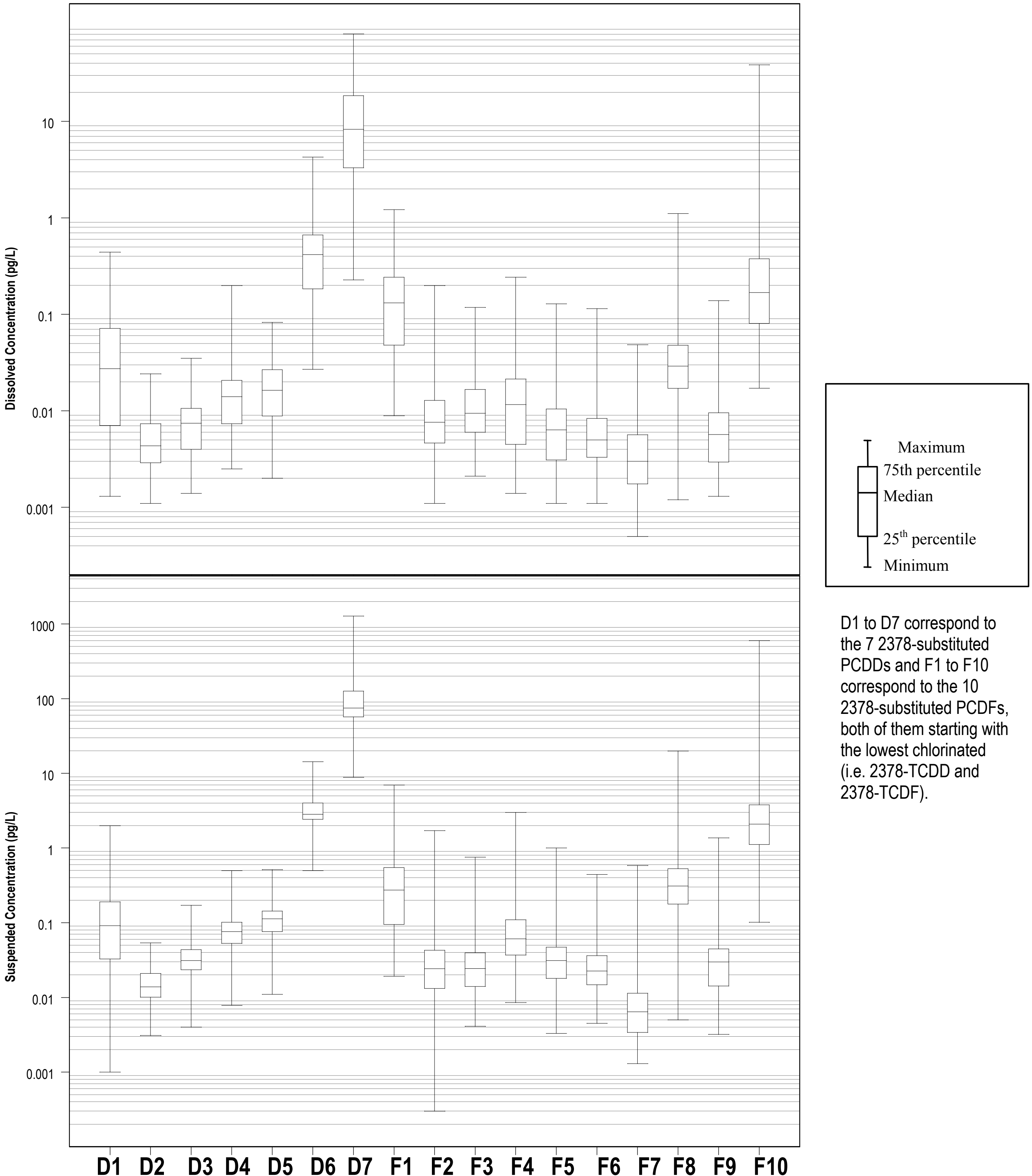
Prepared by: MPS

Date: 04-14-2006

samples were found at stations 15979 (Segment 1006) and 13339 (Segment 2427). The highest dioxin concentrations for the Fall 2002 samples were found at stations 11193 (Segment 1001) and 15979 (Segment 1006), while in Spring 2003, stations 11193 and 11261 exhibited the highest TEQs in water. Similarly, the highest TEQ levels in the spring samples were measured at stations 11193 (Segment 1001) and 15979 (Segment 1006), while the highest TEQ concentrations in fall samples were measured at stations 11261 (Segment 1005) and 15979 (Segment 1006).

Figure 2.4 shows the concentration distribution for the seventeen 2378-substituted congeners and TEQ in dissolved and suspended phases for all the sampling events. The dissolved concentrations for the individual PCDD/PCDFs ranged from 0.0005 to 80.74 pg/L, while the suspended concentrations varied between 0.0003 and 1,277.8 pg/L. Overall, congener concentrations in water samples (dissolved plus suspended) exhibited the sequence OCDD>123478-HpCDD>1234789-HpCDF>OCDF>TCDF>TCDD. Most of the total 2378-substituted PCDD/PCDF concentration can be attributed to OCDD with an average contribution of 90%. However, 2378-TCDD was the major contributor to the total TEQ (47% on average) followed by 2378-TCDF (15% on average).

As expected for hydrophobic compounds, the dissolved concentrations were typically lower than their respective suspended concentrations, with average dissolved/suspended ratios between 0.11 and 0.59 for individual congeners. The dissolved/suspended ratios for total PCDD/PCDF were between 0.01 and 0.94. Overall, the dissolved fraction decreases with increased chlorination. For example, average

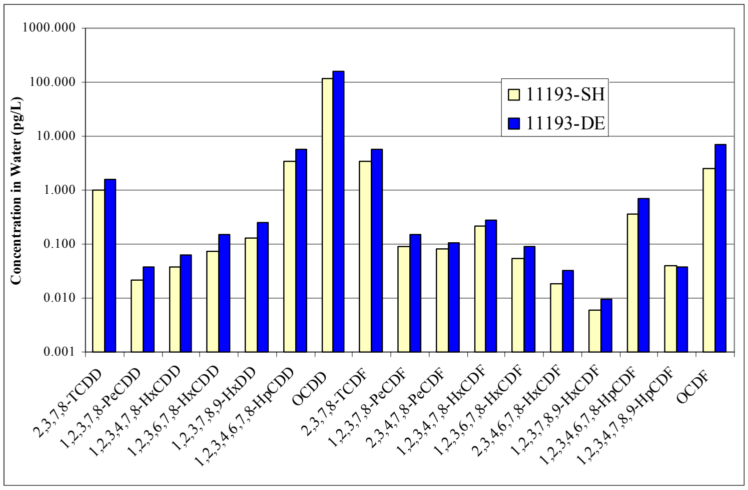


D1 to D7 correspond to the 7 2378-substituted PCDDs and F1 to F10 correspond to the 10 2378-substituted PCDFs, both of them starting with the lowest chlorinated (i.e. 2378-TCDD and 2378-TCDF).

Figure 2.4 Distribution of Individual Congeners in the Dissolved and Suspended Phases dissolved fractions for 2378-TCDD, 123678-HxCDD, and OCDD are 27%, 18%, and 11%, respectively.

Analysis of dioxin data in bottom sediments and water columns collected in 2002-2003 indicated "disequilibrium" between these two media. However, it is noted that the collected data correspond to shallow water, and there is the possibility of thermal and salinity-driven stratification in the channel. To address whether or not dioxin concentrations in the HSC were at equilibrium between bottom sediments and the water column, the project team gathered samples to develop vertical profiles of dioxins at two locations (11193 and 15979) during the Summer 2004. Dioxin concentrations for the vertical profiles are included in Table 2.3. A graphical comparison between shallow and deep dioxin concentrations is presented in Figure 2.5. As can be seen in Figure 2.5, deep concentrations were generally higher than shallow concentrations, with average deep/shallow ratios of up to 1.69 and 1.54 for locations 11193 and 15979, respectively (maximum ratios were 2.85 and 2.67, respectively). The only exceptions were 1234789-HpCDF at station 11193 and 123789-HxCDF at Station 15979 for which the shallow concentrations were higher than those measured in the deep samples.

A database of water sampling results reported by PSC/Maxxam Analytical Laboratory is included in Appendix B. A summary of average dissolved, suspended, and total water concentrations by station is included in Table B-1 of Appendix B.



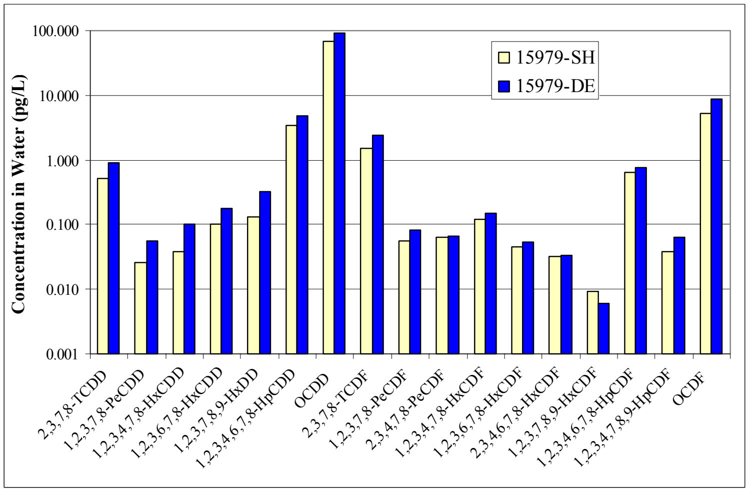


Figure 2.5 Comparison of Dioxin Concentrations in Shallow and Deep Water Samples

2.4 DATA ANALYSIS

2.4.1 Spatial Trends

A summary of average TEQ concentrations in water by segment is presented in Table 2.4a and b for TEQ and 23478-TCDD, respectively. It can be observed in Table 2.4a that for the Summer 2002 samples, Segment 2430 showed the highest average concentration in water, while Segment 1006 showed the highest average TEQ in water in the Fall 2002 and Spring 2004 sample. Finally, Segment 1001 exhibited the highest average dioxin concentration in water in the Spring 2003 and Fall 2004.

Data in Table 2.4b indicate that the maximum average 2378-TCDD concentration in water was measured in the Fall 2002 in Segment 1006. Figure 2.6 shows concentration profiles along the main channel for total water dioxin concentrations measured in 2004 (WO7) compared to those measured in 2002-2003 (WO4) as well as the overall average. These data provide an indication of spatial patterns. As can be seen in Figure 2.6, the longitudinal profile was fairly consistent for all events: the water concentrations start low, they then increase until reaching the highest dioxin concentration and then concentrations decrease downstream. For all the events the profiles show peak TEQ concentrations in Segment 1006 (at Station 15979) and most of the side bays and tributaries at or above the levels observed in the main channel at the confluence segments. In addition, the dioxin concentration at Station 11193 in the San Jacinto River (Segment 1001) is higher than those measured at the confluence with the main channel and higher than that measured at Station 15979.

Table 2.4a Summary of Average TEQ Concentrations in Water by Segment

Segment	**Summer 2002**		**Fall 2002**		**Spring 2003**		**Spring 2004**		**Fall 2004**	
	# of Samples	**TEQ (pg/L)**	**# of Samples**	**TEQ (pg/L)**	**# of Samples**	**TEQ (pg/L)**	**# of Samples**	**TEQ (pg/L)**	**# of Samples**	**TEQ (pg/L)**
901	1[a]	0.267	ns	-	ns	-	1[a]	0.241	1[a]	0.232
1001	3	0.194	2	1.369	2	1.597	2	0.674	3	0.794
1005	3	0.319	2	0.271	3	0.356	3	0.330	3	0.410
1006	3	0.528	1	1.633	2	0.399	6	0.869	7	0.695
1007	3	0.166	2	0.143	2	0.232	7	0.261	7	0.272
1013	ns	-	ns	-	ns	-	2	0.067	2	0.085
1014	ns	-	ns	-	ns	-	ns	-	2	0.065
2421	5	0.146	2	0.148	4	0.138	1[a]	0.127	1[a]	0.095
2426	3	0.376	2	0.642	1[a]	0.294	2	0.295	2	0.297
2427	2	0.440	1[a]	1.140	1[a]	0.313	1[a]	0.266	1[a]	0.247
2428	2	0.125	1[a]	0.127	1[a]	0.108	1[a]	0.089	1[a]	0.075
2429	2	0.349	2	0.306	1[a]	0.374	1[a]	0.273	1[a]	0.176
2430	3	0.603	1[a]	0.271	2	0.320	1[a]	0.131	1[a]	0.370
2436	1[a]	0.223	1[a]	0.968	ns	-	ns	-	ns	-
2438	2	0.091	1[a]	0.401	1[a]	0.074	ns	-	ns	-

[a] The value presented corresponds to the result for the single sample for that segment
ns = not sampled

Table 2.4b Summary of Average 2378-TCDD Concentrations in Water by Segment

Segment	**Summer 2002**		**Fall 2002**		**Spring 2003**		**Spring 2004**		**Fall 2004**	
	# of Samples	**TCDD (pg/L)**	**# of Samples**	**TCDD (pg/L)**	**# of Samples**	**TCDD (pg/L)**	**# of Samples**	**TCDD (pg/L)**	**# of Samples**	**TCDD (pg/L)**
901	1[a]	0.108	ns	-	ns	-	1[a]	0.088	1[a]	0.064
1001	3	0.111	2	0.965	2	1.093	2	0.466	3	0.536
1005	3	0.176	2	0.173	3	0.214	3	0.207	3	0.271
1006	3	0.326	1	1.231	2	0.235	6	0.411	7	0.357
1007	3	0.084	2	0.055	2	0.116	7	0.119	7	0.257
1013	ns	-	ns	-	ns	-	2	0.004	2	0.013
1014	ns	-	ns	-	ns	-	ns	-	2	0.009
2421	5	0.064	2	0.076	4	0.049	1[a]	0.043	1[a]	0.017
2426	3	0.202	2	0.413	1[a]	0.140	2	0.121	2	0.021
2427	2	0.265	1[a]	0.819	1[a]	0.188	1[a]	0.047	1[a]	0.125
2428	2	0.039	1[a]	0.059	1[a]	0.044	1[a]	0.154	1[a]	0.151
2429	2	0.210	2	0.197	1[a]	0.231	1[a]	0.035	1[a]	0.035
2430	3	0.172	1[a]	0.222	2	0.170	1[a]	0.168	1[a]	0.112
2436	1[a]	0.112	1[a]	0.176	ns	-	ns	-	ns	-
2438	2	0.027	1[a]	0.636	1[a]	0.195	ns	-	ns	-

[a] The value presented corresponds to the result for the single sample for that segment
ns = not sampled

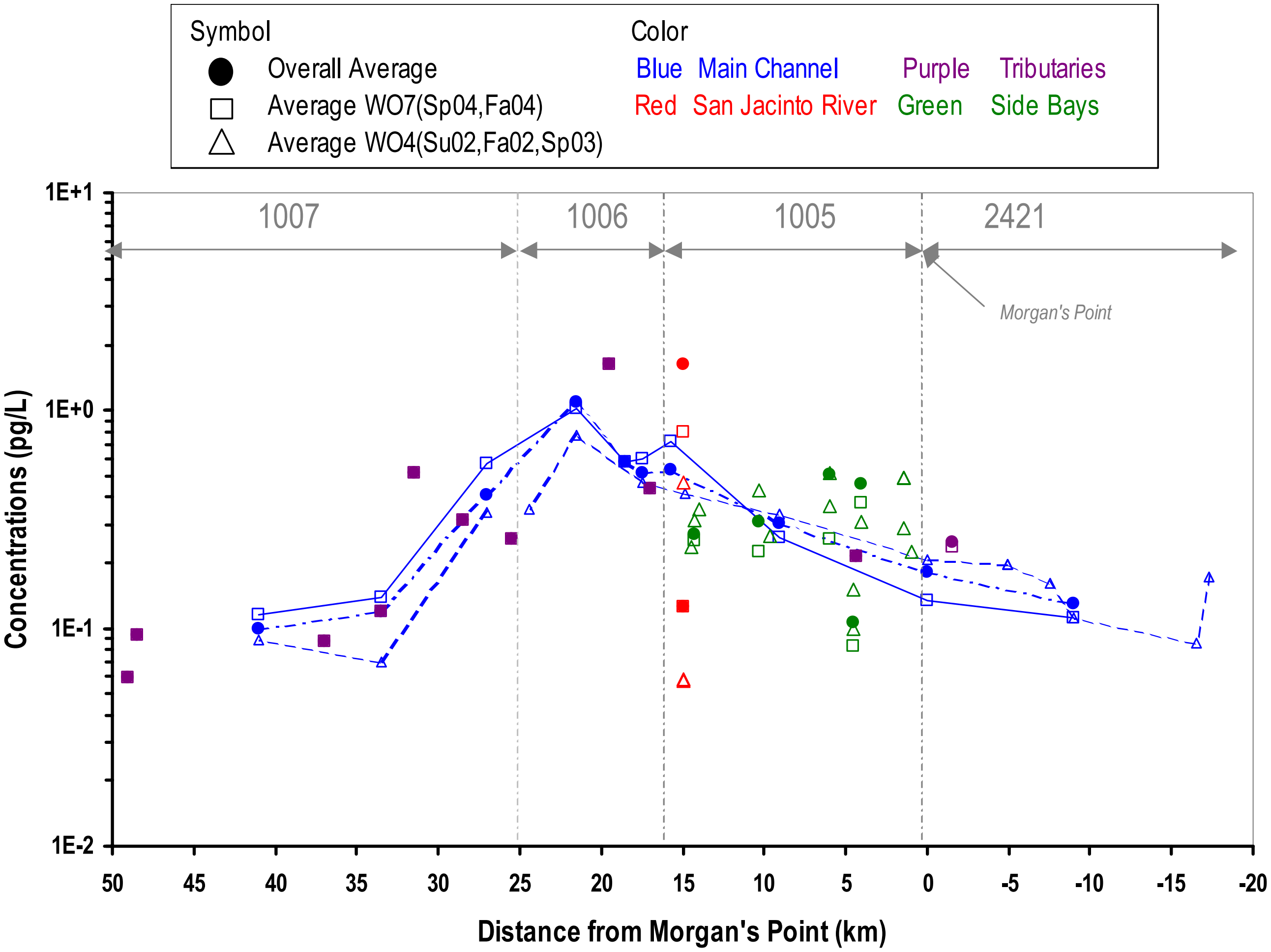


Figure 2.6 Total Water TEQ Concentration Profiles

2.4.2 Temporal Trends

PCDD/PCDF concentrations in water at the locations sampled during all five sampling events (Summer 2002, Fall 2002, Spring 2003, Spring 2004, and Fall 2004) of this project were analyzed using the Mann-Kendall test to evaluate possible trends over time. The Mann-Kendall test was selected because it allows for analysis of non-normally distributed data. The test was completed for all congeners at the selected stations. The result was considered significant if the value associated with a given Mann-Kendall statistic (S) was less than the alpha value of 0.05. This would only occur for a value of S greater than 7. A summary of the procedure to compute S values is included in Appendix C.

Table 2.5 presents a summary of the data trends for water samples. Each data "series" is comprised of five data points that correspond to the measurements during each of the sampling events. Because the concentrations were ordered chronologically, the results show trends over time. The values in the table are the resultant probability given by the S-value derived from the critical values table presented in Appendix C. Only at a value less than 0.05 would a trend be considered significant. In Table 2.5, the values highlighted in orange indicate a significant upward trend in the concentrations of that congener over the five-sample time period. Values highlighted in light blue show a significant downward trend in concentrations of that congener for the sampling period. The value 0.592 is highlighted in white and indicates that there is no trend over time.

Table 2.5 Values Probability Results for Mann-Kendall Test for Trend

Media Station	2,3,7,8-TCDD	1,2,3,7,8-PeCDD	1,2,3,4,7,8-HxCDD	1,2,3,6,7,8-HxCDD	1,2,3,7,8,9-HxCDD	1,2,3,4,6,7,8-HpCDD	OCDD	2,3,7,8-TCDF	1,2,3,7,8-PeCDF
susp11193	0.408	0.408	0.042	0.117	0.117	0.042	0.042	0.408	0.408
susp11252	0.042	0.242	0.592	0.408	0.117	0.242	0.242	0.042	0.042
susp11261	0.028	0.408	0.242	0.117	0.042	0.117	0.117	0.042	0.408
susp11280	0.242	0.242	0.592	0.242	0.117	0.592	0.408	0.242	0.117
susp13342	0.117	0.408	0.117	0.242	0.242	0.117	0.242	0.117	0.117
susp14560	0.117	0.242	0.117	0.117	0.117	0.242	0.592	0.408	0.408
dis11193	0.592	0.592	0.242	0.408	0.592	0.408	0.592	0.592	0.408
dis11252	0.408	0.592	0.242	0.042	0.042	0.117	0.117	0.592	0.592
dis11261	0.117	0.408	0.408	0.592	0.408	0.592	0.408	0.408	0.408
dis11280	0.242	0.242	0.408	0.408	0.242	0.408	0.242	0.117	0.592
dis13342	0.592	0.117	0.117	0.408	0.242	0.242	0.242	0.408	0.117
dis14560	0.117	0.592	0.408	0.408	0.242	0.592	0.592	0.408	0.242

Media Station	2,3,4,7,8-PeCDF	1,2,3,4,7,8-HxCDF	1,2,3,6,7,8-HxCDF	2,3,4,6,7,8-HxCDF	1,2,3,7,8,9-HxCDF	1,2,3,4,6,7,8-HpCDF	1,2,3,4,7,8,9-HpCDF	OCDF	Total TEQ
susp11193	0.592	0.592	0.592	0.408	0.242	0.592	0.117	0.042	0.408
susp11252	0.042	0.042	0.117	0.042	0.242	0.042	0.042	0.042	0.042
susp11261	0.242	0.242	0.408	0.592	0.592	0.592	0.242	0.242	0.042
susp11280	0.242	0.408	0.117	0.117	0.408	0.242	0.592	0.042	0.242
susp13342	0.117	0.117	0.042	0.117	0.117	0.042	0.042	0.117	0.117
susp14560	0.408	0.408	0.592	0.592	0.242	0.117	0.242	0.592	0.408
dis11193	0.117	0.042	0.592	0.242	0.408	0.408	0.408	0.242	0.592
dis11252	0.408	0.592	0.592	0.117	0.117	0.592	0.408	0.117	0.408
dis11261	0.408	0.592	0.408	0.592	0.242	0.408	0.408	0.408	0.408
dis11280	0.592	0.592	0.242	0.242	0.242	0.242	0.592	0.117	0.117
dis13342	0.242	0.117	0.408	0.117	0.117	0.408	0.408	0.408	0.408
dis14560	0.592	0.408	0.592	0.242	0.242	0.242	0.242	0.408	0.242

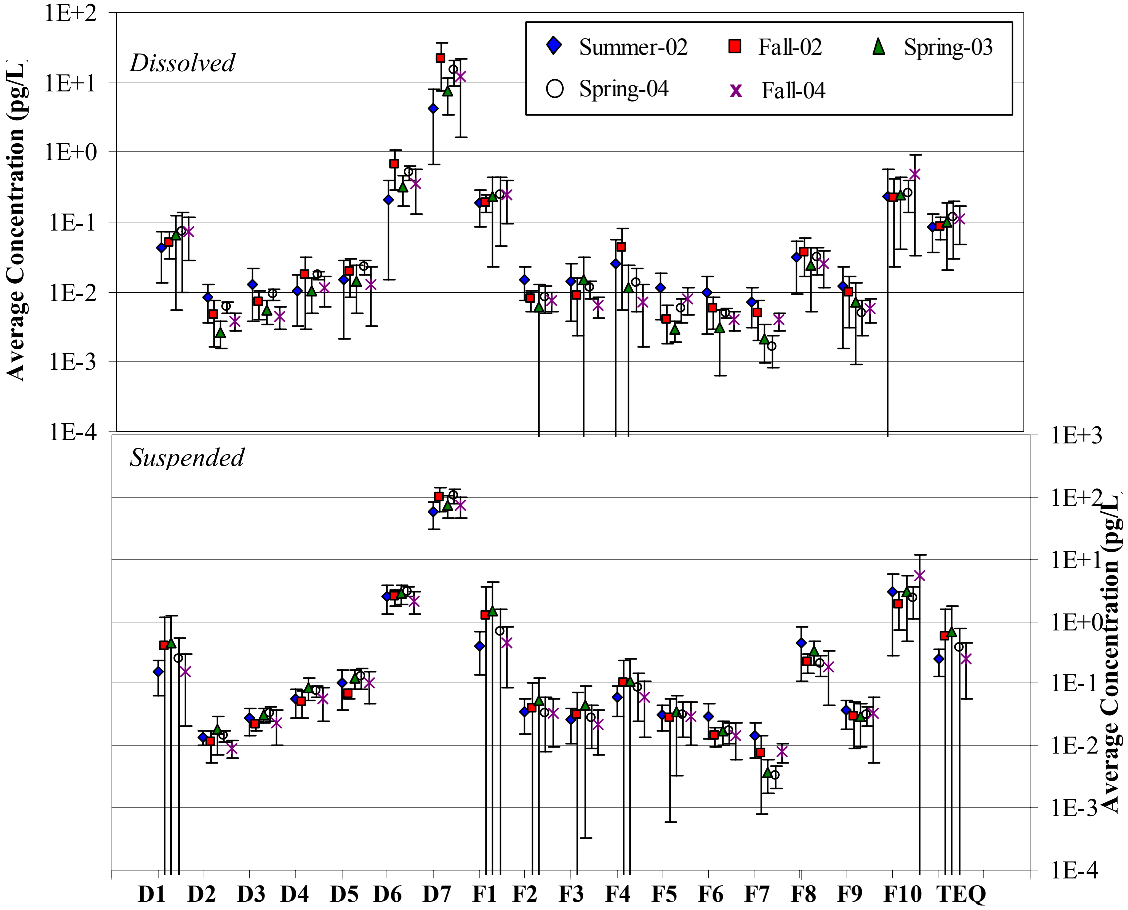
🟦 significant downward trend
🟩 downward trend
⬜ no trend
🟨 upward trend
🟧 significant upward trend

probabilities considered significant if the value is less than the alpha of 0.05
susp = suspended sediment
diss = dissolved

It appears that furans are decreasing more over the sampling period than dioxins. A majority of the green highlighted cells are on the furan half of the table. Also, all but one of the blue highlighted cells are on the furan side of the table. In addition, seven of the 11 significantly increasing congeners were dioxins. When congeners showing no trend (S=0) are taken into account, the overall trend of all data at all stations appears to be downward.

2.4.3 Seasonal Trends

Seasonal trends in data collected in this project were also analyzed. Figure 2.7 shows the average congener profiles for the suspended and dissolved phases by season for the stations that were sampled during each event. In general, the profiles did not change significantly from one season to another. Results from a statistical analysis using a Wilconox Signed Rank test confirmed that the differences among seasons were not statistically significant.



Error bars correspond to the 95% confidence intervals
2378-PCDDs indicated by a letter D followed by a number, with D1 being TCDD and D7 OCDD
2378-PCDFs indicated by a letter F followed by a number, with F1 being TCDF and F10 OCDF

Figure 2.7 Seasonal Variation of Dioxins in Water in the HSC

CHAPTER 3

DIOXIN IN BOTTOM SEDIMENTS OF THE HOUSTON SHIP CHANNEL SYSTEM

3.1 METHODS

3.1.1 Sampling Procedures

Sediment samples were collected with a decontaminated stainless steel Ponar dredge. Samples were collected and deposited into a stainless steel bowl. A minimum of three grab samples were composited using only the top 5 centimeters of sediment, mixed thoroughly with a clean stainless steel spoon, and deposited into a labeled, pre-cleaned amber glass jar with a Teflon seal. A separate sample of the same mixture was prepared and analyzed for total organic carbon (TOC), total solids, and volatile solids. Sampling collection and handling followed the requirements set forth in the approved Quality Assurance Project Plans (QAPPs).

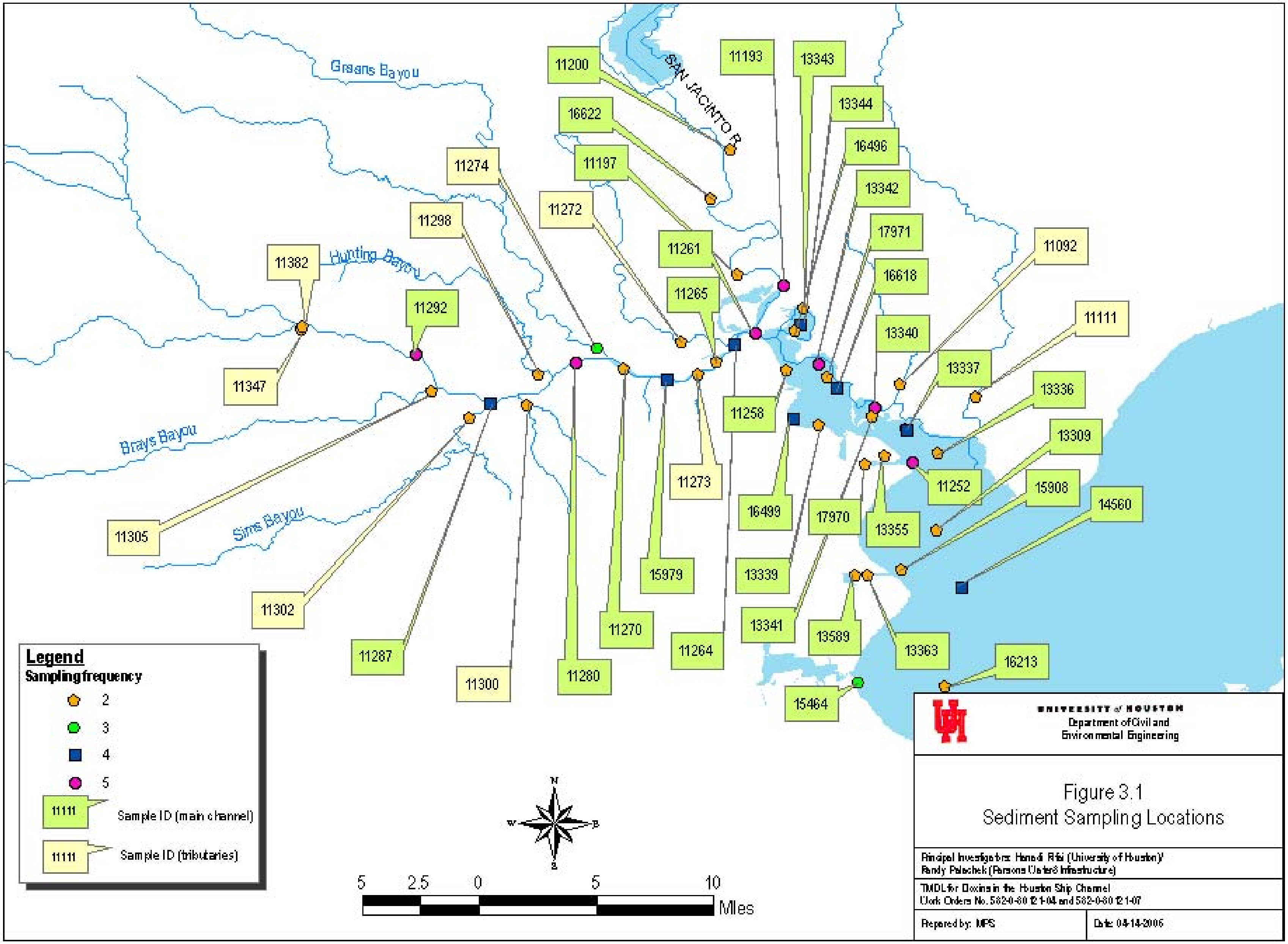
3.1.2 Sampling Locations

A total of 47 stations in the Houston Ship Channel (HSC), Upper Galveston Bay, and major tributaries were sampled in as many as 5 "major" events between Summer 2002 and Fall 2004. Figure 3.1 shows the locations that were sampled to quantify PCDD/PCDFs in sediment. Three of the major sampling events were undertaken during WO4: Summer 2002 (July 25-September 11), Fall 2002 (October 21-December 10), and

Spring 2003 (April 30-June 17), while the remaining two events were completed during WO7: Spring 2004 (March 9-April 29) and Fall 2004 (October 20-December 1).

In addition to the five major events, two high-resolution sediment sampling events were conducted in the summers of 2004 and 2005 to pinpoint the location of unidentified major sources in segments 1001 and 1006. During Summer 2004, 15 locations in segments 1001, 1005, and 1006 were sampled to obtain detailed concentration profiles, and 1 location (15979) was sampled along a transect to measure differences in concentrations across the width of the channel (Figure 3.2).

Sediment sampling conducted during Summer 2005 was an extension of the high-resolution sampling conducted in Summer 2004. The high-resolution sampling was necessary because model calibration indicated that the identified sources did not generate the peaks observed in segments 1001, 1006, and 1007. Additional sampling was undertaken to further investigate the presence of potential unidentified sources of dioxins in the three segments. Recent information suggested the presence of a potential source of dioxin in the San Jacinto River just upstream of I-10. The site consists of old waste pits located on a sand bar that has been partially submerged and could be potentially discharging dioxins into the River. Furthermore, results of detailed sediment sampling in Summer 2004 showed the presence of new hot spots in segments 1006 and 1007 (locations 11280 and 11268), but the sources have not been specifically located. To pinpoint the location of unidentified major sources near sampling locations 11193, 11280, and 11268, the project team conducted sediment sampling at higher resolution (i.e. at ~0.5 km intervals for segments 1006/1007 and at 0.25 km intervals in Segment 1001).



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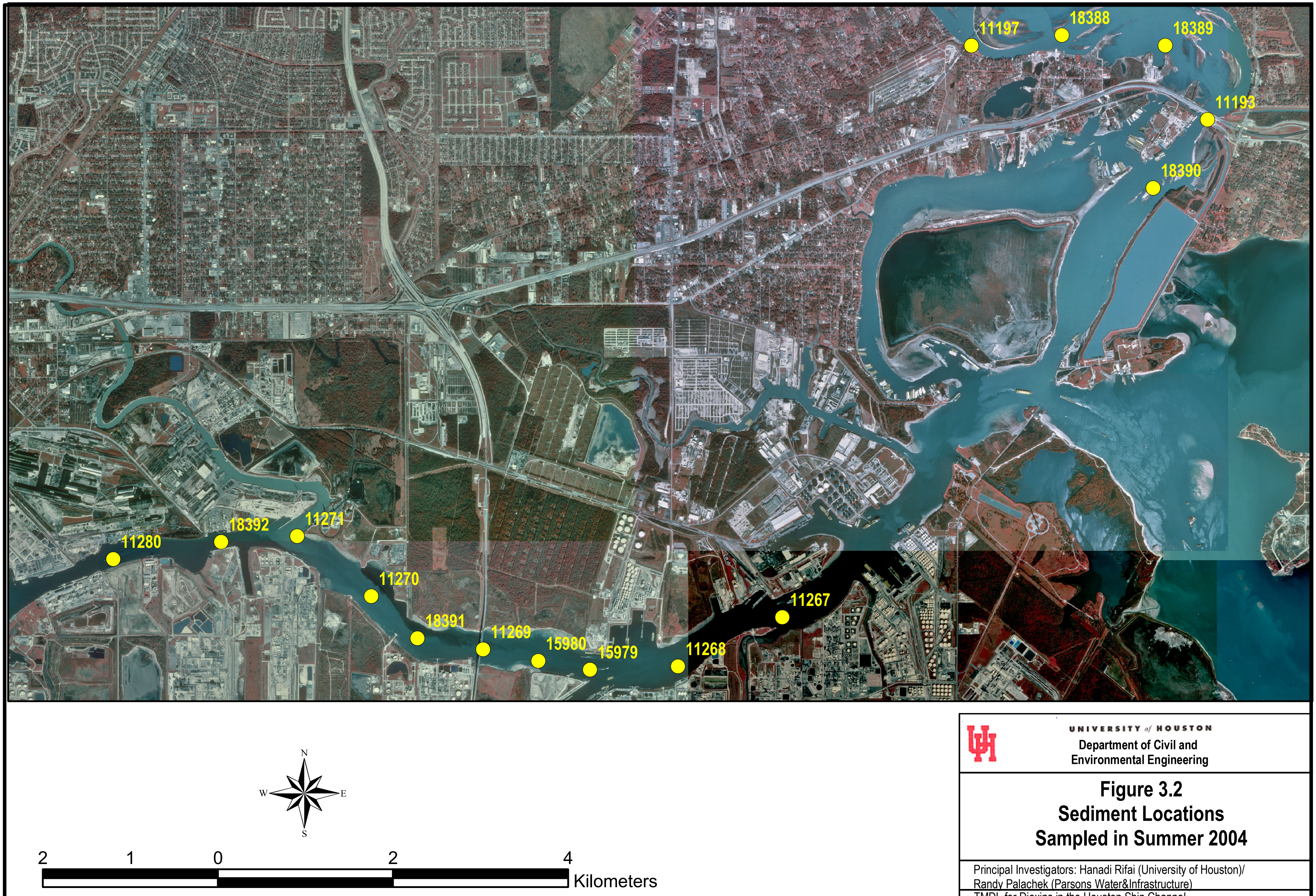
Environmental Engineering

Figure 3.1
Sediment Sampling Locations

Principal Investigators: Hanadi Rifai (University of Houston)/
Randy Palachek (Parsons Water & Infrastructure)

TMDL for Dioxins in the Houston Ship Channel
Work Orders No. 5820-80121-04 and 582-0-80121-07

Prepared by: MPS
Date: 04-14-2006



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Department of Civil and
Environmental Engineering

Figure 3.2
Sediment Locations Sampled in Summer 2004

Principal Investigators: Hanadi Rifai (University of Houston)/
Randy Palachek (Parsons Water&Infrastructure)

TMDL for Dioxins in the Houston Ship Channel
Work Orders No. 582-0-80121-04 and 582-0-80121-07

Prepared by: MPS
Date: 04-15-2006

For Segment 1001, sediment samples were collected from 21 locations at a resolution of 0.25-km within a total area of 1 km^2 as shown in Figure 3.3. The sampled locations included sampling of the old waste pits, wetland mitigation area, recent sand mining area, presubsidence area, and Old San Jacinto River. For Segment 1007, sediment samples were collected at 0.5-km intervals upstream and downstream of location 11280, as shown in Figure 3.4a. In addition, to investigate whether a disproportionate increase in dioxin concentrations in sediments collected during 2004 from location 11280 reflected the presence of a new source or if the increase is the result of dredging operations that uncovered contaminated sediments, a sediment core was collected at location 11280, and 5 intervals were analyzed for dioxins from this core. Finally, for Segment 1006, sediment samples were collected at 6 locations every 0.5 km upstream and downstream of location 11268, as shown in Figure 3.4b. Table 3.1 summarizes the total number of dioxin sediment samples collected in this project.

3.1.3 Analytical Methods

PCDDs and PCDFs in sediment samples were quantified by high-resolution gas chromatography/high resolution mass spectrometry (HRGC/HRMS) using EPA Method 1613B at Pace Analytical. Sediment samples were homogenized, spiked with fifteen $^{13}C_{12}$-labeled PCDD/PCDF internal standards and extracted using Soxhlet extraction apparatus. The extracts were then spiked with 2378-TCDD-$^{37}C_{l4}$ enrichment efficiency standard and subjected to acid/base washes, multiplayer silica, alumina, and carbon column cleanup procedures to remove interferences from the extracts. After cleanup, the extracts were concentrated to near dryness and spiked with recovery standards (1234-

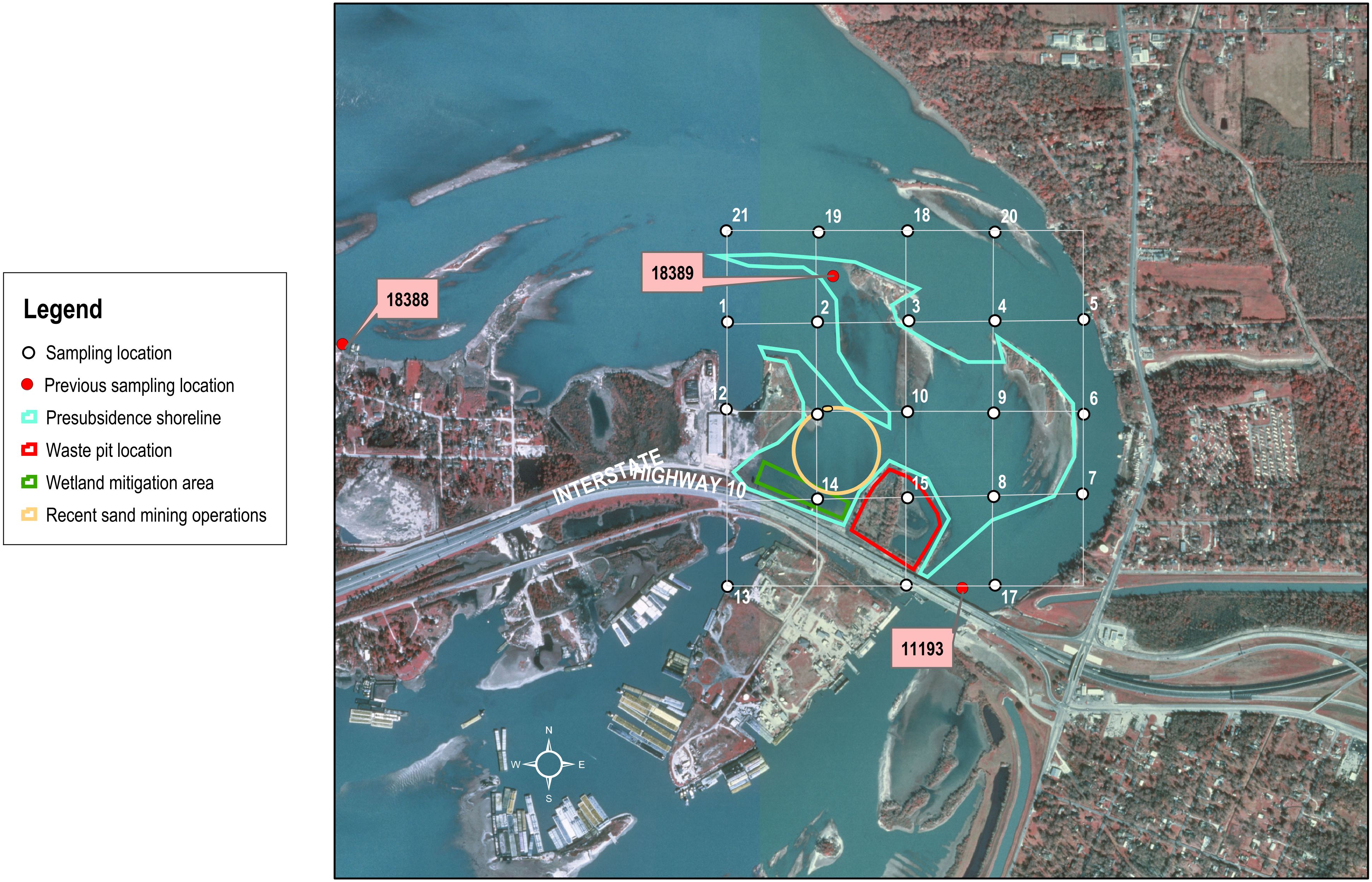

Figure 3.3 Sampled Locations in the San Jacinto River in Summer 2005

Figure 3.4a Sampled Locations in Segment 1007 in Summer 2005

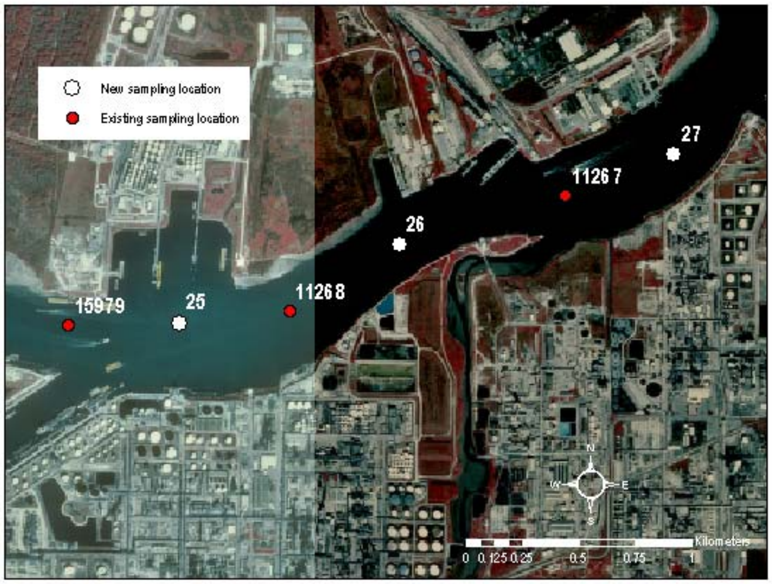

Figure 3.4b Sampled Locations in Segment 1006 in Summer 2005

Table 3.1 Number of Dioxin Sediment Samples

Sampling event	**# sites**	**QC samples**[a]	**total # samples**
Summer 2002	45	11	56
Fall 2002	16	2	18
Spring 2003	37	4	41
Spring 2004	18	6	24
Summer 2004	15, 1(5)[b]	4	24
Fall 2004	17	3	20
Summer 2005	32	8	40
Totals			*223*

[a] Field duplicates and field blanks specified in the QAPP.

[b] Sediment samples were collected along a transect (5 samples) at one location.

TCDD-$^{13}C_{12}$ and 123789-HxCDD-$^{13}C_{12}$) immediately prior to injection. Chromatographic separation was achieved with a DB-5, capillary chromatography column (60 m, 0.25 mm i.d., 0.25 μm film thickness). A second column DB-225 (30 m, 0.25 mm i.d., 0.25 μm film thickness) was used for confirmation of TCDF identification.

Physical properties of sediment samples were analyzed at North Water District Laboratory Services (NWDLS) using standard methods (U.S. Environmental Protection Agency, 1983) as follow: organic content of sediments (TOC) Lloyd Kahn, total solids content EPA 160.3, and volatile solids EPA 160.4.

3.2 QUALITY CONTROL

Field duplicates and blanks were collected at a frequency of 6% or higher and 3% or higher, respectively, and processed in an identical manner to samples. In addition, laboratory duplicates and blanks were run at a frequency of 5%. Overall, when detected, both field and laboratory blanks showed levels below 5% of the levels in the samples. Results obtained from the duplicate samples were consistent and in agreement with the method requirements for the different congeners. Recoveries for 2378-substituted congeners ranged from 72 to 92% with an average of 81%. QC data are included in Appendix A. Non-detects were assumed to be equal to half of the detection limit for total equivalence quotient (TEQ) calculations and summary statistics.

3.3 RESULTS

Table 3.2 provides a summary of the physical properties of sediment samples analyzed by NWDLS.

A summary of PCDD/PCDF concentrations in sediment samples collected during the five major events and the resulting Texas-TEQ levels is provided in Table 3.3. Maps showing organic-carbon normalized total TEQ concentrations in sediment for the major sampling events conducted in WO4 and WO7 are shown in Figures 3.5 and 3.6, respectively. For the Summer 2002 in-channel sediment samples, dioxin levels varied from 0.56 to 345.4 ng TEQ/kg-dry wt (dry weight), with an average value of 22.98 ng TEQ/kg-dry wt. Total TEQ levels for in-channel sediment samples collected in Fall 2002 ranged between 0.56 to 64.5 ng TEQ/kg-dry wt, with an average value of 18.7 ng TEQ/kg-dry wt. Organic carbon (OC)-normalized levels ranged from 71.13 to 21,053 ng TEQ/kg-oc in Summer 2002 and from 111.7 to 10,473 ng TEQ/kg-oc in Fall 2002, with respective mean values of 2,175 and 1,794 ng TEQ/kg-oc. Dioxin concentrations in sediment samples collected in Spring 2003 ranged from 0.6 to 138.9 ng/kg-dry wt, with an average value of 15.98 ng/kg dry wt, while OC-normalized concentrations varied from 77.4 to 16,543 ng/kg-oc with an average value of 1,573 ng/kg-dry wt. For sediment samples collected in Spring 2004, dioxin levels varied from 0.92 to 451.4 ng TEQ/kg-dry wt, with an average value of 42.7 ng TEQ/kg-dry wt. OC-normalized levels ranged from 183.7 to 24,008 ng TEQ/kg-oc, with a mean value of 2,701 ng TEQ/kg-oc. It is noted that the data are influenced by three relatively high values. A better estimate of central tendency, in this case, is probably the median, which is equal to 1,048 ng TEQ/kg-oc. Likewise, TEQ concentrations in sediments collected in Fall 2004 ranged from 0.5 to

846.3 ng/kg-dry wt, with an average value of 68.8 ng/kg-dry wt. OC-normalized levels ranged from 247.1 to 30,551 ng/kg-oc, with a median value of 1,433 ng/kg-oc.

The highest TEQ levels were measured in samples from locations 15979 (Segment 1006) and 11193 (Segment 1001) during the Summer 2002 event and from locations 11292 (Segment 1007) and 11193 (Segment 1001) during Fall 2002. Location 11193 had the highest dioxin concentration in water as well. In-channel locations 11193 (Segment 1001) and 16618 (Segment 1005) exhibited the highest dioxin levels during the Spring 2003 sampling event. The highest TEQ levels in the Spring 2004 samples were measured at locations 11280 (Segment 1007) and 11193 (Segment 1001), whereas the highest TEQ concentrations in Fall 2004 samples were measured at locations 11280 (Segment 1007) and 16499 (Segment 2427).

Concentrations of total TEQ were not correlated with organic carbon content in sediment ($r^2 = 0.057$), even though the correlation was statistically significant ($p<0.05$) (Figure 3.7). This suggests that the higher concentrations of dioxins in certain locations may be attributable to hydrological characteristics of the channel (sedimentation) or to the presence of active sources in certain areas of the HSC, rather than to a higher presence of organic material.

Table 3.2 Characteristics of Sediment Samples

Station ID	Date	Total Solids (%)	TOC (%)	Volatile Solids (%)
Summer 2002				
11272	07/25/2002	30.2	0.92	6.40
11298	07/29/2002	49.0	2.59	4.90
11274	07/30/2002	43.5	1.62	5.90
11111	07/31/2002	37.1	1.09	5.20
11092	08/01/2002	35.4	2.04	7.00
11258	08/01/2002	76.6	0.47	1.20
13340	08/06/2002	34.5	1.22	3.90
13341	08/06/2002	34.7	1.03	3.50
11193	08/08/2002	64.8	0.54	2.80
11347	08/12/2002	90.6	0.60	1.80
11382	08/12/2002	70.0	2.56	5.60
11305	08/13/2002	67.1	1.26	3.90
11305-dup	08/13/2002	66.6	1.29	4.20
13337	08/14/2002	43.2	1.14	4.08
13363	08/16/2002	71.3	0.60	1.96
13589	08/16/2002	63.2	0.97	3.09
15464	08/16/2002	80.5	0.27	0.51
17970	08/18/2002	68.3	0.79	N/A
13355	08/18/2002	62.2	1.19	N/A
16618	08/19/2002	74.9	0.14	0.85
11264	08/19/2002	67.9	0.54	1.61
11261	08/19/2002	71.9	0.29	0.95
13343	08/20/2002	60.0	1.06	3.71
16496	08/21/2002	30.3	1.10	5.80
13342	08/21/2002	27.0	1.08	5.65
13344	08/21/2002	26.3	1.22	6.06
13339	08/22/2002	30.8	1.32	5.99
13338	08/22/2002	41.7	1.34	5.53
13338-dup	08/22/2002	41.8	1.34	5.28
16499	08/22/2002	38.1	1.39	4.69
17971	08/24/2002	31.5	1.38	5.26
17971-dup	08/24/2002	28.2	1.54	5.00
11287	08/26/2002	64.2	1.37	2.86
11302	08/26/2002	60.8	2.03	4.28
13336	08/27/2002	36.1	1.14	5.03
13336-dup	08/27/2002	34.6	1.14	5.08
11252	08/27/2002	76.2	0.37	1.49
11252-dup	08/27/2002	73.6	0.23	1.61
11270	08/28/2002	53.6	1.56	4.40
11270-dup	08/28/2002	55.0	1.34	4.01
11273	08/28/2002	44.4	2.23	6.44
11273-dup	08/28/2002	45.3	2.01	6.65
11280	08/29/2002	37.5	2.26	5.46
13309	08/30/2002	77.2	0.36	1.08

Table 3.2 Characteristics of Sediment Samples

Station ID	Date	Total Solids (%)	TOC (%)	Volatile Solids (%)
14560	08/30/2002	55.3	1.09	3.39
11200	09/03/2002	73.7	0.49	0.94
11200-dup	09/03/2002	76.9	0.59	1.08
16622	09/03/2002	71.6	0.26	1.33
15979	09/04/2002	42.5	1.70	4.27
15979-dup	09/04/2002	39.7	1.55	3.84
11292	09/05/2002	35.6	2.65	6.93
11300	09/05/2002	58.5	2.22	3.61
11300-dup	09/05/2002	57.6	1.86	3.96
16213	09/11/2002	35.3	1.29	1.62
15908	09/11/2002	66.8	0.98	1.30
Fall 2002				
13338	10/22/2002	56.0	0.60	1.23
13336	10/22/2002	48.3	0.74	2.15
13340	10/23/2002	33.9	1.44	3.61
17970	10/24/2002	67.8	0.39	1.08
11252	10/24/2002	30.5	1.29	3.27
16499	10/24/2002	47.8	1.33	3.41
11261	10/26/2002	58.4	0.48	1.53
13344	10/27/2002	28.2	1.42	3.96
17971	10/28/2002	43.1	1.01	2.19
13342	10/28/2002	29.9	1.45	4.49
11193	10/31/2002	61.7	0.61	1.41
13363	11/06/2002	57.2	1.08	2.79
15464	11/06/2002	69.3	0.25	0.57
11200	11/21/2002	83.2	0.10	0.10
11280	12/02/2002	43.2	2.17	3.98
11292	12/10/2002	29.9	2.27	4.49
Spring 2003				
11092	04/30/2003	37.3	2.94	8.02
11258	04/30/2003	73.8	0.25	0.79
11272	04/30/2003	33.0	1.88	4.45
11274	05/01/2003	62.5	1.55	2.04
11274-dup	05/01/2003	65.6	1.36	2.11
11302	05/01/2003	37.8	4.27	6.48
11111	05/01/2003	43.7	1.27	4.11
11298	05/02/2003	38.9	3.00	5.63
11273	05/03/2003	38.7	3.12	9.18
11273-dup	05/03/2003	38.5	3.30	8.79
11347	05/04/2003	70.4	0.90	2.10
11305	05/04/2003	73.0	1.46	2.58
13339	05/04/2003	67.1	0.44	1.45
11287	05/05/2003	63.6	1.48	1.88
11270	05/06/2003	74.2	0.61	1.06
11292	05/06/2003	60.5	1.69	2.95

Table 3.2 Characteristics of Sediment Samples

Station ID	Date	Total Solids (%)	TOC (%)	Volatile Solids (%)
11280	05/06/2003	40.1	2.30	4.66
16618	05/06/2003	46.5	1.30	2.53
11261	05/11/2003	69.7	0.43	1.70
13343	05/11/2003	51.4	1.08	4.56
16496	05/11/2003	41.7	1.74	6.13
13342	05/11/2003	27.9	1.29	9.54
16213	05/12/2003	38.5	2.05	5.97
15464	05/12/2003	71.6	0.39	1.50
14560	05/12/2003	63.8	0.64	2.64
13309	05/12/2003	70.7	0.30	1.66
11193	05/13/2003	63.6	0.84	3.07
13589	05/22/2003	59.0	1.30	2.67
11252-dup	05/28/2003	47.1	0.94	4.41
15908	05/28/2003	69.6	0.67	2.01
11252	05/28/2003	45.4	0.92	3.93
13355	05/28/2003	63.5	0.88	5.02
13337	05/28/2003	47.7	1.05	3.58
13341	05/28/2003	81.0	0.10	0.23
15979	05/29/2003	36.2	1.96	6.41
16622	05/29/2003	46.1	1.28	4.28
11264	05/29/2003	43.0	1.43	4.31
13340	05/29/2003	33.8	1.50	5.41
11300	05/29/2003	63.2	2.84	5.04
11382	05/29/2003	39.5	5.35	11.90
Spring 2004				
14560	03/11/2004	67.1	NA	1.78
11252	03/11/2004	57.1	NA	2.9
13342	03/11/2004	27.2	NA	7.83
13340	03/11/2004	31.6	NA	6.62
13338	03/19/2004	40	1.52	4.48
13344	03/19/2004	20.8	1.77	8.13
16618	03/19/2004	61	0.59	2.01
16499	03/19/2004	40.8	1.21	4.69
11197	03/24/2004	68.2	0.48	1.54
11193	03/24/2004	32.1	1.66	6.1
11261	03/24/2004	69.1	0.49	1.74
11264	03/24/2004	65.7	0.99	NA
11280	04/01/2004	49.9	1.88	NA
11265	04/01/2004	44.5	1.39	NA
11287	04/02/2004	49.6	1.7	NA
11287-dup	04/02/2004	49	1.68	NA
11292	04/02/2004	36.5	2.69	NA
11292-dup	04/02/2004	37.1	2.88	NA
15979	04/02/2004	71.5	1.26	NA
11274	05/18/2004	52.4	1.5	NA

Table 3.2 Characteristics of Sediment Samples

Station ID	Date	Total Solids (%)	TOC (%)	Volatile Solids (%)
15979	05/18/2004	42.3	1.77	NA
Summer 2004				
11280	08/10/2004	39.2	2.12	7.37
18392	08/10/2004	42.6	1.84	6.73
11271	08/10/2004	55.2	1.20	5.26
11270	08/10/2004	45.8	1.66	6.00
18391	08/10/2004	47.8	1.50	5.60
11269	08/10/2004	47.5	1.21	5.16
15980	08/10/2004	46.2	1.45	5.32
15979	08/10/2004	47.7	1.36	5.05
15979-TransA	08/10/2004	38.8	1.53	6.73
15979-TransB	08/10/2004	50.1	1.16	5.14
15979-TransC	08/10/2004	58.1	1.11	3.49
15979-TransD	08/10/2004	45.6	1.50	5.66
15979-TransE	08/11/2004	59.0	1.60	3.60
11268	08/11/2004	40.1	1.38	6.16
11267	08/11/2004	34.6	1.87	7.09
11197	08/11/2004	31.2	1.40	5.49
11197-dup	08/11/2004	32.1	1.17	5.65
18388	08/11/2004	48.1	0.90	3.85
18389	08/11/2004	65.5	0.43	2.11
11193	08/11/2004	38.9	1.09	4.59
11193-dup	08/11/2004	39.6	1.52	5.26
18390	08/11/2004	66.5	0.56	2.41
Fall 2004				
14560	11/04/2004	79.1	0.20	0.53
11292	11/04/2004	39.0	2.97	6.94
11287	11/04/2004	32.3	3.65	6.32
11280	11/04/2004	40.8	2.77	5.58
15979	11/04/2004	38.2	1.69	4.27
11265	11/04/2004	38.9	1.37	4.40
11264	11/04/2004	40.4	1.17	3.75
11193	11/04/2004	57.6	0.81	2.00
11193-dup	11/04/2004	56.5	0.81	1.96
13344	11/08/2004	28.0	1.66	NA
13344-dup	11/08/2004	27.4	1.66	NA
13338	11/08/2004	43.7	0.94	NA
11252	11/08/2004	45.2	0.98	NA
13340	11/09/2004	32.1	1.63	NA
11261	11/09/2004	47.5	1.07	NA
11197	11/09/2004	49.8	0.83	NA
13342	11/09/2004	28.9	1.31	NA
16618	11/09/2004	42.5	1.02	NA
16499	11/09/2004	44.7	1.15	NA

NA= not available. Exceeded holding time. Sample rejected.

Table 3.3 Dioxin Concentrations in Sediment (ng/kg-dry wt)

Station ID	Date	TOC (%)	2,3,7,8-TCDD	1,2,3,7,8-PeCDD	1,2,3,4,7,8-HxCDD	1,2,3,6,7,8-HxCDD	1,2,3,7,8,9-HxCDD	1,2,3,4,6,7,8-HpCDD	OCDD	2,3,7,8-TCDF	1,2,3,7,8-PeCDF	2,3,4,7,8-PeCDF	1,2,3,4,7,8-HxCDF	1,2,3,6,7,8-HxCDF	2,3,4,6,7,8-HxCDF	1,2,3,7,8,9-HxCDF	1,2,3,4,6,7,8-HpCDF	1,2,3,4,7,8,9-HpCDF	OCDF	Total TEQ	Total TEQ in OC	Average TEQ[a]	Average TEQ in OC[a]
Summer 2002																							
11272	07/25/2002	0.92	3.8	< 1.3	2	3.9	3.1	110	4000	13	< 1	1.2	< 4.7	< 0.75	0.96	< 1	12	< 1.4	74	7.37	800.92	7.37	800.92
11298	07/29/2002	2.59	10	< 2.1	4	10	6.5	290	6800	33	3	4.8	4.7	3.4	4.2	1.4	48	< 3.4	130	19.80	764.29	19.80	764.29
11274	07/30/2002	1.62	2.2	< 1.3	2.2	6.6	3.6	170	5600	7.4	1.6	3.3	3.9	1.7	2.7	< 0.99	28	< 1.5	73	7.11	439.17	7.11	439.17
11111	07/31/2002	1.09	2.5	< 1.1	3	4.4	5.6	130	3300	5.7	0.78	0.88	1.2	< 1.9	0.98	< 0.5	9.4	1.2	57	5.46	501.10	5.46	501.10
11092	08/01/2002	2.04	1.5	2.6	5.4	20	10	810	13000	3.2	< 0.43	1.9	3.1	< 0.23	2.4	0.53	51	4.2	140	8.24	403.69	8.24	403.69
11258	08/01/2002	0.47	0.47	< 0.65	0.32	< 1.1	< 0.57	9.7	290	1.3	< 0.49	< 0.26	0.94	< 0.26	< 0.4	< 0.49	1.6	0.47	12	1.11	235.48	1.11	235.48
13340	08/06/2002	1.22	3	1.5	2.8	5.4	6.1	150	3200	7.1	< 0.49	1.7	1.8	1.7	1.1	< 0.49	17	2	73	7.24	593.18	7.24	593.18
13341	08/06/2002	1.03	5	1.8	3	6.5	6.6	170	4200	12	2.9	1.5	2.1	< 0.24	1.6	< 0.45	20	< 0.62	100	10.01	971.80	10.01	971.80
11193	08/08/2002	0.54	69	< 0.91	0.4	< 1.2	1	34	1000	290	5.1	6.3	10	1.8	1.1	1.1	6	1.4	20	103.23	19117.13	103.23	19117.13
11347	08/12/2002	0.60	< 0.25	< 0.67	0.7	1.8	1.2	41	610	0.4	< 0.5	0.62	< 0.52	< 2.7	0.77	< 0.5	11	0.55	18	1.29	214.67	1.29	214.67
11382	08/12/2002	2.56	< 0.27	1.1	2	5.6	3.4	140	2000	0.9	0.91	2.3	1.9	1.6	3.3	0.72	28	< 1.7	81	3.82	149.32	3.82	149.32
11305	08/13/2002	1.26	< 0.86	< 1.9	< 1.1	4.4	< 1.2	72	990	1	4.6	< 0.56	1.9	1.4	< 0.85	< 0.92	< 1.2	< 1.8	36	2.35	186.39	2.36	184.98
11305-dup	08/13/2002	1.29	< 0.87	< 1.3	2.1	4	4.3	84	1100	< 0.79	3.2	< 0.7	< 2.1	< 0.68	< 0.58	< 0.51	< 2.3	< 1.3	39	2.37	183.57		
13337	08/14/2002	1.14	10	< 0.59	2.6	6.2	5.3	150	3000	23	2.8	3	5	< 0.23	2.2	0.97	24	2.7	260	16.33	1432.11	16.33	1432.11
13363	08/16/2002	0.60	< 0.29	< 0.66	< 0.35	< 1.2	< 0.58	4.5	140	< 0.16	< 0.49	< 0.26	< 0.51	< 0.26	< 0.41	< 0.49	< 0.27	< 0.39	< 2.3	0.59	97.54	0.59	97.54
13589	08/16/2002	0.97	< 0.29	< 0.66	0.37	< 1.2	0.8	15	600	0.53	< 0.5	< 0.26	< 0.52	< 0.26	< 0.41	< 0.5	1.2	< 0.49	< 2.3	0.70	72.37	0.70	72.37
15464	08/16/2002	0.27	< 0.25	< 0.67	< 0.21	< 1.2	< 0.59	4.5	90	< 0.23	< 0.5	< 0.27	< 0.52	< 0.27	< 0.41	< 0.5	0.65	< 0.39	< 2.4	0.57	210.74	0.57	210.74
13355	08/18/2002	1.19	0.32	< 0.66	0.27	< 1.2	0.67	31	3300	0.46	< 0.5	< 0.26	< 0.51	< 0.26	< 0.41	< 0.5	2.4	< 0.39	12	0.85	71.13	0.85	71.13
17970	08/18/2002	0.79	< 0.3	< 0.68	< 0.47	< 1.2	0.99	55	3500	0.47	< 0.51	< 0.27	< 0.53	< 0.27	< 0.42	< 0.51	1.9	< 0.4	8.1	0.72	90.66	0.72	90.66
11261	08/19/2002	0.29	3.4	< 0.67	0.35	< 1.2	1	27	640	8.4	0.69	0.65	< 0.52	0.54	< 0.41	< 0.5	5.4	0.66	78	5.09	1754.31	5.09	1754.31
11264	08/19/2002	0.54	9.4	< 0.67	0.77	2.7	1.5	62	1300	21	1.3	1.8	2.5	1.3	1	0.54	15	1.6	170	13.66	2530.28	13.66	2530.28
16618	08/19/2002	0.14	5.3	< 0.7	< 0.34	1.6	1.2	27	670	15	< 0.49	0.66	0.95	0.52	< 0.46	< 0.54	5.2	< 0.74	46	7.81	5579.46	7.81	5579.46
13343	08/20/2002	1.06	1	< 0.7	1.2	2.3	2.3	67	3700	2.1	< 0.5	0.78	< 0.52	0.91	0.92	< 0.5	8.5	< 0.78	27	2.60	245.42	2.60	245.42
13342	08/21/2002	1.08	15	2.3	3.7	6.8	7.3	200	5500	35	1.6	3.1	5.1	2.1	2.3	1.5	32	3	290	24.16	2237.04	24.16	2237.04
13344	08/21/2002	1.22	15	2	3.1	7.1	7.7	230	7100	29	< 0.5	3.2	5.8	2.9	2.9	1.7	42	3.6	350	23.63	1937.09	23.63	1937.09
16496	08/21/2002	1.10	20	< 0.67	< 0.29	9.7	10	270	6600	46	< 0.69	4.8	8.3	3.2	3.4	3.1	40	4.9	330	30.97	2815.39	30.97	2815.39
13338	08/22/2002	1.34	15	< 0.66	2.6	7.4	7.1	190	4400	37	< 0.49	4.5	12	4.1	2.8	2.1	29	3.1	330	24.94	1860.99	25.03	1867.99
13338-dup	08/22/2002	1.34	16	< 0.66	3	6.8	7.2	180	4000	44	1.6	3.2	6.3	2.3	2.2	1	32	2.8	320	25.13	1875.00		
13339	08/22/2002	1.32	13	< 0.62	2.5	6	6.8	160	3600	29	< 0.47	2.6	3.7	1.8	1.9	1.1	24	2.5	190	19.75	1495.97	19.75	1495.97
16499	08/22/2002	1.39	16	2.2	2.5	6.9	6.4	150	3300	36	1.2	2.6	4.6	1.8	1.8	1.4	28	2.6	210	24.60	1769.78	24.60	1769.78
17971	08/24/2002	1.38	14	< 0.67	4.7	10	7.8	340	6200	32	< 0.5	2.7	5	1.8	3	0.86	49	4	390	22.05	1597.54	22.52	1545.11
17971-dup	08/24/2002	1.54	15	< 0.66	5.1	11	7.5	280	7000	31	< 0.49	2.5	4.6	1.9	2.8	1.7	45	3.4	320	22.99	1492.68		
11287	08/26/2002	1.37	1.3	0.8	1.6	3.1	2.3	82	1300	3.5	< 0.38	1.1	1.5	1	1.3	0.5	20	1.3	64	3.74	272.96	3.74	272.96
11302	08/26/2002	2.03	< 0.25	< 0.67	1.1	3.3	2.2	100	1600	1	< 0.5	1.3	1.7	< 0.27	1.3	0.8	16	1.5	100	2.11	103.87	2.11	103.87
11252	08/27/2002	0.37	< 0.23	< 0.62	< 0.23	< 1.1	< 0.54	3.8	98	0.3	< 0.46	< 0.24	< 0.48	< 0.24	< 0.38	< 0.46	0.63	< 0.36	2.5	0.54	146.76	0.56	152.40
11252-dup	08/27/2002	0.37	< 0.25	< 0.68	< 0.12	< 1.2	< 0.6	3.4	77	0.27	< 0.51	< 0.27	< 0.53	< 0.27	< 0.42	< 0.51	0.54	< 0.4	6.2	0.58	158.04		
13336	08/27/2002	1.14	1.1	< 0.68	< 0.16	< 1.2	1.5	34	800	2	< 0.51	< 0.27	< 0.53	< 0.27	< 0.42	< 0.51	2.6	< 0.4	29	1.85	162.70	2.58	226.20
13336-dup	08/27/2002	1.14	1.6	0.74	1.2	2	2.6	64	1500	3.6	< 0.5	0.39	0.7	0.43	0.47	< 0.5	4.6	0.51	34	3.30	289.69		
11270	08/28/2002	1.56	24	< 0.67	1.5	2.9	1.6	78	2000	49	3.1	3.5	< 0.52	< 0.57	1.3	< 0.5	13	1.1	92	31.78	2037.31	31.78	2037.31
11273	08/28/2002	2.23	17	< 1.2	< 0.52	< 1.2	< 0.78	390	4700	110	170	170	370	110	48	84	1500	160	42000	183.13	8211.88	182.60	8188.23
11273-dup	08/28/2002	2.23	20	< 0.63	6.9	14	9.1	360	4700	120	< 0.5	180	330	100	51	88	1500	140	39000	182.07	8164.57		
11280	08/29/2002	2.26	18	1.8	4.1	9.4	5.6	250	4100	43	3.9	6.7	6	< 0.27	4.6	1.5	49	4.5	220	29.88	1322.06	29.88	1322.06
13309	08/30/2002	0.36	0.62	< 0.67	0.28	< 1.2	< 0.59	12	260	1.3	< 0.5	< 0.26	< 0.52	< 0.26	< 0.41	< 0.5	1.7	< 0.39	20	1.20	332.50	1.20	332.50
14560	08/30/2002	1.09	3	3.7	7.2	11	7.4	150	3100	6.9	1.1	0.61	1.4	1	0.95	0.73	10	1.4	68	8.87	813.58	8.87	813.58
11200	09/03/2002	0.49	< 0.25	< 0.67	0.24	< 1.2	< 0.59	13	880	< 0.17	< 0.51	< 0.27	< 0.52	< 0.27	< 0.42	< 0.51	0.99	< 0.4	2.5	0.58	118.52	0.57	107.25
11200-dup	09/03/2002	0.59	< 0.25	< 0.68	< 0.12	< 1.2	< 0.6	19	1300	< 0.17	< 0.51	< 0.27	< 0.53	< 0.27	< 0.42	< 0.51	< 0.2	1.6	5.6	0.57	95.97		
16622	09/03/2002	0.26	< 0.25	< 0.67	0.3	< 1.2	< 0.59	11	390	< 0.26	< 0.51	< 0.29	< 0.53	< 0.27	< 0.42	< 0.51	1	< 0.4	3.3	0.60	229.52	0.60	229.52
15979	09/04/2002	1.70	310	8.5	5.4	20	10	360	6300	950	26	25	26	28	7	5.5	140	16	5500	433.24	25484.71	345.43	21052.89
15979-dup	09/04/2002	1.55	180	6.5	6.7	18	9.4	300	5500	590	20	12	< 77	7.8	3	< 0.73	66	15	4100	257.63	16621.06		
11292	09/05/2002	2.65	1.9	< 3.4	4.4	11	6.2	290	4300	11	4.9	8.7	5.5	< 1.3	6	3.4	47	5.6	300	12.16	458.87	12.16	458.87
11300	09/05/2002	2.22	12	< 0.66	2.5	8.7	4.8	200	3500	100	170	74	330	67	19	28	130	36	160	113.67	5120.05	114.17	5642.75
11300-dup	09/05/2002	1.86	14	< 0.67	3.2	11	5.9	250	4100	110	130	74	330	62	19	29	130	36	200	114.68	6165.46		
15908	09/11/2002	0.98	0.49	< 0.66	< 1.6	< 1.2	< 0.58	13	430	0.78	< 0.49	< 0.26	< 0.51	< 0.26	< 0.41	< 0.49	1.2	< 0.39	6.9	1.06	108.44	1.06	108.44
16213	09/11/2002	1.29	0.76	< 0.66	0.62	< 1.2	1.3	30	620	1.4	0.56	0.28	< 0.51	< 0.26	< 0.41	< 0.49	2.6	< 0.39	15	1.57	121.59	1.57	121.59
Fall 2002																							

Table 3.3 Dioxin Concentrations in Sediment (ng/kg-dry wt)

Station ID	Date	TOC (%)	2,3,7,8-TCDD	1,2,3,7,8-PeCDD	1,2,3,4,7,8-HxCDD	1,2,3,6,7,8-HxCDD	1,2,3,7,8,9-HxCDD	1,2,3,4,6,7,8-HpCDD	OCDD	2,3,7,8-TCDF	1,2,3,7,8-PeCDF	2,3,4,7,8-PeCDF	1,2,3,4,7,8-HxCDF	1,2,3,6,7,8-HxCDF	2,3,4,6,7,8-HxCDF	1,2,3,7,8,9-HxCDF	1,2,3,4,6,7,8-HpCDF	1,2,3,4,7,8,9-HpCDF	OCDF	Total TEQ	Total TEQ in OC	Average TEQ[a]	Average TEQ in OC[a]
13336	10/22/2002	0.74	3.7	1.5	4.2	7.6	7.1	220	5300	8.9	1.3	1.9	3.3	2	2.9	< 0.58	27	1.7	130	9.09	1228.92	9.09	1228.92
13338	10/22/2002	0.60	4.4	< 0.58	1.3	2.6	3.1	77	1800	11	1.3	1	3	1.3	0.66	0.36	10	1	150	7.44	1240.33	7.44	1240.33
13340	10/23/2002	1.44	5.7	1	2	4	5	120	3100	14	1	1.4	2.1	1	1.2	< 0.51	13	1.3	120	9.91	687.88	9.91	687.88
11252	10/24/2002	1.29	3.4	2.2	3.2	5.3	7.3	170	3800	7.7	0.79	1	1.3	1	1.1	< 0.51	13	1.3	86	7.76	601.16	7.76	601.16
16499	10/24/2002	1.33	9.9	1.3	2.6	7	5.5	140	3200	20	1.6	1.9	4.1	1.9	2.1	0.78	26	3	170	15.98	1201.35	15.98	1201.35
17970	10/24/2002	0.39	1	< 0.64	0.74	1.2	1.7	49	1500	3.8	1.3	0.81	0.77	0.34	< 0.39	< 0.48	2.6	< 0.37	16	2.53	648.33	2.53	648.33
11261	10/26/2002	0.48	6.5	< 0.68	0.89	1.8	2	57	1500	16	1	1.2	1.6	0.72	0.66	< 0.51	8.8	0.83	140	9.71	2023.44	9.71	2023.44
13344	10/27/2002	1.42	21	1.8	3.5	7.6	7.9	240	7400	40	3.4	3.5	5.3	2.7	3.1	1.3	41	4.3	460	30.96	2180.28	30.96	2180.28
13342	10/28/2002	1.45	14	1.5	2.3	5.9	6.3	190	5400	33	2.5	2.8	4.2	2	2.1	0.92	27	2.9	280	21.95	1513.59	23.81	1641.83
13342-dup	10/28/2002	1.45	17	< 0.66	3.5	7.4	7.1	230	6400	41	3.3	3.5	< 0.52	2.8	2.7	1.1	32	3.1	350	25.67	1770.07		
17971	10/28/2002	1.01	8.3	1.2	1.6	4.1	4.6	120	3500	21	1.6	1.5	3	1.4	1.2	0.64	16	1.5	170	13.48	1335.05	13.48	1335.05
11193	10/31/2002	0.61	44	0.8	0.71	1.8	1.7	51	1500	160	3.9	4.1	4.9	1.9	0.81	0.62	6.4	0.84	32	63.89	10473.61	63.89	10473.61
13363	11/06/2002	1.08	0.54	< 0.64	0.72	< 1.1	1.4	29	1200	0.8	< 0.48	< 0.26	< 0.5	< 0.26	< 0.4	< 0.48	1.6	< 0.38	8.6	1.21	111.67	1.21	111.67
15464	11/06/2002	0.25	< 0.24	< 0.65	< 0.16	< 1.1	< 0.57	8.9	190	0.2	< 0.49	< 0.26	< 0.51	< 0.26	< 0.4	< 0.49	1.2	< 0.38	4.1	0.55	221.70	0.55	221.70
11200	11/21/2002	0.10	< 0.25	< 0.68	< 0.12	< 1.2	< 0.6	1.9	99	< 0.17	< 0.51	< 0.27	< 0.53	< 0.27	< 0.42	< 0.51	0.36	< 0.4	< 2.4	0.57	566.25	0.57	566.25
11280	12/02/2002	2.17	20	0.64	4.6	12	6.7	350	6200	53	3.7	7.4	11	5.5	2.7	1.9	73	5.7	320	33.95	1564.29	39.73	1830.76
11280-dup	12/02/2002	2.17	27	< 0.7	6.6	18	8.1	480	7700	65	6.9	11	11	9.1	4.6	2.5	100	7.4	510	45.51	2097.24		
11292	12/10/2002	2.27	25	< 9.1	12	71	24	2100	41000	48	14	23	49	24	13	9.4	460	29	1400	64.52	2842.07	64.52	2842.07
Spring 2003																							
11092	04/30/2003	2.94	0.91	3	3.5	9.1	5.2	250	6500	2.1	< 1.1	2.6	4.8	2.3	3.8	< 0.84	48	3	140	6.86	233.32	6.86	233.32
11258	04/30/2003	0.25	2.7	< 0.82	< 1.1	< 1.2	< 1	14	360	4.8	< 0.89	< 0.51	< 0.68	< 0.53	< 0.56	< 0.67	3.8	< 0.83	30	3.82	1528.70	3.82	1528.70
11272	04/30/2003	1.88	3.8	2.3	2.4	4.4	5.6	160	10000	7.9	< 0.6	1.2	2	1.4	1.9	< 0.58	18	2	140	8.15	433.72	8.15	433.72
11111	05/01/2003	1.27	2.1	1.8	3.4	5.9	6.2	130	4200	3.7	0.67	0.78	< 0.6	< 0.75	0.94	< 0.77	9.2	1.8	44	5.54	436.50	5.54	436.50
11274	05/01/2003	1.55	1.5	< 0.69	1.5	3	3.3	72	2900	3.6	0.53	1.3	1.8	0.61	1.2	< 0.5	10	0.96	32	3.88	250.00	3.23	208.45
11274-dup	05/01/2003	1.55	0.98	< 0.68	0.84	1.3	1.1	51	2300	2.4	< 0.64	1.3	1.1	< 0.62	< 0.67	< 0.65	7.6	< 1.1	25	2.59	166.90		
11302	05/01/2003	4.27	2.5	< 2.6	4.1	8.7	6	230	2900	4.4	< 1.3	2.3	< 1.6	< 1.7	5.4	< 1.4	51	< 2.5	190	7.43	173.95	7.43	173.95
11298	05/02/2003	3.00	6.4	< 0.73	2.9	7.6	5.2	210	4600	20	< 0.61	3.3	3.9	2.5	3.3	0.82	33	3	82	12.87	428.99	12.87	428.99
11273	05/03/2003	3.12	23	< 1.6	8.4	18	11	430	6400	100	82	120	210	76	22	76	1100	140	34000	139.64	4475.64	134.32	4305.05
11273-dup	05/03/2003	3.12	21	< 1.5	8	19	9.2	420	5700	100	76	110	200	71	15	66	1100	140	39000	129.00	4134.46		
11305	05/04/2003	1.46	< 0.91	< 1.4	1.9	4.3	2.4	88	1100	1.4	< 0.83	1.9	2.1	1.2	2	< 0.65	14	2.1	39	3.34	228.65	3.34	228.65
11347	05/04/2003	0.90	< 0.27	< 0.67	0.97	2.7	1.7	75	960	0.55	< 0.5	< 0.26	0.78	0.57	0.91	< 0.5	14	< 0.93	65	1.22	135.44	1.22	135.44
13339	05/04/2003	0.44	2.8	< 0.67	0.98	2.2	2.3	190	2700	3.8	0.54	< 0.28	0.55	0.6	0.89	< 0.5	6.5	< 0.68	47	4.22	955.09	4.22	955.09
11287	05/05/2003	1.48	1.6	< 0.85	1.5	3.2	2.3	88	1200	3.3	< 0.5	1.1	2	1	1.3	< 0.79	17	< 1.3	60	3.87	261.79	3.87	261.79
11382	05/05/2003	5.35	< 0.5	< 0.76	1.4	3.5	2.5	120	1700	0.78	< 0.65	1.5	< 0.52	1.2	2	< 0.63	21	< 1	78	2.40	44.89	2.40	44.89
11270	05/06/2003	0.61	2.3	< 0.68	0.81	1.3	0.97	37	1400	5.5	< 0.51	0.91	1.1	0.51	0.69	< 0.51	6.8	< 0.46	33	4.05	664.14	4.05	664.14
11280	05/06/2003	2.30	27	< 0.91	4.3	10	7.1	330	5600	62	3	6.7	9.6	3.9	3.5	2.3	59	5.5	290	41.00	1782.50	41.00	1782.50
11292	05/06/2003	1.69	< 0.81	< 0.79	2.2	6	3.5	190	2600	1.7	< 0.5	3	2.2	2.4	2.9	0.68	40	3.8	160	4.27	252.84	4.27	252.84
16618	05/06/2003	1.30	41	3.1	3.5	8	6.3	230	4100	100	< 0.71	4.5	5.9	2.4	3.1	1.6	47	6.4	540	57.90	4453.67	57.90	4453.67
11261	05/11/2003	0.43	9.5	0.85	0.73	1.9	1.7	53	1700	26	< 0.51	1.2	1.4	< 0.27	< 0.42	< 0.51	8	0.77	85	13.77	3202.50	13.77	3202.50
13342	05/11/2003	1.29	15	2.3	3.6	6.5	8.3	250	6300	30	< 0.5	3	5.6	2.3	2.4	1.3	35	3.5	310	23.66	1834.30	23.66	1834.30
13343	05/11/2003	1.08	2.6	0.71	1.3	2.5	2.5	85	3800	5.1	0.54	0.69	1.4	0.9	0.9	< 0.5	12	0.8	80	4.81	445.56	4.81	445.56
16496	05/11/2003	1.74	21	< 0.67	2.5	5.3	5.3	180	4600	50	< 0.5	3.3	6	2	2	0.96	32	3.2	340	30.24	1737.70	30.24	1737.70
13309	05/12/2003	0.30	0.64	< 0.67	< 0.24	< 1.2	0.84	21	430	1.2	< 0.51	< 0.27	< 0.53	< 0.27	< 0.42	< 0.51	2	< 0.4	11	1.25	416.75	1.25	416.75
14560	05/12/2003	0.64	0.36	< 0.65	0.47	< 1.1	0.92	28	540	0.97	< 0.49	< 0.26	< 0.51	< 0.26	< 0.4	< 0.49	1.8	< 0.38	8.8	0.97	152.15	0.97	152.15
15464	05/12/2003	0.39	< 0.25	< 0.67	< 0.22	< 1.2	< 0.59	10	190	0.3	< 0.5	< 0.27	< 0.52	< 0.27	< 0.41	< 0.5	4.5	< 0.39	7.4	0.59	150.77	0.59	150.77
16213	05/12/2003	2.05	0.96	< 0.67	0.87	< 1.2	1.2	43	990	2	< 0.51	< 0.29	< 0.53	0.53	< 0.42	< 0.51	3.4	< 0.42	24	1.81	88.09	1.81	88.09
11193	05/13/2003	0.84	94	< 0.67	0.53	1.2	1.5	42	1500	390	7.5	7.5	9.9	2.1	0.61	0.87	6.4	1.3	25	138.96	16543.27	138.96	16543.27
13589	05/22/2003	1.30	0.4	< 0.67	0.69	< 1.2	1.3	32	1300	0.73	< 0.5	< 0.27	< 0.52	< 0.27	< 0.42	< 0.5	2.1	< 0.4	10	1.07	81.92	1.07	81.92
11252	05/28/2003	0.92	3.5	1.5	1.6	4	3.9	94	2300	8.1	0.62	0.63	1.4	0.63	< 0.41	< 0.5	7.7	0.73	51	6.60	717.88	6.63	720.16
11252-dup	05/28/2003	0.92	3.8	0.9	1.5	3.5	3.9	92	2200	8.7	0.73	0.76	1.2	0.55	< 0.41	< 0.49	5.8	0.56	47	6.65	722.45		
13337	05/28/2003	1.05	8.3	< 0.72	1.9	3.3	3.3	100	2000	20	1.5	1.6	2.3	1.2	0.85	0.6	12	1.5	110	12.70	1209.52	12.70	1209.52
13340	05/28/2003	1.50	2.7	1.4	2.2	4.2	4.8	140	2700	6.3	< 0.5	1.6	2	1.3	0.69	0.55	17	1.3	68	6.42	427.77	6.42	427.77
13341	05/28/2003	0.10	< 0.25	< 0.68	< 0.59	< 1.2	< 0.67	12	39	0.24	< 0.51	< 0.36	< 0.53	< 0.27	< 0.42	< 0.51	4.3	< 0.4	< 2.4	0.63	631.25	0.63	631.25
13355	05/28/2003	0.88	< 0.24	< 0.65	0.76	< 1.1	1	18	380	< 0.16	< 0.49	< 0.26	< 0.5	< 0.26	< 0.4	< 0.49	< 0.19	< 0.38	< 2.3	0.68	77.41	0.68	77.41
15908	05/28/2003	0.67	0.57	< 0.65	0.26	< 1.1	< 0.57	15	400	1	< 0.48	< 0.26	< 0.5	< 0.26	< 0.4	< 0.48	1.5	< 0.38	7.3	1.10	164.33	1.10	164.33
11264	05/29/2003	1.43	16	< 0.68	1.8	3.8	4.1	100	2100	33	3.3	4.2	6.2	2.1	0.92	1.5	26	3.9	530	23.78	1662.73	23.78	1662.73

Table 3.3 Dioxin Concentrations in Sediment (ng/kg-dry wt)

Station ID	Date	TOC (%)	2,3,7,8-TCDD	1,2,3,7,8-PeCDD	1,2,3,4,7,8-HxCDD	1,2,3,6,7,8-HxCDD	1,2,3,7,8,9-HxCDD	1,2,3,4,6,7,8-HpCDD	OCDD	2,3,7,8-TCDF	1,2,3,7,8-PeCDF	2,3,4,7,8-PeCDF	1,2,3,4,7,8-HxCDF	1,2,3,6,7,8-HxCDF	2,3,4,6,7,8-HxCDF	1,2,3,7,8,9-HxCDF	1,2,3,4,6,7,8-HpCDF	1,2,3,4,7,8,9-HpCDF	OCDF	Total TEQ	Total TEQ in OC	Average TEQ[a]	Average TEQ in OC[a]
11300	05/29/2003	2.84	13	< 0.66	5.6	16	8.6	390	4600	64	58	22	93	19	5.6	12	100	17	320	49.45	1741.02	49.45	1741.02
15979	05/29/2003	1.96	16	< 0.68	2.5	6.8	6.4	150	3900	36	< 0.51	4.3	7	2.8	1.3	1.8	30	4.8	410	24.79	1264.94	24.79	1264.94
16622	05/29/2003	1.28	0.55	< 0.63	1.7	4.3	4.4	150	6600	1.2	< 0.47	0.82	1.3	1.1	< 0.39	< 0.47	13	1.3	44	2.57	200.96	2.57	200.96
Spring 2004																							
11252	03/11/2004	0.68	2.6	0.92	< 1	1.9	2.6	69	1400	6.9	0.53	< 0.52	1.5	0.39	0.38	0.29	< 4.8	< 0.53	44	4.66	685.66	4.66	685.66
14560	03/11/2004	0.50	< 0.75	< 0.36	< 0.42	0.68	0.75	26	470	< 0.82	0.21	0.27	0.48	0.34	< 0.19	< 0.23	3	< 0.58	19	0.92	183.70	0.92	183.70
13340	03/11/2004	2.04	4	< 1	3.3	5.6	7.6	220	4500	9.3	< 0.92	< 1.4	< 3.4	1.8	1.5	0.53	25	1.9	100	7.76	380.20	7.76	380.20
13342	03/11/2004	1.81	17	< 1.6	2.6	5.6	6.3	190	4500	43	3.1	3.1	< 6.6	2.5	2.2	0.86	27	3.1	220	25.74	1422.15	25.74	1422.15
13338	03/19/2004	1.52	8.9	0.93	1.9	3.4	3.7	93	2000	29	1.5	1.3	< 4.6	1.9	0.98	0.5	9.6	1.2	88	14.46	951.18	14.46	951.18
13344	03/19/2004	1.77	11	1.1	2.1	4.5	4.9	150	4800	28	2.5	2.6	< 6.1	1.7	2	1.2	22	< 2.3	170	17.72	1001.13	17.72	1001.13
16499	03/19/2004	1.21	29	2.2	2.9	9.6	6.3	160	2700	55	2.7	2.5	7.4	3.4	2	0.75	29	3.9	210	40.22	3323.97	40.22	3323.97
16618	03/19/2004	0.59	3.3	< 0.57	1.1	1.7	2	58	1400	7.3	0.55	0.51	1.3	0.48	0.38	0.28	6.4	1	53	5.18	877.80	5.18	877.80
11265	04/01/2004	1.39	15	1.4	2.6	6.6	4.6	180	4100	40	6.9	6.7	< 16	5.6	4.1	4.9	100	14	2100	27.04	1944.96	27.04	1944.96
11280	04/01/2004	1.88	330	6.8	9.7	28	15	720	9000	810	22	39	40	26	42	2.9	160	15	740	451.36	24008.51	451.36	24008.51
11287	04/02/2004	1.70	8.5	2	3.3	8.4	5.3	260	3500	22	2.1	3.2	5.8	2.7	3.5	1.4	46	3.9	150	16.45	967.35	16.11	953.32
11287-dup	04/02/2004	1.68	8.6	< 1.6	3.1	7.2	4.8	220	3000	25	2.1	2.9	< 8.3	2.9	3.4	1.7	46	4.4	150	15.78	939.29		
11292	04/02/2004	2.88	0.93	2.3	3.3	8.1	5.7	270	3900	3	1.2	2.6	< 6.2	2.5	4	1.5	42	3.1	120	6.56	227.78	6.46	232.01
11292-dup	04/02/2004	2.69	0.64	2.4	3.3	8.9	6.3	270	3900	2.7	1.1	2.7	2.5	2.7	3.6	1.1	41	3.2	120	6.36	236.25		
11193	03/24/2004	1.66	61	2.3	< 2.1	< 3.6	5.5	160	5200	230	6.6	6.2	11	3.6	2.2	1.7	19	2.8	160	91.27	5497.89	91.27	5497.89
11197	03/24/2004	0.48	5.9	0.72	< 0.61	1.7	< 1.4	67	2600	16	< 0.64	0.98	< 1.4	0.62	0.56	0.37	6	0.64	39	8.86	1846.15	8.86	1846.15
11261	03/24/2004	0.49	5.5	0.45	0.73	1.4	1.3	36	1000	17	0.81	0.73	1.2	0.32	0.42	0.33	4.9	0.68	83	8.40	1714.39	8.40	1714.39
11264	03/24/2004	0.99	10	0.93	1.3	3.4	1.8	84	1700	39	16	10	10	2.3	1.8	1.8	32	3.5	610	22.41	2263.13	22.41	2263.13
11274	05/18/2004	1.50	1.3	0.76	1.1	2.1	2.2	83	220	4.2	0.57	1.1	1.5	0.96	0.98	0.38	10	0.92	26	3.60	240.03	3.60	240.03
15979-A	04/02/2004	1.26	9.8	0.67	0.76	< 1.5	1.2	50	1100	26	1.2	1.3	2	0.92	0.84	1	24	3.6	510	14.19	1126.35	16.52	1095.77
15979-B	05/18/2004	1.77	12	1.4	1.7	4.3	3.6	130	380	32	1.8	2.3	3.3	1.8	1.7	0.74	26	2.8	54	18.85	1065.20		
Fall 2004																							
11193	11/04/2004	0.81	27	0.62	0.73	1.9	2.2	71	2300	100	2.6	2.5	3.4	0.96	0.53	0.39	8	0.92	110	39.70	4919.58	42.73	5287.66
11193-dup	11/04/2004	0.81	31	0.84	0.7	1.5	1.9	57	2000	120	2.5	2.6	3.2	1.1	0.6	< 0.2	8.1	1	100	45.76	5655.75		
11264	11/04/2004	1.17	11	1	1.3	3	3.3	100	2600	28	2.1	2	3.1	1.1	1.2	0.67	13	2.1	190	16.77	1433.50	16.77	1433.50
11265	11/04/2004	1.37	17	1.2	1.8	3.7	3.9	110	2700	42	2.4	< 0.29	4.3	1.4	1.6	0.95	20	2.8	370	23.76	1734.12	23.76	1734.12
11280	11/04/2004	2.77	650	13	9.2	30	16	680	9500	1600	27	34	30	12	12	5.1	130	15	760	846.28	30551.62	846.28	30551.62
11287	11/04/2004	3.65	10	1.8	3.5	8	5.8	230	3800	27	2.4	3.7	3.7	3.4	3.8	1	44	3.9	140	18.49	506.58	18.49	506.58
11292	11/04/2004	2.97	1.2	2	3.4	9.1	5.8	250	3800	4.9	1.1	2.9	6.5	2.7	3.5	0.96	44	3.5	120	7.39	248.86	7.39	248.86
14560	11/04/2004	0.20	< 0.36	< 0.35	< 0.36	< 0.29	0.48	11	220	0.37	< 0.21	< 0.23	< 0.21	< 0.23	< 0.25	< 0.24	0.48	< 0.25	2.1	0.49	247.13	0.49	247.13
15979	11/04/2004	1.69	12	1.4	2	5	4	150	5100	29	2	2.7	4	2	2.3	0.93	26	2.6	210	19.07	1128.58	19.07	1128.58
11252	11/08/2004	0.98	1.4	1	1.6	2.9	4.1	96	2000	3.1	0.31	0.52	0.72	< 0.32	0.41	< 0.45	5.3	< 0.38	27	3.50	357.20	3.50	357.20
13338	11/08/2004	0.94	5	< 0.33	2.4	4.3	5.6	150	3900	14	0.89	1.2	2.2	0.97	0.79	< 0.62	18	1.6	95	8.78	932.48	8.78	932.48
13344	11/08/2004	1.66	15	1.7	3.2	6.7	6.4	240	6900	38	2.9	3.2	5.3	2.5	2.4	1.5	35	3.8	290	24.20	1457.53	23.98	1444.58
13344-dup	11/08/2004	1.66	15	1.9	2.9	5.8	6.3	210	6300	36	2.9	3.2	4	1.9	2.4	1.4	32	3.3	250	23.77	1431.63		
11197	11/09/2004	1.66	8.8	0.69	1.1	2.7	2.9	100	3800	26	1.1	1.2	2	0.71	0.82	< 0.27	9.2	1.1	72	13.44	809.43	13.44	809.43
11261	11/09/2004	1.07	12	0.63	1.3	2.4	3.1	79	2000	36	1.3	1.5	2.5	0.7	0.83	0.62	11	1.5	170	17.88	1670.56	17.88	1670.56
13340	11/09/2004	1.63	2.9	1.2	1.7	3.9	4.3	120	2400	7.4	0.96	1.4	1.3	1.1	1	0.46	12	1.3	49	6.36	390.43	6.36	390.43
13342	11/09/2004	1.31	15	1.4	3.3	7.1	7.8	220	7900	49	2.9	3.1	3.1	2.5	2.1	1	33	3.6	300	24.99	1907.25	24.99	1907.25
16499	11/09/2004	1.15	56	5.7	5.5	28	18	360	5100	110	4	4.4	< 0.18	3.9	3.8	1.6	64	5.7	360	78.34	6812.09	78.34	6812.09
16618	11/09/2004	1.02	12	0.84	1.7	3.5	4.5	110	3500	31	1.2	1.3	< 0.17	0.87	0.76	0.41	12	1.3	150	17.41	1707.11	17.41	1707.11

[a] Average of duplicate samples, otherwise concentration of a single sample

dup = duplicate

trans=transect

Values reported to the Detection Limit

Non-detects assumed as 1/2 MDL for TEQ calculations

▨ Tributary

🟦 Value between the detection and the reporting limits

🟨 Value is an estimate due to blank contamination (concentration < 20 times lowest concentration)

🟥 Value is an estimate due to QC issues (interference, signal to noise ratio)

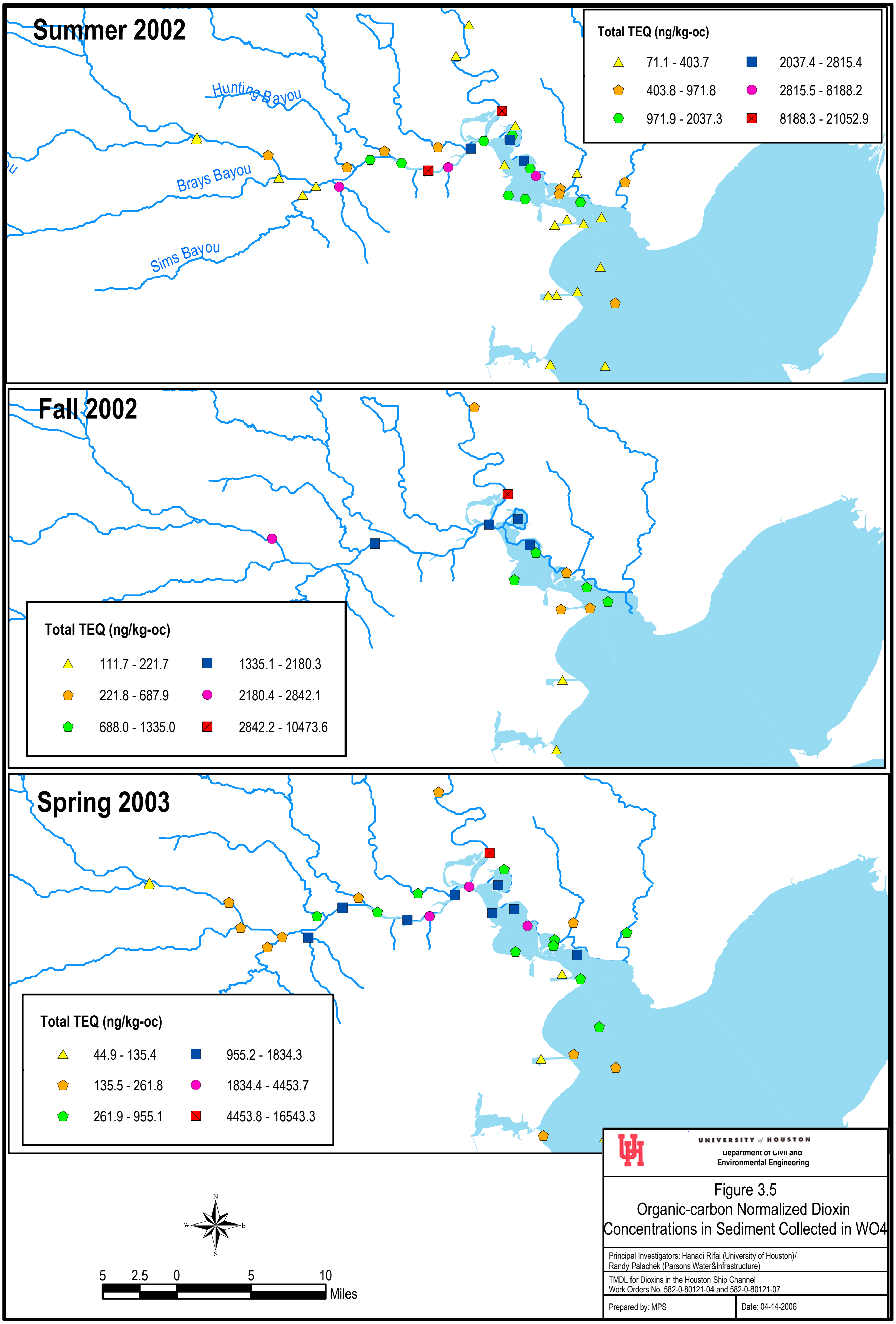

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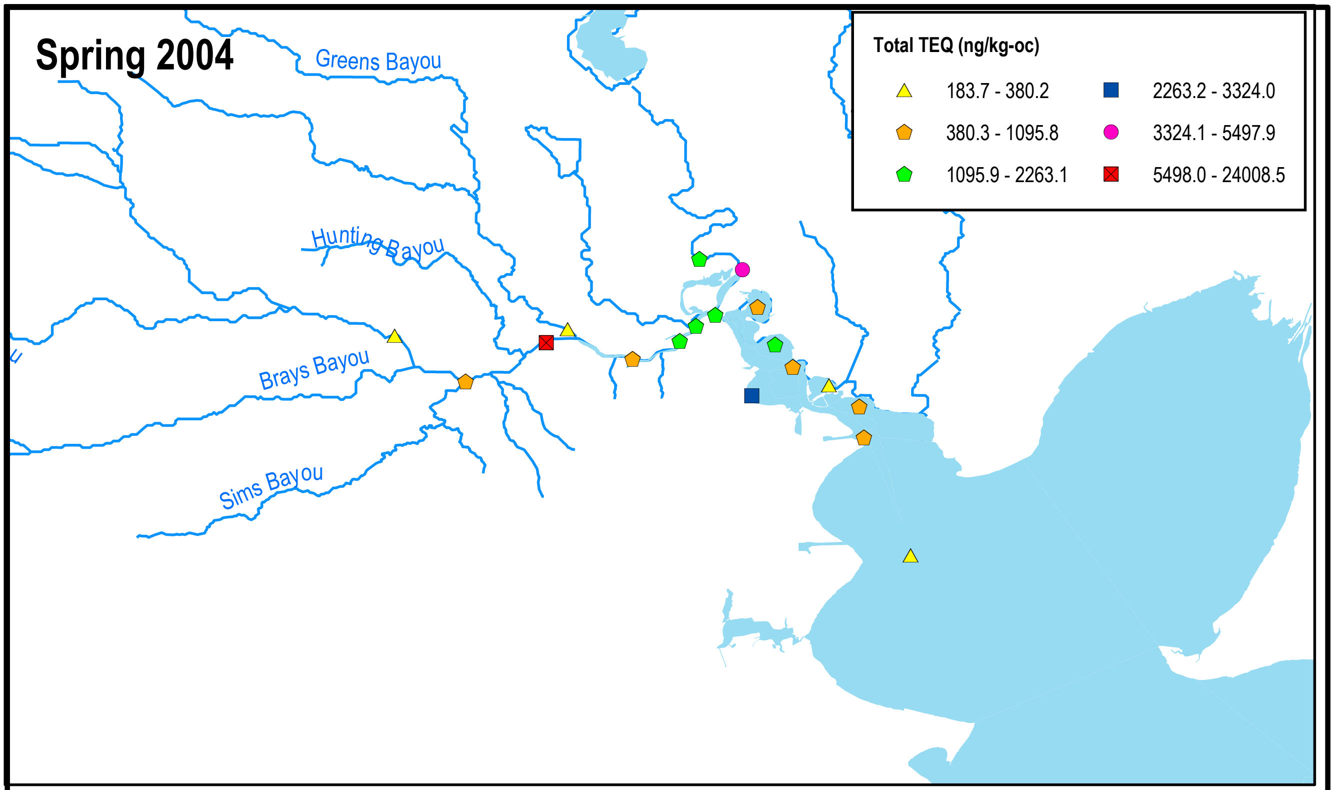
Figure 3.5
Organic-carbon Normalized Dioxin
Concentrations in Sediment Collected in WO4

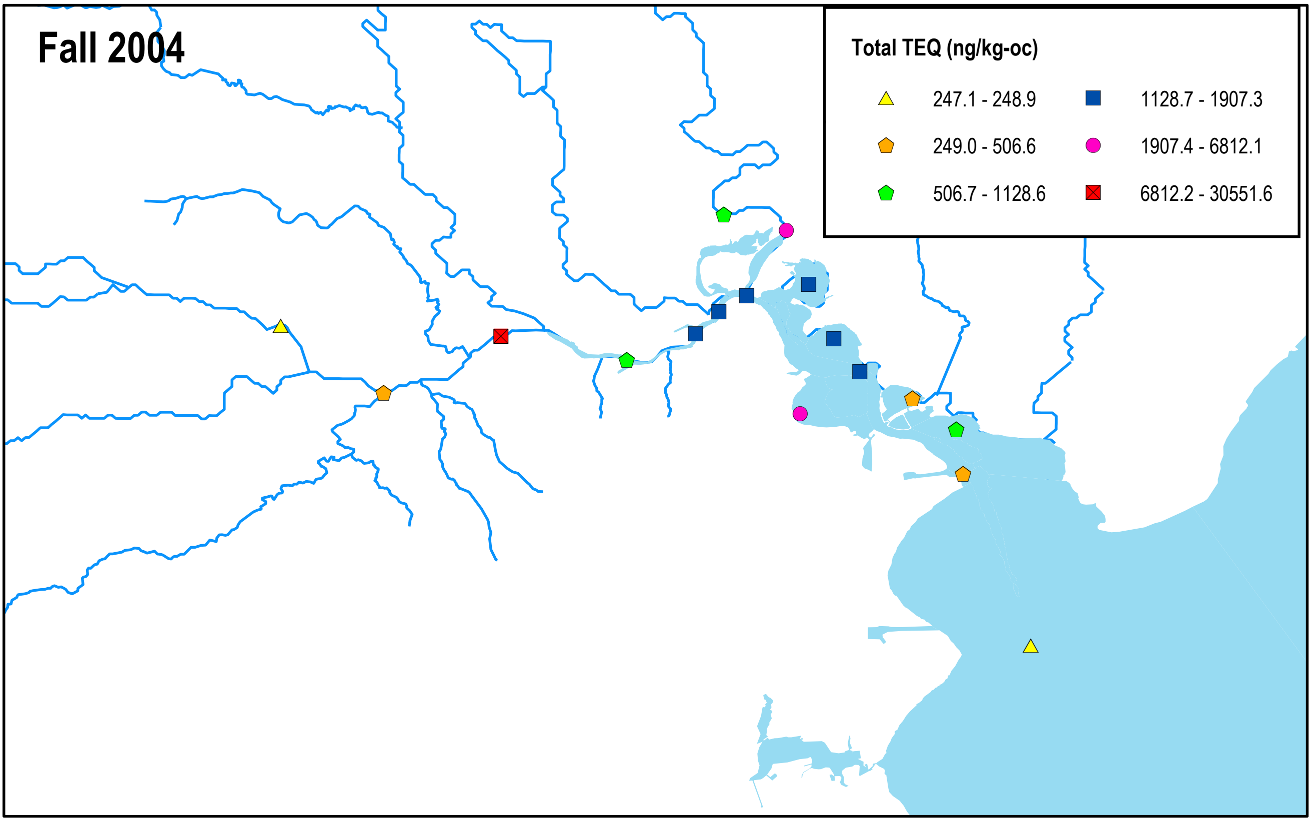
Principal Investigators: Hanadi Rifai (University of Houston)/
Randy Palachek (Parsons Water&Infrastructure)

TMDL for Dioxins in the Houston Ship Channel
Work Orders No. 582-0-80121-04 and 582-0-80121-07

Prepared by: MPS

Date: 04-14-2006





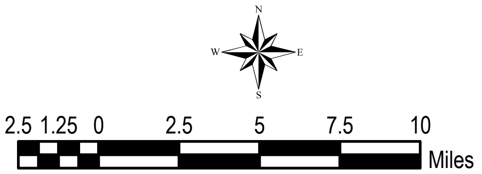


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Figure 3.6
Organic-carbon Normalized Dioxin
Concentrations in Sediment Collected in WO7

Principal Investigators: Hanadi Rifai (University of Houston)/
Randy Palachek (Parsons Water&Infrastructure)

TMDL for Dioxins in the Houston Ship Channel
Work Orders No. 582-0-80121-04 and 582-0-80121-07

Prepared by: MPS

Date: 04-14-2006

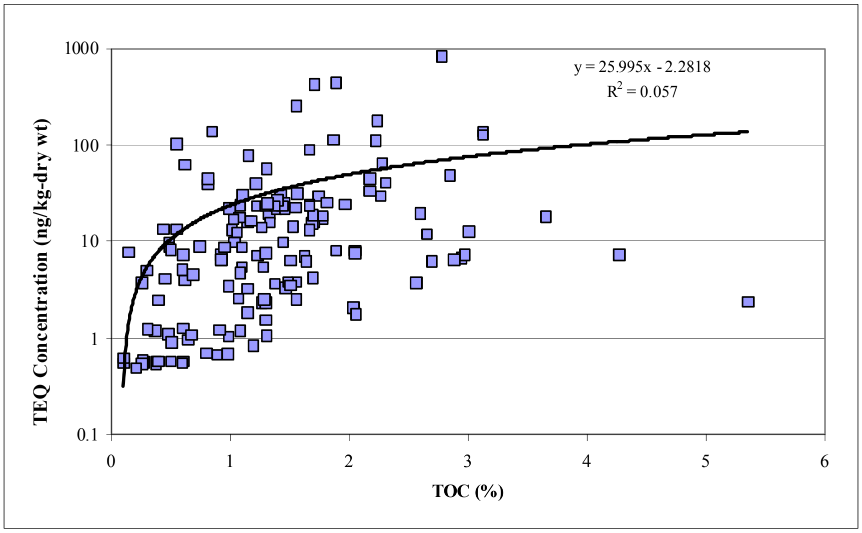
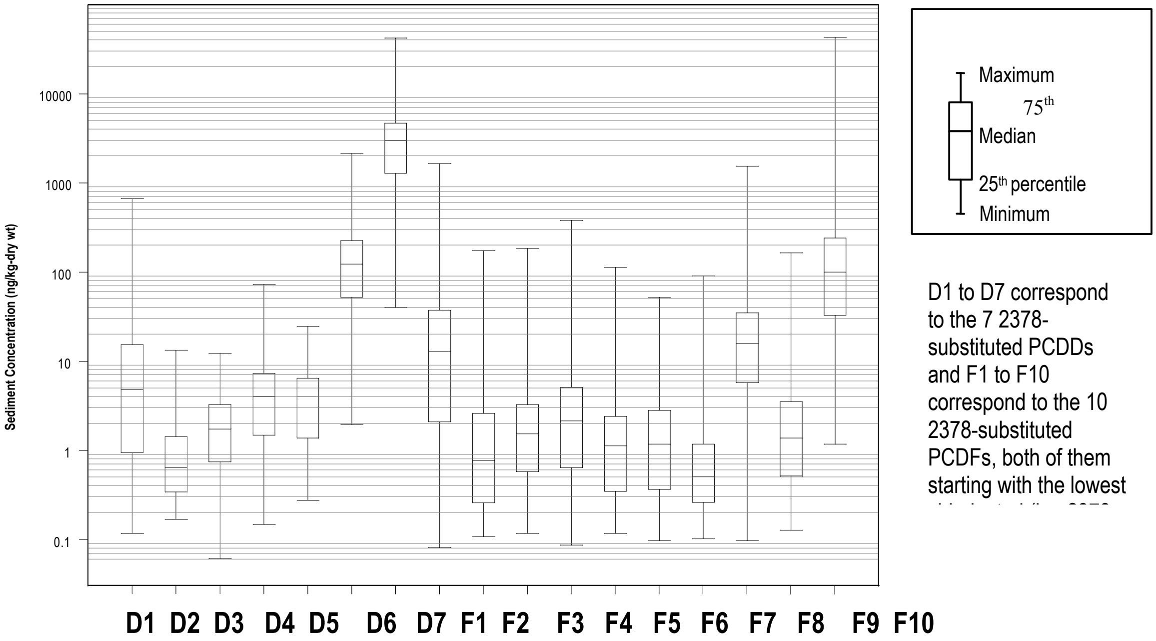


Figure 3.7 Relationship between TEQ and Total Organic Carbon Content

Figure 3.8 shows the concentration distribution for the seventeen 2378-substituted congeners in bottom sediments for the five major sampling events. The concentrations for the individual congeners ranged from 0.06 to 42,000 ng/kg dry wt. In general, sediment samples exhibited congener concentrations that followed the sequence OCDD>HpCDD>OCDF>HpCDF>TCDF>TCDD. As with water samples, most of the total concentration of 2378-substituted PCDD/PCDFs can be attributed to OCDD with an average contribution of 89%, while 2378-TCDD is the major contributor to the total TEQ (41% on average).

Dioxin results of high-resolution sediment sampling, conducted in Summer 2004 to pinpoint the location of unidentified major sources near stations 15979 and 11193, are included in Table 3.4. Total TEQ concentrations varied between 8.07 and 92.38 ng/kg-dry wt. with an average of 22.57 ng/kg-dry wt. Figure 3.9 shows profiles of oc-normalized 2378-TCDD and TEQ concentrations at the 15 sampling locations. The highest organic-carbon normalized TEQ concentrations were observed at stations 11268 and 11193 for segments 1006 and 1001, respectively. Both 2378-TCDD and TEQ levels at stations 11193 and 18389 (~1 km upstream of Station 11193) are significantly higher than those observed at the remaining locations in Segment 1001, which might suggest the presence of an identified source of 2378-TCDD. This finding prompted additional high-resolution sediment sampling at the bend in the San Jacinto River (Segment 1001) in Summer 2005. In the main channel, results suggest that additional unidentified sources might be present in the vicinity of Station 11280 and between stations 11268 and 11267.



D1 to D7 correspond to the 7 2378-substituted PCDDs and F1 to F10 correspond to the 10 2378-substituted PCDFs, both of them starting with the lowest

Figure 3.8 Distribution of Individual Congeners in Bottom Sediments

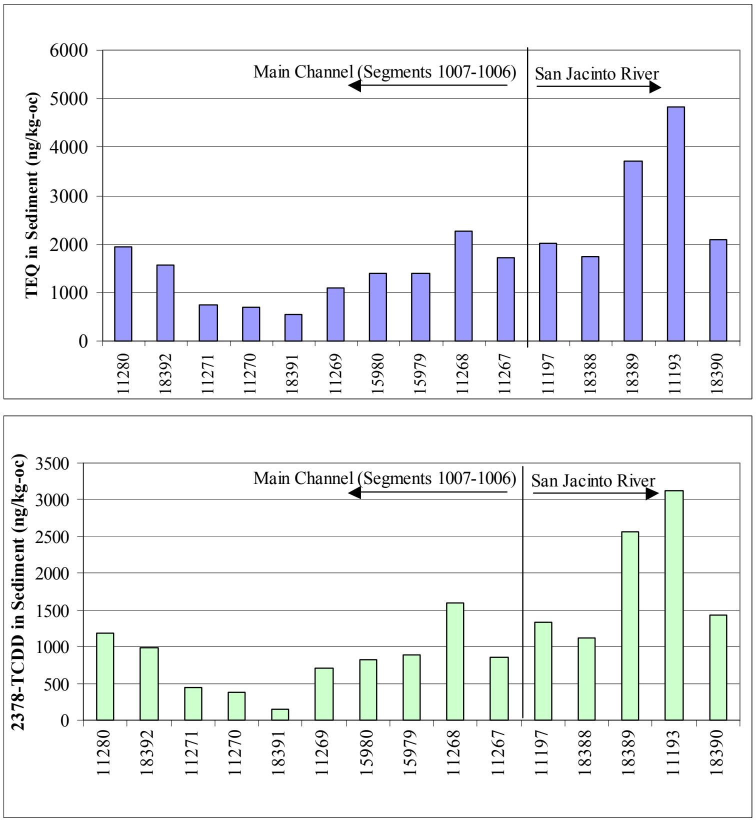


Figure 3.9 Organic-carbon Normalized Concentrations from Summer 2004 High-resolution Sediment Sampling

Table 3.4 Dioxin Concentrations in Sediment from High-resolution Sampling (ng/kg-dry wt)

Station ID	Date	TOC (%)	2,3,7,8-TCDD	1,2,3,7,8-PeCDD	1,2,3,4,7,8-HxCDD	1,2,3,6,7,8-HxCDD	1,2,3,7,8,9-HxCDD	1,2,3,4,6,7,8-HpCDD	OCDD	2,3,7,8-TCDF	1,2,3,7,8-PeCDF	2,3,4,7,8-PeCDF	1,2,3,4,7,8-HxCDF	1,2,3,6,7,8-HxCDF	2,3,4,6,7,8-HxCDF	1,2,3,7,8,9-HxCDF	1,2,3,4,6,7,8-HpCDF	1,2,3,4,7,8,9-HpCDF	OCDF	Total TEQ	Total TEQ in OC	Average TEQ[a]	Average TEQ in OC[a]
Summer 2004																							
18388	08/02/2004	0.90	10.00	0.87	1.60	4.10	3.60	140.00	4800.0	28.00	2.00	1.60	2.70	1.40	1.40	0.63	14.00	2.50	140.0	15.68	1742.00	15.68	1742.00
11269	08/10/2004	1.21	8.50	1.30	1.30	3.10	3.00	93.00	3100.0	20.00	1.30	1.60	1.70	1.60	1.20	0.60	15.00	2.00	170.0	13.27	1096.28	13.27	1096.28
18391	08/10/2004	1.50	< 4.30	< 3.90	< 4.40	< 3.50	< 3.40	110.00	3700.0	30.00	< 3.70	< 2.80	< 3.60	< 2.30	< 2.60	< 3.20	23.00	< 3.20	170.0	8.07	537.83	8.07	537.83
11270	08/10/2004	1.66	6.20	1.30	2.00	5.10	4.00	160.00	6600.0	16.00	1.80	2.60	< 0.18	2.40	2.00	0.97	28.00	2.80	130.0	11.50	692.53	11.50	692.53
11271	08/10/2004	1.20	5.30	< 0.39	1.40	3.10	2.80	98.00	4700.0	13.00	1.20	1.80	2.10	1.50	1.50	0.66	16.00	1.70	82.0	8.96	746.96	8.96	746.96
18392	08/10/2004	1.84	18.00	2.10	2.90	6.70	5.20	200.00	5200.0	50.00	< 0.33	4.30	5.70	3.20	3.20	1.50	34.00	4.20	220.0	29.05	1578.71	29.05	1578.71
11280	08/10/2004	2.12	25.00	3.00	3.60	9.60	6.50	310.00	6200.0	63.00	6.70	6.80	12.00	6.50	5.10	2.60	50.00	4.70	230.0	41.13	1939.86	41.13	1939.86
15979	08/10/2004	1.36	12.00	1.30	2.10	4.60	3.50	150.00	4400.0	29.00	2.40	2.60	3.80	2.00	1.80	1.40	29.00	3.80	310.0	18.89	1388.97	18.89	1388.97
15980	08/10/2004	1.45	12.00	1.70	2.30	5.80	4.30	160.00	5000.0	30.00	2.60	3.30	8.10	3.10	2.30	1.50	32.00	4.20	360.0	20.37	1404.83	20.37	1404.83
18390	08/11/2004	0.56	8.00	0.49	0.62	1.10	1.40	39.00	1500.0	26.00	0.82	0.71	< 0.25	0.61	< 0.35	< 0.33	4.60	< 0.82	36.0	11.66	2082.23	11.66	2082.23
11193	08/11/2004	1.52	11.00	0.46	0.45	0.89	1.10	31.00	1400.0	55.00	1.00	1.40	0.70	0.49	0.32	< 0.21	2.70	< 0.38	17.0	17.89	1176.68	55.13	4825.95
11193-dup	08/11/2004	1.09	60.00	1.90	2.00	4.00	5.20	170.00	7800.0	260.00	6.00	5.70	6.40	2.90	1.30	1.00	15.00	2.20	120.0	92.38	8475.23		
18389	08/11/2004	0.43	11.00	0.60	0.76	1.60	1.70	59.00	2100.0	33.00	< 0.20	1.20	1.80	0.77	0.55	0.36	5.60	0.68	56.0	15.96	3711.40	15.96	3711.40
11197	08/11/2004	1.17	17.00	1.50	2.30	4.90	5.50	190.00	7300.0	53.00	2.60	2.40	4.50	2.90	1.40	0.89	15.00	2.10	100.0	26.62	2275.13	25.76	2027.03
11197-dup	08/11/2004	1.40	17.00	< 3.90	< 4.30	< 3.30	< 3.00	190.00	6800.0	52.00	< 2.80	< 2.50	< 2.60	< 2.30	< 2.80	< 2.40	11.00	< 3.40	110.0	24.91	1778.93		
11268	08/11/2004	1.38	22.00	< 3.30	< 4.20	< 2.90	< 3.50	190.00	4900.0	51.00	5.10	3.90	< 2.40	< 2.30	< 2.70	< 2.50	52.00	< 3.70	800.0	31.16	2257.61	31.16	2257.61
11267	08/11/2004	1.87	16.00	1.90	3.70	8.30	6.40	230.00	5700.0	< 0.24	20.00	14.00	29.00	5.60	7.00	10.00	270.00	30.00	6500.0	31.96	1709.20	31.96	1709.20
15979-transA	08/10/2004	1.53	4.80	0.65	1.20	2.50	2.10	71.00	2100.0	12.00	1.00	1.60	2.00	1.20	1.10	0.50	12.00	1.70	110.0	8.24	538.24	8.24	538.24
15979-transB	08/10/2004	1.16	12.00	1.20	1.90	5.00	3.70	150.00	4200.0	30.00	2.60	2.90	< 0.42	2.30	2.10	1.40	27.00	3.80	290.0	18.84	1624.22	18.84	1624.22
15979-transC	08/10/2004	1.11	11.00	0.85	1.60	3.90	3.20	110.00	3100.0	35.00	3.50	3.00	< 1.10	2.00	1.80	1.10	25.00	4.50	360.0	18.02	1622.97	18.02	1622.97
15979-transD	08/10/2004	1.50	11.00	1.20	1.70	4.30	3.10	110.00	2900.0	27.00	2.40	2.80	< 0.32	1.90	1.90	1.10	23.00	2.10	210.0	17.24	1149.07	17.24	1149.07
15979-transE	08/10/2004	1.60	10.00	< 2.90	< 2.80	< 2.50	< 2.90	74.00	2800.0	30.00	< 2.20	< 2.30	< 1.80	< 2.30	< 2.60	< 2.10	< 3.10	< 2.50	660.0	15.21	950.31	15.21	950.31
Summer 2005																							
7	8/15/2005	0.65	9.7	0.38	0.54	1.1	1.3	33	1300	31	0.95	0.92	1.8	< 0.1	0.41	< 0.15	4.8	0.65	65	14.03	2174.42	14.03	2174.42
6	8/15/2005	0.55	7.4	< 0.37	0.9	< 0.37	1.4	40	1500	24	0.83	0.8	1.3	0.64	< 0.21	< 0.32	4.7	0.6	35	10.80	1957.07	10.80	1957.07
11267	8/16/2005	2.14	14	1.6	2.7	6.6	4.1	140	1900	58	29	29	54	< 1.8	10	16	460	62	12000	45.98	2148.60	45.98	2148.60
15979	8/16/2005	2.35	19	1.5	< 0.52	5.6	4.8	150	3100	52	3.5	3.5	< 0.65	3.6	2.5	2.6	39	7.8	520	28.84	1227.38	28.84	1227.38
18392	8/16/2005	1.67	12	< 0.82	< 0.59	4	< 0.68	88	3100	36	2.8	3.5	< 0.51	1.8	< 0.48	1.5	16	2.7	140	18.54	1110.06	18.48	958.93
18392-dup	8/16/2005	2.28	12	< 0.89	2.1	3.5	4.3	94	2200	33	1.9	2.7	< 0.41	1.5	1.6	1.3	15	< 0.75	87	18.42	807.81		
22	8/16/2005	2.41	15	1	3.7	7.5	10	260	3900	38	< 0.42	4.9	5.2	2.3	1.4	1.6	25	2.7	140	24.93	1034.46	24.93	1034.46
11280	8/16/2005	1.74	14	1.1	1.8	4.7	3.5	130	2500	38	3.4	3.1	6.3	2.4	1.3	1	23	2.3	120	22.17	1274.14	22.17	1274.14
24	8/16/2005	2.26	41	1.9	2.7	8.2	5.7	220	4500	110	6.4	6.1	8.5	3.5	1.8	1.9	38	4.3	230	59.55	2634.96	59.55	2634.96
23	8/16/2005	2.24	23	1.4	1.8	5.3	3.8	120	2700	72	2.7	6.7	4.6	2.5	1.6	1.1	29	2.3	150	36.46	1627.46	36.46	1627.46
25	8/16/2005	1.55	22	0.74	1.2	2.6	2.5	64	1800	50	1.9	2.2	4.3	1.5	1.2	0.65	14	2.3	270	29.96	1932.90	29.96	1932.90
11268	8/16/2005	1.28	36	1.7	2.4	6.4	5.5	150	3600	96	5.1	4.7	7.1	3.1	2.7	3.3	49	8.8	1300	52.11	4070.70	52.11	4070.70
26	8/17/2005	0.96	13	0.84	1.6	3.2	3	92	1800	29	1.9	2	3.6	1.7	1.3	1.4	28	4.7	480	19.00	1984.85	19.00	1984.85
27	8/17/2005	1.75	12	1.1	1.7	4.3	3.4	110	3100	31	3.4	3.4	5.1	2.3	2	0.76	37	5.4	940	19.48	1112.91	19.48	1112.91
13	8/17/2005	0.87	8	0.3	0.42	0.94	1.2	26	730	29	2.5	1.3	2.8	0.97	< 0.092	0.63	3.6	0.57	33	12.53	1436.42	12.53	1436.42
17	8/17/2005	0.83	21	0.55	0.81	1.9	2.3	66	2400	73	2.2	2	3.1	0.86	0.65	0.3	8.1	1.2	86	30.68	3687.14	30.68	3687.14
21	8/17/2005	1.54	27	0.97	1.4	3.3	3.8	100	3900	94	3	2.8	4	1.3	1.1	0.78	10	1.4	68	40.00	2597.60	40.00	2597.60
5	8/17/2005	0.72	6.8	0.41	0.81	1.5	1.6	52	1700	23	0.83	0.86	1.3	0.43	0.42	0.26	5.7	0.68	54	10.41	1445.63	10.41	1445.63
4	8/17/2005	0.56	8.1	0.35	0.56	1.4	1.7	46	1800	28	0.98	0.87	1.4	0.8	0.38	0.27	4.7	0.68	41	12.21	2172.60	13.71	2281.70
4-dup	8/17/2005	0.64	10	0.48	0.84	1.6	2	56	2000	35	1.3	1.1	2.6	0.78	0.61	< 0.15	6	0.93	51	15.21	2390.80		
18	8/17/2005	1.02	25	0.97	1.7	3.8	4	120	3700	63	5.1	3.6	4.7	2.8	1.6	2.6	19	3.1	310	35.96	3525.49	35.96	3525.49
19	8/17/2005	0.48	13	0.38	0.76	1.7	1.9	62	2700	41	1.8	1.4	2.3	0.75	0.51	0.41	6.8	0.96	58	18.91	3940.21	18.91	3940.21
1	8/17/2005	1.56	54	1.1	1.2	3	3.2	83	2800	200	5.1	4.5	5.1	2.4	1.2	0.93	8.2	1.6	58	78.76	5048.59	78.76	5048.59
2	8/17/2005	1.37	45	0.94	1.5	3	3.7	96	3600	150	4.8	4	5.8	2	1.1	0.92	9.9	1.7	63	64.51	4708.91	64.51	4708.91
16	8/18/2005	0.53	89	1.1	< 0.11	0.79	0.86	21	590	440	7.6	7.3	7.2	2.3	0.66	0.91	2.9	0.95	8.7	138.86	26298.77	138.86	26298.77
8	8/18/2005	0.88	20	0.59	0.78	1.9	2.2	58	2000	71	2.1	1.9	3	1.1	0.61	0.56	7.3	1.3	90	29.47	3333.14	29.47	3333.14
9	8/18/2005	1.19	7.8	0.49	0.76	1.3	1.8	58	2900	25	0.99	0.84	1.4	< 0.12	0.38	0.3	4.3	0.54	36	11.61	976.01	11.61	976.01
20	8/18/2005	0.15	1.2	< 0.082	0.15	0.28	0.33	8.8	330	3.8	0.2	0.14	0.25	0.12	0.13	< 0.069	0.85	< 0.14	6.6	1.81	1206.63	1.81	1206.63
3	8/18/2005	1.24	19	0.59	1	2.3	2.7	77	3200	63	2	1.8	2.7	0.92	0.69	0.27	8.6	1.3	93	27.65	2230.08	27.65	2230.08

Table 3.4 Dioxin Concentrations in Sediment from High-resolution Sampling (ng/kg-dry wt)

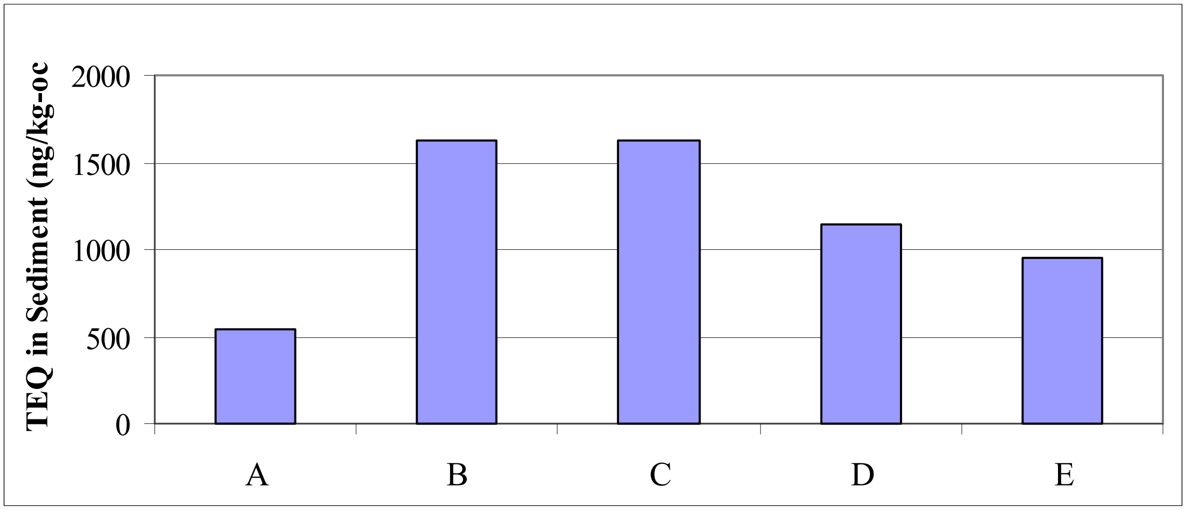
Station ID	Date	TOC (%)	2,3,7,8-TCDD	1,2,3,7,8-PeCDD	1,2,3,4,7,8-HxCDD	1,2,3,6,7,8-HxCDD	1,2,3,7,8,9-HxCDD	1,2,3,4,6,7,8-HpCDD	OCDD	2,3,7,8-TCDF	1,2,3,7,8-PeCDF	2,3,4,7,8-PeCDF	1,2,3,4,7,8-HxCDF	1,2,3,6,7,8-HxCDF	2,3,4,6,7,8-HxCDF	1,2,3,7,8,9-HxCDF	1,2,3,4,6,7,8-HpCDF	1,2,3,4,7,8,9-HpCDF	OCDF	Total TEQ	Total TEQ in OC	Average TEQ[a]	Average TEQ in OC[a]
15	8/18/2005	10.70	21000	240	3.5	8.2	< 4.5	95	1200	82000	2800	2200	3900	1100	210	410	1100	440	390	31123	290873	32752	310731
15-dup	8/18/2005	10.40	23000	290	< 3.5	8.1	< 4.5	90	1200	93000	2900	2300	4600	1200	210	390	1300	520	450	34381	330589		
14	8/18/2005	0.35	24	0.34	0.19	< 0.098	0.43	13	450	85	2.5	2	3.4	0.92	0.27	0.33	2	0.55	7.5	34.35	9787.44	34.35	9787.44
11	8/18/2005	0.83	360	3.7	1.1	2	1.8	75	2700	1400	35	30	47	13	2.7	4.7	18	5.3	65	525.83	63353.01	550.75	66147.76
11-dup	8/18/2005	0.84	390	3.9	1.1	2.7	2.6	90	2300	1600	36	31	40	11	2.5	4.3	14	4.3	47	575.67	68942.51		
10	8/30/2005	0.96	110	< 0.25	0.96	2.3	2.4	68	2700	380	11	9.2	15	3.5	1.1	1.8	11	2.3	89	155.92	16224.61	155.92	16224.61
12	8/30/2005	1.64	35	0.92	6.2	15	5.3	1300	11000	130	3.9	3.7	6	2.4	1.7	0.9	52	3.8	390	54.26	3308.23	54.26	3308.23

[a] Average of duplicate samples, otherwise concentration of a single sample
dup = duplicate
trans=transect
Values reported to the Detection Limit
Non-detects assumed as 1/2 MDL for TEQ calculations

🟦	Value between the detection and the reporting limits
🟨	Value is an estimate due to blank contamination (concentration < 20 times lowest concentration)
🟥	Value is an estimate due to QC issues (interference, signal to noise ratio)

In addition to high-resolution sediment sampling, five samples along a transect at location 15979 were collected during the Summer 2004 to evaluate the difference in dioxin concentrations between the dredged channel and the channel banks. Concentrations of dioxins along the transect are presented in Table 3.4 and depicted in Figure 3.10. Data show that the concentrations in the main channel are higher than those measured at the banks.

Finally, results from the high-resolution sampling conducted in Summer 2005 (Table 3.4) yielded TEQ concentrations between 1.81 and 32,752 ng/kg-dry wt. with a median value of 29.71 ng/kg-dry wt. Organic carbon (OC)-normalized levels ranged from 958.9 to 310,731 ng TEQ/kg-oc, with a mean value of 2,701 ng TEQ/kg-oc. Figure 3.11 shows the distribution of Texas TEQ in sediment samples in the San Jacinto River. It can be seen in Figure 3.11 that the OC-normalized dioxin concentration in sediment from the old waste pit (location 15) is substantially higher than those measured in the remaining samples in the grid and is higher than those measured in sediments collected between 2002 and 2004 (between 10 and 7,000 times higher). This is a strong indication that the waste pit is a current source of dioxin in the San Jacinto River. The OC-normalized 2378-TCDD concentration measured in Sample 15 is about 9 times greater than the highest concentration measured in this project.



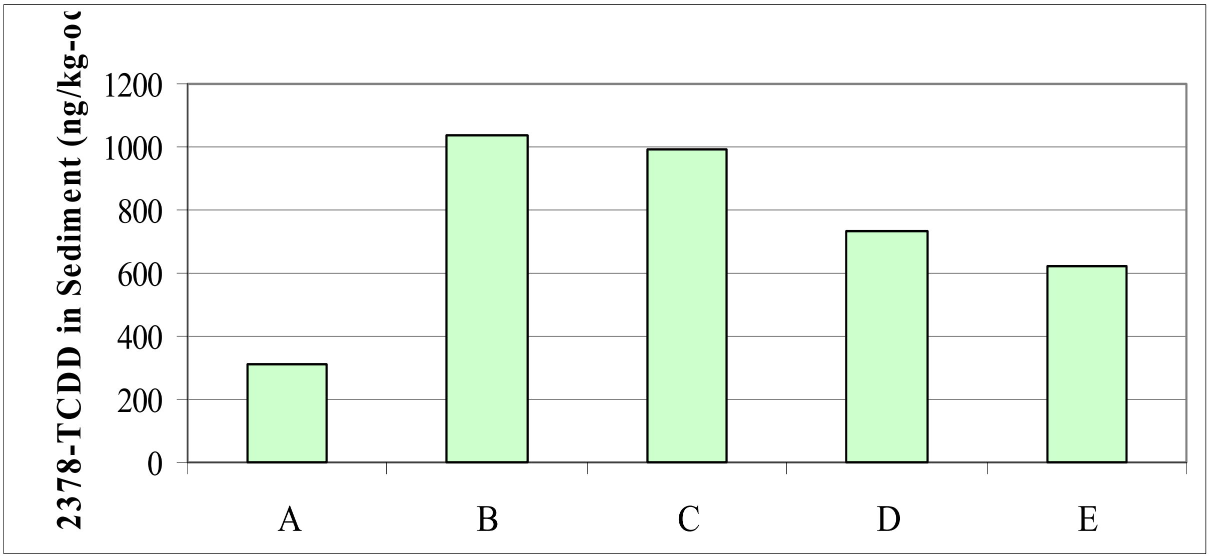


Figure 3.10 Dioxin Concentrations along Transect at Station 15979

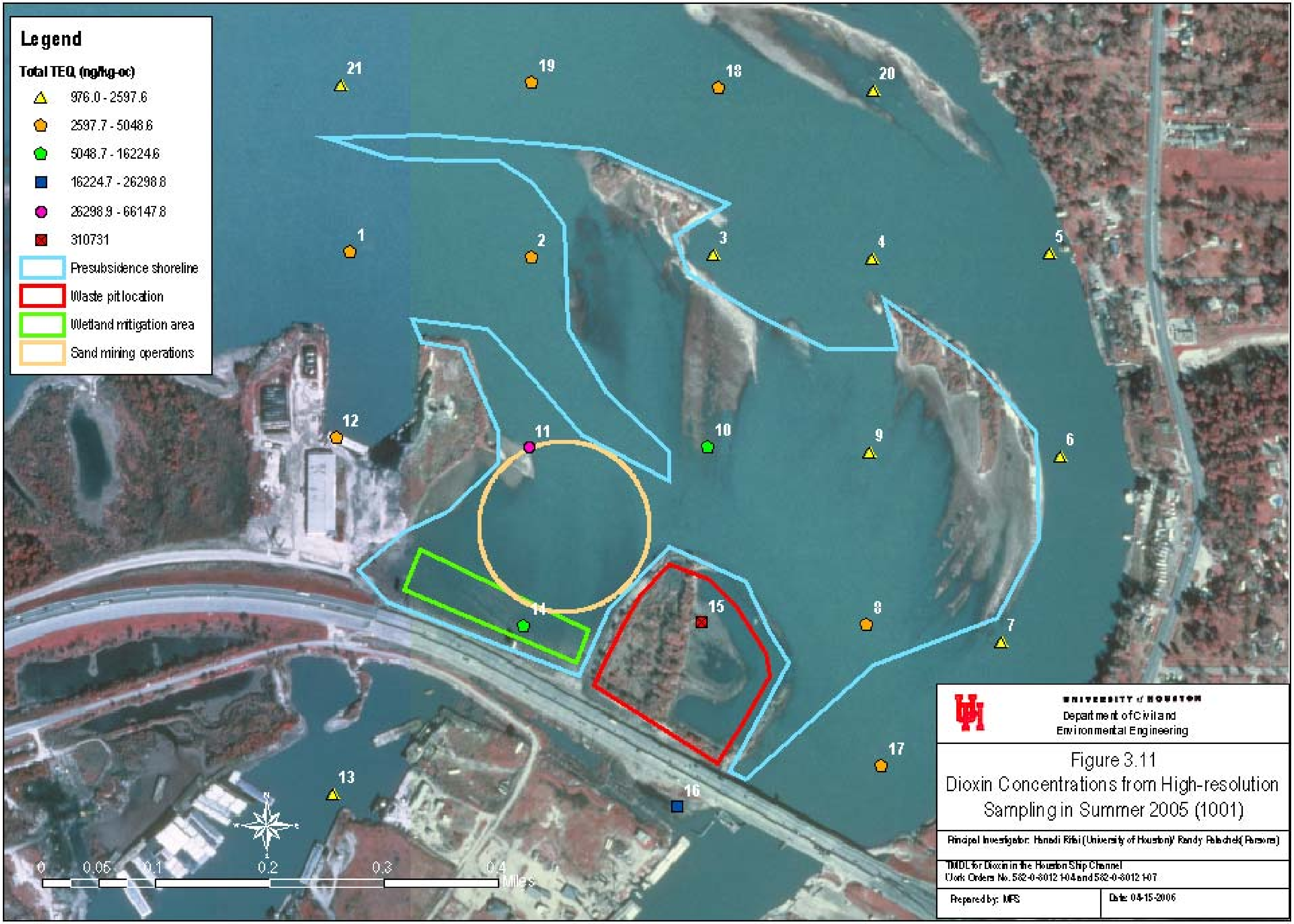


Figure 3.11
Dioxin Concentrations from High-resolution Sampling in Summer 2005 (1001)

Figure 3.12 shows profiles of OC-normalized 2378-TCDD and TEQ concentrations at the 11 sampling locations in the main channel. The highest organic-carbon normalized TEQ concentrations were observed at locations 24 and 11268 for segments 1007 and 1006, respectively. Consistent with measurements from the Summer 2004 high-resolution sediment samples, both 2378-TCDD and TEQ levels at Station 11268 were significantly higher than those observed at the remaining locations in Segment 1006, which might suggest the presence of an identified source of 2378-TCDD. Finally, sampling conducted in 2004 showed very high concentrations in the vicinity of Station 11280. That and the fact that Summer 2005 results showed a peak at Location 24 may suggest the presence of an additional source somewhere between stations 11280 and 24. A database of sediment dioxin results reported by Pace Analytical Laboratory is included in Appendix B. A summary of average concentrations in bottom sediment by station is presented in Table B-2 of Appendix B.

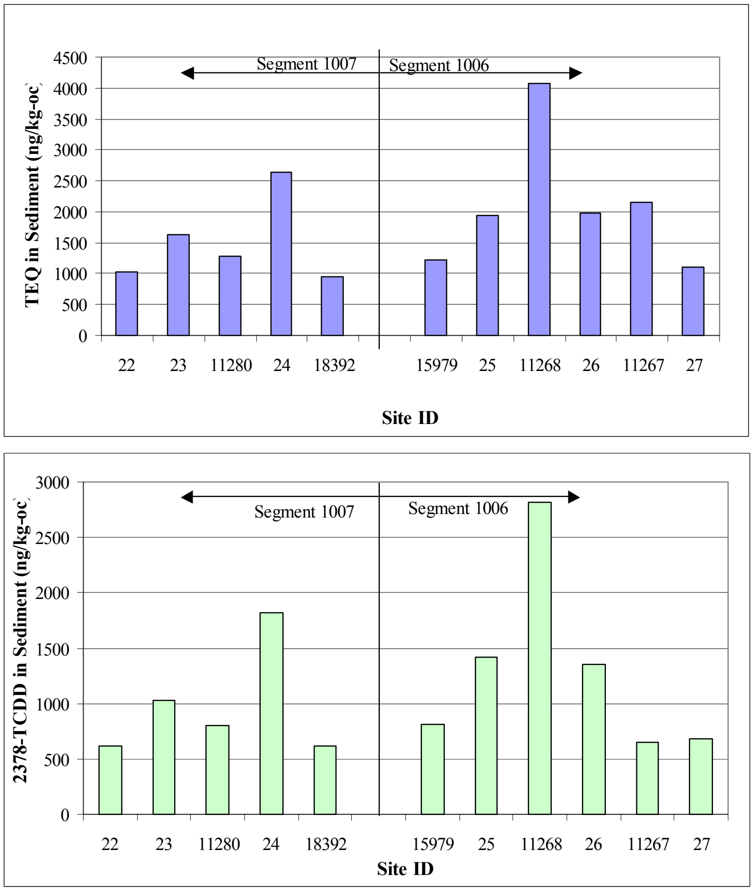


Figure 3.12 Organic-carbon Normalized Concentrations from Summer 2005 High-Resolution Sediment Sampling

3.4 DATA ANALYSIS

3.4.1 Spatial Trends

A summary of average TEQ concentrations in bottom sediment by segment is presented in Table 3.5a and b for TEQ and 2378-TCDD, respectively. It can be observed in Table 3.5a and b that for the samples collected in WO4 (Summer 2002, Fall 2002, and Spring 2003), Segment 1001 exhibited the highest average OC-normalized TEQ and 2378-TCDD concentrations, while Segment 1007 showed the highest average concentrations for samples collected in WO7 (Spring and Fall 2004).

Figure 3.13 shows concentration profiles along the main channel for TEQ concentrations in sediment measured in 2004 (WO7) compared to those measured in 2002-2003 (WO4), as well as the overall average. Figure 3.13 shows that for 2004 samples, OC-normalized TEQ concentrations start low and increase to a peak at Station 11280 (Segment 1007), then they drop at Station 15979 (Segment 1006); in Segment 1006, concentrations maintain a general increasing trend up to Station 16618 (Segment 1005) to finally decrease towards Galveston Bay. Dioxin concentrations were lower for most of the locations (upstream and downstream of Station 11280). Sediment TEQ concentration for Station 11193 in the San Jacinto River (Segment 1001) was the only exception, with a concentration almost as high as that measured at Station 11280. Concentrations in side bays were, in general, higher than those measured at the receiving main channel. The concentrations measured in WO4 showed similar behavior, but the peak was at Station 15979 in Segment 1006.

Table 3.5a Summary of Average OC-normalized TEQ Concentrations in Sediment by Segment (ng/kg-oc)

Segment	Summer 2002		Fall 2002		Spring 2003		Spring 2004		Fall 2004	
	# of Samples	TEQ	# of Samples	TEQ	# of Samples	TEQ	# of Samples	TEQ	# of Samples	TEQ
901	1[a]	501	ns	-	1[a]	233	ns	-	ns	-
1001	3	6485	2	5520	2	8372	2	3672	2	3049
1005	4	1942	2	1312	4	2474	3	1093	3	1245
1006	6	5916	ns	-	6	1406	4	1386	3	1432
1007	7	1250	2	2336	7	696	3	8398	3	10436
1013	2	182	ns	-	2	90	ns	-	ns	-
2421	5	317	1[a]	222	5	194	1[a]	184	1[a]	247
2426	4	982	2	1235	2	823	1[a]	951	1[a]	932
2427	2	1633	1[a]	1201	1[a]	955	1[a]	3324	1[a]	6812
2428	2	782	1[a]	688	2	530	1[a]	380	1[a]	390
2429	2	1891	2	1485	1[a]	1834	1[a]	1422	1[a]	1907
2430	3	1666	1[a]	2180	2	1092	1[a]	1001	1[a]	1445
2436	2	81	1[a]	648	1[a]	77	ns	-	ns	-
2438	2	85	1[a]	112	1[a]	82	ns	-	ns	-

[a] The value presented corresponds to the result for the single sample for that segment

ns = not sampled

Table 3.5b Summary of Average OC-normalized 2378-TCDD Concentrations in Sediment by Segment (ng/kg-oc)

Segment	Summer 2002		Fall 2002		Spring 2003		Spring 2004		Fall 2004	
	# of Samples	TCDD	# of Samples	TCDD	# of Samples	TCDD	# of Samples	TCDD	# of Samples	TCDD
901	1[a]	229	ns	-	1[a]	165	ns	-	ns	-
1001	3	4283	2	3669	2	5617	2	2452	2	1938
1005	4	1273	2	809	4	1706	3	688	3	814
1006	6	3264	ns	-	6	558	4	738	3	964
1007	7	291	2	1011	7	295	3	6028	3	7927
1013	2	13	ns	-	2	10	ns	-	ns	-
2421	5	121	1[a]	48	5	87	1[a]	75	1[a]	90
2426	4	556	2	617	2	411	1[a]	586	1[a]	531
2427	2	1068	1[a]	744	1[a]	633	1[a]	2397	1[a]	4870
2428	2	366	1[a]	396	2	153	1[a]	196	1[a]	178
2429	2	1187	2	894	1[a]	1163	1[a]	939	1[a]	1145
2430	3	1047	1[a]	1479	2	724	1[a]	621	1[a]	904
2436	2	23	1[a]	256	1[a]	14	ns	-	ns	-
2438	2	20	1[a]	50	1[a]	31	ns	-	ns	-

[a] The value presented corresponds to the result for the single sample for that segment
ns = not sampled

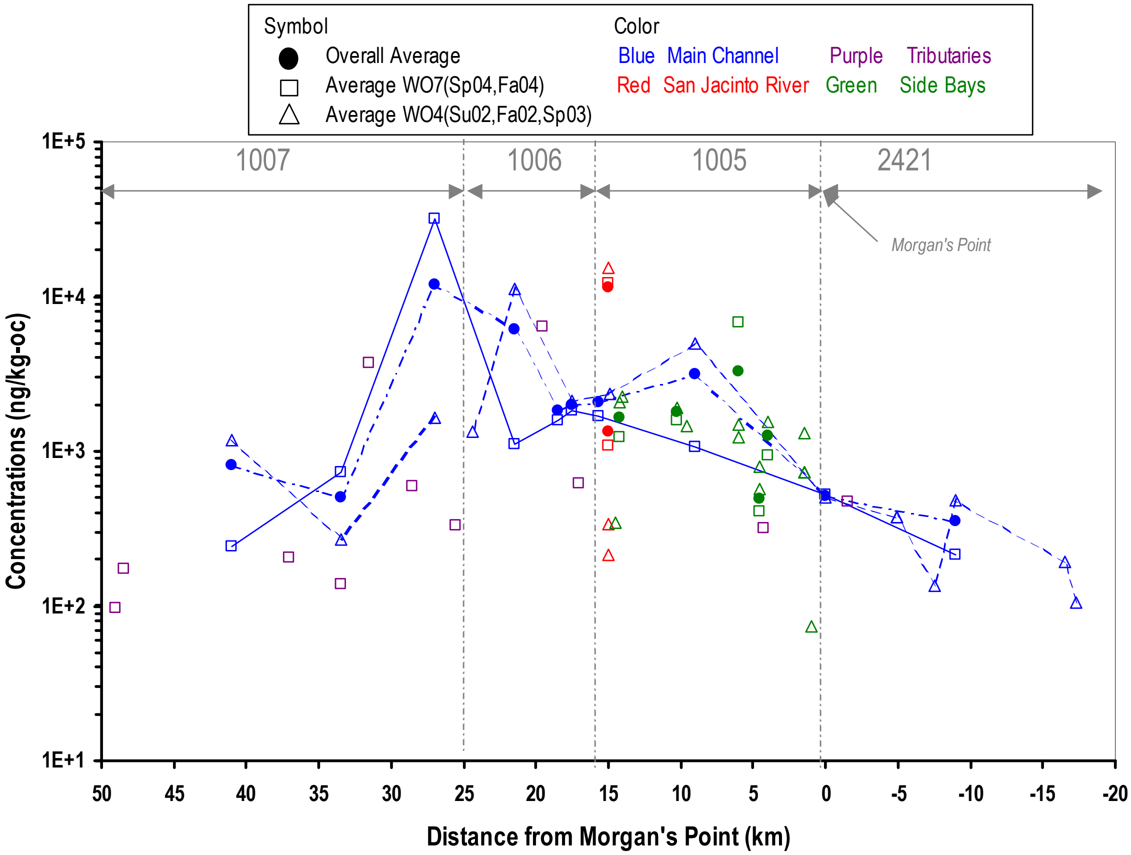


Figure 3.13 Total Sediment TEQ Concentration Profiles

3.4.2 Temporal Trends

Similarly to water data, PCDD/PCDF concentrations in sediment at the locations sampled during all five sampling events (Summer 2002, Fall 2002, Spring 2003, Spring 2004, and Fall 2004) of this project were analyzed using the Mann-Kendall test to evaluate possible trends over time. Table 3.6 presents a summary of the data trends for water samples. Each data "series" is comprised of five data points that correspond to the measurements during each of the sampling events. Because the concentrations were ordered chronologically, the results are showing trends over time. The values in the table are the resultant probability given by the S-value derived from the critical values table presented in Appendix C. It appears that dioxins are increasing more over time than furans. No congener presented a significant decreasing trend. A majority of the green highlighted cells are on the furan half of the table. Also, all but one of the blue highlighted cells are on the furan side of the table. When congeners that show no trend (S=0) are taken into account, the overall trend of all data at all stations appears to be upward.

3.4.3 Seasonal Trends

Figure 3.14 shows the average congener profiles in bottom sediment by season for the stations that were sampled during each event. In general, the profiles did not change significantly from one season to another. Results from a statistical analysis using a Wilconox Signed Rank test confirmed that the differences among seasons were not statistically significant.

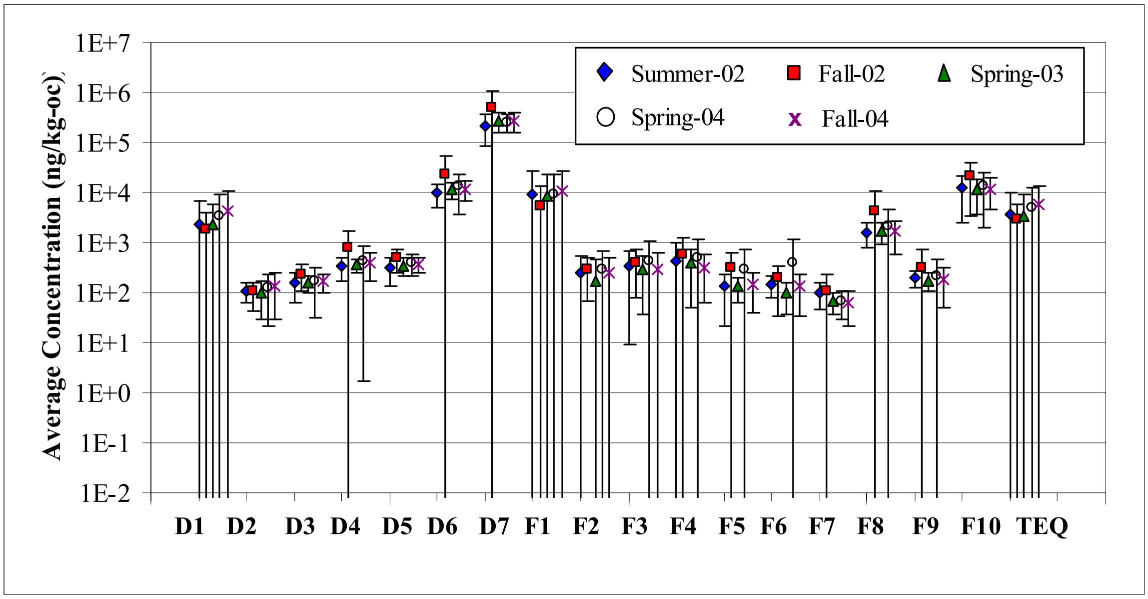
Table 3.6 Probability Results for Mann-Kendall Test for Trend of Sediment Samples

Station	2,3,7,8-TCDD	1,2,3,7,8-PeCDD	1,2,3,4,7,8-HxCDD	1,2,3,6,7,8-HxCDD	1,2,3,7,8,9-HxCDD	1,2,3,4,6,7,8-HpCDD	OCDD	2,3,7,8-TCDF	1,2,3,7,8-PeCDF
11193	0.242	0.242	0.117	0.080	0.117	0.117	0.080	0.242	0.408
11252	0.592	0.592	0.408	0.592	0.408	0.408	0.592	0.592	0.408
11261	0.117	0.117	0.180	0.117	0.242	0.242	0.117	0.042	0.242
11280	0.028	0.024	0.117	0.042	0.042	0.117	0.042	0.028	0.117
11292	0.408	0.592	0.408	0.408	0.242	0.242	0.242	0.408	0.242
11340	0.408	0.242	0.408	0.408	0.242	0.500	0.242	0.592	0.242
13342	0.500	0.325	0.242	0.408	0.592	0.408	0.242	0.117	0.325

Media Station	2,3,4,7,8-PeCDF	1,2,3,4,7,8-HxCDF	1,2,3,6,7,8-HxCDF	2,3,4,6,7,8-HxCDF	1,2,3,7,8,9-HxCDF	1,2,3,4,6,7,8-HpCDF	1,2,3,4,7,8,9-HpCDF	OCDF	Total TEQ
11193	0.242	0.408	0.408	0.408	0.408	0.080	0.592	0.117	0.242
11252	0.592	0.325	0.408	0.242	0.592	0.592	0.325	0.408	0.408
11261	0.180	0.242	0.592	0.117	0.035	0.408	0.242	0.242	0.117
11280	0.180	0.117	0.117	0.408	0.028	0.117	0.080	0.042	0.028
11292	0.117	0.592	0.242	0.242	0.242	0.408	0.117	0.080	0.408
11340	0.180	0.117	0.592	0.592	0.242	0.500	0.325	0.242	0.242
13342	0.500	0.408	0.080	0.180	0.117	0.592	0.080	0.408	0.408

🟦 significant downward trend
🟩 downward trend
⬜ no trend
🟨 upward trend
🟧 significant upward trend

probabilities considered significant if the value is less than the alpha of 0.05



Error bars correspond to the 95% confidence intervals
2378-PCDDs indicated by a letter D followed by a number, with D1 being TCDD and D7 OCDD
2378-PCDFs indicated by a letter F followed by a number, with F1 being TCDF and F10 OCDF

Figure 3.14 Seasonal Variation of Dioxins in Sediment in the HSC

CHAPTER 4

DIOXIN IN TISSUE FROM THE HOUSTON SHIP CHANNEL SYSTEM

4.1 METHODS

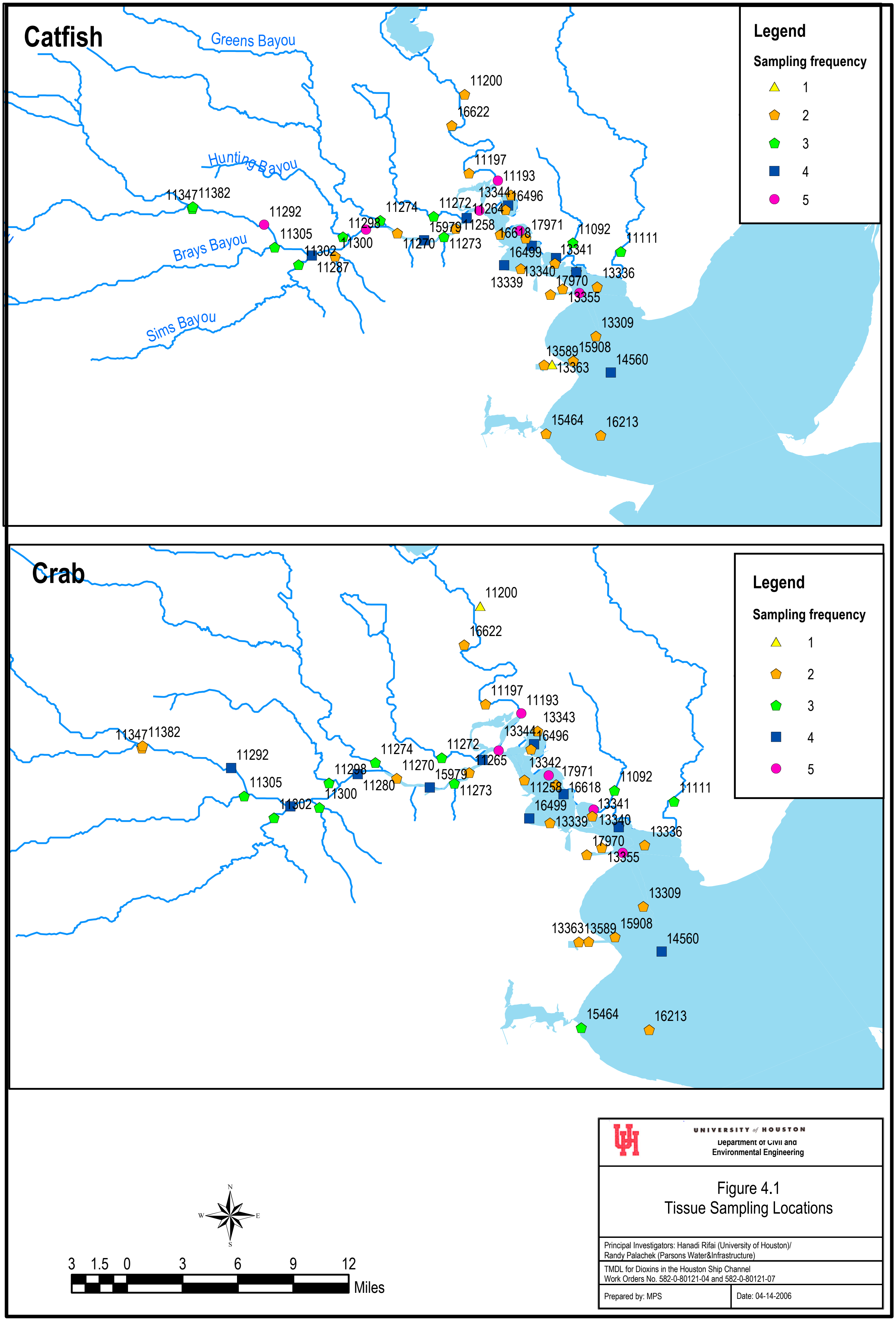
4.1.1 Sampling Procedures

Tissue was sampled along with water and sediment to obtain data on bioaccumulation and/or transport of dioxin. Catfish tissue was harvested at selected sites based on the following selection order: hardhead catfish (*Arius felis*), blue catfish (*Ictalurus furcatus*), gafftopsail catfish (*Bagre marinus*), and channel catfish (*Ictalurus punctatus*). Gill nets or a fishing line with bait (shrimp or chicken) were used to catch enough catfish to obtain 50-100 grams of muscle tissue. A minimum of three catfish was collected from each selected sample site to give a representative sample. Hardhead catfish with a total length of 300 mm was the target length for collection. Typically, blue catfish were collected in the upper stations and tributaries (probably due to greater presence of freshwater) while hardhead catfish were collected in lower reaches, side bays, and the Houston Ship Channel (HSC) main stem (more presence of saltwater). Crab tissue was collected from blue crabs (*Callinectes sapidus*) using standard plastic coated wire mesh crab traps. A minimum of three blue crabs, and typically five to seven, were collected from each selected sample site to obtain the needed 50-100 grams of muscle tissue. Blue crabs with a carapace width of 125 mm and greater were targeted. All fish used for samples were inspected for stomach contents to determine if a sizeable quantity of food existed to make a stomach content sample. Using a decontaminated stainless steel knife and forceps, the stomachs were opened and inspected for contents. If any prey items were in the stomach, they were identified to the lowest practical taxonomic level to determine prey species. Stomach contents were then placed in a sample container for separate dioxin and lipid analysis. Sampling collection and handling followed the requirements outlined in the approved Quality Assurance Project Plans (QAPPs).

4.1.2 Sampling Locations

Catfish and crabs were collected between 1 and 5 times at a total of 47 stations in the HSC System between Summer 2002 and Fall 2004. Figure 4.1 shows the locations that were sampled to quantify PCDD/PCDFs in tissue. Three sampling events were undertaken during WO4: Summer 2002 (July 25-September 11), Fall 2002 (October 21-December 10), and Spring 2003 (April 30-June 17), while two events were completed during WO7: Spring 2004 (March 9-April 29) and Fall 2004 (October 20-December 1). Sampling dates were selected to evaluate seasonal differences, if any, in the measured concentrations. Table 4.1 summarizes the total number of dioxin tissue samples collected in this project.

Stomach content and prey species samples were collected at 4 and 6 locations, respectively. During the Summer 2002 event, only two fish contained enough stomach content mass to make samples (stations 11270 and 15464). No fish collected during the



UNIVERSITY of HOUSTON
Department of Civil and
Environmental Engineering

Figure 4.1
Tissue Sampling Locations

Principal Investigators: Hanadi Rifai (University of Houston)/
Randy Palachek (Parsons Water&Infrastructure)

TMDL for Dioxins in the Houston Ship Channel
Work Orders No. 582-0-80121-04 and 582-0-80121-07

Prepared by: MPS

Date: 04-14-2006

Table 4.1 Number of Dioxin Tissue Samples

Sampling Event	**Catfish**			**Crab**		
	# sites	**QC samples**[a]	**total # samples**	**# sites**	**QC samples**[a]	**total # samples**
Summer 2002	45	13	58	45	8	53
Fall 2002	13	5	18	13	2	15
Spring 2003	36	5	41	37	3	40
Spring 2004	28	4	32	26	2	28
Fall 2004	17	4	21	17	2	19
Totals			*170*			*155*

[a] Field duplicates and field blanks specified in the QAPP.

4.2 QUALITY CONTROL

Field duplicates and blanks were collected at a frequency of 4% or higher and processed in an identical manner to samples. In addition, laboratory duplicates and blanks were run at a frequency of 5%. Overall, when detected, both field and laboratory blanks showed levels below 5% of the levels in the samples. Results obtained from the duplicate samples were consistent and in agreement with the method requirements for the different congeners. Recoveries for 2378-substituted congeners ranged from 72 to 92% with an average of 81%. A summary of QC sample results is included in Appendix A. Non-detects were assumed to be equal to half of the detection limit for total equivalence quotient (TEQ) calculations and summary statistics.

4.3 RESULTS

Tables 4.2 and 4.3 provide summaries of species, weight, and length of individuals composited to make catfish and crab samples, respectively. A summary of the stomach content and prey species samples is provided in Table 4.4.

Fall 2002 event had enough stomach content mass to constitute a sample, but one sample of a prey species (shad) was collected. Two fish samples collected during Spring 2003 had enough stomach content mass to make a sample (stations 13342 and 13309). Additionally, 17 samples of prey species (shad, shrimp, mullet, silverside minnow, and croaker) were collected from 6 sampling locations during Spring 2003.

4.1.3 Analytical Methods

PCDDs and PCDFs in tissue samples were quantified by high-resolution gas chromatography/high resolution mass spectrometry (HRGC/HRMS) using EPA Method 1613B at PSC/Maxxam Analytical. Tissue samples were homogenized, mixed with sodium sulphate until free flowing, and spiked with fifteen $^{13}C_{12}$-labeled PCDD/PCDF internal standards, and mixed with sodium sulfate. Subsequently, the samples were extracted for 18-24 hours using methylene chloride: hexane (1:1) in a Soxhlet extractor. The extract was evaporated to 10 mL, with 9 mL loaded on the GPC and 1 mL taken for lipid determination. The GPC extracts were then concentrated to approximately 1 mL, ready for cleanup. The extracts were then spiked with 2378-TCDD-$^{37}C_{14}$ enrichment efficiency standard and subjected to acid/base washes, multiplayer silica, alumina, and carbon column cleanup procedures to remove interferences from the extracts. After cleanup, the extracts were concentrated to near dryness and spiked with recovery standards (1234-TCDD-$^{13}C_{12}$ and 123789-HxCDD-$^{13}C_{12}$) immediately prior to injection. Chromatographic separation was achieved with a DB-5, capillary chromatography column, (60 m, 0.25 mm i.d., 0.25 µm film thickness). A second column DB-225 (30 m, 0.25 mm i.d., 0.25 µm film thickness) was used for confirmation of TCDF identification.

Table 4.2 Catfish Tissue Samples Collected from HSC & Upper Galveston Bay

Station	Date	Time	Species	Sample 1		Sample 2		Sample 3		Sample 4		Sample 5		Sample 6		Average	
				Length (mm)	Weight (g)	Length (mm)	Weight (g)	Length (mm)	Weight (g)	Length (mm)	Weight (g)	Length (mm)	Weight (g)	Length (mm)	Weight (g)	Length (mm)	Weight (g)
Summer 2002																	
11111	07/31/02	16:50	Hardhead	381.0	453.0	317.5	297.3	355.6	424.7	304.8	184.0					339.7	339.75
11193	08/09/02	15:00	Hardhead	342.9	339.8	381.0	543.6	412.8	634.2	304.8	311.4					360.4	457.25
11200	09/03/02	14:00	Blue	279.4	155.7	254.0	106.2	235.0	99.1	342.9	297.3	311.2	286.0			284.5	188.84
16622	09/04/02		Blue	609.6	2236.7	406.4	608.7	336.6	254.8							450.9	1033.41
11252	08/26/02	13:45	Hardhead	355.6	453.0	355.6	413.4	323.9	311.4	285.8	269.0					330.2	361.69
11258	08/01/02	9:20	Hardhead	254.0	141.6	311.2	247.7	327.0	297.3	0.0	0.0					223.0	171.64
11261	08/23/02	10:10	Hardhead	323.9	376.6	323.9	342.6	292.1	370.9	317.5	271.8					314.3	340.46
16618	08/20/02	10:30	Hardhead	355.6	433.2	368.3	481.3	342.9	368.1	368.3	396.4					358.8	419.73
11272	07/25/02	13:45	Blue	438.2	1047.6	558.8	1500.6	419.1	707.8							472.0	1085.31
11273	08/30/02	10:10	Hardhead	355.6	424.7	330.2	294.5	362.0	416.2							349.3	378.44
11270	08/28/02	14:45	Hardhead	342.9	379.4	330.2	317.1	304.8	254.8	292.1	220.8					317.5	293.03
11264	08/20/02	13:30	Hardhead	400.1	608.7	362.0	481.3	406.4	622.9	387.4	566.3					388.9	569.79
15979	09/05/02	15:30	Hardhead	374.7	537.9	260.4	147.2	285.8	212.3							306.9	299.17
11287	08/25/02	16:30	Blue	393.7	594.6	368.3	410.5	438.2	1019.3	419.1	877.7	514.4	1840.3			426.7	948.47
11292	09/11/02	16:30	Blue	317.5	274.6	304.8	184.0									311.2	229.33
11298	07/29/02	13:30	Blue	317.5	311.4	393.7	566.3									355.6	438.84
11300	09/06/02	11:00	Blue	508.0	1698.8											508.0	1698.75
11302	08/26/02	13:30	Blue	393.7	600.2	330.2	271.8	311.2	269.0	362.0	424.7	368.3	438.8			353.1	400.91
11305	08/14/02	8:30	Bullhead	304.8	240.7	381.0	543.6	317.5	311.4							334.4	365.23
11280	08/28/02	16:00	Hardhead	317.5	283.1	304.8	254.8	304.8	226.5							309.0	254.81
11347-F1	08/12/02	11:35	Blue	717.6	4983.0											717.6	4983.00
11347-F2/Dup	08/12/02	11:35	Blue	552.5	1613.8	342.9	283.1									447.7	948.47
11347-F3	08/12/02	11:35	Channel	362.0	297.3	387.4	537.9	336.6	318.5							362.0	384.58
11274	07/30/02	13:30	Blue	360.7	368.1	335.3	368.1	381.0	481.3	304.8	311.4					345.4	382.22
11382	08/11/02	19:05	Channel	358.8	396.4	362.0	339.8	330.2	339.8							350.3	358.63
13309	08/30/02	11:05	Hardhead	406.4	679.5	393.7	543.6	374.7	523.8	381.0	526.6					388.9	568.37
14560	08/30/02	12:14	Hardhead	336.6	339.8	317.5	311.4	304.8	229.3	387.4	509.6					336.6	347.54
15464	08/18/02	9:20	Hardhead	339.7	382.2	387.4	546.4	362.0	438.8							363.0	455.83
15908	09/11/02	15:00	Hardhead	330.2	424.7	336.6	325.6	355.6	410.5	330.2	311.4					338.1	368.06
16213	09/11/02	10:45	Hardhead	450.9	877.7	406.4	741.8	400.1	696.5	355.6	424.7					403.2	685.16
13337	08/14/02	14:30	Hardhead	362.0	424.7	323.9	339.8	317.5	254.8	342.9	325.6	431.8	679.5			355.6	404.87
13337-Dup	08/15/02	15:30	Hardhead	279.4	155.7	323.9	297.3	311.2	254.8	311.2	254.8					306.4	240.66
13338	08/23/02	11:20	Hardhead	330.2	356.7	308.0	322.8	304.8	288.8							314.3	322.76
13336	08/27/02	12:30	Hardhead	317.5	410.5	342.9	379.4	323.9	368.1	323.9	390.7					327.0	387.17
13336-Dup	08/28/02	13:30	Hardhead	387.4	594.6	342.9	438.8	304.8	266.1	317.5	254.8					338.1	388.59
11092	08/02/02	11:45	Hardhead	406.4	594.6	431.8	764.4	362.0	566.3	406.4	651.2					401.6	644.11
13339	08/23/02	10:30	Hardhead	349.3	393.5	362.0	495.5	330.2	334.1	308.0	297.3					337.3	380.10
13339-Dup	08/24/02	10:30	Hardhead	362.0	464.3	362.0	450.2	304.8	266.1	304.8	269.0	304.8	269.0			327.7	343.71
16499	08/23/02	9:45	Hardhead	374.7	540.8	311.2	288.8	298.5	305.8	304.8	311.4					322.3	361.69
16499-Dup	08/24/02	10:45	Hardhead	304.8	297.3	365.1	495.5	317.5	319.9	355.6	498.3					335.8	402.75
13340	08/07/02	13:00	Hardhead	374.7	566.3	304.8	169.9	304.8	141.6	304.8	169.9					322.3	261.89
13341	08/09/02	15:00	Hardhead	346.1	396.4	336.6	396.4	317.5	339.8							333.4	377.50
13342	08/22/02	11:00	Hardhead	419.1	792.8	387.4	622.9	349.3	453.0	330.2	396.4	342.9	410.5			365.8	535.11
17971	08/24/02	11:15	Hardhead	374.7	569.1	368.3	509.6									371.5	539.35
13343	08/20/02	14:30	Hardhead	298.5	254.8	362.0	537.9	285.8	254.8							315.4	349.19

Table 4.2 Catfish Tissue Samples Collected from HSC & Upper Galveston Bay

Station	Date	Time	Species	Sample 1		Sample 2		Sample 3		Sample 4		Sample 5		Sample 6		Average	
				Length (mm)	Weight (g)	Length (mm)	Weight (g)	Length (mm)	Weight (g)	Length (mm)	Weight (g)	Length (mm)	Weight (g)	Length (mm)	Weight (g)	Length (mm)	Weight (g)
13344	08/21/02	10:30	Hardhead	362.0	512.5	387.4	651.2	381.0	597.4	355.6	492.6					371.5	563.42
16496	08/21/02	11:20	Hardhead	317.5	319.9	311.2	297.3	317.5	271.8	314.3	336.9	308.0	271.8			313.7	299.55
13355	08/18/02	12:20	Hardhead	374.7	537.9	406.4	594.6	355.6	368.1	400.1	537.9	387.4	566.3			384.8	520.95
17970	08/18/02	11:00	Hardhead	406.4	594.6	393.7	509.6	304.8	325.6	438.2	906.0	330.2	325.6			374.7	532.28
13363	08/17/02	13:30	Hardhead	393.7	566.3	349.3	311.4	320.7	269.0	336.6	297.3	311.2	247.7			342.3	338.33
13589	08/17/02	13:00	Hardhead	352.4	410.5	368.3	453.0	358.8	424.7							359.8	429.41
13589-Dup	08/17/02	13:00	Hardhead	409.6	594.6	387.4	502.5	393.7	554.9							396.9	550.68
Fall 2002																	
11193	11/20/02	12:30	Blue	362.0	396.4	400.1	474.2	362.0	455.0	406.4	564.8					382.6	472.61
11200-1	11/19/02	17:30	Blue	355.6	421.9	320.7	249.2	320.7	274.6	317.5	365.2					328.6	327.72
11200-2	11/21/02	16:15	Blue	571.5	2633.1											571.5	2633.06
11252	10/24/02	11:00	Hardhead	311.2	269.0	308.0	283.1	317.5	311.4	317.5	297.3	323.9	325.6			315.6	297.28
11261	10/26/02	10:30	Hardhead	431.8	1029.2	381.0	644.1	247.7	264.7	279.4	240.7					335.0	544.66
13338	10/22/02	10:00	Hardhead	336.6	305.8	349.3	291.6	381.0	537.9	368.3	509.6	333.4	368.1	330.2	353.9	349.8	394.49
13338-Dup	10/22/02	10:00	Hardhead	390.5	622.9	384.2	515.3	362.0	532.3	381.0	594.6					379.4	566.25
13336	10/22/02	9:00	Hardhead	330.2	339.8	342.9	348.2	393.7	665.3	393.7	526.6	412.8	707.8			374.7	517.55
16499	10/24/02	---	Hardhead	355.6	467.2	374.7	552.1	374.7	637.0							355.6	552.09
13342	10/28/02	8:00	Hardhead	406.4	676.7	400.1	666.8	403.2	661.1							403.2	668.18
17971	10/28/02	10:00	Hardhead	431.8	791.3	438.2	1039.1	393.7	588.9							421.2	806.43
13344	10/27/02	12:10	Hardhead	355.6	465.7	342.9	471.4	406.4	775.8							368.3	570.97
17970	10/24/02	8:20	Hardhead	317.5	311.4	342.9	396.4	317.5	339.8	323.9	339.8	330.2	353.9			326.4	348.24
17970-Dup	10/24/02	8:20	Hardhead	355.6	436.0	393.7	495.5	425.5	750.3	406.4	637.0					395.3	579.70
Spring 2003																	
11273	04/29/03	9:50	Hardhead	330.2	254.8	355.6	495.5	336.6	361.0	330.2	410.5	330.2	304.4			336.6	365.23
11258	04/29/03	8:43	Hardhead	330.2	382.2	400.1	622.9	336.6	368.1	330.2	325.6	330.2	325.6	330.2	311.4	342.9	389.30
11092	04/30/03	8:15	Blue	387.4	523.8	406.4	509.6	368.3	403.5	330.2	240.7	342.9	290.2			363.2	375.14
		8:15	Blue	342.9	283.1	387.4	453.0	381.0	445.9	330.2	283.1	355.6	318.5				
11272	04/30/03	13:20	Blue	355.6	368.1	368.3	410.5	336.6	325.6	336.6	311.4	342.9	325.6			348.0	348.24
11274	05/01/03	12:00	Blue	317.5	325.6	609.6	665.3	355.6	410.5	381.0	481.3	342.9	382.2	368.3	424.7	395.8	448.28
11302	05/01/03	12:30	Blue	419.1	523.8	304.8	283.1	330.2	297.3							351.4	368.06
11111	05/01/03	16:00	Hardhead	374.7	410.5	342.9	311.4	336.6	318.5	304.8	339.8	355.6	353.9			342.9	346.83
11298	05/01/03	9:00	Blue	304.8	269.0	304.8	254.8	304.8	226.5	304.8	226.5					304.8	244.20
11347	05/02/03	10:00	Blue	362.0	382.2	362.0	325.6	368.3	283.1	304.8	127.4					349.3	279.59
11382	05/02/03	9:00	Blue	387.4	269.0	355.6	269.0	342.9	212.3	419.1	502.5	355.6	269.0	419.1	453.0	371.2	303.72
		9:00	Blue	362.0	254.8	355.6	297.3	349.3	240.7	368.3	247.7	368.3	325.6				
11305	05/03/03	9:35	Blue	457.2	651.2	406.4	481.3	355.6	424.7							406.4	519.06
13339	05/04/03	15:15	Hardhead	330.2	261.9	317.5	325.6	304.8	297.3	304.8	269.0	304.8	254.8			312.4	281.71
16618	05/05/03	15:15	Hardhead	406.4	552.1	304.8	339.8	368.3	339.8							359.8	410.53
11287	05/05/03	9:50	Blue	482.6	1267.0	304.8	155.7	508.0	1500.6							431.8	974.42
13343	05/06/03	12:00	Hardhead	304.8	254.8	317.5	254.8	304.8	254.8							309.0	254.81
11270	05/06/03	11:40	Hardhead	317.5	240.7	317.5	283.1	304.8	254.8	304.8	311.4					311.2	272.51
11280	05/06/03	10:50	Hardhead	304.8	155.7	304.8	240.7	330.2	297.3							313.3	231.22
11261	05/10/03	11:40	Hardhead	368.3	679.5	342.9	424.7	355.6	453.0							355.6	519.06
13342	05/11/03	12:45	Hardhead	349.3	481.3	400.1	622.9	406.4	467.2							385.2	523.78
16496	05/11/03	11:40	Hardhead	406.4	637.0	419.1	821.1	406.4	764.4	304.8	467.2	381.0	552.1	317.5	339.8	372.5	596.92
13309	05/12/03	14:20	Gafftopsail	552.5	1698.8	571.5	1925.3	590.6	1585.5							571.5	1736.50

Table 4.2 Catfish Tissue Samples Collected from HSC & Upper Galveston Bay

Station	Date	Time	Species	Sample 1		Sample 2		Sample 3		Sample 4		Sample 5		Sample 6		Average	
				Length (mm)	Weight (g)	Length (mm)	Weight (g)	Length (mm)	Weight (g)	Length (mm)	Weight (g)	Length (mm)	Weight (g)	Length (mm)	Weight (g)	Length (mm)	Weight (g)
15464	05/12/03	10:30	Gafftopsail	584.2	1642.1	406.4	679.5	292.1	155.7							427.6	825.78
16213	05/12/03	10:30	Hardhead	406.4	778.6	355.6	509.6	381.0	580.4							381.0	622.88
14560	05/12/03	12:00	Hardhead	381.0	622.9	317.5	509.6	349.3	467.2							349.3	533.22
11193	05/14/03	13:30	Hardhead	355.6	424.7	412.8	679.5	390.5	622.9	330.2	311.4					372.3	509.63
11264	05/15/03	9:30	Hardhead	393.7	630.0	444.5	1047.6	381.0	438.8							406.4	705.45
11252	05/16/03	7:30	Hardhead	312.4	311.4	360.7	594.6	368.3	679.5	292.1	269.0					333.4	463.62
13589	05/16/03	10:00	Hardhead	315.0	328.4	320.0	373.7	284.5	203.9							306.5	302.00
13355	05/28/03	9:30	Hardhead	355.6	424.7	381.0	410.5	381.0	566.3	330.2	353.9					362.0	438.84
15908	05/28/03	8:00	Hardhead	381.0	467.2	381.0	424.7	355.6	403.5	330.2	297.3	342.9	368.1			358.1	392.13
13340	05/28/03	11:50	Hardhead	355.6	566.3	412.8	962.6	393.7	877.7	381.0	608.7					385.8	753.82
13337	05/28/03	10:20	Hardhead	342.9	509.6	425.5	1104.2	381.0	651.2	330.2	438.8	381.0	679.5			372.1	676.67
13341	05/28/03	11:10	Hardhead	355.6	495.5	381.0	714.9	304.8	325.6	349.3	537.9					347.7	518.47
15979	05/29/03	8:30	Hardhead	304.8	297.3	342.9	594.6	330.2	552.1							326.0	481.31
11292	05/30/03	11:25	Channel	457.2	849.4	355.6	849.4	330.2	283.1							381.0	660.63
16622	05/30/03	8:30	Blue	355.6	453.0	355.6	481.3	304.8	368.1	304.8	283.1					330.2	396.38
Spring 2004																	
11252	3/9/2004	5:40	hardhead	352.4	411	317.5	277	323.9	276							331.3	321.3
13342	03/09/04	7:30	hardhead	412.8	763.0	362.0	399.0	393.7	638.0							389.5	600.0
13340	03/09/04	5:30	hardhead	355.6	370	368.3	359	419.1	600	406.4	562	355.6	360			381.0	450.2
14560	03/09/04	6:15	hardhead	362.0	581	327.0	279	336.6	292							341.8	384.0
11193	03/23/04	16:00	blue	355.6	365	317.5	264	362.0	441	342.9	310					344.5	345.0
11261	03/24/04	11:30	hardhead	317.5	316	412.8	572	381.0	496	362.0	386	330.2	311			360.7	416.2
11264-D	04/02/04	8:10	hardhead	374.7	537	393.7	699	419.1	660	368.3	465	363.2	422			383.8	556.6
16499	03/18/04	9:50	hardhead	342.9	317	348.0	380	381.0	465							357.3	387.3
16618	03/18/04	10:30	hardhead	374.7	475	406.4	590	400.1	616	381.0	616	381.0	450	362.0	400	384.2	524.5
13344	03/18/04	12:00	hardhead	419.1	675	317.5	315	393.7	553	393.7	512					381.0	513.8
13338	03/18/04	9:00	hardhead	330.2	326	374.7	448	400.1	570	387.4	524	368.3	457			372.1	465.0
11197	03/24/04	8:15	blue	349.3	290	374.7	432	349.3	335	368.3	358	370.8	400			362.5	363.0
11280	04/02/04	13:30	hardhead	336.6	374	2851.2	235	317.5	279							1168.4	296.0
15979	03/31/04	12:00	hardhead	317.5	274	368.3	461	355.6	477							347.1	404.0
11287	04/02/04	9:00	blue	336.6	329	419.1	612	387.4	511							381.0	484.0
11265	04/02/04	15:00	hardhead	311.2	213	327.7	268	317.5	253	323.9	263	327.7	321			321.6	263.6
11305	04/15/04	9:50	blue	336.6	244	520.7	1786.02	419.1	647							425.5	892.3
11272-A	04/15/04	14:00	blue	330.2	297	342.9	410	342.9	353	323.9	262					335.0	330.5
11272-B	04/15/04	14:00	blue	438.2	769	520.7	1264	584.2	1940							514.4	1324.3
11292	04/03/04	11:00	blue	342.9	288	387.4	494	381.0	422							370.4	401.3
11092	04/27/04	14:50	blue	425.5	615	362.0	412	362.0	330	400.1	491					387.4	462.0
11300	04/21/04	10:30	blue	660.4	2920.00	317.5	293.00	350.5	327.00							442.8	1180.0
11347	04/22/04	9:56	blue	381.0	499.00	336.6	332.00	374.7	414.00	342.9	325.00					358.8	392.5
11382	04/20/04	11:50	channel	368.3	459.00	342.9	329.00	330.2	285.00	342.9	295.00					346.1	342.0
11302-A	04/15/04	9:20	blue	368.3	368.00	317.5	295.00	248.9	92.00							311.6	251.7
11302-B	04/15/04	9:20	blue	635.0	1956.00	660.4	3175.15									647.7	2565.6
11298	04/22/04	13:45	blue	311.2	263.00	362.0	361.00	546.1	1927.77							406.4	850.6
11274	04/21/04	13:00	blue	457.2	877.00	355.6	341.00	577.9	2239.61	622.3	2523.11					503.2	1495.2
11273	04/21/04	13:50	hardhead	355.6	443.00	317.5	383.00	360.7	526.00	309.9	328.00	332.7	371.00			335.3	410.2
11111	04/27/04	13:30	blue	342.9	306.00	301.6	181.00	360.7	348.00							335.1	278.3

Table 4.2 Catfish Tissue Samples Collected from HSC & Upper Galveston Bay

Station	Date	Time	Species	Sample 1		Sample 2		Sample 3		Sample 4		Sample 5		Sample 6		Average	
				Length (mm)	Weight (g)	Length (mm)	Weight (g)	Length (mm)	Weight (g)	Length (mm)	Weight (g)	Length (mm)	Weight (g)	Length (mm)	Weight (g)	Length (mm)	Weight (g)
Fall 2004																	
11292	10/20/2004	12:00	Channel	323.9	368	408.9	654	320.0	302							350.9	441.3
11280	10/21/2004	09:30	Hardhead	307.3	276	317.5	294	317.5	290	323.9	264					316.5	281.0
11264	10/26/2004	15:07	Hardhead	393.7	520	325.1	414	322.6	268	317.5	298	340.4	431			339.9	386.2
15979	10/26/2004	12:12	Hardhead	406.4	747	370.8	625	434.3	623	414.0	628	393.7	625			403.9	649.6
11265*	10/26/2004	10:20	Hardhead	386.1	693	348.0	456	375.9	546	398.8	562	360.7	479			373.9	547.2
11261	10/27/2004	09:22	Hardhead	393.7	580	375.9	557	391.2	506	403.9	810	424.2	965			397.8	683.6
13344	10/28/2004	14:12	Hardhead	386.1	427	416.6	790	375.9	465	414.0	620	375.9	393			393.7	539.0
11197	10/28/2004	11:40	Hardhead	467.4	1036	393.7	681	363.2	359	309.9	270					383.5	586.5
11287	10/28/2004	09:00	Blue	360.7	360	365.8	336	396.2	570							374.2	422.0
11193*	10/28/2004	10:52	Hardhead	350.5	363	335.3	308	340.4	353	348.0	361	320.0	263			338.8	329.6
16499	10/29/2004	09:20	Hardhead	393.7	505	375.9	444	414.0	544	378.5	433					390.5	481.5
13342	10/29/2004	08:40	Hardhead	424.2	598	393.7	478	429.3	642	419.1	568	452.1	598			423.7	576.8
16618	11/03/2004	12:05	Hardhead	411.5	728	421.6	717	381.0	599	403.9	664	447.0	852			413.0	712.0
14560	11/03/2004	08:30	Hardhead	411.5	612	332.7	312	391.2	440	454.7	777	429.3	810			403.9	590.2
11252	11/03/2004	10:10	Hardhead	386.1	608	355.6	374	340.4	252	408.9	748	370.8	474			372.4	491.2
13338	11/05/2004	09:20	Hardhead	337.8	374	335.3	229	355.6	394	368.3	574	381.0	555			355.6	425.2
13340	11/05/2004	10:01	Hardhead	411.5	681	406.4	683	315.0	244	424.2	691					389.3	574.8

* Duplicate taken from right side of sample.

Table 4.3 Blue Crab Tissue Samples Collected from HSC & Upper Galveston Bay

			Sample 1		Sample 2		Sample 3		Sample 4		Sample 5		Sample 6		Sample 7		Sample 8		Sample 9		Sample 10		Average	
Station	Date	Time	Length (mm)	Weight (g)	Length (mm)	Weight (g)	Length (mm)	Weight (g)	Length (mm)	Weight (g)	Length (mm)	Weight (g)	Length (mm)	Weight (g)	Length (mm)	Weight (g)	Length (mm)	Weight (g)	Length (mm)	Weight (g)	Length (mm)	Weight (g)	Length (mm)	Weight (g)
Summer 2002																								
11111	07/31/02	14:50	158.8	283.1	174.6	311.4	155.6	169.9	127.0	84.9													154.0	212.3
11193	08/08/02	9:15	165.1	254.8	158.8	254.8	177.8	226.5	177.8	226.5	152.4	169.9											166.4	226.5
11200	09/02/02	14:00	101.6	70.8	139.7	155.7	146.1	155.7	139.7	127.4	146.1	177.0	152.4	184.0	139.7	141.6	139.7	127.4					138.1	142.4
16622	09/02/02	17:30	152.4	169.9	133.4	141.6	127.0	127.4	146.1	155.7	133.4	113.3	139.7	134.5	139.7	141.6	139.7	141.6	139.7	127.4	4.75	3.5	125.6	125.6
11252	08/29/02	13:00	152.4	184.0	127.0	127.4	152.4	198.2	127.0	133.1													139.7	160.7
11252-Dup	08/29/02	13:00	152.4	198.2	146.1	198.2	149.2	175.5	127.0	87.8													143.7	164.9
11258	08/01/02	8:30	161.9	219.4	165.1	240.7	146.1	169.9	171.5	308.6	161.9	226.5											161.3	233.0
11261	08/20/02	11:50	184.2	339.8	177.8	311.4	171.5	325.6	177.8	283.1	165.1	269.0											175.3	305.8
16618	08/20/02	16:30	177.8	252.0	146.1	212.3	152.4	203.9	127.0	107.6													150.8	193.9
11272	07/26/02	8:50	127.0	113.3	127.0	141.6	130.2	113.3	133.4	169.9	108.0	113.3											125.1	130.2
11273	08/28/02	12:45	177.8	311.4	171.5	247.7	171.5	254.8	171.5	254.8													173.0	267.2
11273-Dup	08/28/02	12:45	152.4	162.8	152.4	212.3	158.8	269.0	158.8	283.1	152.4	198.2	152.4	184.0	152.4	177.0							154.2	212.3
11270	08/28/02	15:15	152.4	240.7	146.1	226.5	165.1	226.5	127.0	141.6	127.0	141.6											143.5	195.4
11264	08/20/02	12:15	146.1	184.0	171.5	325.6	171.5	311.4	165.1	283.1	165.1	254.8	165.1	254.8									164.0	269.0
15979	09/05/02	11:30	152.4	184.0	139.7	169.9	146.1	155.7	133.4	120.3	139.7	169.9	127.0	141.6									139.7	156.9
11287	08/25/02	12:15	127.0	127.4	158.8	184.0	127.0	99.1	127.0	99.1	142.9	158.6	136.5	124.6	133.4	138.7							136.1	133.1
11292	09/11/02	16:30	120.7	93.4	120.7	99.1	127.0	99.1	161.9	198.2	152.4	155.7	120.7	113.3	139.7	118.9	127.0	113.3	127.0	87.8			133.0	119.9
11298	07/29/02	13:30	161.9	311.4	165.1	283.1	152.4	254.8	133.4	198.2	133.4	254.8											149.2	260.5
11300	09/09/02	11:25	127.0	107.6	146.1	155.7	136.5	141.6	146.1	169.9	152.4	184.0	127.0	130.2	114.3	84.9							135.6	139.1
11302	08/26/02	13:45	114.3	70.8	139.7	127.4	108.0	70.8	139.7	84.9	139.7	127.4	152.4	169.9									132.3	108.5
11305	08/14/02	8:30	139.7	169.9	101.6	113.3	127.0	113.3	133.4	127.4	152.4	169.9	152.4	155.7	114.3	113.3	133.4	141.6					131.8	138.0
11280	08/28/02	16:00	152.4	155.7	152.4	184.0	152.4	184.0	88.9	134.5	101.6	141.6	171.5	226.5									136.5	171.1
11280-Dup	08/28/02	16:00	177.8	311.4	177.8	283.1	165.1	254.8	177.8	311.4	165.1	198.2	152.4	169.9									169.3	254.8
11347	08/12/02	11:35	120.7	70.8	101.6	70.8	114.3	84.9	139.7	133.1													119.1	89.9
11274	07/30/02	13:30	171.5	226.5	120.7	113.3	114.3	113.3	114.3	84.9	114.3	56.6											127.0	118.9
11382	08/13/02	11:15	149.2	167.0	127.0	99.1	114.3	76.4															130.2	114.2
13309	09/11/02	10:15	152.4	198.2	161.9	269.0	158.8	215.2	171.5	277.5	152.4	201.0	146.1	155.7									157.2	219.4
14560	08/30/02	12:14	155.6	252.0	139.7	201.0	171.5	300.1	120.7	130.2	133.4	110.4											144.1	198.8
15464	08/17/02	11:30	127.0	138.7	149.2	201.0	149.2	198.2	149.2	172.7													143.7	177.7
15908	09/11/02	15:00	133.4	158.6	152.4	133.1	152.4	167.0	146.1	155.7	146.1	133.1	111.1	96.3									140.2	140.6
16213	09/10/02	16:00	177.8	283.1	161.9	184.0	130.2	118.9	114.3	87.8	108.0	79.3											138.4	150.6
13337	08/14/02	14:30	133.4	141.6	152.4	212.3	139.7	155.7	130.2	127.4	146.1	212.3											140.3	169.9
13338	08/23/02	11:20	136.5	104.8	130.2	113.3	130.2	118.9	123.8	96.3	127.0	116.1											129.5	109.9
13336	08/27/02	12:00	171.5	314.3	181.0	322.8	158.8	195.4															170.4	277.5
11092	08/02/02	13:30	108.0	84.9	133.4	141.6	171.5	155.7	133.4	127.4	114.3	99.1											132.1	121.7
13339	08/23/02	10:30	152.4	198.2	171.5	240.7	165.1	254.8	165.1	212.3													163.5	226.5
13339-Dup	08/25/02	13:30	158.8	249.2	168.3	314.3	165.1	240.7	114.3	99.1													151.6	225.8
16499	08/29/02	13:15	108.0	56.6	127.0	84.9	139.7	127.4	146.1	134.5													130.2	100.9
13340	08/07/02	13:00	117.5	113.3	101.6	56.6	101.6	56.6	104.8	70.8	104.8	42.5											106.0	68.0
13341	08/16/02	16:45	120.7	92.0	139.7	155.7	152.4	184.0															137.6	143.9
13342	08/24/02	11:02	177.8	283.1	177.8	198.2	165.1	198.2	139.7	84.9	127.0	70.8											157.5	167.0
17971	08/24/02	11:15	174.6	297.3	177.8	382.2	165.1	290.2	155.6	254.8													168.3	306.1
13343	08/21/02	11:30	139.7	120.3	177.8	247.7	184.2	325.6	203.2	339.8													176.2	258.4
13344	08/23/02	12:00	177.8	339.8	177.8	311.4	177.8	382.2	152.4	184.0	127.0	99.1											162.6	263.3
13344-Dup	08/23/02	12:00	187.3	336.9	190.5	300.1	171.5	263.3	177.8	226.5													181.8	281.7
16496	08/24/02	10:35	165.1	226.5	133.4	130.2	120.7	101.9	117.5	79.3													134.1	134.5
13355	08/18/02	12:25	130.2	169.9	149.2	209.5	155.6	277.5	165.1	266.1	158.8	300.1											151.8	244.6
17970	08/18/02	11:00	171.5	311.4	165.1	325.6	152.4	141.6	139.7	198.2	165.1	254.8											158.8	246.3
17970-Dup	08/18/02	11:00	177.8	339.8	158.8	226.5	177.8	311.4	171.5	353.9													171.5	307.9
13363	08/17/02	13:30	146.1	181.2	155.6	226.5	146.1	181.2															149.2	196.3
13589	08/17/02	13:30	158.8	223.7	146.1	169.9	155.6	148.6	139.7	148.6	130.2	113.3	149.2	243.5	158.8	158.6							148.3	172.3
13589-Dup	08/17/02	13:30	155.6	138.7	123.8	138.7	158.8	269.0	152.4	192.5	127.0	127.4	146.1	198.2	152.4	198.2							145.1	180.4
Fall 2002																								
11252	11/13/02	16:00	177.8	297.3	165.1	205.3	181.0	232.2	168.3	235.0	168.3	253.4	149.2	161.4									168.28	230.75
11261	10/25/02	10:30	165.1	218.0	177.8	168.5	139.7	106.2	158.8	148.6	177.8	164.2	174.6	225.1	152.4	182.6	152.4	148.6					162.32	170.23

Table 4.3 Blue Crab Tissue Samples Collected from HSC & Upper Galveston Bay

			Sample 1		Sample 2		Sample 3		Sample 4		Sample 5		Sample 6		Sample 7		Sample 8		Sample 9		Sample 10		Average	
Station	Date	Time	Length (mm)	Weight (g)	Length (mm)	Weight (g)	Length (mm)	Weight (g)	Length (mm)	Weight (g)	Length (mm)	Weight (g)	Length (mm)	Weight (g)	Length (mm)	Weight (g)	Length (mm)	Weight (g)	Length (mm)	Weight (g)	Length (mm)	Weight (g)	Length (mm)	Weight (g)
15464	11/13/02	12:45	171.5	235.0	177.8	237.8	171.5	198.2	165.1	150.1	158.8	171.3	127.0	106.2	133.4	92.0							157.84	170.08
13338	10/22/02	10:00	165.1	198.2	177.8	240.7	165.1	226.5	152.4	169.9	177.8	169.9	190.5	311.4									171.45	219.42
13336	10/22/02	9:00	158.8	181.2	187.3	339.8	177.8	297.3	133.4	113.3													164.31	232.87
16499	10/24/02	---	171.5	195.4	177.8	213.8	158.8	127.4	171.5	171.3	174.6	198.2	152.4	179.8	165.1	182.6	152.4	151.5					165.50	177.48
13340	10/22/02	7:50	165.1	253.4	161.9	223.7	152.4	185.4	139.7	137.3	158.8	246.3	136.5	117.5	0.0	0.0	0.0	0.0					114.30	145.46
13342	10/28/02	8:00	171.5	210.9	196.9	321.3	158.8	174.1	168.3	247.7	161.9	185.4	165.1	189.7	152.4	157.1	181.0	222.3					169.47	213.58
17971	10/28/02	10:00	158.8	288.8	165.1	254.8	171.5	269.0	171.5	263.3	146.1	226.5	171.5	325.6									164.04	271.33
17971-Dup	10/28/02	10:00	158.8	254.8	171.5	311.4	171.5	274.6	177.8	334.1	165.1	311.4	171.5	269.0									169.33	292.56
13344	10/27/02	12:10	177.8	301.5	203.2	293.0	177.8	198.2	158.8	143.0	152.4	130.2	190.5	362.4									176.74	238.06
13344-Dup	11/14/02	14:00	184.2	368.1	184.2	378.0	193.7	407.7	177.8	269.0													184.94	355.68
17970	10/24/02	8:20	155.6	240.7	190.5	351.1	171.5	226.5	165.1	226.5	139.7	135.9	165.1	152.9	139.7	155.7							161.02	212.75
13363	11/06/02	10:00	171.5	286.0	152.4	213.8	146.1	150.1	139.7	160.0	146.1	185.4	133.4	134.5	133.4	117.5	139.7	157.1					145.26	175.54
Spring 2003																								
11258	04/30/03	12:00	196.9	368.1	177.8	261.9	177.8	177.0	177.8	205.3													182.6	253.0
11273	04/29/03	9:50	152.4	113.3	184.2	311.4	152.4	198.2	171.5	240.7													165.1	215.9
11274	04/30/03	14:40	139.7	141.6	127.0	99.1	127.0	113.3	114.3	84.9	114.3	70.8	114.3	77.9									122.8	97.9
11272	04/29/03	10:50	133.4	113.3	152.4	127.4	152.4	127.4	127.0	99.1	127.0	84.9											138.4	110.4
11298	05/01/03	9:00	177.8	167.0	152.4	186.9	165.1	192.5	146.1	169.9	139.7	155.7											156.2	174.4
13339	05/04/03	15:15	174.6	155.7	168.3	220.8	158.8	212.3	142.9	70.8													161.1	164.9
11305	05/03/03	9:55	152.4	113.3	139.7	56.6	165.1	87.8	146.1	107.6	136.5	42.5											148.0	81.5
11382	05/02/03	9:00	133.4	118.9	142.9	107.6	120.7	84.9															132.3	103.8
11193	05/10/03	15:30	101.6	56.6	165.1	209.5	139.7	184.0	152.4	152.9	139.7	106.2											139.7	141.8
11287	05/05/03	9:50	174.6	261.9	186.1	240.7	158.8	169.9	171.5	246.3													172.7	229.7
13343	05/10/03	12:00	200.0	260.5	190.5	325.6	171.5	254.8	152.4	184.0													178.6	256.2
11264	05/06/03	9:00	142.9	118.9	130.2	99.1	127.0	113.3	130.2	101.9	117.5	79.3	120.7	93.4									128.1	101.0
11270	05/06/03	11:40	181.0	223.7	155.6	226.5	165.1	266.1	139.7	113.3	149.2	121.7											158.1	190.3
16496	05/10/03	12:15	171.5	243.5	184.2	260.5	181.0	263.3	177.8	186.9													178.6	238.5
13342	05/10/03	12:50	187.3	189.7	171.5	235.0	139.7	107.6	136.5	96.3													158.8	157.1
11280	05/06/03	10:50	171.5	155.7	146.1	110.4	127.0	84.9	139.7	62.3	114.3	82.1											139.7	99.1
11302	05/11/03	12:30	139.7	84.9	158.5	99.1	146.1	145.0	139.7	118.9	114.3	82.1	101.6	56.6									133.3	97.8
16618	05/05/03	8:00	203.2	294.5	171.5	184.0	177.8	169.9	136.5	113.3													172.2	190.4
11292	05/05/03	11:30	155.6	147.2	142.9	152.9	142.9	133.1	155.6	124.6													149.2	139.4
11261	05/10/03	11:40	184.2	223.7	139.7	84.9	120.7																148.2	154.3
15979	05/23/03	11:30	165.1	247.7	133.4	148.6	120.7	84.9	139.7	141.6	133.4	127.4											138.4	150.1
11300	05/30/03	10:30	146.1	141.6	152.4	169.9	120.7	113.3	114.3	99.1	146.1	191.1											135.9	143.0
13340	05/23/03	13:40	165.1	212.3	146.1	155.7	127.0	148.6	127.0	148.6	127.0	141.6	114.3	92.0									134.4	149.8
13355	05/23/03	8:10	146.1	134.5	139.7	141.6	127.0	120.3	127.0	134.5	133.4	120.3	120.7	84.9	127.0	99.1	114.3	99.1					129.4	116.8
11300	05/29/03	15:00	158.8	113.3	146.1	141.6																	152.4	127.4
15908	05/22/03	13:00	171.5	226.5	165.1	169.9	165.1	191.1	158.8	212.3	177.8	226.5	152.4	169.9	165.1	240.7	158.8	212.3	146.1	141.6	158.8	148.6	164.3	206.2
13337	05/23/03	14:00	158.8	184.0	127.0	99.1	158.8	233.6	127.0	56.6													142.9	143.3
16622	05/22/03	15:25	158.8	134.5	146.1	120.3	165.1	198.2	152.4	127.4	139.7	141.6											152.4	144.4
11092	04/29/03	14:40	152.4	133.0	139.7	135.8	136.5	101.9	139.7	113.2													142.1	121.0
11092-dup	04/29/03	14:40	149.2	167.0	155.6	175.5	146.1	87.7	136.5	127.4	127.0	76.4											142.9	126.8
11111	05/01/03	10:00	136.5	62.3	130.2	104.7	127.0	124.5	127.0	76.4	142.9	130.2	133.4	73.6									132.8	95.3
11111-dup	05/01/03	10:00	165.1	184.0	127.0	56.6	120.7	84.9	133.4	99.1	149.2	127.4											139.1	110.4
11347	05/02/03	10:00	134.6	104.7	127.0	73.6	108.0	36.8	120.7	56.6	114.3	73.6											120.9	69.1
13309	05/12/03	14:20	139.7	147.2	120.7	93.4	120.7	70.8	121.9	82.1	152.4	203.8											131.1	119.4
13341	05/06/03	7:45	82.6	50.9	133.4	130.2	139.7	155.7															118.5	112.3
13589	05/16/03	10:00	152.4	206.6	152.4	206.6	154.9	195.3	152.4	184.0	152.4	226.4											152.9	203.8
16213	05/12/03	10:30	158.8	226.4	101.6	70.8	165.1	161.3	127.0	76.4	119.4	76.4											134.4	122.3
Spring 2004																								
11252	03/09/04	5:40	69.9	23.0	111.1	60.0	149.2	163.0															110.1	82.0
13342	03/09/04	7:30	171.5	199.0	171.5	246.0	174.6	205.0	184.2	324.0	184.2	258.0											177.2	246.4
13340	03/09/04	5:30	133.4	108.0	158.8	209.0	146.1	104.0	158.8	159.0	127.0	108.0											144.8	137.6
14560	03/09/04	6:15	88.9	40.0	177.8	297.0	170.2	176.0															145.6	171.0
11193	03/23/04	13:10	158.8	232.0	177.8	238.0	142.9	122.0															159.8	197.3

Table 4.3 Blue Crab Tissue Samples Collected from HSC & Upper Galveston Bay

			Sample 1		Sample 2		Sample 3		Sample 4		Sample 5		Sample 6		Sample 7		Sample 8		Sample 9		Sample 10		Average	
Station	Date	Time	Length (mm)	Weight (g)	Length (mm)	Weight (g)	Length (mm)	Weight (g)	Length (mm)	Weight (g)	Length (mm)	Weight (g)	Length (mm)	Weight (g)	Length (mm)	Weight (g)	Length (mm)	Weight (g)	Length (mm)	Weight (g)	Length (mm)	Weight (g)	Length (mm)	Weight (g)
11261	03/19/04	10:00	155.6	173.0	146.1	127.0	146.1	138.0	127.0	90.0													143.7	132.0
11264	03/23/04	15:00	146.1	110.0	130.2	112.0	133.4	114.0	114.3	83.0	108.0	55.0											126.4	94.8
16499	03/17/04	15:30	136.5	138.0	133.4	91.0	136.5	133.0	174.6	190.0													145.3	138.0
16618	03/18/04	10:00	181.0	332.0	158.8	187.0	174.6	249.0															171.5	256.0
11261	03/23/04	14:30	158.8	217.0	168.3	228.0	152.4	180.0	158.8	164.0	152.4	165.0											158.1	190.8
13344	03/18/04	12:00	181.0	281.0	187.3	289.0	165.1	233.0	136.5	122.0													167.5	231.3
13338	03/17/04	9:00	149.2	169.0	127.0	96.0	146.1	124.0	139.7	155.0	133.4	101.0											139.1	129.0
11197	03/23/04	13:45	146.1	128.0	149.2	115.0	114.3	66.0	101.6	51.0													127.8	90.0
11280	04/01/04	12:40	165.1	224.0	155.6	148.0	158.8	193.0	136.5	139.0	152.4	130.0	139.7	104.0									151.3	156.3
15979	03/31/04	16:30	177.8	296.0	146.1	178.0	174.6	178.0	158.8	168.0	152.4	165.0	152.4	173.0									160.3	193.0
11287	04/01/04	13:00	174.6	275.0	158.8	169.0	152.4	152.0	171.5	222.0	152.4	169.0											161.9	197.4
11265	03/30/04	12:00	168.3	155.0	146.1	143.0	165.1	171.0	130.2	101.0													152.4	142.5
11305	04/22/04	12:35	147.3	114.0	114.3	82.0	152.4	129.0	139.7	79.0	142.2	136.0	129.5	100.0	127.0	108.0							136.1	106.9
11272	04/13/04	14:00	101.6	50.0	108.0	47.0	114.3	73.0	114.3	74.0	109.2	61.0											109.5	61.0
11292	04/03/04	11:00	108.0	55.0	106.7	55.0	109.2	70.0	99.1	43.0	108.0	52.0	109.2	58.0									106.7	55.5
11092	04/30/04	8:30	146.1	170.0	147.3	149.0	158.8	233.0	139.7	133.0													148.0	171.3
11300	04/16/04	8:40	157.5	153.1	146.1	147.4	152.4	130.4	132.1	116.2	120.7	76.5	132.1	96.4									140.1	120.0
11302	04/14/04	12:00	139.7	133.2	114.3	85.0	132.1	113.4	139.7	121.9	132.1	85.0											131.6	107.7
11298-D	04/20/04	14:15	149.9	73.7	139.7	113.4	165.1	130.4	160.0	147.4	134.6	99.2	152.4	116.2									150.3	113.4
11298	04/20/04	14:15	133.4	124.7	132.1	121.9	149.9	167.3	133.4	113.4	139.7	110.6	146.1	104.9									139.1	123.8
11274	04/20/04	15:10	133.4	93.6	109.2	56.7	124.5	70.9	114.3	56.7	108.0	31.2	101.6	53.9									115.1	60.5
11273-D	04/21/04	13:50	185.4	292.0	190.5	283.5	177.8	260.8	171.5	226.8	177.8	221.1	158.8	232.5									177.0	252.8
11273	04/21/04	13:50	190.5	334.5	184.2	243.8	184.2	229.6	172.7	229.6	165.1	187.1	158.8	204.1									175.9	238.1
11111	04/27/04	13:30	147.3	155.9	132.1	153.1	152.4	155.9	134.6	136.1	160.0	170.1	129.5	113.4									142.7	147.4
Fall 2004																								
11287	10/19/04	14:20	139.7	98.0	154.9	231.0	165.1	237.0	144.8	166.0	142.2	163.0											149.4	179.0
11280	10/20/04	13:30	165.1	234.0	154.9	175.0	165.1	255.0	152.4	260.0	154.9	163.0											158.5	217.4
11292	10/20/04	12:33	152.4	149.0	154.9	161.0	172.7	241.0	160.0	183.0	165.1	201.0	129.5	155.0	139.7	156.0							153.5	178.0
11264	10/21/04	10:40	142.2	147.0	137.2	152.0	162.6	288.0	152.4	153.0													148.6	185.0
15979*	10/21/04	10:20	157.5	192.0	165.1	182.0	162.6	189.0	172.7	199.0	172.7	269.0	144.8	158.0									162.6	198.2
11265	10/21/04	10:30	160.0	253.0	175.3	266.0	170.2	204.0	165.1	220.0	162.6	195.0											166.6	227.6
13344	10/21/04	11:20	167.6	182.0	188.0	156.0	157.5	117.0	129.5	86.0	182.9	183.0											165.1	144.8
11252	10/26/04	17:23	177.8	301.0	144.8	97.0	182.9	334.0	165.1	131.0	147.3	114.0	182.9	242.0									166.8	203.2
11261	10/26/04	16:30	152.4	203.0	165.1	222.0	170.2	208.0	177.8	326.0	177.8	385.0											168.7	268.8
13342	10/28/04	14:48	185.4	263.0	157.5	182.0	188.0	178.0	180.3	190.0	177.8	192.0											177.8	201.0
11193*	10/27/04	10:04	180.3	277.0	185.4	289.0	175.3	174.0	185.4	252.0	177.8	190.0											180.8	236.4
11197	10/28/04	11:40	203.2	336.0	180.3	181.0	190.5	326.0	182.9	246.0	182.9	265.0											188.0	270.8
13340	11/03/04	13:34	157.5	183.0	149.9	173.0	157.5	166.0	172.7	248.0	175.3	289.0	162.6	187.0									162.6	207.7
16618	11/02/04	17:00	167.6	161.0	147.3	137.0	165.1	199.0	167.6	227.0	160.0	149.0	180.3	414.0									164.7	214.5
16499	11/08/04	14:50	162.6	204.0	160.0	216.0	180.3	249.0	152.4	161.0													163.8	207.5
14560	11/04/04	8:15	162.6	227.0	167.6	213.0	152.4	192.0	157.5	200.0	182.9	312.0	139.7	147.0									160.4	215.2
13338	11/02/04	14:15	165.1	171.0	180.3	213.0	177.8	170.0															174.4	184.7

* Duplicate taken from right side of sample.

Table 4.4 Prey Species Samples Collected from HSC & Upper Galveston Bay

Station	Date	Time	Species	Number of Individuals	Average Length (mm)
11270-SC	08/28/03	14:45	Shiner	1	N/A
15464-SC	08/18/03	9:20	Small fish	5	N/A
11200	11/21/02	16:15	Shad	3	283.6
13342-SC	05/11/03	12:45	Shrimp	1	N/A
13309-SC	05/12/03	14:20	Shrimp	1	N/A
11258	04/29/03	8:42	Shad	5	127.0
11261	05/23/03	9:15	Shrimp	100	38.10
11261	05/23/03	9:15	Croaker	80	38.10
16618	05/23/03	9:00	Shrimp	40	38.10
16618	05/23/03	9:00	Croaker	50	50.80
11270	05/23/03	10:22	Shad	100	41.28
11270	05/23/03	10:22	Minnows	200	38.10
11270	05/23/03	10:22	Mullet	5	76.20
11270	05/23/03	10:22	Shrimp	18	47.63
11270	05/23/03	10:22	Croaker	100	50.80
11298	05/02/03	14:00	Shad	2	N/A
11298	05/02/03	14:00	Shrimp	1	107.95
16499	05/23/03	12:30	Mullet	1	69.85
16499	05/23/03	12:30	Croaker	26	76.20
16499	05/23/03	12:30	Shrimp	100	N/A
16499	05/23/03	12:30	Shad	11	N/A
16499	05/23/03	12:30	Minnows	27	N/A

SC = stomach content
N/A = not available

Dioxin concentrations in catfish and crab samples collected in this project and the resulting Texas-TEQ levels is presented in Tables 4.5 and 4.6, respectively. The distribution of TEQ levels in catfish along the HSC is shown in Figure 4.2a and b, while the distribution of dioxin levels in crabs is presented in Figure 4.3a and b. Dioxin data for Summer 2002 tissue samples varied from 0.349 to 40.086 ng TEQ/kg-wet wt for catfish and from 0.303 to 15.82 ng TEQ/kg-wet wt for crabs, with average values of 5.26 and 3.48 ng TEQ/kg-wet wt, respectively. Fall 2002 tissue samples exhibited TEQ levels between 1.83 and 10.52 ng/kg-wet wt for catfish and between 0.32 and 6.06 ng/kg-wet wt for crabs, with average values equal to 5.06 and 3.01 ng/kg- wet wt, respectively. Lipid-normalized concentrations in catfish showed average values of 9.47 and 8.74 ng TEQ/kg-wet wt for Summer 2002 and Fall 2002 samples, respectively. Similarly, average lipid-normalized TEQ concentrations in crabs were 11.54 ng/kg-wet wt for the Summer 2002 and 10.03 ng/kg-wet wt for the Fall 2002 samples. Results from the tissue samples collected in Spring 2003 showed TEQ concentrations between 0.79 and 15.07 ng/kg-wet wt for catfish and between 0.35 and 9.64 ng/kg-wet wt for crabs, with average values of 6.15 and 3.00 ng TEQ/kg-wet wt. Spring 2004 tissue samples varied from 0.19 to 19.64 ng TEQ/kg-wet wt for catfish and from 0.37 to 8.61 ng TEQ/kg-wet wt for crabs, with average values of 5.68 and 3.32 ng TEQ/kg-wet wt, respectively. Finally, TEQ concentrations in Fall 2004 ranged from 0.93 to 27.4 ng/kg-wet wt for catfish, and from 1.32 to 12.08 ng/kg-wet wt for crabs, with respective average values of 9.39 and 6.93 ng/kg-wet wt. Lipid-normalized concentrations in catfish and crabs showed average values of 11.39 and 6.82 ng TEQ/kg-wet wt in Spring 2004, and 13.1 and 16.19 ng TEQ/kg-wet wt in Fall 2004.

Table 4.5 Total Dioxin Concentrations in Catfish (ng/kg-wet wt)

Station ID	Date	Lipid content (%)	2,3,7,8-TCDD	1,2,3,7,8-PeCDD	1,2,3,4,7,8-HxCDD	1,2,3,6,7,8-HxCDD	1,2,3,7,8,9-HxCDD	1,2,3,4,6,7,8-HpCDD	OCDD	2,3,7,8-TCDF	1,2,3,7,8-PeCDF	2,3,4,7,8-PeCDF	1,2,3,4,7,8-HxCDF	1,2,3,6,7,8-HxCDF	2,3,4,6,7,8-HxCDF	1,2,3,7,8,9-HxCDF	1,2,3,4,6,7,8-HpCDF	1,2,3,4,7,8,9-HpCDF	OCDF	Total TEQ	Lipid- normalized TEQ^{a}	Average TEQ^{b}	Average Lipid-normalized TEQ^{a,b}
Summer 2002																							
11272	07/26/2002	0.5	1.2	< 0.23	< 0.1	< 0.12	0.13	0.67	2.2	0.25	0.13	0.19	< 0.097	< 0.38	< 0.1	< 0.14	< 0.76	< 0.97	0.53	1.44	8.66	2.22	13.31
11272-dup	07/26/2002	0.5	2.6	< 0.22	< 0.16	0.3	0.19	< 0.51	2.1	0.47	< 0.1	0.28	< 0.088	< 1.3	< 0.094	0.18	< 0.33	< 1.1	0.65	2.99	17.96		
11274	07/30/2002	0.4	3.8	0.41	< 0.31	0.44	< 0.3	1.1	3.9	0.27	< 0.26	0.69	< 0.24	< 2	< 0.28	< 0.4	< 0.61	< 0.29	0.89	4.60	34.53	4.60	34.53
11111	08/01/2002	1.7	2.5	0.61	0.5	< 1.2	< 0.31	2.6	5.4	0.66	< 0.21	< 0.26	< 0.099	< 1	0.13	< 0.18	< 0.82	< 0.59	16	3.14	5.55	3.14	5.55
11258	08/01/2002	1.9	7.2	< 0.23	0.22	1.3	0.23	1.7	2.6	< 0.25	< 0.18	0.77	< 0.076	0.84	< 0.089	< 0.13	< 1.9	< 0.57	72	7.93	12.53	7.93	12.53
11092	08/02/2002	1.5	< 0.36	< 0.25	< 0.11	< 0.11	< 0.11	< 0.52	1.8	< 0.19	< 0.066	< 0.25	< 0.072	< 0.065	< 0.08	< 0.11	0.5	< 0.23	1.6	0.35	0.70	0.35	0.70
13340	08/07/2002	0.8	1.5	< 0.099	< 0.14	< 0.16	< 0.15	0.84	1.8	< 0.38	1.1	1	< 0.11	< 0.37	< 0.13	< 0.17	< 0.34	< 0.4	1.7	2.16	8.10	2.16	8.10
11193	08/09/2002	3	12	0.48	0.28	< 0.95	< 0.34	1.4	3.2	1.1	< 0.36	0.68	< 0.2	< 5.8	< 0.22	< 0.28	< 0.39	< 0.57	1.3	13.12	13.12	13.12	13.12
13341	08/09/2002	2.1	4	0.43	< 0.17	0.73	0.21	1.1	2.5	0.44	0.24	0.65	< 0.27	< 1	< 0.31	< 0.43	0.41	< 0.39	1.6	4.80	6.86	4.80	6.86
11382	08/11/2002	0.9	0.61	< 0.3	< 0.22	< 0.25	< 0.23	1.1	1.9	< 0.23	< 0.23	< 0.5	< 0.2	< 0.18	< 0.23	< 0.32	< 0.56	< 0.45	2.2	0.91	3.03	0.91	3.03
11347-1	08/13/2002	2.3	1.3	< 0.26	< 0.22	0.36	< 0.23	1.1	3.4	< 0.22	< 0.2	0.47	< 0.18	< 0.17	0.31	< 0.29	< 0.67	< 0.25	1.9	1.74	2.27	1.67	6.10
11347-2	08/13/2002	0.6	< 1.8	< 0.28	< 0.063	0.42	< 0.065	1.2	5.1	< 0.12	< 0.16	1.3	< 0.12	< 1.3	0.16	< 0.19	< 0.57	< 1.4	1.5	1.77	8.87		
11347-2-dup	08/13/2002	0.6	1.7	< 0.24	< 0.22	< 0.28	< 0.23	1.2	3.4	< 0.21	< 0.24	1.2	< 0.19	< 0.18	< 0.25	< 0.38	< 0.63	< 0.22	1.7	2.46	12.32		
11347-3	08/13/2002	2.2	0.35	0.38	< 0.18	0.26	< 0.19	0.86	1.6	< 0.2	< 0.2	< 0.21	< 0.17	< 0.16	< 0.18	< 0.28	< 0.46	< 0.34	1.7	0.69	0.94		
11305	08/13/2002	3	1	< 0.2	< 0.16	< 0.21	< 0.18	0.92	3.4	0.25	< 0.2	0.7	< 0.26	< 1.7	< 0.28	< 0.38	0.8	< 0.34	7.1	1.59	1.59	2.74	5.66
11305-dup	08/13/2002	1.2	2.7	0.5	< 0.24	0.61	0.35	1.1	2	0.29	< 0.33	1.4	< 0.11	0.25	0.38	0.29	0.48	0.18	2	3.89	9.73		
13337	08/14/2002	1	2.3	< 0.25	0.32	< 0.24	< 0.23	1.2	2.7	0.22	< 0.25	0.29	< 0.23	< 2.5	< 0.23	< 0.29	0.66	0.37	17	2.75	8.26	7.04	21.11
13337-dup	08/14/2002	1	9.9	0.7	< 0.32	1.2	0.47	1.8	3.1	1.2	2.5	0.86	< 0.23	< 3.4	< 0.27	< 0.34	< 1.6	< 0.34	56	11.32	33.96		
13363	08/17/2002	1.3	1.5	< 0.22	0.16	< 0.25	< 0.14	1.1	3	0.25	< 0.14	< 0.12	< 0.14	< 0.57	< 0.16	< 0.25	< 0.36	< 0.39	1.6	1.71	3.93	1.71	3.93
13589	08/17/2002	0.4	1.3	< 0.19	< 0.2	0.31	< 0.2	0.75	1.2	< 0.27	< 0.22	< 0.18	< 0.2	< 0.17	< 0.21	< 0.28	< 0.26	< 0.32	0.67	1.51	11.29	1.35	10.12
13589-dup	08/17/2002	0.4	1	< 0.18	< 0.19	0.28	< 0.2	0.64	1.1	< 0.21	< 0.2	< 0.18	< 0.18	< 0.16	< 0.2	< 0.26	0.39	< 0.29	0.57	1.19	8.95		
13355	08/18/2002	1.2	2.1	< 0.23	< 0.12	0.41	< 0.12	0.73	1.3	< 0.25	< 0.13	0.24	< 0.19	< 2.3	< 0.21	< 0.31	< 0.36	< 0.49	0.64	2.50	6.24	2.50	6.24
17970	08/18/2002	1.1	1.7	< 0.28	< 0.24	< 0.25	< 0.24	0.7	1.4	0.37	< 0.21	< 0.22	< 0.22	< 0.19	< 0.25	< 0.37	0.37	< 0.28	0.85	1.96	5.33	1.96	5.33
15464	08/18/2002	1	< 0.46	< 0.59	< 0.22	< 0.25	< 0.23	0.61	1	< 0.35	< 0.25	< 0.25	< 0.3	< 0.28	< 0.31	< 0.39	0.62	< 0.23	3.3	0.56	1.69	0.56	1.69
16618	08/19/2002	1.4	6.1	< 0.27	< 0.2	< 0.69	0.47	1.1	1.4	0.74	< 0.33	0.68	< 0.18	< 3.3	< 0.21	< 0.32	< 0.41	< 0.56	0.61	6.88	14.75	6.88	14.75
11264	08/20/2002	2.1	7.8	< 0.26	< 0.22	< 0.41	< 0.23	1.1	2.5	0.9	< 0.22	0.74	< 0.14	< 1.3	< 0.15	< 0.32	< 0.63	< 0.84	1.4	8.47	12.10	8.47	12.10
13343	08/20/2002	2.1	5.7	< 0.2	0.2	0.57	0.26	1	2.2	1.8	< 0.3	0.63	< 0.19	< 2.2	< 0.2	< 0.46	< 2.4	< 3	41	6.51	9.30	6.51	9.30
13344	08/21/2002	2.5	5.5	< 0.31	< 0.35	0.5	< 0.37	1.9	8.3	2.8	< 0.3	0.56	< 0.24	< 0.23	< 0.23	< 0.3	< 0.24	< 0.25	0.81	6.28	7.54	6.28	7.54
16496	08/21/2002	2.1	5.8	< 0.34	< 0.29	< 0.3	< 0.41	< 0.65	2.4	4.6	< 0.3	< 0.3	< 0.3	< 0.28	< 0.3	< 0.27	0.42	< 0.3	1.2	6.54	9.34	6.54	9.34
13342	08/22/2002	1.8	5.6	< 0.37	< 0.28	< 0.45	< 0.3	1.7	6	2.1	< 0.27	0.36	< 0.15	< 0.14	< 0.13	< 0.18	< 0.3	< 0.31	0.76	6.17	10.28	6.17	10.28
11261	08/23/2002	3.1	11	< 0.41	< 0.43	1.2	< 0.47	2	4.3	< 1.2	< 0.22	0.83	< 0.16	< 0.15	< 0.16	< 0.19	< 0.28	< 0.29	0.84	11.78	11.40	11.78	11.40
13338	08/23/2002	3.5	5.8	< 0.59	< 0.31	< 0.69	0.43	2.4	7.7	2.2	< 0.33	0.57	< 0.28	< 0.24	< 0.3	< 0.48	0.81	< 1.2	1.2	6.62	5.67	6.62	5.67
13339	08/23/2002	1.9	6.9	< 0.51	< 0.27	0.54	0.29	1.1	3.3	1.3	< 0.85	< 0.32	< 0.19	< 0.17	< 0.2	< 0.23	< 0.6	< 0.69	0.92	7.39	11.68	7.05	11.12
13339-dup	08/23/2002	1.9	5.9	< 0.45	< 0.53	< 0.58	< 0.55	1.1	1.9	0.91	< 0.89	0.73	< 0.44	< 0.39	< 0.45	0.58	< 0.48	< 5.2	0.82	6.70	10.57		
16499	08/23/2002	2.7	8.1	< 0.52	< 0.25	0.48	< 0.25	0.89	1.2	2	< 0.59	< 0.38	< 0.22	< 0.21	< 0.22	< 0.28	< 0.53	< 0.61	< 0.63	8.66	9.62	6.73	7.48
16499-dup	08/23/2002	2.7	4.4	< 0.31	< 0.23	< 0.6	< 0.25	1.2	1.4	0.68	< 0.3	0.31	< 0.25	< 0.24	< 0.25	< 0.2	< 0.28	< 0.33	0.68	4.81	5.34		
17971	08/24/2002	1.2	3.2	< 0.66	< 0.33	< 0.34	< 0.34	0.49	< 1	0.83	< 0.23	< 0.28	< 0.23	< 0.23	< 0.25	< 0.32	< 0.41	< 0.44	< 0.55	3.63	9.06	3.63	9.06
11287	08/25/2002	2.9	2.8	0.73	< 0.27	< 0.74	< 0.28	1.9	2.3	0.77	< 0.28	< 1.6	< 0.25	< 0.23	< 0.25	< 0.31	< 1.1	< 1.3	1.2	3.77	3.90	3.77	3.90
11252	08/26/2002	1.8	2.6	< 0.25	0.24	0.85	0.36	1.7	5.1	0.73	< 0.24	0.43	< 0.24	< 0.2	< 0.34	< 0.5	< 0.56	0.43	3.4	3.17	5.28	3.17	5.28
11302	08/26/2002	1.1	0.98	< 0.72	< 0.3	0.38	< 0.3	0.67	1.7	< 0.55	< 0.37	0.42	< 0.26	< 0.24	< 0.25	< 0.33	< 0.92	< 1.1	0.93	1.53	4.17	1.53	4.17
13336	08/27/2002	1	2.3	< 0.24	< 0.34	0.64	< 0.21	2.9	20	< 0.31	< 0.38	< 0.38	< 0.3	< 0.28	< 0.36	< 0.6	< 0.61	< 0.73	1.1	2.65	7.95	1.67	5.02
13336-dup	08/27/2002	1	< 0.64	< 0.35	< 0.62	< 0.66	< 0.64	< 0.99	3.6	< 0.45	< 0.18	< 0.18	< 0.51	< 0.44	< 0.52	< 0.98	< 1.1	< 1.3	1.6	0.70	2.09		
11270	08/28/2002	1.2	4.9	0.29	< 0.19	< 0.22	< 0.2	1.3	4.2	0.46	< 0.24	0.57	< 0.28	< 0.26	< 0.31	< 0.52	< 0.46	< 0.9	2.5	5.48	13.70	5.48	13.70
11280	08/28/2002	1.4	4.9	0.42	0.32	0.72	0.39	1.1	1.9	0.67	0.37	0.69	< 0.19	0.26	0.31	0.31	< 0.55	0.27	8.4	5.78	12.39	5.78	12.39
11298	08/29/2002	0.4	< 0.27	< 0.19	< 0.31	< 0.33	< 0.31	1.1	5.1	< 0.3	< 0.25	0.26	< 0.26	< 0.23	< 0.3	< 0.47	4.8	< 0.42	230	0.44	3.33	0.44	3.33

Table 4.5 Total Dioxin Concentrations in Catfish (ng/kg-wet wt)

Station ID	Date	Lipid content (%)	2,3,7,8-TCDD	1,2,3,7,8-PeCDD	1,2,3,4,7,8-HxCDD	1,2,3,6,7,8-HxCDD	1,2,3,7,8,9-HxCDD	1,2,3,4,6,7,8-HpCDD	OCDD	2,3,7,8-TCDF	1,2,3,7,8-PeCDF	2,3,4,7,8-PeCDF	1,2,3,4,7,8-HxCDF	1,2,3,6,7,8-HxCDF	2,3,4,6,7,8-HxCDF	1,2,3,7,8,9-HxCDF	1,2,3,4,6,7,8-HpCDF	1,2,3,4,7,8,9-HpCDF	OCDF	Total TEQ	Lipid- normalized TEQ[a]	Average TEQ[b]	Average Lipid-normalized TEQ[a,b]
11273	08/30/2002	2.1	7.4	< 0.45	< 0.22	< 0.23	< 0.22	1.3	2.8	0.76	< 0.3	0.76	< 0.13	0.27	0.33	< 0.27	< 0.51	< 0.73	< 1.2	8.09	11.56	8.09	11.56
13309	08/30/2002	1.4	2.6	< 0.36	< 0.27	1.1	0.52	< 1.2	< 1.5	< 0.36	< 0.3	< 0.32	< 0.37	< 0.3	< 0.57	< 0.83	< 0.51	< 0.71	2.8	3.07	6.59	3.07	6.59
14560	08/30/2002	1.7	< 2	< 0.4	0.45	< 0.74	0.36	< 1.4	3	< 0.45	< 0.39	< 0.47	< 0.24	< 0.21	< 0.38	< 0.46	< 0.66	< 0.87	2.6	1.43	2.53	1.43	2.53
11200	09/03/2002	1.3	0.6	0.23	< 0.18	0.38	0.21	0.52	1.9	< 0.27	< 0.2	0.24	< 0.14	< 0.15	< 0.16	< 0.15	< 0.35	0.27	0.8	0.95	2.20	0.95	2.20
16622	09/04/2002	0.4	3.5	< 0.54	< 0.29	0.64	< 0.31	1.2	3.5	< 0.43	< 0.2	< 0.47	< 0.37	< 0.31	< 0.47	0.71	< 0.93	< 1.1	1.8	4.00	30.01	4.00	30.01
15979	09/05/2002	1.9	10	0.51	0.31	0.8	0.38	1.6	3	0.9	0.7	0.82	6.2	0.2	0.3	< 0.36	< 0.64	0.22	18	11.63	18.36	11.63	18.36
11300	09/06/2002	4.8	27	1.9	0.68	2.3	0.89	4.3	7.3	8.4	16	17	11	3.1	1.3	0.69	< 5.1	< 1.3	200	40.09	25.05	40.09	25.05
11292	09/11/2002	1	1.1	0.52	0.29	0.69	0.39	1.4	2	0.21	0.29	1.2	< 0.14	0.29	0.32	0.3	< 0.57	0.24	4.1	2.23	6.69	2.23	6.69
15908	09/11/2002	2.7	2.2	< 0.36	0.29	< 0.44	0.31	0.85	1.6	0.37	< 1.7	0.45	< 3	0.19	< 0.23	0.28	< 0.51	< 0.15	5.3	2.89	3.21	4.74	5.26
15908-dup	09/11/2002	2.7	5	0.61	0.39	0.9	0.46	1.4	2.5	0.59	< 0.1	0.65	< 12	0.23	0.48	0.51	< 0.76	0.25	11	6.59	7.32		
16213	09/11/2002	2.4	2	0.48	0.31	0.88	0.37	1.3	2.4	0.66	< 4.7	0.45	< 0.12	0.17	0.33	0.43	< 0.48	0.19	1.4	2.90	3.63	2.90	3.63
Fall 2002																							
13336	10/22/2002	1.2	2.1	< 0.73	< 0.41	< 0.49	< 0.42	< 1.3	3.2	< 0.71	< 0.78	< 0.75	< 0.5	0.46	< 0.56	< 0.56	< 0.78	< 0.71	3.4	2.72	6.80	2.72	6.80
13338	10/22/2002	3.1	6.8	0.6	0.47	0.82	0.47	1.5	3.7	0.8	0.85	1	< 0.19	0.37	0.35	0.72	< 0.78	0.39	4.3	8.05	7.79	5.76	5.57
13338-dup	10/22/2002	3.1	2.3	0.69	0.49	1.2	0.63	1.5	2.9	0.39	0.53	0.73	< 0.12	0.46	0.5	0.6	< 0.82	< 0.25	6.6	3.47	3.36		
11252	10/24/2002	2.3	7.2	0.69	0.53	1.3	0.73	2.1	3.6	0.6	0.9	1.2	< 0.16	< 0.33	0.54	0.9	< 0.66	< 0.31	1.8	8.67	11.31	8.67	11.31
17970	10/24/2002	2.1	4.3	0.57	0.44	0.72	0.49	1.2	3.2	0.66	< 0.38	0.78	< 0.13	0.29	0.44	0.48	< 0.7	< 0.37	1.6	5.34	7.63	4.11	5.87
17970-dup	10/24/2002	2.1	2	0.49	< 0.36	0.63	0.35	1.2	2.9	0.28	< 1.7	0.55	< 0.27	0.36	0.48	0.7	< 0.63	0.57	1.5	2.87	4.11		
16499	10/24/2002	1.9	6.1	0.55	0.41	0.8	0.5	1.3	2.9	0.29	0.48	0.88	< 0.13	0.31	0.4	0.58	< 0.62	< 0.23	1.8	7.17	11.33	7.17	11.33
11261	10/26/2002	2.1	8	< 0.28	0.19	0.8	< 0.21	0.84	1.8	0.37	< 0.2	0.58	< 0.11	< 0.12	< 0.12	< 0.12	< 0.3	< 0.18	< 0.65	8.54	12.19	8.54	12.19
13344	10/27/2002	3.1	10	0.29	< 0.18	0.75	0.25	1.1	2	0.93	< 0.18	< 0.54	< 0.16	< 0.17	< 0.18	< 0.18	< 0.19	< 0.19	0.3	10.52	10.18	10.52	10.18
13342	10/28/2002	1.4	2.4	< 0.17	< 0.19	< 0.22	< 0.19	< 0.41	1.9	0.28	< 0.3	< 0.29	< 0.23	< 0.25	< 0.26	< 0.26	< 0.19	< 0.18	0.38	2.63	5.64	2.63	5.64
17971	10/28/2002	3.1	8	< 0.3	0.2	< 0.73	0.25	1.1	2.5	0.6	< 0.22	< 0.51	< 0.18	< 0.2	< 0.2	< 0.2	< 0.73	< 0.73	< 0.74	8.39	8.12	8.39	8.12
11200-1	11/19/2002	2.2	2.3	< 0.29	< 0.29	< 0.32	0.27	1.2	5.6	0.39	0.63	< 0.2	< 0.24	< 5.5	< 0.31	< 0.44	< 0.31	< 0.29	< 0.41	2.88	3.92	1.83	2.25
11200-2	11/21/2002	4.1	< 0.81	< 0.24	< 0.28	0.84	< 0.28	1.3	5.3	0.36	1.2	< 0.25	< 0.17	< 0.17	< 0.34	< 0.29	< 0.97	< 0.31	1	0.78	0.57		
11193	11/20/2002	0.8	4.3	0.27	< 0.18	0.43	0.37	< 0.82	3.6	< 0.19	0.64	0.41	< 0.18	< 0.17	< 0.25	0.44	< 0.75	< 0.4	1.4	4.84	18.17	4.84	18.17
11292	12/02/2002	1.7	4.2	0.49	< 0.25	0.72	< 0.26	0.86	3.9	< 0.16	< 0.2	0.83	< 0.14	< 0.14	< 0.19	< 0.25	< 6	< 0.33	120	5.01	8.84	5.01	8.84
11280	12/05/2002	1.1	2.4	< 0.22	< 0.28	< 0.31	< 0.29	0.52	4.2	0.18	< 0.15	0.31	< 0.16	< 0.15	< 0.2	< 0.28	< 0.28	< 0.38	1.9	2.72	7.41	2.72	7.41
Spring 2003																							
11258	04/28/2003	0.6	5.2	0.27	< 0.14	0.72	0.26	1.4	4.1	< 0.12	0.46	0.48	< 0.15	< 0.17	< 0.17	0.23	< 0.27	< 0.2	< 0.99	5.76	28.78	5.76	28.78
11273	04/29/2003	3.6	10	0.54	< 0.22	0.97	0.27	1.3	3.2	0.47	< 0.34	1.2	< 0.13	< 2.2	< 0.14	0.2	< 0.16	< 0.19	0.41	11.20	9.34	11.20	9.34
11092	04/30/2003	0.7	0.56	< 0.17	< 0.15	< 0.18	< 0.16	0.39	1.7	< 0.16	< 0.26	< 0.25	< 0.16	< 2.1	< 0.17	< 0.17	< 0.26	< 0.2	1.7	0.83	3.57	0.95	3.57
11092-dup	04/30/2003	0.9	0.79	< 0.25	< 0.21	< 0.26	< 0.23	0.38	2.4	< 0.29	< 0.35	< 0.32	< 0.22	< 0.88	< 0.24	< 0.23	4.3	< 0.21	72	1.07	3.56		
11272	04/30/2003	0.5	0.79	< 0.11	< 0.19	< 0.22	< 0.2	< 0.22	1.8	< 0.14	< 0.26	< 0.24	< 0.17	< 0.58	< 0.19	< 0.18	< 0.26	< 0.28	< 0.33	0.98	5.87	0.98	5.87
11111	05/01/2003	2.1	2.6	0.34	0.15	0.51	0.2	1	4	0.2	0.21	0.28	< 0.11	< 2.3	< 0.12	< 0.12	< 0.19	< 0.15	0.59	3.16	4.51	3.16	4.51
11302	05/01/2003	0.6	0.85	< 0.2	< 0.18	< 0.22	< 0.19	< 0.39	2.1	< 0.17	< 0.16	0.23	< 0.16	< 2.7	< 0.18	< 0.17	< 0.21	< 0.27	0.58	1.22	6.09	1.22	6.09
11274	05/01/2003	1.8	3	0.39	0.14	0.42	< 0.21	1	5.9	0.36	< 0.2	0.43	< 0.1	< 0.11	< 0.11	< 0.18	< 0.29	< 0.27	0.71	3.54	5.90	3.54	5.90
11298	05/01/2003	1.6	3	< 0.32	< 0.17	0.36	0.23	0.82	7.4	0.48	< 0.13	< 0.21	0.13	0.15	0.12	0.15	< 0.39	< 0.16	1.8	3.31	6.20	3.31	6.20
11347	05/02/2003	1.5	2.6	0.43	< 0.13	0.74	0.17	0.63	2.3	< 0.1	< 0.18	0.75	< 0.11	< 8.8	< 0.12	< 0.11	< 0.31	< 0.14	0.73	3.75	7.51	3.75	7.51
11382	05/02/2003	0.7	1	0.22	< 0.17	< 0.23	< 0.18	0.82	8.8	< 0.12	< 0.13	0.36	< 0.14	< 3.2	< 0.15	< 0.15	< 0.28	< 0.14	1.4	1.51	6.47	2.40	6.53
11382-dup	05/02/2003	1.5	2.5	0.44	< 0.17	0.55	< 0.19	1.2	8.7	< 0.2	< 0.18	0.63	< 0.12	< 3.1	< 0.13	< 0.13	< 0.36	< 0.2	1.3	3.30	6.59		
11305	05/03/2003	1.2	5.4	1.1	0.36	1.2	0.51	0.78	1.8	0.41	0.37	0.8	0.2	< 0.26	< 0.22	0.37	< 0.3	0.27	0.64	6.70	16.74	6.70	16.74
13339	05/04/2003	2.5	9.2	0.46	< 0.18	0.65	< 0.22	0.95	1.8	0.29	< 0.24	0.64	< 0.14	< 0.15	< 0.15	< 0.15	< 0.29	< 0.31	0.86	9.90	11.88	9.90	11.88
16618	05/05/2003	2.8	8.9	0.48	< 0.27	0.84	< 0.27	< 0.91	< 2.8	0.23	0.35	0.74	< 0.34	< 0.32	< 0.39	< 0.53	< 1.3	< 2.3	0.57	9.74	10.44	9.74	10.44
11287	05/05/2003	3.1	7.5	0.81	0.34	0.82	0.52	1.3	3.1	0.49	0.46	1.2	< 0.16	< 0.16	0.42	0.43	< 1.2	< 2.1	1.1	8.85	8.56	8.85	8.56
11270	05/06/2003	2.6	9.8	0.37	< 0.2	< 0.59	0.25	1.1	5.1	0.42	< 0.19	0.81	< 0.099	< 0.097	< 0.11	0.25	< 0.18	< 0.26	0.46	10.54	12.16	12.55	25.92
11270-dup	05/06/2003	1.1	13	< 0.17	< 0.16	0.86	0.37	1.4	3.2	0.52	0.73	1	< 0.46	< 14	< 0.5	0.41	< 0.48	< 0.27	< 0.71	14.55	39.68		
11280	05/06/2003	3.8	14	0.46	0.17	0.81	0.3	1.2	3.4	1.6	< 0.25	1	< 0.1	< 0.099	< 0.11	0.33	< 0.19	< 0.28	< 0.34	15.07	11.90	15.07	11.90
13343	05/06/2003	0.7	8.6	< 0.2	< 0.21	0.91	< 0.2	1.3	2.7	0.25	0.61	0.81	< 0.4	< 9.8	< 0.44	< 0.39	< 0.24	< 0.13	< 0.57	9.77	41.89	9.77	41.89
11261	05/10/2003	2.9	10	< 0.41	0.25	0.87	0.31	1.4	3.2	0.46	< 0.18	0.71	< 0.13	< 0.14	< 0.14	< 0.14	< 0.76	< 0.82	0.54	10.68	11.05	10.68	11.05
16496	05/11/2003	1.8	10	0.51	0.21	1.1	0.33	1.5	3.5	0.42	< 0.22	0.77	< 0.13	< 0.15	< 0.15	< 0.14	< 0.25	< 0.51	< 0.61	10.88	18.13	10.86	15.57
16496-dup	05/11/2003	2.5	9.9	0.57	0.25	1.1	0.34	1.4	2.4	0.32	< 0.3	0.74	< 0.12	< 1.1	< 0.13	< 0.13	< 0.15	< 0.13	< 0.34	10.84	13.01		
13342	05/11/2003	2.3	12	0.42	0.16	0.81	0.18	0.86	2.6	0.56	< 0.15	0.77	< 0.1	< 0.11	< 0.11	< 0.11	< 0.46	< 0.11	7.9	12.79	16.68	12.79	16.68
13309	05/12/2003	1.1	1.9	< 0.31	0.22	1.6	0.32	0.64	2.4	< 0.14	< 0.22	0.23	< 0.11	0.18	< 0.12	< 0.11	< 0.17	< 0.15	< 0.36	2.35	6.42	2.35	6.42
15464	05/12/2003	1.4	2	0.54	< 0.24	1.2	< 0.39	1.1	2.3	< 0.28	< 1.3	< 0.34	< 0.41	< 11	< 0.45	< 0.44	< 0.31	< 0.18	< 2	3.17	6.79	3.17	6.79

Table 4.5 Total Dioxin Concentrations in Catfish (ng/kg-wet wt)

Station ID	Date	Lipid content (%)	2,3,7,8-TCDD	1,2,3,7,8-PeCDD	1,2,3,4,7,8-HxCDD	1,2,3,6,7,8-HxCDD	1,2,3,7,8,9-HxCDD	1,2,3,4,6,7,8-HpCDD	OCDD	2,3,7,8-TCDF	1,2,3,7,8-PeCDF	2,3,4,7,8-PeCDF	1,2,3,4,7,8-HxCDF	1,2,3,6,7,8-HxCDF	2,3,4,6,7,8-HxCDF	1,2,3,7,8,9-HxCDF	1,2,3,4,6,7,8-HpCDF	1,2,3,4,7,8,9-HpCDF	OCDF	Total TEQ	Lipid- normalized TEQ[a]	Average TEQ[b]	Average Lipid-normalized TEQ[a,b]
16213	05/12/2003	0.5	1.2	0.6	0.32	0.58	0.34	1	2.3	0.29	< 0.91	0.46	0.21	< 5	0.28	0.31	0.47	0.34	0.94	2.24	13.41	2.24	13.41
14560	05/12/2003	0.7	4.5	4.5	6.8	7.6	7.5	10	17	2	5	4.4	6.5	7.8	7.5	6.4	9	10	17	14.41	61.76	14.41	61.76
11193	05/14/2003	0.4	5.1	0.38	0.21	< 0.51	0.32	0.73	2.7	0.18	0.26	0.55	< 0.12	< 0.11	0.27	< 0.41	< 0.36	< 0.43	1	5.73	43.00	5.73	43.00
11264	05/15/2003	2.7	9.9	0.47	0.21	0.85	0.35	1.2	2.8	0.44	< 0.26	< 0.54	< 0.13	< 1.6	< 0.14	0.22	< 0.24	< 0.52	1.5	10.58	11.75	10.58	11.75
13589	05/16/2003	0.2	0.51	< 0.16	0.1	0.22	0.2	< 0.43	2.3	0.12	0.22	0.23	< 0.11	0.12	< 0.14	0.28	< 0.27	< 0.29	1	0.79	11.89	0.79	11.89
11252	05/16/2003	0.5	1.8	0.28	0.18	0.64	0.22	< 0.74	2.8	0.25	0.3	< 0.32	< 0.12	< 0.11	< 0.18	0.33	< 0.34	< 0.32	0.96	2.22	13.31	2.22	13.31
13355	05/28/2003	2.1	4.4	< 0.35	0.12	0.57	0.18	< 0.62	2.4	0.35	< 0.19	0.31	< 0.11	< 0.11	< 0.12	0.19	< 0.23	< 0.23	3.2	4.81	6.86	4.81	6.86
15908	05/28/2003	2	2.5	0.33	< 0.22	0.75	0.36	1.1	3.1	0.44	< 0.42	0.37	< 0.17	< 0.15	< 0.19	< 0.27	< 0.47	< 0.89	0.6	3.07	4.60	3.07	4.60
13337	05/28/2003	0.5	5.6	0.52	0.27	1	< 0.26	1.2	0.59	0.27	< 0.67	0.38	< 0.13	< 1.1	< 0.029	< 0.028	< 0.046	< 0.034	0.62	6.30	37.79	6.30	37.79
13341	05/28/2003	0.4	2	< 0.35	< 0.12	0.39	< 0.14	0.62	1.5	0.2	< 0.29	< 0.27	< 0.13	< 0.15	< 0.15	< 0.14	< 0.15	< 0.16	0.47	2.26	16.97	2.26	16.97
13340	05/28/2003	0.8	3.9	< 0.51	< 0.14	0.68	< 0.19	0.85	2.2	< 0.23	< 0.32	< 0.3	< 0.18	< 0.2	< 0.2	< 0.19	< 0.17	< 0.18	0.49	4.25	15.92	4.25	15.92
15979	05/29/2003	1.2	11	< 0.41	0.23	1	0.31	1.4	3	0.68	< 0.33	< 0.79	< 0.17	< 0.67	< 0.18	< 0.18	< 0.3	< 0.14	< 0.54	11.59	28.98	11.59	28.98
11292	05/30/2003	1	2.7	< 0.45	< 0.13	< 0.48	0.18	< 0.41	1.8	< 0.23	< 0.4	1.4	< 0.11	< 0.11	< 0.13	< 0.22	< 0.29	< 0.26	0.56	3.61	10.83	3.61	10.83
16622	05/30/2003	0.1	0.62	< 0.3	< 0.12	0.21	< 0.13	0.23	1.6	< 0.12	< 0.31	< 0.29	< 0.14	< 0.15	< 0.15	< 0.15	0.28	< 0.13	0.82	0.84	25.33	0.84	25.33
Spring 2004																							
14560	03/09/2004	1.20	4.2	0.33	0.23	0.96	0.38	1.4	5.3	0.19	< 0.1	0.45	< 0.098	< 0.11	< 0.1	0.13	0.2	0.16	0.68	4.80	11.99	4.80	11.99
13342	03/09/2004	2.10	4.6	0.24	< 0.12	0.56	0.27	1.2	7.1	1.1	0.21	0.46	0.22	< 0.29	0.15	< 0.11	< 0.59	< 0.16	6.4	5.22	7.45	5.22	7.45
13340	03/09/2004	1.20	1.1	0.19	0.12	0.43	0.18	1.1	5.7	0.16	< 0.1	0.19	< 0.099	< 0.11	< 0.11	< 0.11	0.18	< 0.12	0.78	1.40	3.51	1.40	3.51
11252	03/09/2004	0.80	1.9	0.16	< 0.095	0.37	0.15	1.1	6.9	0.15	< 0.11	0.2	< 0.093	< 0.1	< 0.1	< 0.1	0.23	< 0.11	0.84	2.17	8.15	2.17	8.15
13338	03/18/2004	1.60	3.9	0.38	0.22	0.72	0.29	1.4	5.1	0.19	0.16	0.45	< 0.099	< 0.39	< 0.089	< 0.082	< 0.24	< 0.18	0.52	4.50	8.43	4.50	8.43
16499	03/18/2004	1.00	3.9	0.24	0.12	0.42	0.14	0.82	4.9	0.2	0.14	0.32	< 0.12	< 0.44	0.094	< 0.086	< 0.24	< 0.18	0.5	4.32	12.95	4.32	12.95
16618	03/18/2004	0.80	3	0.22	< 0.28	0.57	< 0.3	1.1	7.2	0.2	0.13	0.29	< 0.085	< 0.094	< 0.095	< 0.092	< 0.41	< 0.41	0.64	3.39	12.70	3.39	12.70
13344	03/18/2004	3.60	11	0.51	0.37	1.3	0.47	2.8	10	2.6	0.21	0.8	< 0.086	< 0.095	0.11	< 0.093	< 0.41	< 0.44	0.66	12.16	10.14	12.16	10.14
11193	03/23/2004	2.40	4.6	0.29	< 0.14	0.4	0.23	1.5	7	0.29	0.13	0.37	0.12	0.1	0.11	0.088	< 0.35	< 0.18	0.91	5.08	6.35	5.08	6.35
11197	03/24/2004	0.70	1.6	0.17	< 0.099	0.29	< 0.14	0.88	5.7	0.27	< 0.088	< 0.22	0.067	< 0.29	0.083	< 0.064	< 0.23	< 0.12	2.8	1.84	7.90	2.18	9.34
11197-dup	03/24/2004	0.70	2.1	0.21	0.17	0.57	0.2	1.3	6.3	0.42	0.11	0.27	0.092	< 0.2	0.1	< 0.079	< 0.25	< 0.16	0.89	2.51	10.78		
11261	03/24/2004	1.20	4.2	0.25	0.14	0.4	0.14	1.3	6.8	0.21	< 0.11	< 0.33	< 0.074	< 0.43	< 0.074	< 0.072	< 0.71	< 0.13	10	4.53	11.33	4.53	11.33
15979	03/31/2004	2.20	13	0.46	0.2	0.97	0.29	1.5	5.8	0.48	< 0.11	0.71	< 0.092	< 0.11	< 0.1	< 0.099	< 0.26	< 0.14	0.61	13.80	18.82	13.80	18.82
11264	04/02/2004	1.80	7.9	0.38	< 0.18	0.57	< 0.2	1.4	8.5	0.41	< 0.21	0.59	< 0.17	< 0.18	< 0.19	< 0.18	0.31	< 0.29	0.79	8.54	14.24	7.69	12.82
11264-dup	04/02/2004	1.80	6.4	< 0.33	< 0.19	0.55	< 0.21	1.2	6.2	0.25	< 0.19	0.45	< 0.16	< 0.17	< 0.17	< 0.17	< 0.28	< 0.3	0.73	6.85	11.41		
11280	04/02/2004	1.90	12	0.45	< 0.19	0.76	0.25	1.8	7.8	0.44	< 0.23	0.8	< 0.15	< 0.17	< 0.17	< 0.16	0.42	< 0.29	3.3	12.82	20.24	12.82	20.24
11265	04/02/2004	1.30	6	0.32	< 0.17	0.55	0.25	1.4	5.9	< 0.25	< 0.23	0.53	< 0.19	< 0.21	< 0.21	< 0.2	< 0.26	< 0.22	0.68	6.57	15.17	6.57	15.17
11287	04/02/2004	1.40	1.9	< 0.35	< 0.36	< 0.42	< 0.37	1.3	6.7	< 0.18	< 0.3	0.4	< 0.32	< 0.33	< 0.35	< 0.33	< 0.31	< 0.33	< 0.93	2.33	4.99	2.33	4.99
11292	04/03/2004	1.30	2.1	0.37	0.28	0.48	0.27	0.96	5.3	0.17	< 0.17	< 0.49	0.23	< 0.15	< 0.21	< 0.14	< 0.29	< 0.15	0.72	2.58	5.95	2.58	5.95
11302-A	04/15/2004	0.80	2.3	< 0.36	< 0.3	0.41	< 0.3	1.2	6.5	0.27	< 0.29	0.43	< 0.3	< 0.31	< 0.33	< 0.31	0.27	< 0.26	0.88	2.77	10.40	12.85	25.42
11302-B	04/15/2004	1.70	21	1.5	0.43	1.6	0.53	1.7	7.3	0.5	0.21	1.5	0.34	0.29	0.33	< 0.1	< 0.55	< 0.38	1	22.92	40.44		
11272-A	04/15/2004	0.40	3	< 0.51	< 0.58	< 0.62	< 0.53	2.3	8.4	0.3	< 0.59	< 0.57	< 0.42	0.53	< 0.32	< 0.45	< 0.89	< 0.86	2.6	3.51	26.35	2.13	14.70
11272-A-dup	04/15/2004	0.40	1.2	0.26	< 0.16	0.31	0.19	1.2	5.8	0.16	0.2	0.33	0.19	0.19	0.16	0.11	0.41	0.16	2.6	1.64	12.33		
11272-B	04/15/2004	0.50	1.3	0.21	< 0.14	0.29	0.18	0.79	5.1	0.12	0.19	0.27	0.17	0.2	0.18	< 0.15	0.28	0.14	0.66	1.68	10.07		
11305	04/15/2004	1.10	2.9	0.23	< 0.092	0.23	< 0.099	0.59	2.5	< 0.1	< 0.11	0.3	< 0.097	< 0.11	< 0.11	< 0.11	< 0.17	< 0.1	< 0.34	3.23	8.80	3.23	8.80
11298	04/20/2004	2.00	12	0.56	0.17	0.77	0.26	1.2	4.2	0.92	< 0.11	0.7	0.12	< 0.11	< 0.11	< 0.11	< 0.22	< 0.12	0.41	12.87	19.31	12.87	19.31
11382	04/20/2004	0.80	< 0.79	< 0.57	< 0.73	< 0.86	< 0.74	< 1.1	7.1	< 0.34	< 0.52	< 0.5	< 0.65	< 0.68	< 0.72	< 0.69	0.78	< 0.78	1.3	0.95	3.55	0.95	3.55
11300	04/21/2004	3.90	18	1.1	0.38	1.3	< 0.45	2.2	7.6	0.59	0.34	1.4	0.25	0.55	0.34	< 0.17	< 0.58	< 0.28	1.2	19.64	15.11	19.64	15.11
11274	04/21/2004	0.60	6.7	0.58	< 0.36	0.62	< 0.36	1.4	6.2	0.46	< 0.42	0.9	< 0.2	0.25	< 0.23	< 0.22	0.59	< 0.44	3.3	7.65	38.26	7.65	38.26
11273	04/21/2004	1.60	2.4	0.29	0.26	< 0.28	< 0.24	< 0.98	5.8	< 0.15	< 0.23	0.36	< 0.2	0.22	< 0.22	< 0.21	< 0.25	< 0.23	1	2.84	5.33	2.84	5.33
11347	04/22/2004	0.60	< 0.11	< 0.11	< 0.097	< 0.11	< 0.1	0.46	2.5	< 0.11	< 0.099	0.13	< 0.097	< 0.11	< 0.11	< 0.11	< 0.13	< 0.11	0.32	0.19	0.96	0.19	0.96
11111	04/27/2004	0.50	< 0.36	< 0.61	< 0.65	< 0.77	< 0.66	< 1	6.7	< 0.43	< 0.25	< 0.24	< 0.45	< 0.47	< 0.5	< 0.47	< 0.47	< 0.51	1.3	0.62	3.71	0.62	3.71
11092	04/27/2004	0.60	0.44	< 0.2	< 0.25	< 0.3	< 0.26	0.99	5.5	< 0.19	< 0.3	< 0.29	< 0.24	< 0.25	< 0.27	< 0.26	< 0.24	< 0.26	< 0.82	0.67	3.36	0.67	3.36
Fall 2004																							
14560	10/03/2004	1.10	0.96	< 0.17	< 0.22	0.32	< 0.24	0.51	0.99	0.3	< 0.2	< 0.2	< 0.19	< 0.18	< 0.21	< 0.26	< 0.19	< 0.24	< 0.26	1.18	3.23	1.18	3.23
11252	10/03/2004	2.60	26	0.58	< 0.28	1.9	0.45	2.2	3.7	0.95	< 0.29	1.1	< 0.21	< 0.2	< 0.24	< 0.34	< 0.27	< 0.34	0.73	27.24	31.43	27.24	31.43
16618	10/03/2004	0.90	3.2	< 0.21	< 0.27	< 0.29	< 0.28	0.55	1.4	0.35	< 0.21	< 0.22	< 0.24	< 0.22	< 0.26	< 0.42	< 0.24	< 0.35	< 0.31	3.45	11.49	3.45	11.49
13338	10/04/2004	0.90	1.5	< 0.28	< 0.36	< 0.4	< 0.38	0.6	0.99	< 0.4	< 0.36	< 0.37	< 0.2	< 0.18	< 0.22	< 0.3	< 0.29	< 0.34	< 0.39	1.79	5.98	1.79	5.98
13340	10/05/2004	0.60	0.63	< 0.3	< 0.34	< 0.38	< 0.36	< 0.47	< 1	< 0.34	< 0.33	< 0.35	< 0.28	< 0.26	< 0.31	< 0.41	< 0.28	< 0.33	< 0.69	0.93	4.67	0.93	4.67
11292	10/20/2004	1.90	0.64	0.31	0.25	< 0.44	< 0.24	0.65	1.1	0.26	< 0.16	0.6	0.27	0.24	0.21	0.17	< 0.33	< 0.16	0.42	1.27	2.01	1.27	2.01

Table 4.5 Total Dioxin Concentrations in Catfish (ng/kg-wet wt)

Station ID	Date	Lipid content (%)	2,3,7,8-TCDD	1,2,3,7,8-PeCDD	1,2,3,4,7,8-HxCDD	1,2,3,6,7,8-HxCDD	1,2,3,7,8,9-HxCDD	1,2,3,4,6,7,8-HpCDD	OCDD	2,3,7,8-TCDF	1,2,3,7,8-PeCDF	2,3,4,7,8-PeCDF	1,2,3,4,7,8-HxCDF	1,2,3,6,7,8-HxCDF	2,3,4,6,7,8-HxCDF	1,2,3,7,8,9-HxCDF	1,2,3,4,6,7,8-HpCDF	1,2,3,4,7,8,9-HpCDF	OCDF	Total TEQ	Lipid- normalized TEQ^{a}	Average TEQ^{b}	Average Lipid-normalized TEQ^{a,b}
11280	10/21/2004	2.80	18	0.46	0.33	0.99	0.38	1.5	4.1	1.5	0.34	0.99	0.41	< 0.22	0.24	< 0.21	< 0.29	0.19	0.45	19.15	20.52	19.15	20.52
11265	10/26/2004	2.60	8.8	0.33	0.24	0.55	0.22	0.67	1.5	0.59	< 0.16	0.48	< 0.25	0.18	0.22	< 0.12	< 0.22	< 0.12	0.35	9.43	10.88	9.92	11.68
11265-dup	10/26/2004	2.50	9.7	0.41	< 0.27	0.59	0.32	0.87	1.7	0.5	0.26	0.54	< 0.25	< 0.23	0.28	< 0.22	< 0.33	0.28	0.76	10.41	12.49		
15979	10/26/2004	1.70	7	0.27	0.25	0.48	< 0.21	0.64	1.3	0.65	< 0.19	0.47	0.18	0.19	0.18	< 0.11	< 0.23	< 0.16	< 0.46	7.58	13.38	7.58	13.38
11264	10/26/2004	2.80	13	0.36	< 0.24	0.65	< 0.27	0.88	1.7	0.94	0.19	0.66	0.23	0.18	< 0.21	0.11	< 0.29	0.16	2.2	13.77	14.75	13.77	14.75
11261	10/27/2004	3.70	14	< 0.51	< 0.31	1.1	0.42	1.3	2.5	0.74	< 0.13	0.67	< 0.37	0.22	0.23	< 0.11	< 0.22	< 0.15	< 0.51	14.78	11.98	14.78	11.98
11287	10/28/2004	1.80	4.4	0.42	< 0.3	0.8	0.34	1.2	1.9	0.45	0.21	0.57	0.28	< 0.22	< 0.29	0.2	< 0.37	0.22	2.2	5.15	8.59	5.15	8.59
11193	10/28/2004	3.50	14	0.5	0.41	0.86	0.38	1.3	3.6	1	< 0.11	0.75	< 0.3	0.19	< 0.2	< 0.17	< 0.28	< 0.19	0.61	14.95	12.81	14.34	14.04
11193-dup	10/28/2004	2.70	13	0.35	0.34	< 0.67	0.29	1	2.4	0.77	0.19	0.66	< 0.24	0.22	< 0.18	0.13	< 0.25	< 0.16	0.5	13.74	15.27		
11197	10/28/2004	4.00	14	0.5	0.45	1.3	0.43	1.7	3.8	0.76	0.19	0.82	< 0.36	0.18	0.22	< 0.12	< 0.31	< 0.17	< 0.44	15.03	11.27	15.03	11.27
13344	10/28/2004	1.20	5	0.15	< 0.13	0.43	< 0.17	0.77	1.4	0.68	< 0.12	0.31	< 0.085	< 0.079	< 0.094	< 0.12	< 0.11	< 0.14	0.32	5.38	13.44	5.38	13.44
13342	10/29/2004	2.10	13	0.47	0.29	1	0.37	1.3	2.6	0.3	< 0.12	0.61	< 0.24	< 0.18	0.21	0.12	< 0.25	< 0.11	0.64	13.79	19.70	13.79	19.70
16499	10/29/2004	0.60	4.4	0.28	< 0.26	0.5	0.22	0.58	1.3	< 0.13	0.11	0.38	0.2	0.2	0.21	< 0.11	< 0.25	< 0.15	0.42	4.89	24.47	4.89	24.47

[a] Catfish tissue normalized to 3% lipids

[b] Average of duplicate samples, otherwise concentration of a single sample

dup = duplicate

Values reported to the Detection Limit

Non-detects assumed as 1/2 MDL for TEQ calculations

🟦	Value between the detection and the reporting limits
🟨	Value is an estimate due to blank contamination (concentration < 20 times lowest concentration)
🟥	Value is an estimate due to QC issues (interference, signal to noise ratio)
⬜	Tributary
🟩	Exceeds the Texas Health Standard (0.47 ng/kg)

Table 4.6 Total Dioxin Concentrations in Crab (ng/kg-wet wt)

Station ID	Date	Lipid content (%)	2,3,7,8-TCDD	1,2,3,7,8-PeCDD	1,2,3,4,7,8-HxCDD	1,2,3,6,7,8-HxCDD	1,2,3,7,8,9-HxCDD	1,2,3,4,6,7,8-HpCDD	OCDD	2,3,7,8-TCDF	1,2,3,7,8-PeCDF	2,3,4,7,8-PeCDF	1,2,3,4,7,8-HxCDF	1,2,3,6,7,8-HxCDF	2,3,4,6,7,8-HxCDF	1,2,3,7,8,9-HxCDF	1,2,3,4,6,7,8-HpCDF	1,2,3,4,7,8,9-HpCDF	OCDF	Total TEQ	Lipid- normalized TEQ^{a}	Average TEQ^{b}	Average Lipid-normalized TEQ^{a,b}
Summer 2002																							
11272	07/26/2002	1.2	1.6	< 0.19	< 0.32	< 0.28	< 0.3	0.69	2.7	2	< 0.23	< 0.19	< 0.25	< 0.19	< 0.23	< 0.34	0.41	< 0.43	0.69	2.00	3.33	2.00	3.33
11298	07/29/2002	0.5	4.7	< 0.26	< 0.23	< 0.23	< 0.23	< 0.69	2.7	6.8	0.43	0.54	< 0.24	0.31	< 0.24	< 0.34	< 0.37	< 0.52	0.7	5.84	23.37	5.84	23.37
11274	07/30/2002	0.6	2.7	< 0.35	< 0.3	< 0.26	< 0.28	0.76	3.6	5	< 0.28	0.49	0.28	< 0.29	< 0.22	< 0.32	< 0.35	< 0.3	0.75	3.65	12.17	3.65	12.17
11111	07/31/2002	0.8	0.7	< 0.23	< 0.2	< 0.23	< 0.21	< 0.57	3.2	1.5	< 0.24	0.27	< 0.21	< 0.19	< 0.26	< 0.37	< 0.46	< 0.27	2.1	1.13	2.83	1.13	2.83
11258	08/01/2002	0.7	6.3	< 0.32	< 0.16	< 0.31	0.33	1.3	1.7	14	0.73	0.76	1.9	< 0.95	< 0.39	< 0.27	3.3	< 0.34	7.9	8.52	24.35	8.52	24.35
11092	08/02/2002	1.5	< 0.74	< 0.28	< 0.2	0.41	0.26	1.1	4.2	1.9	< 0.25	0.29	< 0.19	< 0.17	< 0.24	< 0.27	< 0.66	< 0.69	2.3	0.90	1.20	0.90	1.20
13340	08/07/2002	1.1	0.59	< 0.18	< 0.19	< 0.18	< 0.2	0.59	1.8	1.5	< 0.19	0.29	< 0.15	< 0.14	< 0.17	< 0.19	< 0.27	< 0.22	1.1	1.00	1.81	1.00	1.81
11193	08/09/2002	0.9	3.9	< 0.32	0.21	0.24	< 0.12	0.71	1.6	11	0.49	0.56	< 0.18	< 0.58	0.24	0.21	< 0.26	< 0.29	1.4	5.52	12.26	5.52	12.26
11347	08/12/2002	0.6	< 1.5	1.5	1.4	1.8	1.7	< 4.4	20	< 1.1	< 1.2	1.7	2	1.6	1.6	1.9	< 2.9	< 1.5	37	3.64	12.12	3.64	12.12
11382	08/13/2002	0.4	< 0.44	< 0.31	< 0.48	< 0.53	< 0.51	2.3	7.8	< 0.69	< 0.33	< 0.33	< 0.45	< 0.42	< 0.52	< 1.2	< 1.3	< 1.4	2.9	0.63	3.14	0.63	3.14
13337	08/14/2002	0.6	1.1	< 0.68	< 0.14	< 0.15	< 0.14	0.63	2.1	2.1	< 0.11	< 0.13	< 0.21	< 0.22	< 0.18	< 0.24	0.4	< 0.2	1.3	1.58	5.26	1.58	5.26
11305	08/14/2002	0.2	0.57	0.31	< 0.25	< 0.4	< 0.26	1.2	2.4	2.6	< 0.27	0.51	< 0.28	0.28	< 0.29	< 0.44	1.1	< 0.3	13	1.37	13.71	1.37	13.71
13341	08/16/2002	0.8	< 0.58	< 0.68	< 0.28	< 0.3	< 0.29	0.96	1.7	1.2	< 0.28	< 0.27	< 0.35	< 0.3	< 0.34	< 0.45	< 0.57	< 0.69	0.77	0.77	1.93	0.77	1.93
13363	08/17/2002	1.1	0.47	< 0.26	< 0.18	< 0.2	< 0.19	< 0.48	1.9	0.69	< 0.24	0.2	< 0.18	< 0.15	< 0.2	< 0.32	< 0.29	< 0.28	1.5	0.78	1.42	0.78	1.42
15464	08/17/2002	0.1	< 0.21	< 0.21	< 0.19	< 0.21	< 0.2	0.53	1	0.4	< 0.14	< 0.12	< 0.21	< 0.17	< 0.19	< 0.27	< 0.57	< 0.26	2.1	0.30	6.06	0.30	6.06
13589	08/17/2002	0.3	0.65	< 0.25	< 0.27	< 0.29	< 0.28	< 0.47	1.6	0.7	< 0.19	< 0.091	< 0.2	< 0.16	< 0.18	< 0.24	< 0.28	< 0.29	0.82	0.89	5.94	1.06	7.05
13589-dup	08/17/2002	0.3	0.91	< 0.23	< 0.2	< 0.22	< 0.21	0.69	1.5	1.2	< 0.21	< 0.21	< 0.23	< 0.18	< 0.2	< 0.34	< 0.49	< 0.34	0.91	1.22	8.16		
13355	08/18/2002	0.3	1.5	< 0.24	< 0.22	< 0.27	< 0.24	0.48	0.35	2.6	< 0.22	< 0.18	< 0.21	< 0.18	< 0.2	< 0.28	< 0.3	< 0.33	< 1.3	1.95	13.00	2.12	14.11
13355-dup	08/18/2002	0.3	1.7	< 0.3	< 0.16	0.25	< 0.17	0.48	1.7	3.1	< 0.12	0.25	< 0.13	< 0.11	< 0.12	< 0.21	0.34	< 0.41	1.4	2.28	15.22		
17970	08/18/2002	1.1	3.2	< 0.33	< 0.21	< 0.29	< 0.22	0.82	2.3	6.4	< 0.23	< 0.23	< 0.24	< 0.22	< 0.29	< 0.43	0.56	< 0.31	1.7	4.08	7.42	4.08	7.42
11261	08/20/2002	0.8	3.6	< 0.3	< 0.24	< 0.27	< 0.26	0.62	2.3	7	< 0.27	0.37	< 0.26	< 0.22	< 0.26	< 0.56	< 0.39	< 0.3	1.4	4.67	11.68	4.67	11.68
11264	08/20/2002	0.9	4.2	0.26	< 0.25	< 0.27	< 0.26	0.74	1.9	6.9	0.35	0.38	< 0.18		< 0.19	< 0.4	< 0.63	< 0.81	1.6	5.31	11.79	5.31	11.79
16618	08/20/2002	0.6	12	< 0.57	< 0.34	< 0.36	< 0.35	3	19	30	0.35	1.1	< 0.33	<	< 0.29	< 0.25	< 0.32	< 0.37	3.6	15.81	52.73	15.81	52.73
13338	08/23/2002	0.6	0.75	< 0.65	< 0.31	< 0.33	< 0.32	< 0.7	2.3	1	< 0.29	< 0.28	< 0.37	< 0.32	< 0.38	< 0.77	< 0.97	< 1.3	0.6	1.23	4.10	1.23	4.10
13344	08/23/2002	0.8	4	< 0.59	< 0.44	< 0.46	< 0.45	< 1.3	6.8	9.9	< 0.38	0.88	0.51	< 0.37	0.63	< 0.72	< 0.8	< 1.1	5.6	5.82	14.56	4.90	12.26
13344-dup	08/23/2002	0.8	2.6	0.4	0.43	0.55	< 0.47	1.2	4	5.1	0.37	0.61	0.5	0.41	0.51	0.88	0.89	0.98	3.5	3.99	9.96		
16499	08/23/2002	0.4	4	< 1.1	< 1.2	< 1.3	< 1.3	3.3	15	8.7	< 0.39	< 0.39	< 0.77	< 0.67	< 0.81	< 1.3	< 2.4	< 2.9	2.2	5.62	28.10	5.62	28.10
13342	08/24/2002	1	3.6	< 0.6	< 0.35	< 0.37	< 0.36	< 0.74	3.4	9.9	< 0.33	< 0.3	< 0.37	< 0.34	< 0.36	< 0.46	< 0.46	< 0.51	1	4.95	9.91	4.95	9.91
16496	08/24/2002	0.9	3.5	< 0.78	< 0.38	< 0.37	< 0.37	1.1	3.3	6.4	< 0.45	0.58	< 0.43	< 0.39	< 0.43	0.65	< 0.63	< 0.69	1.6	4.82	10.71	4.82	10.71
17971	08/24/2002	1	3.7	< 0.62	< 0.38	< 0.44	< 0.41	< 0.58	2.1	11	< 0.34	0.36	< 0.45	< 0.4	< 0.43	< 0.58	< 0.4	< 0.46	0.65	5.30	10.60	5.30	10.60
11287	08/25/2002	0.4	2.2	< 0.52	< 0.25	< 0.27	0.26	1.5	5.3	2.8	0.41	0.54	< 0.51	0.45	< 0.53	< 1.3	0.79	< 0.67	3.4	3.11	15.57	6.51	21.93
11287-dup	08/25/2002	0.7	6.9	0.78	0.38	0.65	0.53	2	5.2	15	0.96	1.3	< 1	0.86	0.52	0.67	1.1	< 0.7	3.2	9.90	28.28		
13339	08/25/2002	1.1	4.8	< 0.42	< 0.25	< 0.27	< 0.26	1.1	2.1	12	< 0.29	< 0.27	< 0.26	< 0.22	< 0.25	< 0.37	0.46	< 0.28	0.52	6.27	9.24	5.68	10.33
13339-dup	08/25/2002	1.1	4	< 0.44	< 0.27	< 0.29	< 0.28	0.53	1.3	8	< 0.33	< 0.31	< 0.27	< 0.21	< 0.23	< 0.21	0.42	< 0.23	0.76	5.08	11.41		
11302	08/26/2002	0.9	1.1	< 0.73	< 0.24	< 0.28	< 0.26	1.1	2.5	3	< 0.22	< 0.68	< 0.33	< 0.29	< 0.32	< 0.42	< 0.65	< 0.75	1.2	1.87	4.14	1.87	4.14
11270	08/28/2002	0.9	4.3	0.42	0.29	0.4	0.31	0.82	2.2	7	0.5	0.59	< 0.57	0.29	0.3	0.29	< 0.96	0.29	24	5.75	12.77	5.75	12.77
11273	08/28/2002	0.6	5.1	< 0.36	< 0.24	0.37	0.37	1.3	4.8	8.7	0.88	0.7	0.58	0.32	0.45	0.55	< 2.5	< 0.78	41	6.73	22.43	8.49	28.30
11273-dup	08/28/2002	0.6	7.5	< 0.51	< 0.3	0.57	0.51	1.3	4.9	15	1.4	1.3	1.6	0.76	< 0.51	< 0.33	12	1.5	260	10.25	34.16		
11280	08/28/2002	0.5	4.2	< 0.25	< 0.28	< 0.29	< 0.28	0.78	3.4	7.6	0.49	0.68	< 0.21	< 0.2	< 0.23	< 0.39	< 0.34	< 0.39	2.6	5.48	21.92	4.74	17.61
11280-dup	08/28/2002	0.6	3.1	< 0.37	< 0.34	< 0.4	< 0.37	< 0.83	2.7	5.8	< 0.37	< 0.34	< 0.58	< 0.14	< 0.16	0.24	0.48	< 0.34	1.1	3.99	13.30		
13336	08/28/2002	0.3	0.68	< 0.41	< 0.35	< 0.39	< 0.37	< 1	6.4	1.4	< 0.16	< 0.15	< 0.27	< 0.23	< 0.26	< 0.42	< 1.2	< 1.3	0.77	1.08	7.19	1.08	7.19
11252	08/29/2002	0.6	0.9	< 0.42	< 0.56	< 0.56	< 0.55	0.81	3	1.8	< 0.19	< 0.18	< 0.34	< 0.31	< 0.37	< 0.79	< 0.93	< 0.9	19	1.41	4.70	1.66	5.53
11252-dup	08/29/2002	0.6	1.4	< 0.27	< 0.19	< 0.23	< 0.21	0.89	3.2	2.1	0.18	0.25	< 0.25	< 0.22	< 0.25	< 0.62	< 0.56	< 0.64	1.9	1.91	6.37		
14560	08/30/2002	0.7	3.1	< 0.22	< 0.15	0.23	< 0.16	< 0.65	1.9	7.1	< 0.17	< 0.41	< 0.15	< 0.13	0.21	0.2	0.6	< 0.4	9.8	4.07	11.62	4.07	11.62
11200	09/02/2002	0.7	0.71	< 0.28	< 0.27	< 0.3	< 0.28	0.81	3.8	< 0.41	< 0.33	< 0.33	< 0.22	< 0.19	< 0.26	< 0.38	< 0.42	< 0.54	0.82	0.99	2.82	0.99	2.82
16622	09/02/2002	0.7	0.87	0.16	0.18	0.3	< 0.21	0.91	3.9	1.6	< 0.13	0.23	< 0.12	0.15	< 0.13	< 0.13	< 0.37	0.28	2.1	1.32	3.77	1.32	3.77

Table 4.6 Total Dioxin Concentrations in Crab (ng/kg-wet wt)

Station ID	Date	Lipid content (%)	2,3,7,8-TCDD	1,2,3,7,8-PeCDD	1,2,3,4,7,8-HxCDD	1,2,3,6,7,8-HxCDD	1,2,3,7,8,9-HxCDD	1,2,3,4,6,7,8-HpCDD	OCDD	2,3,7,8-TCDF	1,2,3,7,8-PeCDF	2,3,4,7,8-PeCDF	1,2,3,4,7,8-HxCDF	1,2,3,6,7,8-HxCDF	2,3,4,6,7,8-HxCDF	1,2,3,7,8,9-HxCDF	1,2,3,4,6,7,8-HpCDF	1,2,3,4,7,8,9-HpCDF	OCDF	Total TEQ	Lipid- normalized TEQ[a]	Average TEQ[b]	Average Lipid-normalized TEQ[a,b]
13343	09/04/2002	0.7	2.6	0.17	< 0.11	0.22	< 0.11	< 0.48	2.4	7	0.23	0.4	< 0.12	< 0.13	< 0.13	< 0.13	< 0.24	< 0.11	0.5	3.66	10.44	3.66	10.44
15979	09/05/2002	0.6	3.1	0.3	0.3	0.45	0.31	1	2.6	4.9	0.64	0.56	< 0.14	0.29	0.27	0.26	< 0.6	0.26	1.6	4.25	14.16	4.25	14.16
11300	09/09/2002	0.2	3	0.37	0.25	0.38	< 0.27	0.88	2	5.1	0.82	0.68	< 1.1	< 0.27	0.27	0.27	< 0.54	0.23	5.1	4.28	42.75	4.28	42.75
16213	09/10/2002	0.5	< 0.27	0.27	0.22	0.28	0.29	< 0.67	1.9	0.54	0.28	0.28	0.37	0.23	0.24	0.24	< 0.41	0.25	2.3	0.67	2.66	0.67	2.66
11292	09/11/2002	0.4	< 0.38	0.33	0.23	< 0.48	0.26	1.3	4.8	0.96	0.42	0.48	< 1.5	0.27	0.22	< 0.21	< 0.54	0.26	4.2	0.92	4.60	0.92	4.60
13309	09/11/2002	0.5	1.2	< 0.24	< 0.24	0.39	0.35	0.82	2	1.7	0.4	0.4	< 0.49	0.27	0.27	0.3	0.48	0.3	0.98	1.84	7.38	1.84	7.38
15908	09/11/2002	0.5	0.57	0.25	< 0.22	0.27	0.26	0.6	< 1.4	0.88	0.25	< 0.25	0.36	< 0.21	0.24	0.23	< 0.38	0.19	1.4	1.02	4.06	1.02	4.06
Fall 2002																							
11193	10/21/2002	0.7	< 1.6	< 0.33	< 0.25	< 0.28	< 0.26	1.4	15	3.3	< 0.23	< 0.23	< 0.18	< 0.17	< 0.23	< 0.34	0.5	< 0.28	2	1.36	3.89	1.36	3.89
13338	10/22/2002	0.8	3	< 0.18	< 0.21	< 0.24	< 0.21	< 0.37	1.7	7	< 0.19	0.32	0.25	< 0.21	< 0.21	< 0.21	< 0.2	< 0.11	0.45	4.00	10.00	4.00	10.00
13336	10/22/2002	1.1	2.1	< 0.2	< 0.22	< 0.26	< 0.22	0.35	1	5.2	< 0.21	< 0.2	< 0.18	< 0.19	< 0.2	< 0.2	< 0.21	< 0.12	2.2	2.80	5.09	2.80	5.09
13340	10/22/2002	0.6	1.4	< 0.49	< 0.25	< 0.33	< 0.28	0.96	4.2	2.2	0.29	0.26	< 0.13	< 0.35	< 0.16	< 0.22	< 0.44	< 0.26	2.2	1.97	6.58	1.97	6.58
16499	10/24/2002	0.8	2.5	< 0.24	< 0.27	< 0.29	< 0.28	0.71	4.5	3.8	< 0.19	< 0.23	< 0.26	< 0.23	< 0.31	< 0.47	< 0.41	< 0.37	1.6	3.11	11.10	3.11	11.10
17970	10/24/2002	0.6	1.6	< 0.21	< 0.14	0.23	< 0.14	0.62	2.2	3.1	< 0.14	< 0.23	< 0.18	< 0.18	< 0.18	< 0.18	< 0.27	< 0.25	< 0.23	2.10	6.99	2.10	6.99
11261	10/25/2002	0.6	3.5	< 0.19	< 0.27	< 0.27	< 0.27	< 0.61	5.1	5.3	0.47	0.35	< 0.24	< 0.23	< 0.29	< 0.45	< 1.2	< 0.27	26	4.38	14.59	4.38	14.59
13344	10/27/2002	0.6	3.9	< 0.25	< 0.19	0.36	< 0.21	1.1	10	7.8	0.62	< 0.27	0.44	0.3	< 0.26	< 0.42	14	1.4	410	5.01	16.68	4.55	15.17
13344-dup	11/14/2002	0.6	3.2	< 0.39	< 0.21	0.3	< 0.22	1.2	7.6	5.3	< 0.23	0.32	< 0.21	< 0.19	< 0.25	< 0.38	< 0.49	< 0.32	3	4.10	13.65		
13342	10/28/2002	0.6	3.8	< 0.21	< 0.21	< 0.24	< 0.21	< 0.34	< 1.3	9	< 0.17	0.35	< 0.19	< 0.2	< 0.21	< 0.21	< 0.21	< 0.24	0.25	5.01	16.68	5.01	16.68
17971	10/28/2002	0.4	4.7	< 0.2	< 0.15	< 0.18	< 0.15	< 0.34	1.6	11	0.29	0.42	< 0.42	< 0.15	< 0.15	< 0.15	< 0.27	< 0.12	0.39	6.14	29.89	6.06	30.30
17971-dup	10/28/2002	0.4	4.5	< 0.2	< 0.17	0.24	< 0.17	< 0.35	1.5	11	0.29	0.44	0.22	< 0.2	< 0.21	< 0.21	< 0.33	< 0.3	0.35	5.98	30.71		
11252	11/13/2002	0.8	2.4	< 0.27	< 0.26	< 0.25	< 0.25	0.83	4.6	3.4	< 0.27	< 0.24	< 0.19	< 0.18	< 0.24	< 0.35	< 0.52	< 0.32	0.95	2.96	7.40	2.96	7.40
15464	11/13/2002	0.8	< 0.21	< 0.15	< 0.21	< 0.21	< 0.21	< 0.69	8.3	0.33	< 0.24	< 0.23	< 0.23	< 0.2	< 0.27	< 0.33	< 0.43	< 0.4	1.4	0.32	0.81	0.32	0.81
13363	11/16/2002	0.5	< 0.24	< 0.36	< 0.3	< 0.28	< 0.29	1.1	13	0.78	< 0.22	< 0.22	< 0.25	< 0.22	< 0.29	< 0.38	< 1.1	< 0.47	15	0.45	1.80	0.45	1.80
Spring 2003																							
11272	04/29/2003	0.5	< 0.43	< 0.11	< 0.11	< 0.14	< 0.12	0.31	2.8	0.34	< 0.14	< 0.13	< 0.11	< 0.12	< 0.12	< 0.11	0.14	< 0.12	1.3	0.35	1.42	0.35	1.42
11273	04/29/2003	0.8	1.8	< 0.13	< 0.11	< 0.14	< 0.12	0.25	1.6	2.9	0.32	0.25	0.25	< 0.19	< 0.14	< 0.13	0.26	< 0.12	0.31	2.33	5.83	2.33	5.83
11092	04/29/2003	0.2	0.38	< 0.12	< 0.1	0.17	0.18	1.9	32	0.35	< 0.12	0.21	< 0.12	< 0.12	< 0.11	< 0.21	< 0.55	0.33	2.5	0.62	6.21	0.53	3.73
11092-dup	04/29/2003	0.7	0.19	< 0.12	< 0.11	0.16	0.2	0.52	4	0.27	< 0.16	0.2	< 0.15	< 0.12	< 0.13	0.24	0.23	< 0.22	0.54	0.44	1.25		
11274	04/30/2003	0.8	1.4	< 0.19	< 0.11	< 0.13	< 0.12	0.26	1.7	1.8	< 0.19	< 0.18	< 0.18	0.24	< 0.2	< 0.2	< 0.18	< 0.1	0.73	1.75	4.37	1.75	4.37
11258	04/30/2003	0.7	2.2	< 0.34	< 0.23	< 0.28	< 0.25	0.67	< 6	3.5	< 0.43	< 0.4	< 0.27	< 0.3	< 0.3	< 0.29	< 0.79	< 0.23	8.4	2.84	8.12	2.84	8.12
11298	04/30/2003	1.4	4.5	0.21	< 0.089	0.19	< 0.096	0.53	4.2	8.5	0.24	0.34	0.23	0.16	< 0.1	< 0.099	< 0.54	< 0.1	4.6	5.71	8.16	5.71	8.16
11111	05/01/2003	1.2	0.58	< 0.17	< 0.17	< 0.19	< 0.18	0.53	5.1	0.93	0.15	< 0.2	< 0.13	< 0.13	< 0.14	< 0.19	< 0.21	< 0.19	0.55	0.83	1.38	0.93	2.74
11111-dup	05/01/2003	0.5	0.61	0.29	< 0.16	< 0.19	< 0.17	0.64	6.8	0.81	< 0.19	< 0.18	< 0.42	< 0.9	< 0.46	< 0.45	< 0.46	< 0.15	4.6	1.02	4.09		
11347	05/02/2003	1.1	1.9	0.38	< 0.13	0.3	0.2	0.6	5.2	0.84	< 0.17	0.45	< 0.31	0.15	0.16	< 0.17	< 0.64	< 0.94	< 0.21	2.51	4.57	2.51	4.57
11382	05/02/2003	1	2.3	0.26	< 0.1	0.28	< 0.11	< 0.3	1.5	1.1	< 0.16	0.38	< 0.093	< 0.24	< 0.1	< 0.099	< 0.19	< 0.12	0.46	2.80	5.60	2.80	5.60
11305	05/03/2003	1.1	3.2	0.3	0.12	0.38	< 0.12	0.97	5.8	6.3	0.3	0.54	0.25	< 0.18	< 0.11	< 0.11	< 0.48	< 0.11	1.4	4.37	7.94	4.37	7.94
13339	05/04/2003	1.4	7	0.29	0.14	0.41	0.27	0.85	6.6	16	0.3	0.58	0.17	< 0.16	< 0.1	< 0.1	1.7	< 0.15	22	9.17	13.10	9.17	13.10
11292	05/05/2003	0.8	1.8	0.44	< 0.14	0.51	0.28	1.2	6.8	3.8	0.38	0.7	< 0.37	0.27	< 0.21	< 0.2	< 0.55	< 0.86	1.6	2.92	7.30	2.92	7.30
16618	05/05/2003	1.6	7.5	0.37	< 0.17	0.48	0.37	0.76	4.8	15	0.36	0.62	< 0.23	0.15	< 0.098	< 0.12	< 0.29	< 0.22	3.2	9.64	12.05	9.64	12.05
11287	05/05/2003	0.7	4.9	0.24	< 0.12	0.19	< 0.12	0.92	7.9	9.2	0.44	0.58	< 0.21	0.2	0.12	< 0.11	0.49	0.16	7	6.33	18.09	6.33	18.09
11280	05/06/2003	1.1	4.7	0.21	< 0.15	< 0.2	< 0.15	0.58	3.4	9.2	< 0.28	0.4	0.25	< 0.13	< 0.15	< 0.21	< 0.22	< 0.34	0.87	6.01	10.92	6.01	10.92
13341	05/06/2003	0.9	0.41	< 0.33	< 0.25	< 0.27	< 0.26	0.74	6.9	0.66	< 5.7	< 5.9	< 8.9	< 8.4	< 10	< 14	< 1.6	< 2.7	23	4.28	9.51	4.28	9.51
11264	05/06/2003	0.7	2.4	< 0.1	< 0.093	< 0.11	< 0.1	0.29	2.1	4.3	< 0.17	0.18	< 0.11	< 0.1	< 0.1	< 0.1	< 0.15	< 0.1	0.34	2.98	8.53	2.98	8.53
11270	05/06/2003	1	4.8	< 0.16	< 0.1	0.23	< 0.11	0.43	3.3	9	0.24	0.35	0.21	0.12	< 0.11	< 0.1	< 0.2	< 0.11	0.38	6.00	12.01	6.00	12.01
13342	05/10/2003	0.6	2.4	< 0.45	< 0.12	0.21	< 0.12	0.78	6.3	3.9	< 0.21	0.32	0.17	< 0.11	< 0.13	< 0.19	< 0.25	< 0.2	1.3	3.14	10.46	3.14	10.46
11261	05/10/2003	0.8	2.1	< 0.24	< 0.11	0.16	< 0.12	0.58	4.4	3.5	0.16	< 0.22	< 0.16	< 0.1	< 0.12	< 0.16	< 0.43	< 0.16	7.6	2.63	6.57	2.63	6.57
13343	05/10/2003	1.2	4.1	< 0.18	< 0.11	0.19	< 0.12	0.45	4.5	7.2	< 0.17	< 0.29	< 0.1	0.13	< 0.11	< 0.11	< 0.16	< 0.11	0.43	5.00	8.34	5.00	8.34
16496	05/10/2003	0.9	3.3	< 0.14	< 0.11	< 0.13	< 0.12	< 0.33	3.5	5.7	< 0.15	0.27	< 0.11	< 0.16	< 0.12	< 0.12	< 0.2	< 0.1	0.53	4.09	9.08	4.09	9.08
11193	05/10/2003	0.9	3.6	< 0.16	< 0.11	< 0.13	< 0.12	0.44	3.1	7.4	< 0.17	< 0.23	0.14	< 0.11	< 0.11	< 0.11	< 0.12	< 0.12	< 0.29	4.49	9.98	4.49	9.98
11302	05/11/2003	0.7	1.8	< 0.27	< 0.13	< 0.18	< 0.13	0.67	3.8	2.9	0.2	0.27	< 0.21	< 0.1	0.15	< 0.18	< 0.29	< 0.48	0.69	2.36	6.75	2.36	6.75
11252	05/12/2003	0.3	1.6	< 0.24	< 0.17	< 0.17	< 0.17	0.6	4.2	1.8	< 0.2	< 0.21	0.69	< 0.19	< 0.15	< 0.21	4.6	< 0.42	90	2.02	13.46	2.02	13.46
13309	05/12/2003	0.3	0.99	0.23	< 0.12	0.34	0.2	0.47	3.3	1.7	< 0.15	0.24	< 0.12	< 0.1	< 0.12	< 0.19	< 0.2	< 0.22	0.41	1.49	9.90	1.49	9.90

Table 4.6 Total Dioxin Concentrations in Crab (ng/kg-wet wt)

Station ID	Date	Lipid content (%)	2,3,7,8-TCDD	1,2,3,7,8-PeCDD	1,2,3,4,7,8-HxCDD	1,2,3,6,7,8-HxCDD	1,2,3,7,8,9-HxCDD	1,2,3,4,6,7,8-HpCDD	OCDD	2,3,7,8-TCDF	1,2,3,7,8-PeCDF	2,3,4,7,8-PeCDF	1,2,3,4,7,8-HxCDF	1,2,3,6,7,8-HxCDF	2,3,4,6,7,8-HxCDF	1,2,3,7,8,9-HxCDF	1,2,3,4,6,7,8-HpCDF	1,2,3,4,7,8,9-HpCDF	OCDF	Total TEQ	Lipid- normalized TEQ[a]	Average TEQ[b]	Average Lipid-normalized TEQ[a,b]
14560	05/12/2003	0.2	0.69	< 0.21	< 0.14	< 0.14	< 0.14	< 0.35	< 2.3	1.3	< 0.12	0.16	< 0.19	< 0.11	< 0.14	< 0.2	< 0.19	< 0.17	< 0.45	1.01	10.09	1.01	10.09
16213	05/12/2003	0.3	0.51	< 0.19	< 0.11	0.26	< 0.11	< 0.39	2.5	0.76	< 0.15	0.2	< 0.18	0.15	< 0.12	< 0.17	< 0.21	< 0.2	< 0.44	0.81	5.42	0.81	5.42
15464	05/12/2003	0.2	0.26	< 0.37	< 0.22	< 0.22	0.41	0.77	3.8	0.25	< 0.2	< 0.21	< 0.31	< 0.2	< 0.22	0.56	< 0.36	0.48	1.1	0.59	5.91	0.59	5.91
13589	05/16/2003	0.2	0.56	< 0.13	< 0.11	< 0.12	< 0.14	< 0.32	2.9	0.51	0.19	< 0.19	< 0.1	< 0.097	< 0.12	< 0.17	< 0.21	< 0.32	< 0.59	0.74	7.43	0.74	7.43
15908	05/22/2003	0.6	0.5	< 0.42	< 0.16	< 0.19	< 0.17	0.31	1.4	0.52	< 0.21	< 0.19	< 0.14	< 0.16	< 0.16	< 0.15	< 0.15	0.16	0.53	0.77	2.55	0.62	1.95
15908-dup	05/22/2003	0.7	< 0.4	< 0.44	< 0.12	< 0.14	< 0.13	0.31	1.6	0.52	< 0.26	< 0.24	< 0.094	< 0.1	< 0.1	< 0.1	< 0.13	< 0.14	< 0.36	0.47	1.34		
16622	05/22/2003	0.7	< 0.27	< 0.45	< 0.17	< 0.21	< 0.19	0.29	1.7	< 0.21	< 0.22	< 0.21	< 0.19	< 0.21	< 0.21	< 0.2	< 0.36	< 0.39	0.38	0.39	1.10	0.39	1.10
13355	05/23/2003	0.7	0.54	< 0.44	< 0.19	< 0.23	< 0.2	0.23	0.97	0.52	< 0.15	< 0.14	< 0.11	< 0.12	< 0.12	< 0.12	< 0.12	< 0.1	< 0.34	0.80	2.27	0.80	2.27
15979	05/23/2003	0.6	2.4	< 0.45	< 0.18	< 0.21	< 0.19	0.24	1	2.5	< 0.17	< 0.21	< 0.13	< 0.15	< 0.15	< 0.14	< 0.14	< 0.16	0.37	2.88	9.59	2.88	9.59
13340	05/23/2003	1	0.6	< 0.35	< 0.16	< 0.19	< 0.17	0.34	1.2	0.8	< 0.25	< 0.29	< 0.1	0.15	0.16	< 0.12	0.22	< 0.15	0.9	0.91	1.83	0.91	1.83
13337	05/23/2003	0.8	1.1	< 1.7	< 0.6	< 0.72	< 0.65	0.78	4.4	1.2	< 1.3	< 1.2	< 0.41	< 0.45	< 0.45	< 0.44	< 0.5	< 0.54	1.2	2.16	5.41	2.16	5.41
11300	05/30/2003	1.1	2.8	< 0.49	< 0.16	< 0.2	< 0.18	0.36	1.4	3.5	< 0.44	< 0.41	< 0.16	< 0.15	< 0.15	< 0.15	< 0.22	< 0.23	0.47	3.44	6.26	3.44	6.26
Spring 2004																							
13340	03/09/2004	1.50	0.97	0.36	< 0.36	0.46	< 0.55	1.1	6.1	2	0.33	0.48	0.32	0.38	0.4	0.58	0.58	0.59	1.4	1.87	2.49	1.87	2.49
11252	03/09/2004	1.10	1.4	< 0.33	< 0.33	< 0.38	0.48	0.92	7.1	3.2	< 0.37	< 0.37	< 0.3	< 0.33	< 0.34	< 0.58	0.5	0.51	1.2	2.07	3.76	2.07	3.76
14560	03/09/2004	1.10	1.5	< 0.2	< 0.2	< 0.23	< 0.21	< 0.61	6.5	2.2	< 0.22	0.25	< 0.16	< 0.19	< 0.19	< 0.18	< 0.29	< 0.24	0.75	1.97	3.58	1.97	3.58
13342	03/09/2004	0.90	4.4	0.29	< 0.15	< 0.28	0.25	0.77	10	9.8	0.32	0.51	0.21	0.21	< 0.16	< 0.15	< 0.37	< 0.17	0.72	5.90	13.11	5.90	13.11
13338	03/17/2004	1.20	0.66	< 0.19	< 0.29	< 0.32	< 0.29	0.68	6.4	1.6	0.41	0.4	< 0.34	0.37	< 0.19	< 0.18	1	< 0.28	10	1.21	2.01	1.21	2.01
16499	03/17/2004	1.30	2.9	0.15	< 0.14	0.22	0.17	0.78	8.2	5.8	0.26	0.32	< 0.18	< 0.22	0.13	< 0.093	< 0.35	< 0.1	0.73	3.81	5.86	3.81	5.86
16618	03/18/2004	1.10	5.9	0.34	< 0.22	0.26	0.27	1.2	12	8.2	0.33	0.46	< 0.18	< 0.23	0.094	< 0.091	< 0.5	< 0.33	0.67	7.23	13.15	7.23	13.15
13344	03/18/2004	0.80	3.8	0.2	< 0.25	< 0.3	< 0.27	0.82	8.1	8.2	0.25	0.38	0.2	0.17	< 0.1	< 0.097	0.43	< 0.42	0.59	5.01	12.53	5.01	12.53
11193	03/23/2004	1.00	2.7	0.18	< 0.12	< 0.14	0.19	0.92	10	3.7	0.18	0.25	< 0.12	< 0.12	< 0.074	< 0.072	0.25	< 0.26	0.53	3.35	6.69	3.35	6.69
11197	03/23/2004	1.20	1.4	0.17	0.15	0.3	0.24	1.1	9.5	3.5	0.16	0.27	< 0.11	< 0.18	< 0.095	< 0.092	< 0.24	< 0.12	0.45	2.07	3.45	2.07	3.45
11264	03/23/2004	1.30	2.2	0.17	< 0.13	0.23	< 0.19	1.1	9	4.1	0.26	0.26	< 0.17	< 0.18	0.095	< 0.079	< 0.36	< 0.18	0.6	2.91	4.47	2.91	4.47
11261	03/23/2004	1.20	2.3	< 0.22	< 0.14	0.25	0.18	1.1	9.9	6.8	0.18	0.26	0.16	< 0.11	< 0.11	< 0.11	< 0.25	< 0.18	0.58	3.26	5.43	3.26	5.43
11265	03/30/2004	0.90	2.2	< 0.19	< 0.15	0.21	< 0.16	0.73	6.7	4.6	0.18	0.24	0.13	< 0.12	< 0.12	< 0.12	< 0.25	< 0.17	0.59	2.90	6.45	2.90	6.45
15979	03/31/2004	0.90	5	0.22	< 0.14	0.19	< 0.15	0.74	6.4	8.4	0.26	0.38	< 0.17	< 0.11	< 0.11	< 0.11	< 0.31	< 0.19	1.9	6.21	13.80	6.21	13.80
11280	04/01/2004	0.80	5.1	0.35	< 0.14	0.26	0.22	1.1	8.4	8.9	0.31	0.41	0.2	0.16	< 0.14	< 0.14	< 0.64	< 0.16	7.6	6.49	16.23	6.49	16.23
11287	04/01/2004	0.80	4.5	0.3	< 0.18	< 0.21	< 0.19	1.1	7	8.2	0.3	0.43	< 0.18	< 0.2	< 0.2	< 0.19	< 0.39	< 0.3	1	5.77	14.42	5.77	14.42
11292	04/03/2004	1.30	< 0.43	< 0.5	< 0.49	< 0.62	< 0.5	1.4	7.2	1.2	< 0.36	0.58	< 0.43	< 0.43	< 0.46	< 0.43	0.59	0.47	1.1	0.93	1.43	0.93	1.43
11272	04/15/2004	0.60	0.99	< 0.59	< 0.64	< 0.75	< 0.65	1.5	9.2	1.2	< 0.44	< 0.43	< 0.41	< 0.43	< 0.46	< 0.43	0.53	< 0.43	1.1	1.56	5.22	1.56	5.22
11302	04/16/2004	0.80	1.3	< 0.44	< 0.32	0.47	< 0.33	1.6	6.8	1.9	< 0.49	< 0.47	< 0.35	< 0.37	< 0.39	< 0.37	0.58	< 0.38	0.81	1.88	4.71	1.88	4.71
11300	04/16/2004	0.80	0.85	< 0.85	< 0.33	< 0.29	< 0.3	< 0.79	1.2	4.4	0.58	< 0.56	0.39	< 0.32	< 0.31	< 0.28	< 0.31	1.2	5.9	1.80	4.51	1.80	4.51
11298	04/20/2004	1.20	1.9	0.37	< 0.22	0.3	< 0.23	0.99	6.3	4.6	< 0.35	0.41	0.32	0.22	< 0.21	< 0.2	< 0.31	< 0.2	< 0.61	2.89	4.81	4.43	7.38
11298-dup[c]	04/20/2004	1.20	4.3	0.41	0.32	< 0.43	0.38	1.6	14	9.7	0.4	0.58	0.38	< 0.29	0.24	0.17	0.47	< 0.25	0.78	5.97	9.95		
11274	04/20/2004	0.90	1.3	0.4	0.25	< 0.28	0.19	1.2	11	2.9	0.28	0.39	0.27	< 0.22	0.13	0.16	0.34	< 0.26	0.91	2.12	4.72	2.12	4.72
11273	04/21/2004	1.60	5.9	0.46	< 0.28	0.41	0.31	1.3	7.6	11	1.5	1.1	0.95	0.42	< 0.29	< 0.27	0.8	< 0.2	2.9	8.11	10.13	8.61	11.58
11273-dup[c]	04/21/2004	1.40	6.2	0.81	0.48	0.64	0.62	2	12	12	1.7	1.4	1.4	0.83	0.71	0.55	2.6	0.7	18	9.11	13.02		
11305	04/22/2004	0.60	1.2	< 0.37	< 0.41	< 0.48	< 0.42	1.1	6.4	2.3	< 0.55	< 0.54	< 0.38	< 0.39	< 0.42	< 0.4	0.38	< 0.27	0.86	1.82	6.05	1.82	6.05
11111	04/27/2004	0.50	0.46	< 0.22	< 0.22	< 0.26	< 0.22	0.96	6.6	0.65	< 0.17	0.28	0.23	0.24	< 0.14	< 0.14	< 0.29	< 0.2	0.96	0.82	3.28	0.82	3.28
11092	04/30/2004	0.80	< 0.18	< 0.23	< 0.29	< 0.34	< 0.29	1.2	11	0.4	< 0.33	< 0.33	< 0.21	< 0.22	< 0.24	< 0.23	0.36	< 0.24	0.78	0.37	0.92	0.37	0.92
Fall 2004																							
13338	10/02/2004	0.70	2	< 0.14	< 0.11	< 0.16	< 0.11	4.2	62	3.5	< 0.099	0.13	< 0.16	< 0.083	< 0.097	< 0.14	< 0.83	< 0.3	3.7	2.50	7.13	2.50	7.13
16618	10/02/2004	0.60	5.1	< 0.32	< 0.2	< 0.2	< 0.2	0.44	1.8	11	< 0.3	0.37	< 0.13	< 0.12	< 0.15	< 0.18	< 0.19	< 0.24	0.47	6.53	21.77	6.53	21.77
13340	10/03/2004	0.80	0.86	< 0.27	< 0.23	< 0.26	< 0.24	0.42	1.3	1.9	< 0.4	< 0.44	< 0.2	< 0.19	< 0.23	< 0.31	< 0.22	< 0.27	< 0.44	1.32	3.30	1.32	3.30
14560	10/04/2004	0.70	1	< 0.45	< 0.25	< 0.27	< 0.26	0.34	1.2	1.7	< 0.42	< 0.44	< 0.25	< 0.23	< 0.27	< 0.4	< 0.23	< 0.26	< 0.36	1.50	4.28	1.50	4.28
13342	10/05/2004	0.60	8.9	< 0.26	< 0.16	< 0.18	< 0.17	0.47	3.8	19	< 0.33	0.46	< 0.15	< 0.14	< 0.17	< 0.22	0.22	< 0.15	3	11.16	37.21	11.16	37.21
16499	10/08/2004	0.90	3.8	< 0.23	< 0.12	0.21	< 0.16	0.41	1.7	7.6	< 0.28	< 0.26	< 0.29	< 0.26	< 0.31	< 0.39	< 0.19	< 0.25	0.34	4.79	10.64	4.79	10.64
11287	10/19/2004	0.80	5.9	0.36	0.32	< 0.45	< 0.35	0.8	2.2	9.5	0.58	< 0.65	< 0.4	0.31	< 0.31	0.29	< 0.46	0.27	0.81	7.39	18.47	7.39	18.47
11292	10/20/2004	0.90	0.86	< 0.44	0.2	3.1	< 0.33	1.1	2.1	1.9	0.75	0.86	0.84	0.37	0.33	0.13	0.52	< 0.12	0.36	2.14	4.76	2.14	4.76
11280	10/20/2004	0.70	8.7	0.35	0.24	< 0.29	< 0.22	0.51	3.3	12	0.57	0.68	0.43	0.21	< 0.22	0.14	< 0.32	0.17	0.44	10.58	30.23	10.58	30.23
15979	10/21/2004	0.80	12	0.31	0.25	0.35	< 0.23	0.54	1.9	17	0.56	0.66	0.4	0.22	0.19	0.15	< 0.32	0.16	0.35	14.38	35.95	11.20	27.99

Table 4.6 Total Dioxin Concentrations in Crab (ng/kg-wet wt)

Station ID	Date	Lipid content (%)	2,3,7,8-TCDD	1,2,3,7,8-PeCDD	1,2,3,4,7,8-HxCDD	1,2,3,6,7,8-HxCDD	1,2,3,7,8,9-HxCDD	1,2,3,4,6,7,8-HpCDD	OCDD	2,3,7,8-TCDF	1,2,3,7,8-PeCDF	2,3,4,7,8-PeCDF	1,2,3,4,7,8-HxCDF	1,2,3,6,7,8-HxCDF	2,3,4,6,7,8-HxCDF	1,2,3,7,8,9-HxCDF	1,2,3,4,6,7,8-HpCDF	1,2,3,4,7,8,9-HpCDF	OCDF	Total TEQ	Lipid- normalized TEQ[a]	Average TEQ[b]	Average Lipid-normalized TEQ[a,b]
15979-dup	10/21/2004	0.80	6.6	0.23	0.19	0.26	< 0.19	0.4	1.6	9.4	0.42	0.41	0.32	0.21	0.17	< 0.12	0.41	0.21	1.4	8.01	20.03		
11265	10/21/2004	0.70	5.4	< 0.2	0.19	0.28	< 0.15	0.39	1.9	8.1	0.26	< 0.32	0.24	0.19	0.22	< 0.13	< 0.24	< 0.18	0.24	6.48	18.51	6.48	18.51
11264	10/21/2004	1.00	5.7	0.17	< 0.14	0.21	0.19	< 0.4	1.4	9.6	0.32	0.39	0.28	0.18	< 0.17	0.11	0.31	0.15	0.27	7.07	14.14	7.07	14.14
13344	10/21/2004	0.90	3.4	0.15	0.2	0.23	< 0.13	0.45	2.4	5.8	0.21	0.33	< 0.19	< 0.16	0.17	< 0.11	0.28	< 0.11	0.27	4.32	9.60	4.32	9.60
11252	10/26/2004	1.50	9.5	0.34	< 0.32	0.56	0.43	0.81	2.3	19	0.42	0.61	0.26	< 0.23	< 0.21	0.16	0.33	0.17	0.58	12.08	16.10	12.08	16.10
11261	10/26/2004	1.10	7.3	0.37	0.3	0.44	< 0.33	< 0.56	2	13	0.38	0.56	0.34	0.26	0.26	0.28	< 0.32	< 0.18	0.59	9.29	16.89	9.29	16.89
11193	10/27/2004	1.10	6.6	0.12	< 0.12	0.21	0.23	0.84	5.2	17	< 0.2	0.39	0.16	0.11	0.13	< 0.13	0.28	< 0.18	0.93	8.66	15.74	11.49	20.90
11193-dup	10/27/2004	1.10	11	0.14	< 0.1	0.23	0.18	0.61	3.3	29	0.43	0.54	< 0.11	< 0.089	< 0.11	< 0.14	< 0.17	< 0.12	0.51	14.33	26.05		
11197	10/28/2004	1.20	6.2	0.18	< 0.12	0.6	0.26	0.8	3.7	14	0.26	0.4	0.19	< 0.098	< 0.12	< 0.14	< 0.2	< 0.11	0.39	8.03	13.39	8.03	13.39

[a] Crab tissue normalized to 2% lipids

[b] Average of duplicate samples, otherwise concentration of a single sample

[c] The duplicate sample is an additional set of crabs

dup = duplicate

Values reported to the Detection Limit

Non-detects assumed as 1/2 MDL for TEQ calculations

🟦	Value between the detection and the reporting limits
🟨	Value is an estimate due to blank contamination (concentration < 20 times lowest concentration)
🟥	Value is an estimate due to QC issues (interference, signal to noise ratio)
▨	Tributary
🟩	Exceeds the Texas Health Standard (0.47 ng/kg)

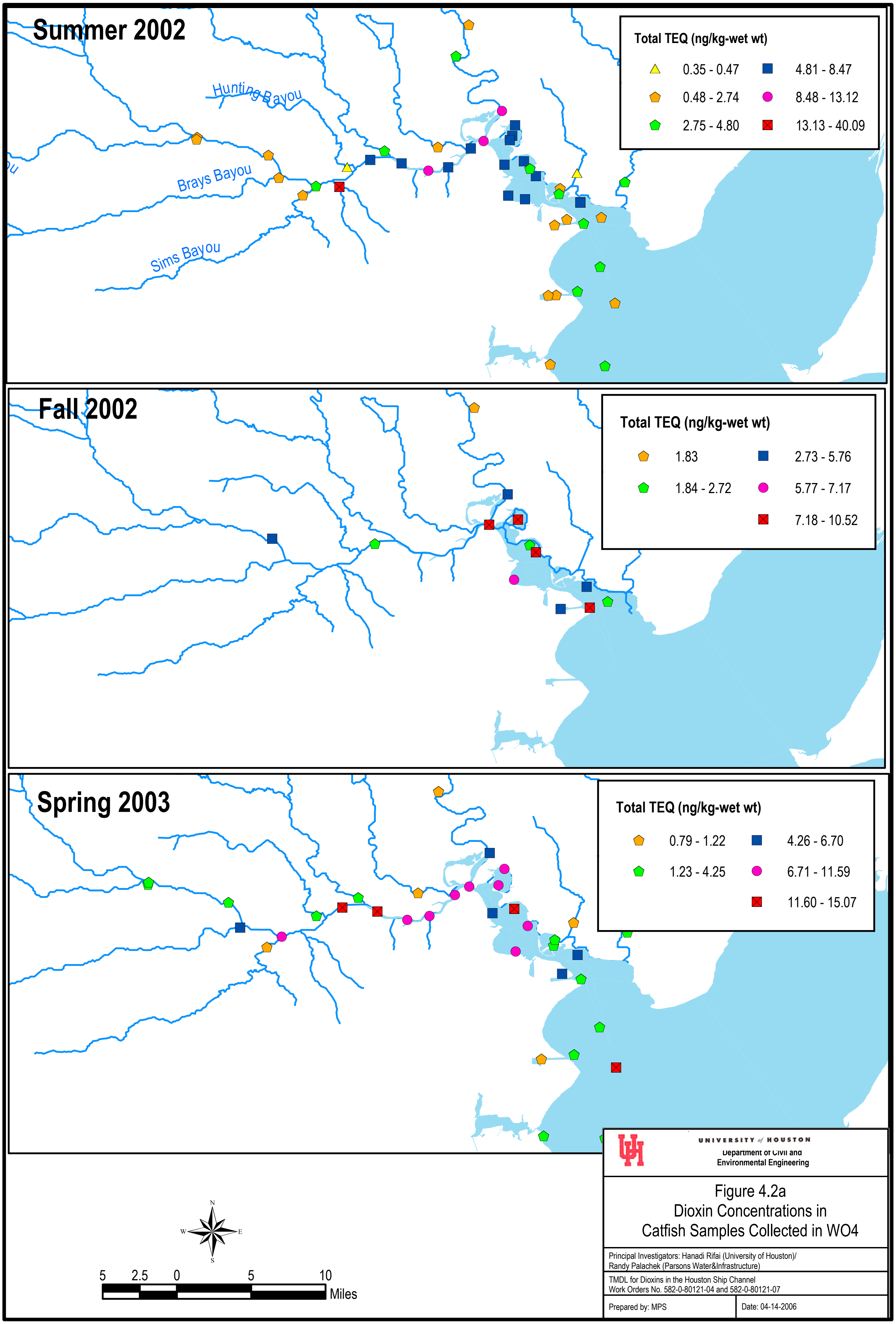


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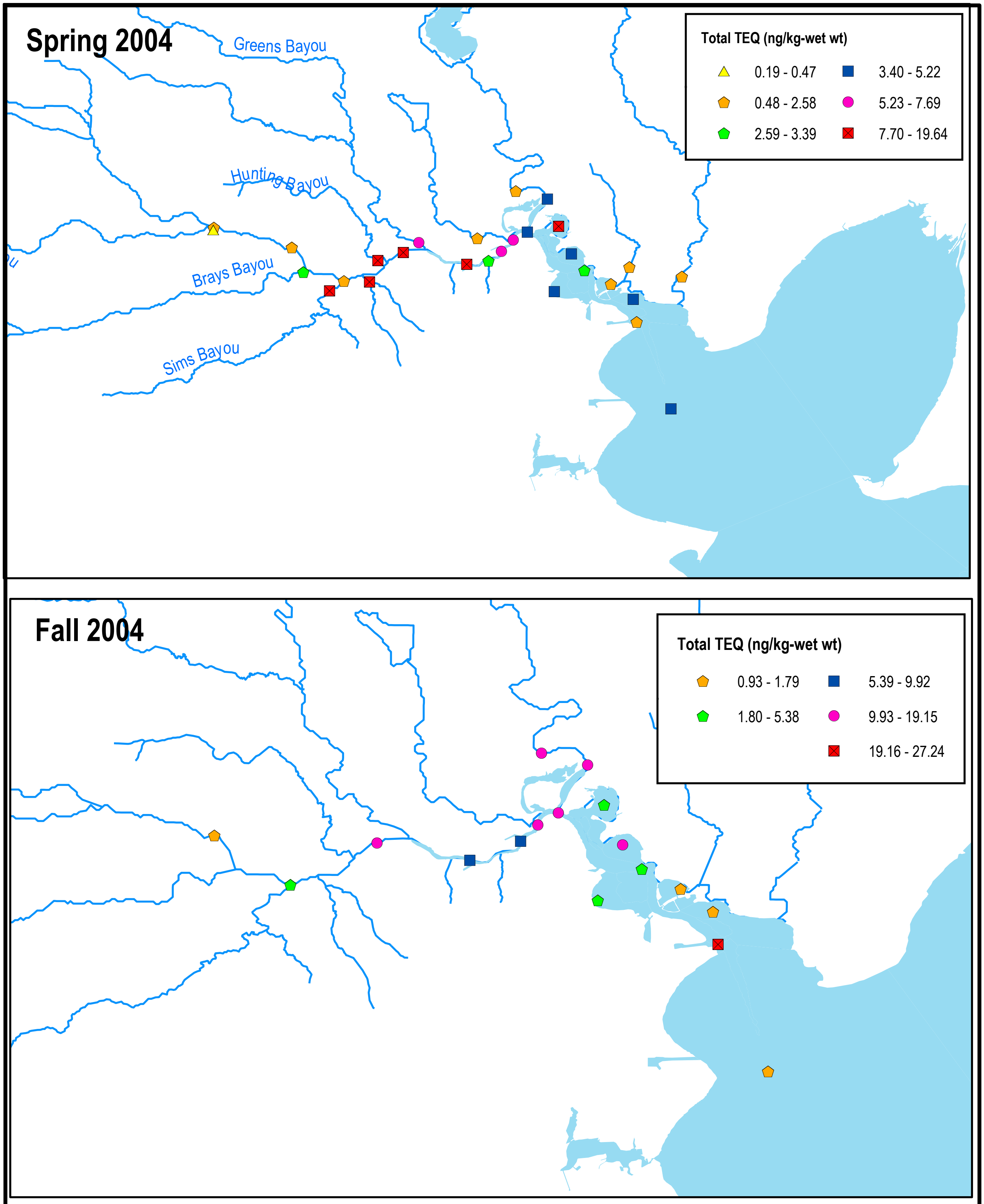
Figure 4.2a
Dioxin Concentrations in
Catfish Samples Collected in WO4

Principal Investigators: Hanadi Rifai (University of Houston)/
Randy Palachek (Parsons Water&Infrastructure)

TMDL for Dioxins in the Houston Ship Channel
Work Orders No. 582-0-80121-04 and 582-0-80121-07

Prepared by: MPS
Date: 04-14-2006



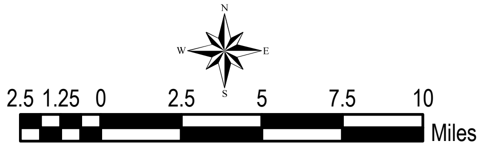


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Figure 4.2b
Dioxin Concentrations in
Catfish Samples Collected in WO7

Principal Investigators: Hanadi Rifai (University of Houston)/
Randy Palachek (Parsons Water&Infrastructure)

TMDL for Dioxins in the Houston Ship Channel
Work Orders No. 582-0-80121-04 and 582-0-80121-07

Prepared by: MPS

Date: 04-14-2006

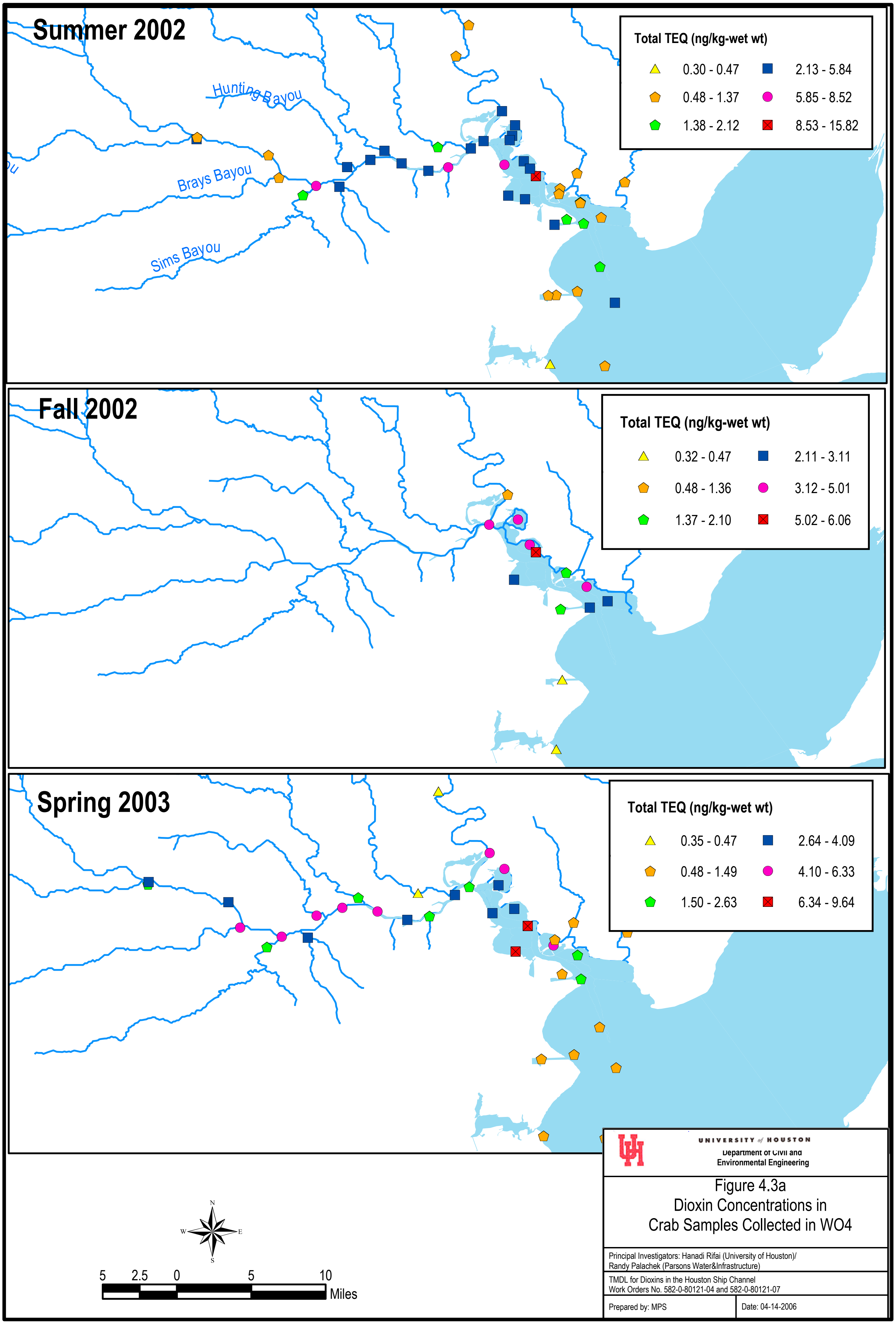

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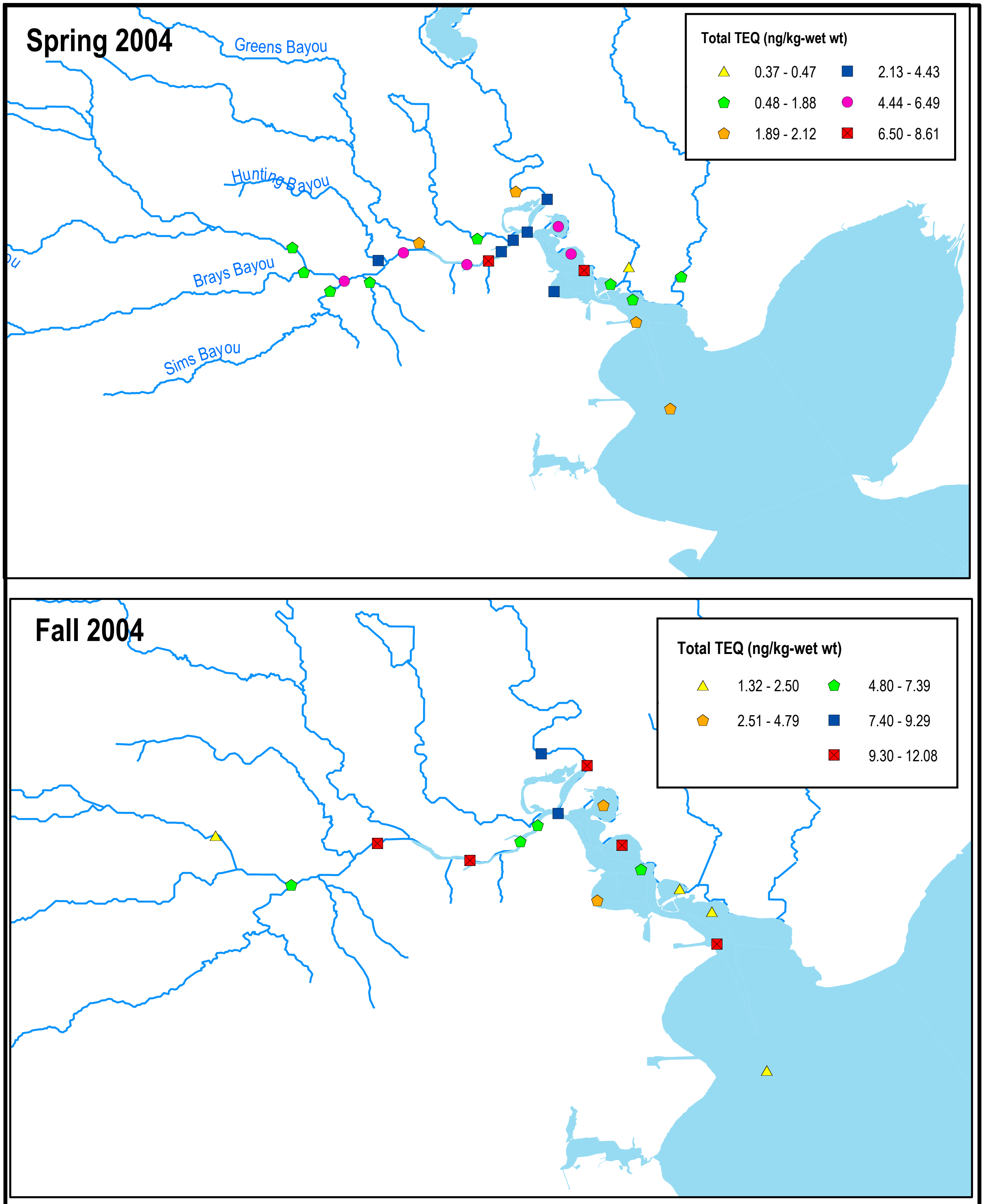
Figure 4.3a
Dioxin Concentrations in
Crab Samples Collected in WO4

Principal Investigators: Hanadi Rifai (University of Houston)/
Randy Palachek (Parsons Water&Infrastructure)

TMDL for Dioxins in the Houston Ship Channel
Work Orders No. 582-0-80121-04 and 582-0-80121-07

Prepared by: MPS

Date: 04-14-2006



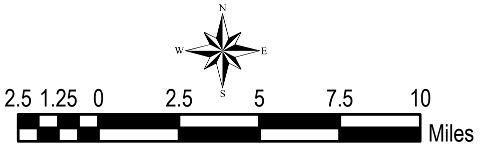


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Figure 4.3b
Dioxin Concentrations in
Crab Samples Collected in WO7

Principal Investigators: Hanadi Rifai (University of Houston)/
Randy Palachek (Parsons Water&Infrastructure)

TMDL for Dioxins in the Houston Ship Channel
Work Orders No. 582-0-80121-04 and 582-0-80121-07

Prepared by: MPS	Date: 04-14-2006

The health-based standard of 0.47 ng TEQ/kg (derived from the Texas WQS) was exceeded in 97% of the catfish samples and in 95% of the crab samples collected in WO4 (2002-2003). Additionally, the 0.47 ng TEQ/kg standard was exceeded in 96% of the Spring 2004 samples (for both catfish and crabs) and in all tissue samples collected in Fall 2004.

Overall, locations 11300 (Vince Bayou) and 11193 (Segment 1001) showed the highest dioxin catfish concentrations in Summer 2002, while locations 16618 (Segment 1005) and 11258 (Segment 1005) presented the highest dioxin concentrations in crabs for the same sampling event. Among the locations sampled in Fall 2002, stations 13344 (Segment 2430), 11252 (Segment 1005), and 17971 (Segment 2429) exhibited the highest TEQ concentrations in catfish, whereas stations 17971 and 13342 in Segment 2429 presented the highest dioxin levels in crabs. For Spring 2003, samples collected at stations 11280 (Segment 1007) and 14560 (Segment 2421) showed the highest TEQ concentrations in catfish, while stations 16618 (Segment 1005) and 13339 (Segment 2427) exhibited the highest concentrations in crabs. In Spring 2004, locations 11300 (Vince Bayou) and 15979 (Segment 1006) showed the highest dioxin catfish concentrations, while locations 11273 (Patrick Bayou) and 16618 (Segment 1005) presented the highest dioxin concentrations in crabs. Finally, the highest dioxin concentrations in tissue collected in Fall 2004 were found at locations 11252 (Segment 1005) and 11280 (Segment 1007) for catfish, and 11193 (Segment 1001) and 11252 (Segment 1005) for crabs. It is noted that tissue was not sampled in tributaries during Fall 2004.

Correlation between TEQ and lipid content was significant for catfish, even though the fit is weak ($r^2 = 0.36$) as shown in Figure 4.4. No correlation between TEQ concentrations in crabs and lipid content was found. Relationships between dioxin concentrations and size and weight of the individual were also investigated but no statistically significant catfish or crab correlations were found.

Figure 4.5 shows the concentration distribution for the 2378-substituted congeners in the catfish and crab samples. The concentrations for the individual dioxin congeners ranged from 0.01 to 230.0 ng/kg wet wt for catfish and from 0.03 to 410.0 ng/kg wet wt for crabs. Most of the dioxin concentration in catfish can be attributed to OCDD with an average contribution of 28% to the total PCDD/PCDF sum (only the 2378-substituted congeners), while 2378-TCDF was the major contributor (25% on average) to dioxin concentrations in crabs. In both cases, 2378-TCDD was the major contributor to the total TEQ (average contribution of 80 and 68% for catfish and crab, respectively).

A summary of dioxin levels in stomach content/prey species samples and their corresponding TEQs is presented in Table 4.7. Dioxin data for stomach content/prey species samples varied from 0.8 to 31.9 ng TEQ/kg-wet wt with an average value of 6.97 ng TEQ/kg-wet wt. Lipid-normalized concentrations showed an average value of 18.7 ng TEQ/kg-wet wt. All the stomach content/prey species samples exceeded the health-based criterion of 0.47 ng/kg.

A database of PCDD/PCDF levels in tissue reported by PSC/Maxxam Analytical Laboratory is included in Appendix B.

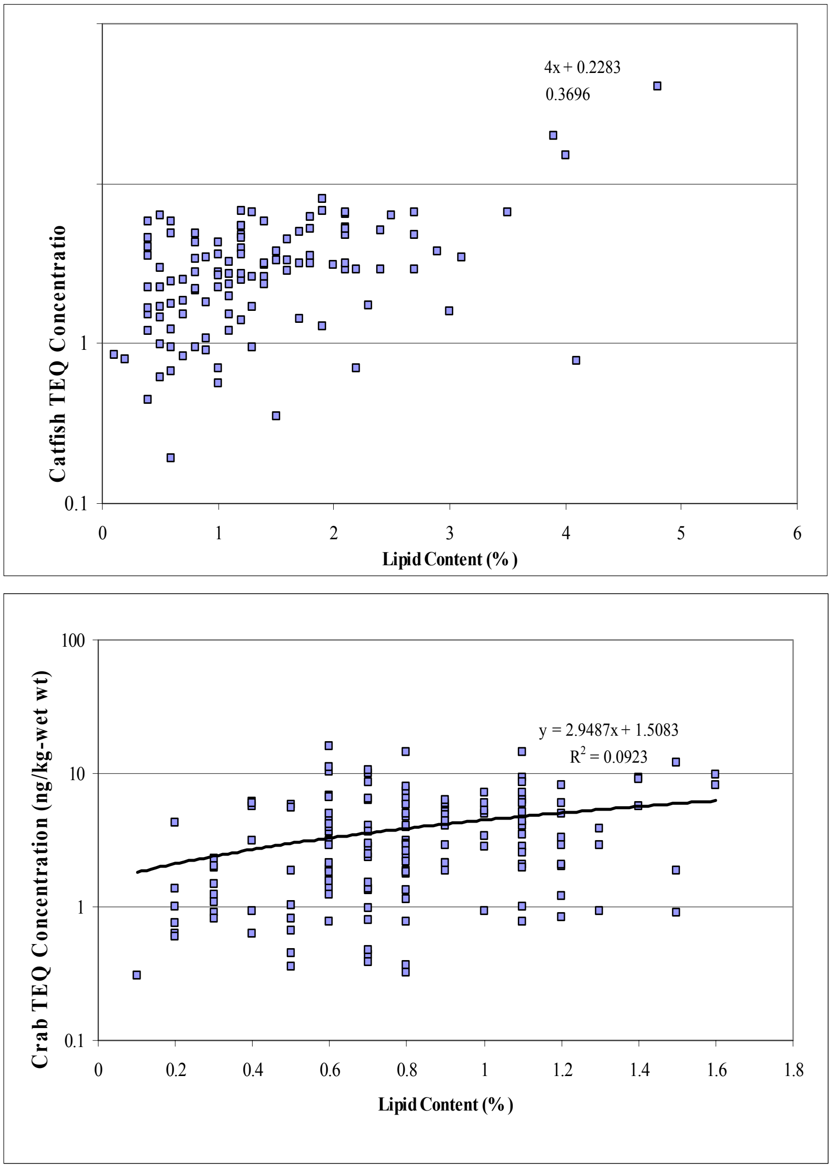
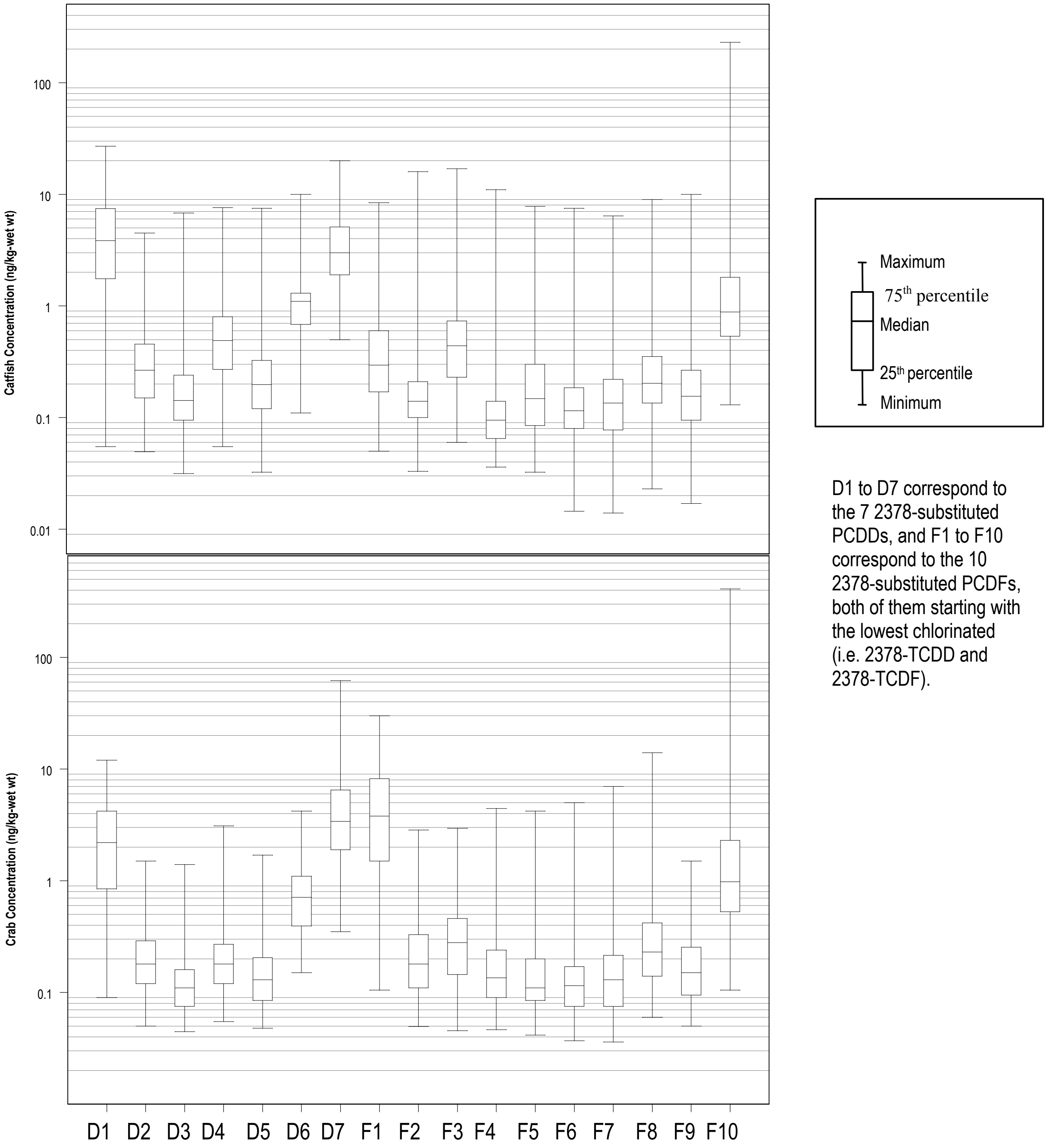


Figure 4.4 Relationship between TEQ and Lipid Content



D1 to D7 correspond to the 7 2378-substituted PCDDs, and F1 to F10 correspond to the 10 2378-substituted PCDFs, both of them starting with the lowest chlorinated (i.e. 2378-TCDD and 2378-TCDF).

Figure 4.5 Distribution of Individual Congeners in Tissue

Table 4.7 Total Dioxin Concentrations in Stomach Content/Prey Species (ng/kg-wet wt)

Station ID	Date	Species	Lipid content (%)	2,3,7,8-TCDD	1,2,3,7,8-PeCDD	1,2,3,4,7,8-HxCDD	1,2,3,6,7,8-HxCDD	1,2,3,7,8,9-HxCDD	1,2,3,4,6,7,8-HpCDD	OCDD	2,3,7,8-TCDF	1,2,3,7,8-PeCDF	2,3,4,7,8-PeCDF	1,2,3,4,7,8-HxCDF	1,2,3,6,7,8-HxCDF	2,3,4,6,7,8-HxCDF	1,2,3,7,8,9-HxCDF	1,2,3,4,6,7,8-HpCDF	1,2,3,4,7,8,9-HpCDF	OCDF	Total TEQ	Lipid- normalized TEQ[a]
Summer 2002																						
15464-SC	08/18/2002	Small fish	2.4	< 5.1	6.6	5.4	7.4	7.3	16	36	< 4.2	< 5	7.8	< 13	6.4	6.4	6.4	12	6	130	14.67	18.33
11270-SC	08/28/2002	Shiner	1.6	8	3.3	3	3.4	3.6	8.7	28	3.1	3.2	4.3	< 6.8	3.1	3.5	3.8	5.4	2.9	27	14.65	27.47
Fall 2002																						
11200-PS	11/21/2002	Shad	5.6	1.7	< 0.26	< 0.25	1	0.6	2.2	10	4.1	1.2	< 0.18	< 0.19	< 0.18	< 0.25	0.32	< 0.71	< 0.44	2.1	2.52	1.35
Spring 2003																						
11258-PS	04/29/2003	Shad	4.1	1.6	< 0.4	< 0.12	0.5	0.29	1.2	14	1.9	< 0.61	0.38	< 0.12	< 3	< 0.14	< 0.13	< 0.19	< 0.15	0.93	2.35	1.72
11298-PS	05/02/2003	Shad	3.4	26	< 0.38	< 0.095	< 0.62	< 0.16	0.88	3.3	47	1.2	1.1	< 0.11	< 8.6	0.2	< 0.11	< 0.23	< 0.17	1.2	31.91	28.16
11298-PS	05/02/2003	Shrimp	0.5	15	0.46	< 0.34	0.61	< 0.37	4.3	32	30	0.96	0.77	0.29	< 1.3	< 0.21	< 0.2	< 1.1	< 0.2	2.2	18.87	113.24
13342-SC	05/11/2003	Shrimp	0.9	4.7	< 0.22	< 0.15	< 0.27	< 0.16	1.3	23	8.3	0.31	0.38	0.19	< 0.14	< 0.13	< 0.12	< 0.55	< 0.13	8.9	5.86	19.53
13309-SC	05/12/2003	Shrimp	1.4	1	< 0.29	< 0.24	0.37	< 0.26	0.88	7.8	1.9	< 0.31	0.28	< 0.19	< 0.21	< 0.21	< 0.2	< 0.22	< 0.22	0.63	1.51	3.24
16618-PS	05/23/2003	Croaker	1.1	2.5	< 0.13	< 0.12	< 0.17	< 0.13	1.2	18	1.1	< 0.15	0.26	< 0.11	< 0.47	< 0.13	< 0.12	0.33	< 0.11	1.7	2.84	7.74
16618-PS	05/23/2003	Shrimp	0.5	2.6	< 0.2	< 0.12	0.35	0.26	1.9	15	4.3	< 0.23	< 0.23	0.18	< 0.17	< 0.12	< 0.11	0.61	< 0.16	0.85	3.25	19.49
11261-PS	05/23/2003	Croaker	1.0	3.5	< 0.19	< 0.14	< 0.24	< 0.19	5.2	46	1.2	0.25	0.3	< 0.13	< 2.4	< 0.14	< 0.14	0.78	< 0.18	1.7	4.00	12.00
11261-PS	05/23/2003	Shrimp	0.6	< 2.8	< 0.19	< 0.1	0.22	0.2	1.7	13	5.7	< 0.2	< 0.21	0.1	< 0.32	< 0.1	< 0.1	< 0.38	< 0.14	< 0.7	2.16	10.79
11270-PS	05/23/2003	Shrimp	1.2	2.1	< 0.53	< 0.48	< 0.58	< 0.52	2.7	29	3.6	< 0.66	< 0.61	< 0.34	< 0.65	< 0.37	< 0.36	< 0.88	< 0.52	< 1.3	2.93	7.32
11270-PS	05/23/2003	Mullet	1.4	5.2	< 0.22	0.15	0.39	0.28	8.3	120	6	< 0.21	0.36	0.15	< 1.7	< 0.13	< 0.12	5.7	< 0.21	1.9	6.23	13.36
11270-PS	05/23/2003	Shad	1.3	12	0.5	0.13	< 0.54	< 0.34	6	110	5.7	0.62	0.96	0.13	< 8.9	0.18	0.71	< 1.1	< 0.36	3.7	13.94	32.16
11270-PS	05/23/2003	Minnows	1.5	3.4	< 0.18	< 0.14	0.29	< 0.21	1.1	7.8	3.7	0.38	< 0.26	< 0.19	< 3.2	< 0.2	< 0.2	< 0.26	< 0.19	0.59	4.14	8.27
11270-PS	05/23/2003	Croaker	0.9	5	< 0.16	< 0.15	< 0.18	< 0.16	1.3	22	1.5	< 0.24	< 0.28	< 0.12	< 2.3	< 0.13	< 0.13	< 0.21	< 0.16	1	5.42	18.08
16499-PS	05/23/2003	Shrimp	0.7	1.5	< 0.32	< 0.2	< 0.24	< 0.22	1.6	12	2.5	< 0.23	< 0.22	< 0.13	< 0.34	< 0.14	< 0.13	0.37	< 0.13	0.63	1.96	8.40
16499-PS	05/23/2003	Shad	2.4	5.6	< 0.68	< 0.84	< 1	< 0.91	5.4	73	3.1	< 0.99	< 0.92	< 0.87	< 0.95	< 0.95	< 0.92	< 1.1	< 1	5	6.66	8.32
16499-PS	05/23/2003	Minnows	0.5	1.8	< 0.33	< 0.32	0.53	< 0.34	2	9.9	2.6	0.47	0.3	< 0.31	< 0.34	< 0.34	< 0.33	< 0.64	< 0.34	1	2.47	14.81
16499-PS	05/23/2003	Mullet	0.4	0.44	< 0.52	< 0.27	< 0.32	< 0.29	0.82	11	< 0.49	< 0.35	< 0.33	< 0.32	< 0.35	< 0.35	< 0.34	< 0.34	< 0.37	1.2	0.80	5.98
16499-PS	05/23/2003	Croaker	0.4	3.5	0.4	< 0.14	< 0.29	0.24	0.85	9	0.98	< 0.31	0.43	< 0.13	< 2.5	< 0.15	< 0.14	0.31	< 0.17	0.77	4.21	31.59

[a] Normalized to 3% lipids

SC = stomach content; PS = prey species

Values reported to the Detection Limit

Non-detects assumed as 1/2 detection limit

0.80	1.35
31.91	113.24
6.97	18.70
4.07	12.68

🟦	Value between the detection and the reporting limits
🟨	Value is an estimate due to blank contamination (concentration < 20 times lowest concentration)
🟥	Value is an estimate due to QC issues (interference, signal to noise ratio)
🟩	Exceeds the Texas Health Standard (0.47 ng/kg)

4.4 DATA ANALYSIS

4.4.1 Spatial Trends

A summary of average TEQ concentrations in catfish by segment is presented in Table 4.8a and b for TEQ and 2378-TCDD, respectively. It can be observed in Table 4.8a that for the Summer 2002 samples, Segment 1007 showed the highest average concentration in catfish, while Segment 2430 showed the highest average TEQ in the Fall 2002 and Spring 2004 samples. Finally, segments 2429 and 1005 exhibited the highest average dioxin concentrations in catfish in the Spring 2003 and Fall 2004, respectively. It is noted, however, that for all but the Summer 2002 and Fall 2004 events, the highest average TEQ concentrations correspond to single samples collected in the mentioned segments.

Data in Table 4.8b indicate that the maximum average 2378-TCDD concentration in catfish was measured in Fall 2004 in Segment 1005. Similar average concentrations in crabs by segment are summarized in Tables 4.9a and b for TEQ and 2378-TCDD, respectively.

The highest average TEQ levels in crabs in Summer 2002 and Spring 2003 were observed in segments 1005 and 2427. Segment 2429 exhibited the highest average TEQ for the remaining events. Again, the highest average levels measured in Spring 2003, Spring 2004, and Fall 2004 correspond to single samples collected at the mentioned segments. The highest average 2378-TCDD concentration in crabs was observed in Fall 2004 in Segment 2429.

Table 4.8a Summary of Average TEQ Concentrations in Catfish by Segment

Segment	**Summer 2002**		**Fall 2002**		**Spring 2003**		**Spring 2004**		**Fall 2004**	
	# of Samples	**TEQ (pg/L)**	**# of Samples**	**TEQ (pg/L)**	**# of Samples**	**TEQ (pg/L)**	**# of Samples**	**TEQ (pg/L)**	**# of Samples**	**TEQ (pg/L)**
901	1[a]	3.144	ns	-	1[a]	3.159	1[a]	0.619	ns	-
1001	3	6.023	2	3.337	2	3.289	2	3.628	2	14.686
1005	4	7.440	2	8.605	4	7.098	3	3.364	3	15.155
1006	6	6.748	ns	-	6	8.406	6	6.807	3	10.422
1007	7	8.082	2	3.861	6	6.458	7	9.473	3	8.525
1013	2	1.288	ns	-	2	3.079	2	0.569	ns	-
2421	5	2.542	ns	-	5	5.047	1[a]	4.797	1[a]	1.185
2426	4	3.919	2	4.239	2	3.625	2	2.585	1[a]	1.794
2427	2	6.890	1[a]	7.175	1[a]	9.900	1[a]	4.317	1[a]	4.894
2428	2	3.480	ns	-	2	3.254	1[a]	1.403	1[a]	0.935
2429	2	4.898	2	5.510	1[a]	12.791	1[a]	5.217	1[a]	13.793
2430	3	6.441	1[a]	10.521	2	10.316	1[a]	12.164	1[a]	5.378
2436	2	2.226	1[a]	4.109	1[a]	4.805	ns	-	ns	-
2438	2	1.527	ns	-	1[a]	0.793	ns	-	ns	-

[a] The value presented corresponds to the result for the single sample for that segment
ns = not sampled

Table 4.8b Summary of Average 2378-TCDD Concentrations in Catfish by Segment

Segment	Summer 2002		Fall 2002		Spring 2003		Spring 2004		Fall 2004	
	# of Samples	TCDD (pg/L)	# of Samples	TCDD (pg/L)	# of Samples	TCDD (pg/L)	# of Samples	TCDD (pg/L)	# of Samples	TCDD (pg/L)
901	1[a]	2.500	ns	-	1[a]	2.600	1[a]	0.180	ns	-
1001	3	5.367	2	2.826	2	2.860	2	3.225	2	13.750
1005	4	6.725	2	7.600	4	6.475	3	3.033	3	14.400
1006	6	5.967	ns	-	6	7.682	6	6.181	3	9.750
1007	7	5.538	2	3.300	6	5.575	7	8.650	3	7.680
1013	2	0.836	ns	-	2	2.175	2	0.225	ns	-
2421	5	1.886	ns	-	5	2.420	1[a]	4.200	1[a]	0.960
2426	4	3.348	2	3.325	2	3.138	2	2.170	1[a]	1.500
2427	2	6.325	1[a]	6.100	1[a]	9.200	1[a]	3.900	1[a]	4.400
2428	2	2.750	ns	-	2	2.950	1[a]	1.100	1[a]	0.630
2429	2	4.400	2	5.200	1[a]	12.000	1[a]	4.600	1[a]	13.000
2430	3	5.667	1[a]	10.000	2	9.275	1[a]	11.000	1[a]	5.000
2436	2	1.900	1[a]	3.150	1[a]	4.400	ns	-	ns	-
2438	2	1.325	ns	-	1[a]	0.510	ns	-	ns	-

[a] The value presented corresponds to the result for the single sample for that segment
ns = not sampled

Table 4.9a Summary of Average TEQ Concentrations in Crab by Segment

Segment	Summer 2002		Fall 2002		Spring 2003		Spring 2004		Fall 2004	
	# of Samples	**TEQ (pg/L)**	**# of Samples**	**TEQ (pg/L)**	**# of Samples**	**TEQ (pg/L)**	**# of Samples**	**TEQ (pg/L)**	**# of Samples**	**TEQ (pg/L)**
901	1[a]	1.132	ns	-	1[a]	0.926	1[a]	0.820	ns	-
1001	3	2.609	1[a]	1.361	2	2.438	2	2.708	2	9.763
1005	4	7.668	2	3.669	4	4.283	3	4.186	3	9.298
1006	6	4.906	ns	-	6	2.716	6	4.054	3	8.248
1007	7	3.645	ns	-	7	4.449	7	3.302	3	6.704
1013	2	2.132	ns	-	2	2.657	ns	-	ns	-
2421	5	1.579	1[a]	0.322	5	0.903	1[a]	1.969	1[a]	1.500
2426	4	1.197	2	3.399	2	1.346	2	0.787	1[a]	2.495
2427	2	5.649	1[a]	3.108	1[a]	9.167	1[a]	3.812	1[a]	4.787
2428	2	0.883	1[a]	1.973	2	2.597	1[a]	1.866	1[a]	1.321
2429	2	5.126	2	5.533	1[a]	3.139	1[a]	5.900	1[a]	11.163
2430	3	4.460	1[a]	4.551	2	4.544	1[a]	5.010	1[a]	4.320
2436	2	3.099	1[a]	2.097	1[a]	0.795	ns	-	ns	-
2438	2	0.919	1[a]	0.449	1[a]	0.743	ns	-	ns	-

[a] The value presented corresponds to the result for the single sample for that segment
ns = not sampled

Table 4.9b Summary of Average 2378-TCDD Concentrations in Crab by Segment

Segment	**Summer 2002**		**Fall 2002**		**Spring 2003**		**Spring 2004**		**Fall 2004**	
	# of Samples	**TCDD (pg/L)**	**# of Samples**	**TCDD (pg/L)**	**# of Samples**	**TCDD (pg/L)**	**# of Samples**	**TCDD (pg/L)**	**# of Samples**	**TCDD (pg/L)**
901	1[a]	0.700	ns	-	1[a]	0.595	1[a]	0.460	ns	-
1001	3	1.827	1[a]	0.800	2	1.868	2	2.050	2	7.500
1005	4	5.763	2	2.950	4	3.350	3	3.200	3	7.300
1006	6	3.700	ns	-	6	2.169	6	2.957	3	6.800
1007	7	2.537	ns	-	7	3.386	7	2.324	3	5.153
1013	2	0.485	ns	-	2	2.100	ns	-	ns	-
2421	5	1.022	1[a]	0.105	5	0.560	1[a]	1.500	1[a]	1.000
2426	4	0.725	2	2.550	2	0.693	2	0.375	1[a]	2.000
2427	2	4.200	1[a]	2.500	1[a]	7.000	1[a]	2.900	1[a]	3.800
2428	2	0.440	1[a]	1.400	2	0.505	1[a]	0.970	1[a]	0.860
2429	2	3.650	2	4.200	1[a]	2.400	1[a]	4.400	1[a]	8.900
2430	3	3.133	1[a]	3.550	2	3.700	1[a]	3.800	1[a]	3.400
2436	2	2.400	1[a]	1.600	1[a]	0.540	ns	-	ns	-
2438	2	0.625	1[a]	0.120	1[a]	0.560	ns	-	ns	-

[a] The value presented corresponds to the result for the single sample for that segment
ns = not sampled

Figure 4.6 shows TEQ concentration profiles along the main channel for catfish and crab samples collected in 2004 (WO7) compared to those measured in 2002-2003 (WO4) as well as the overall averages. As can be seen in Figure 4.6, the longitudinal profile for catfish presented a peak in Segment 1006 for the 2002-2003 samples and two peaks (segments 1007 and 1005) for the 2004 samples. Most of the tributary and side bay samples were at or below the levels in the main channel, with the exception of segments 2429 (Scott Bay) and 2430 (Burnett Bay). In addition, the dioxin concentration at Station 11193 in the San Jacinto River is comparable to those measured at the confluence with the main channel. This is interesting given that the water and sediment data showed a disproportionate peak at Station 11193. Crab data showed flatter profiles, with a small peak in Segment 1005. Once again, crabs samples collected at Station 11193 did not show TEQ concentrations much higher than those measured in the main channel. Data in Figure 4.6 also suggest that spatial variability is attenuated between water/sediment and tissue samples. (See Figures 2.6 and 3.13 for water and sediment profiles, respectively.) Possible explanations include biota mobility and preferential bioaccumulation of lower chlorinated congeners.

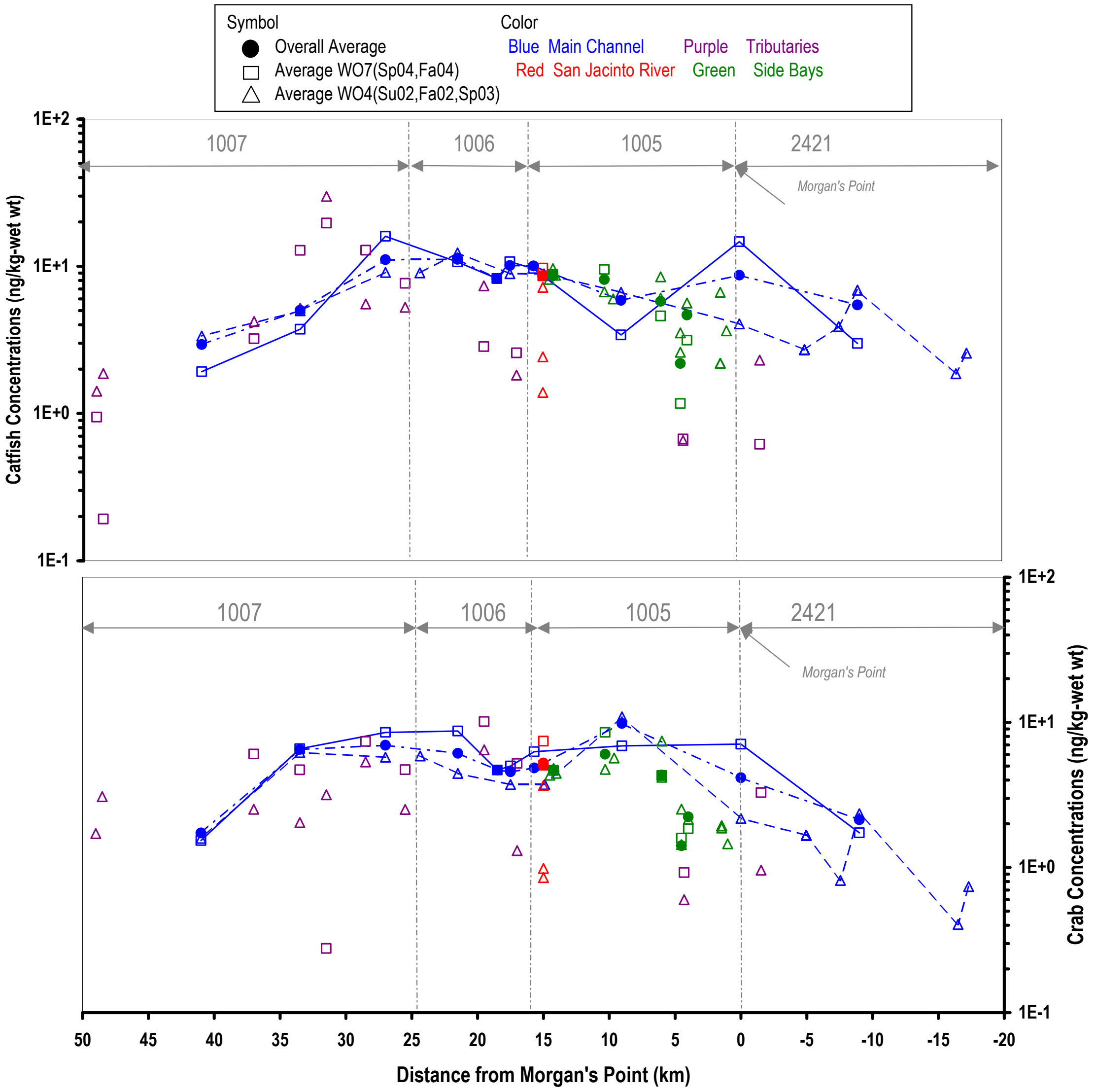


Figure 4.6 Total Tissue TEQ Concentration Profiles

4.4.2 Temporal Trends

PCDD/PCDF concentrations in water at the locations sampled during all five sampling events (Summer 2002, Fall 2002, Spring 2003, Spring 2004, and Fall 2004) of this project were analyzed using the Mann-Kendall test to evaluate possible trends over time. Table 4.10 presents a summary of the data trends for water samples. Each data "series" is comprised of five data points that correspond to the measurements during each of the sampling events. Because the concentrations were ordered chronologically, the results are showing trends over time. The values in the table are the resultant probability given by the S-value derived from the critical values table presented in Appendix C.

It appears that the higher chlorinated furans are decreasing over the sampling period, while dioxins are for the most part either stable or increasing, though only two series presented a significant upward trend (123678-HxCDD in crabs from 11261 and 123789-HxCDD in catfish from 13342).

4.4.3 Seasonal Trends

Average congener profiles for catfish and crabs by season for the stations that were sampled during each event are presented in Figure 4.7. Similar to observations made from water and sediment data, the profiles did not change significantly from one season to another. Exceptions to note are 2378-TCDD in catfish and crab and 2378-TCDF in catfish samples, whose averages showed a considerable increase in Fall 2004. Results from a statistical analysis using a Wilconox Signed Rank indicated that

2378-TCDD concentrations in catfish were significantly different between time periods 3-4, 5-1, 5-2, and 5-4 (1 is Summer 2002, 2 is Fall 2002, 3 is Spring 2003, 4 is Spring 2004, and 5 is Fall 2004), and the test results for 2378-TCDF show significant

Table 4.10 Probability Results for Mann-Kendall Test for Trend of Tissue Samples

Media Station	**2,3,7,8-TCDD**	**1,2,3,7,8-PeCDD**	**1,2,3,4,7,8-HxCDD**	**1,2,3,6,7,8-HxCDD**	**1,2,3,7,8,9-HxCDD**	**1,2,3,4,6,7,8-HpCDD**	**OCDD**	**2,3,7,8-TCDF**	**1,2,3,7,8-PeCDF**
cat11193	0.408	0.592	0.592	0.592	0.408	0.408	0.592	0.408	0.117
cat11252	0.408	0.408	0.117	0.592	0.408	0.408	0.592	0.408	0.408
cat11261	0.592	0.080	0.242	0.408	0.242	0.325	0.592	0.592	0.042
cat11280	0.408	0.592	0.592	0.592	0.242	0.180	0.242	0.242	0.592
cat11292	0.242	0.117	0.408	0.117	0.242	0.242	0.408	0.242	0.042
cat13342	0.242	0.117	0.408	0.117	0.042	0.408	0.500	0.408	0.408
crab11193	0.408	0.592	0.080	0.408	0.080	0.592	0.408	0.408	0.592
crab11252	0.242	0.408	0.408	0.408	0.408	0.408	0.592	0.242	0.242
crab11261	0.592	0.408	0.408	0.035	0.242	0.408	0.592	0.408	0.242
crab13340	0.408	0.408	0.408	0.242	0.408	0.592	0.592	0.592	0.242
crab 13342	0.117	0.408	0.242	0.242	0.408	0.408	0.242	0.408	0.325

Media Station	**2,3,4,7,8-PeCDF**	**1,2,3,4,7,8-HxCDF**	**1,2,3,6,7,8-HxCDF**	**2,3,4,6,7,8-HxCDF**	**1,2,3,7,8,9-HxCDF**	**1,2,3,4,6,7,8-HpCDF**	**1,2,3,4,7,8,9-HpCDF**	**OCDF**	**Total TEQ**
cat11193	0.592	0.242	0.592	0.325	0.242	0.042	0.042	0.042	0.408
cat11252	0.592	0.242	0.325	0.242	0.242	0.117	0.408	0.028	0.592
cat11261	0.242	0.592	0.117	0.592	0.117	0.592	0.242	0.408	0.592
cat11280	0.592	0.242	0.592	0.325	0.242	0.042	0.117	0.042	0.408
cat11292	0.242	0.180	0.592	0.592	0.242	0.325	0.042	0.117	0.242
cat13342	0.242	0.242	0.408	0.117	0.500	0.408	0.080	0.592	0.242
crab11193	0.500	0.500	0.242	0.117	0.117	0.592	0.117	0.408	0.408
crab11252	0.242	0.242	0.408	0.408	0.242	0.592	0.592	0.242	0.117
crab11261	0.592	0.242	0.408	0.592	0.325	0.408	0.180	0.242	0.592
crab13340	0.408	0.408	0.408	0.242	0.242	0.500	0.242	0.242	0.592
crab 13342	0.117	0.408	0.408	0.242	0.242	0.408	0.028	0.242	0.117

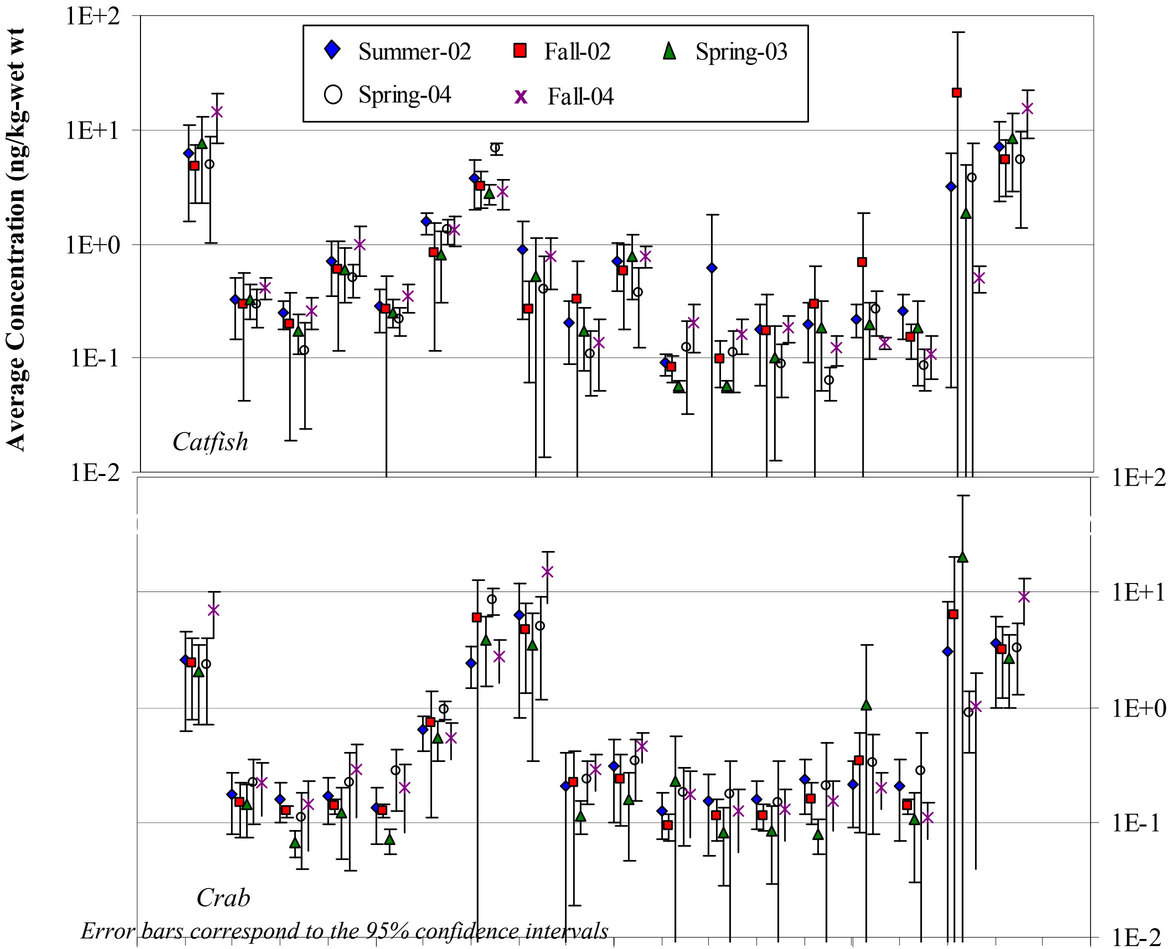
🟦	significant downward trend
🟩	downward trend
⬜	no trend
🟨	upward trend
🟧	significant upward trend

probabilities considered significant if the value is less than the alpha of 0.05

cat = catfish

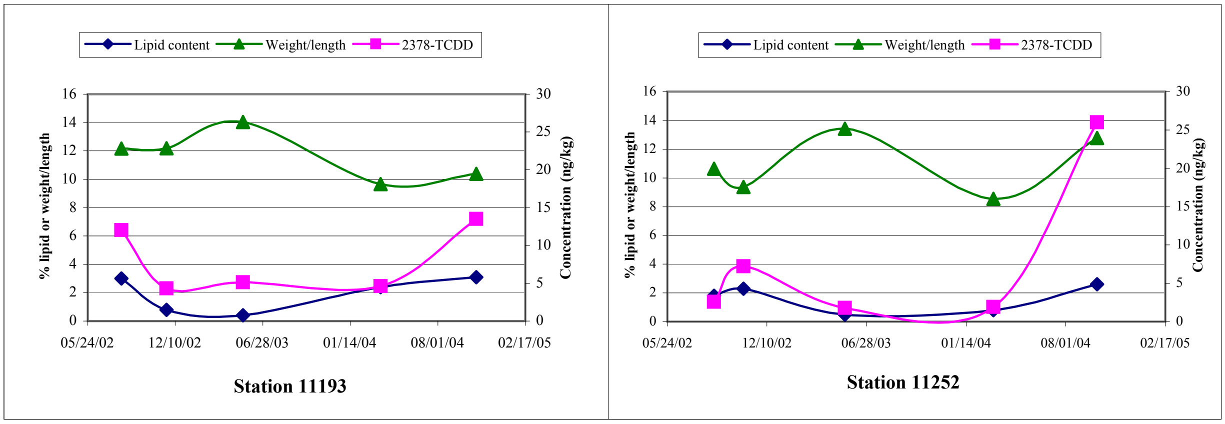
differences between time periods 1-4, 2-4, 3-4, and 5-4. Crab samples exhibited significant differences in 2378-TCDF concentrations between time periods 1-4, 3-4, and 5-4.

Lipid content may play an important role in the differences found in tissue samples, as indicated by much fewer differences found in the lipid-normalized sets. To further evaluate the role of lipid content and size (expressed as the weight/length ratio) on the measured dioxin concentrations, their relationship was plotted in Figures 4.8a and b for catfish and crab, respectively. For catfish, the 2378-TCDD curves seem to mimic the lipid content curves, especially at stations 11261, 11280, and 11292. The relationship with fish size is less marked but present. For crabs, the relationships appear much weaker than those observed for catfish, especially for the weight/length ratio.



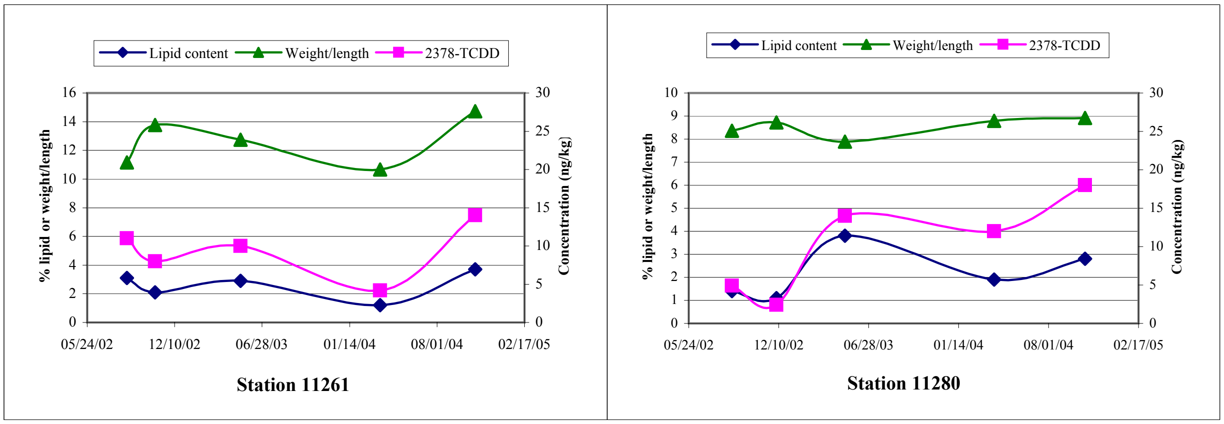
Error bars correspond to the 95% confidence intervals
2378-PCDDs indicated by a letter D followed by a number, with D1 being TCDD and D7 OCDD
2378-PCDFs indicated by a letter F followed by a number, with F1 being TCDF and F10 OCDF

Figure 4.7 Seasonal Variation of Dioxins in Tissue in the HSC



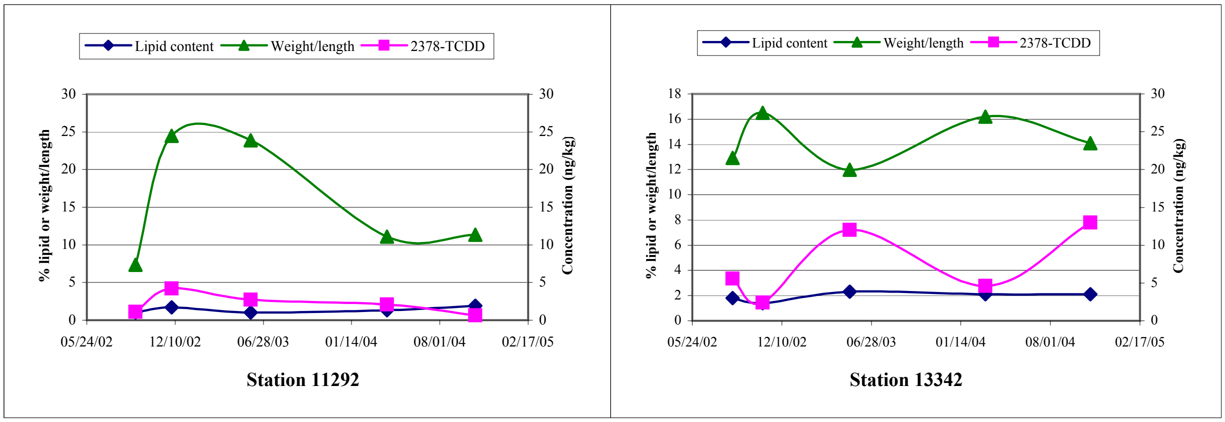
Station 11193

Station 11252



Station 11261

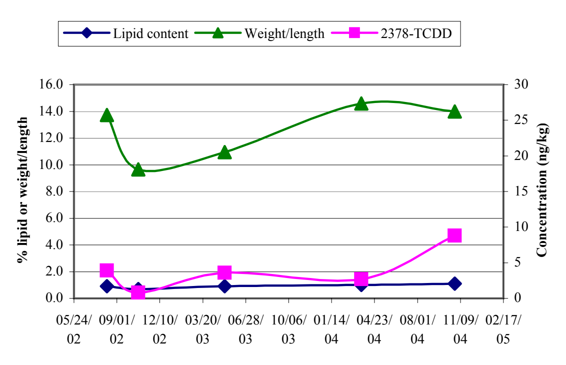
Station 11280



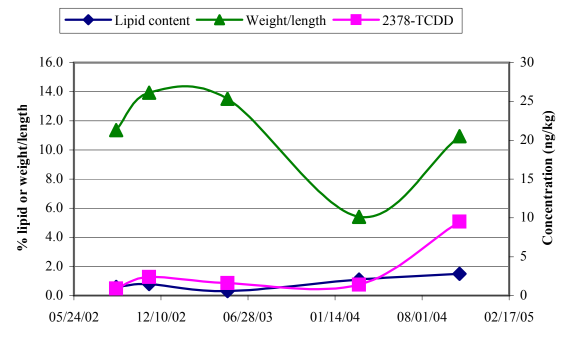
Station 11292

Station 13342

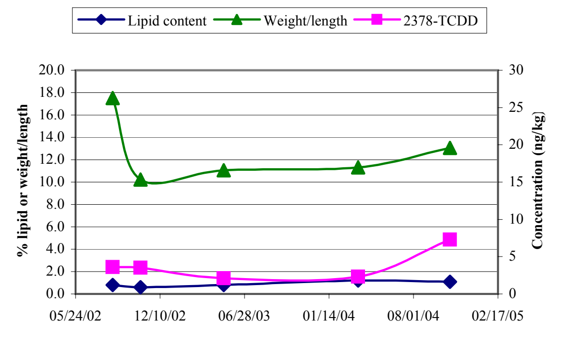
Figure 4.8a Relationship between Lipid Content/Fish Size and 2378-TCDD Concentrations



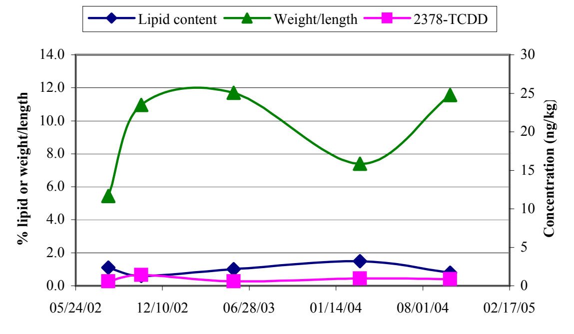
Station 11193



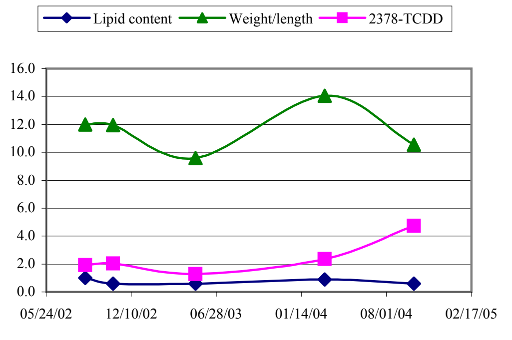
Station 11252



Station 11261



Station 13340



Station 13342

Figure 4.8b Relationship between Lipid Content/Crab Size and 2378-TCDD Concentrations

CHAPTER 5

DIOXIN IN SLUDGE AND EFFLUENT FROM POINT SOURCES DISCHARGING INTO THE HOUSTON SHIP CHANNEL SYSTEM

5.1 METHODS

5.1.1 Sampling Procedures

Sludge was sampled from three different types of sources: recirculation lines, belt presses, and settling ponds. Each of the sources was sampled using a different technique. The sampling of the recirculation lines was conducted by placing a sample container under the outlet valve in the recirculation line and opening the valve to allow the sludge to flow into the container. The belt presses were sampled by taking the dried sludge off of the belt. Various grab samples off the belt presses were subsequently placed in a stainless steel bowl and mixed to ensure representative samples. The composite sample was then put into the sample container. The ponds were sampled in two different ways depending on the configuration of the pond: If the pond had a catwalk or was deeper than five feet, a dredge was used for sampling. The dredge was used to collect samples from different locations around the pond. If the pond was less than five feet in depth or did not have a catwalk, then a Teflon®-lined scoop or sludge judge kit was used to collect samples from different locations around the pond. In both cases, collected samples were put into a stainless steel bowl and composited to ensure a representative sample. The composite sample was then placed in the sample container. In addition to dioxin samples, a sample was collected at each sampled outfall for TOC analysis. Sample collection and handling followed the requirements specified in the QAPP for the project.

Effluent sampling was conducted using the high-volume sampler (see Chapter 2 for a brief explanation of the procedure). Sample sizes varied between 250 and 500 L depending on site characteristics. The sample volume was based on an estimated concentration range for the effluent data. The only exception was site WQ001539-001, at which a sample of only 134 L was collected because the sampling team was asked to leave the facility for safety reasons. In addition to dioxin samples, samples were collected at the beginning and end of high-volume sampling at each sampled outfall for TOC, DOC, TSS, and TDS analyses. Also, water quality parameters (DO, temperature, and pH) were measured at the time of physical sample collection. Sample collection and handling followed the requirements specified in the QAPP for the project. Three of the facilities (Shell Refinery, BP Solvay, and Clean Harbors) requested split samples. Thus, at those facilities samples were collected simultaneously using two high-volume units such that one set of samples (XAD-resin and filter) could be kept by the facility for independent analysis of dioxins. In addition to requesting a split sample, BP Solvay requested that a second sludge sample be collected and analyzed for dioxins. This was done.

5.1.2 Sampling Locations

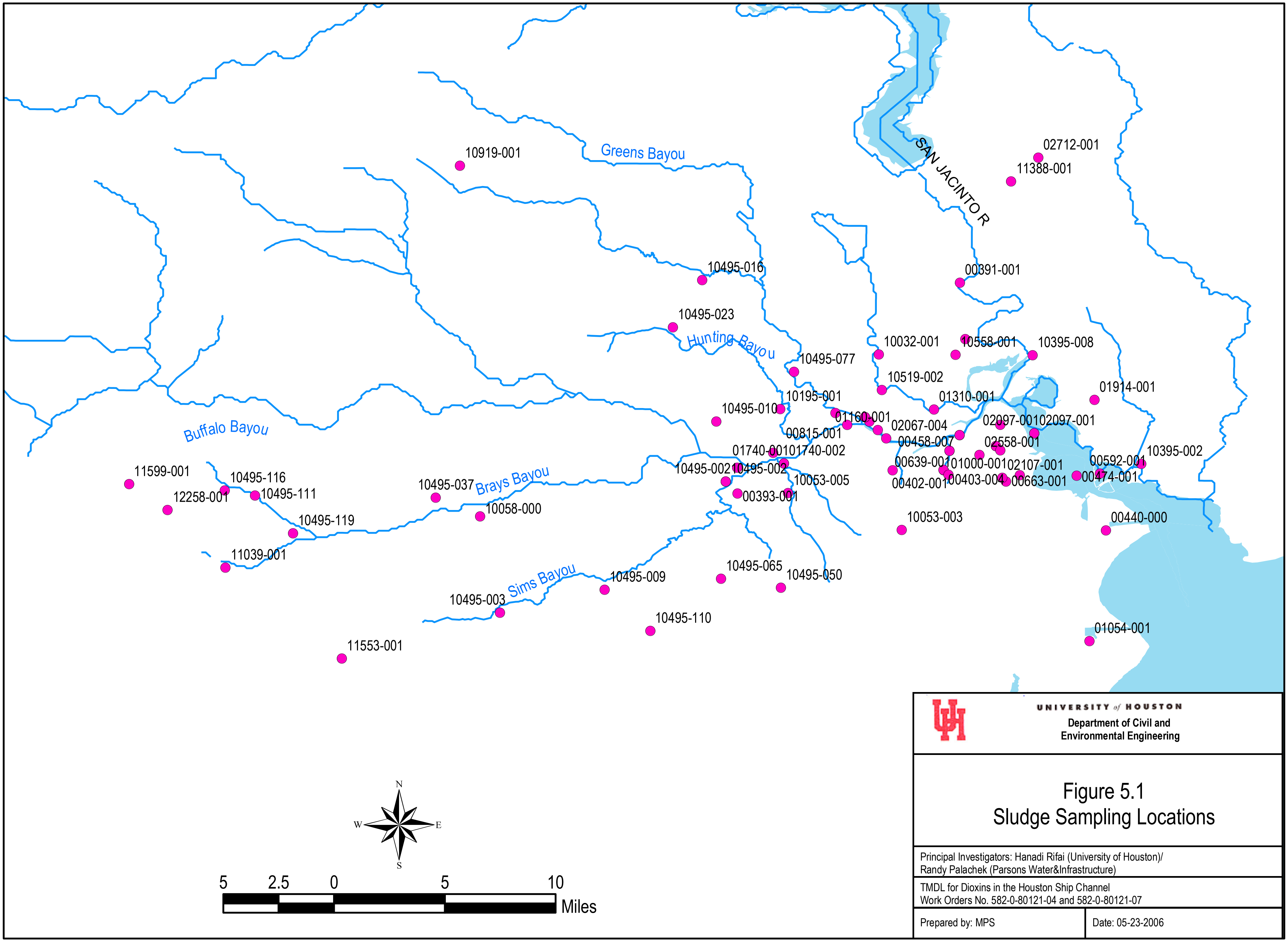
Sludge sampling was conducted during Summer 2002 at various industrial plants and municipalities discharging to the HSC system; these were identified as potential sources of dioxins based on their SIC classification. A total of 32 industrial facilities and

29 municipal wastewater treatment plants (WWTPs) were sampled for a total of 69 sampled outfalls. One outfall (BP Solvay 1) was resampled on 04/28/03 at the facility's request. The City of South Houston location was not sampled because the city denied access, and the Renn Road Municipal Utility District was not sampled due to its failure to respond to repeated attempts to contact. Figure 5.1 shows the location of the sampled facilities and Table 5.1 presents a list of the sampled outfalls.

A large number of facilities or outfalls (60) scheduled in the QAPP to be sampled for sludge were not sampled. Reasons for not sampling included absence of sludge, SIC code outside the ones listed in the QAPP, inactive facility, and access to facility denied. Table 5.2 includes a summary of the facilities not sampled. Twenty-five facilities or additional outfalls at the same facilities were sampled even though they were not included in the initial list of outfalls to be sampled.

Effluent samples were collected as part of the Spring 2003 sampling event. Site selection was based on two different criteria: concentration of dioxin in sludge and estimated load of dioxin in effluent. In both cases, the project team used the dioxin sludge data collected during Summer 2002 for the assessment. The rationale for site selection is described below and the selection matrix is included in Appendix D:

1. Rank all sludge sampled facilities by concentration (from highest to lowest).
2. Rank all sludge-sampled facilities by load (from highest to lowest), using the permitted flow and assuming each outfall discharges 10 mg/L of solids (TSS) with a dioxin concentration equal to the one measured in sludge.



UNIVERSITY of HOUSTON
Department of Civil and
Environmental Engineering

Figure 5.1
Sludge Sampling Locations

Principal Investigators: Hanadi Rifai (University of Houston)/
Randy Palachek (Parsons Water&Infrastructure)

TMDL for Dioxins in the Houston Ship Channel
Work Orders No. 582-0-80121-04 and 582-0-80121-07

Prepared by: MPS

Date: 05-23-2006

Table 5.1 List of Industrial Facilities and Municipalities Sampled for Sludge

Segment	Industrial Facilities	Permit Number	Date Sampled	Sludge Outfalls Sampled	Outfalls *Not* sampled (water, storm, etc.)
1006	Rohm and Haas Texas, Inc.	WQ0000458-000	8/5/2002	OTFL 001& OTFL 007	INPT 107
2427	Millenium Petrochemicals La	WQ0000534-000	8/6/2002	OTFL 001	INPT 701, OTFL 002- OTFL
2427	(Sunoco)Aristech Chemical Corporation	WQ0002107-000	8/6/2002	OTFL 001	OTFL 002
1006	Albermarle Corporation	WQ0000492-000	8/7/2002	OTFL 001	N/A
2427	Dow Chemical Company	WQ0000663-000	8/7/2002	OTFL 001	OTFL 002 & OTFL 003
1006	Oxy Vinyls, LP (Pasadena)	WQ0000002-000	8/8/2002	OTFL 001	INPT 101
1006	Oxy Vinyls, LP (Deer Park Works)	WQ0000305-000	8/8/2002	OTFL 001 & OTFL 005	INPT 101, INPT 201, OTFL 002- OTFL 004
1006	Reichhold, Inc.	WQ0000662-000	8/9/2002	OTFL 001	N/A
1005	Oxy Vinyls, LP (La Porte)	WQ0002097-000	8/12/2002	OTFL 001 & OTFL 003	OTFL 002
1006	DOW (aka Hampshire Chemical Corporation)	WQ0002558-000	8/12/2002	OTFL 001	
1005	Atofina Petrochemicals, Inc.	WQ0001000-000	8/13/2002	OTFL 001	
1006	The Lubrizol Corporation	WQ0000639-000	8/13/2002	OTFL 001	OTFL 002-OTFL 007
1001	Equistar Chemicals, L.P. & MI	WQ0000391-000	8/14/2002	OTFL 001	INPT 101
1001	Lyondell Chemical Company	WQ0002927-000	8/14/2002	OTFL 001	RUNOFF 202
2427	E.I. Du Pont De Nemours	WQ0000474-000	8/14/2002	OTFL 001	INPT 101 & INPT 201
1007	Chevron Phillips Chemical Co.	WQ0000815-000	8/15/2002	OTFL POND	OTFL 002, OTFL 003, and OTFL 004
2438	Gulf Coast Waste Disposal Authority (Bayport Central)	WQ0001054-000	8/16/2002	OTFL 001	
1006	Donohue Industries, Inc.	WQ0001160-000	8/19/2002	OTFL 001	
1007	Gulf Coast Waste Disposal Authority (WashburnTunnel)	WQ0001740-000	8/19/2002	OTFL 002 (Primary and Secondary)	
1007	Valero Refining Company - Tex	WQ0000535-000	8/20/2002	OTFL 001	OTFL 002
1007	Texmark Chemicals, Inc.	WQ0000786-000	8/20/2002	OTFL 001	OTFL 002
1006	Gulf Performance Polymers	WQ0001310-000	8/21/2002	OTFL 001	
1005	Exxon Mobil Refining and Supply	WQ0000592-000	8/22/2002	OTFL 001	INPT 102, OTFL 002, & OTFL 003
1005	Oxy Vinyls, LP (Battleground)	WQ0001539-000	8/22/2002	OTFL 001	INPT 201 & OTFL 002
1005	Solvay Polymers Inc. (BP Solvay)	WQ0000544-000	8/23/2002	OTFL 001, OTFL 003	OTFL 002, OTFL 004, & OTFL 005
1007	Mobil Chemical Company, Inc. (	WQ0000393-000	8/23/2002	OTFL 001	
1001	KMCO, Inc.	WQ0002712-000	8/26/2002	OTFL 001	
2426	Advanced Aromatics, LP	WQ0001914-000	8/26/2002	OTFL 001	OTFL 002
1006	Georgia Gulf Chemicals	WQ0002067-000	8/28/2002	OTFL 004	OTFL 001- OTFL 003, OTFL 005, OTFL 006, & INPT 101
1006	Shell Oil Company	WQ0000402-000	9/3/2002	OTFL 001	INPT 101, INPT 104, and OTFL 004
1006	GB Biosciences Corporation	WQ0000749-000	9/5/2002	OTFL 101 & OTFL 201	OTFL 001
2436	EGP Fuels Company (now EOTT)	WQ0000440-000	9/25/2002	OTFL 001	
1006	Shell Refinery	WQ0000403-000	10/23/2002	OTFL 007	OTFL 001, OTFL 002, OTFL 003, OTFL 004, OTFL 005, OTFL 006, OTFL 008, and OTFL 009
1006	Elf Atochem North America (now Atofina)	WQ0000445-000	8/21 - No sludge	OTFL 001	OTFL 002
1006	Specified Fuels & Chemicals	WQ0002419-000	8/28/02- No Sludge	N/A	OTFL 001
2426	Natural Gas Odorizing, Inc.	WQ0001385-000	Does not have a sludge outfall	N/A	OTFL 001
1005	Metton America, Inc.	WQ0002406-000	Does not have a sludge outfall	N/A	OTFL 001
1006	Global Octanes Corporation	WQ0003375-000	Does not have a sludge outfall	N/A	OTFL 002
2427	Noltex L.L.C.	WQ0004029-000	Does not have a sludge outfall	N/A	OTFL 001

Table 5.1 List of Industrial Facilities and Municipalities Sampled for Sludge

Segment	Municipal Facilities	Permit Number	Date Sampled	Sludge Outfalls Sampled	Outfalls *Not* sampled (water, storm, etc.)
1007	City of Houston	WQ0010495-002	8/23/2002	OTFL 001 (SIMS BAYOU NORTH and SIMS BAYOU SOUTH)	
1007	City of Houston	WQ0010495-010	8/23/2002	OTFL 001 CLINTON PARK	
1006	Harris County FWSD 051	WQ0010032-001	8/26/2002	OTFL 001	
1006	City of Houston	WQ0010495-077	8/27/2002	OTFL 001 NE PLT	
1006	City of Houston	WQ0010495-016	8/27/2002	OTFL 001 FWSD 23	
1007	City of Houston	WQ0010495-003	8/27/2002	OTFL 001 ALMEDA SIMS INPT	
1007	City of Houston	WQ0010495-009	8/27/2002	OTFL 001 CHOCOLATE BAYOU	
1007	City of Houston	WQ0010495-023	8/27/2002	OTFL 001 HOMESTEAD	
1007	City of Houston	WQ0010495-037	8/27/2002	OTFL 001 SOUTHWEST PLANT	
1007	City of Houston	WQ0010495-050	8/27/2002	OTFL 001 WCID 047	
1007	City of Houston	WQ0010495-065	8/27/2002	OTFL 001 EASTHAVEN PLANT	
1007	City of Houston	WQ0010495-110	8/27/2002	OTFL 110 GREEN RIDGE MUD	
1007	City of Houston	WQ0010495-111	8/27/2002	OTFL 001 BELTWAY	
1007	City of Houston	WQ0010495-116	8/27/2002	OTFL 001 UPPER BRAYS	
1007	City of Houston	WQ0010495-119	8/27/2002	OTFL 001 KEEGANS BAYOU	
1001	City of Baytown	WQ0010395-008	8/28/2002	OTFL 001 WEST DISTRICT	
1006	City of Pasadena	WQ0010053-003	8/28/2002	OTFL 001 GOLDEN ACRES	
1007	City of Pasadena	WQ0010053- 005	8/28/2002	OTFL 001 VINCE BAYOU	
2426	City of Baytown	WQ0010395-002	8/28/2002	OTFL 001	
1006	Harris County WCID 84	WQ0010558-001	8/29/2002	OTFL 001	
1007	City of West University Place	WQ0010058-001	8/29/2002	OTFL 001	
1007	City of Jacinto City	WQ0010195-001	8/29/2002	OTFL 001	
1007	Beechnut MUD	WQ0012258-001	8/29/2002	OTFL 001	
1001	Crosby Municipal Utility District	WQ0011388-001	8/30/2002	OTFL 001	
1007	Blue Ridge West Mud	WQ0011553-001	9/5/2002	OTFL 001	
1007	Chelford City MUD	WQ0011599-001	9/5/2002	OTFL 001	
1006	City of Deer Park	WQ0010519-002	9/10/2002	OTFL 001 CENTRAL PLANT	
1007	City of Meadows	WQ0011039-001	9/10/2002	OTFL 001	
1006	Fallbrook Utility District	WQ0010919-001	9/24/2002	OTFL 001	

Table 5.2 Facilities Not Sampled for Sludge

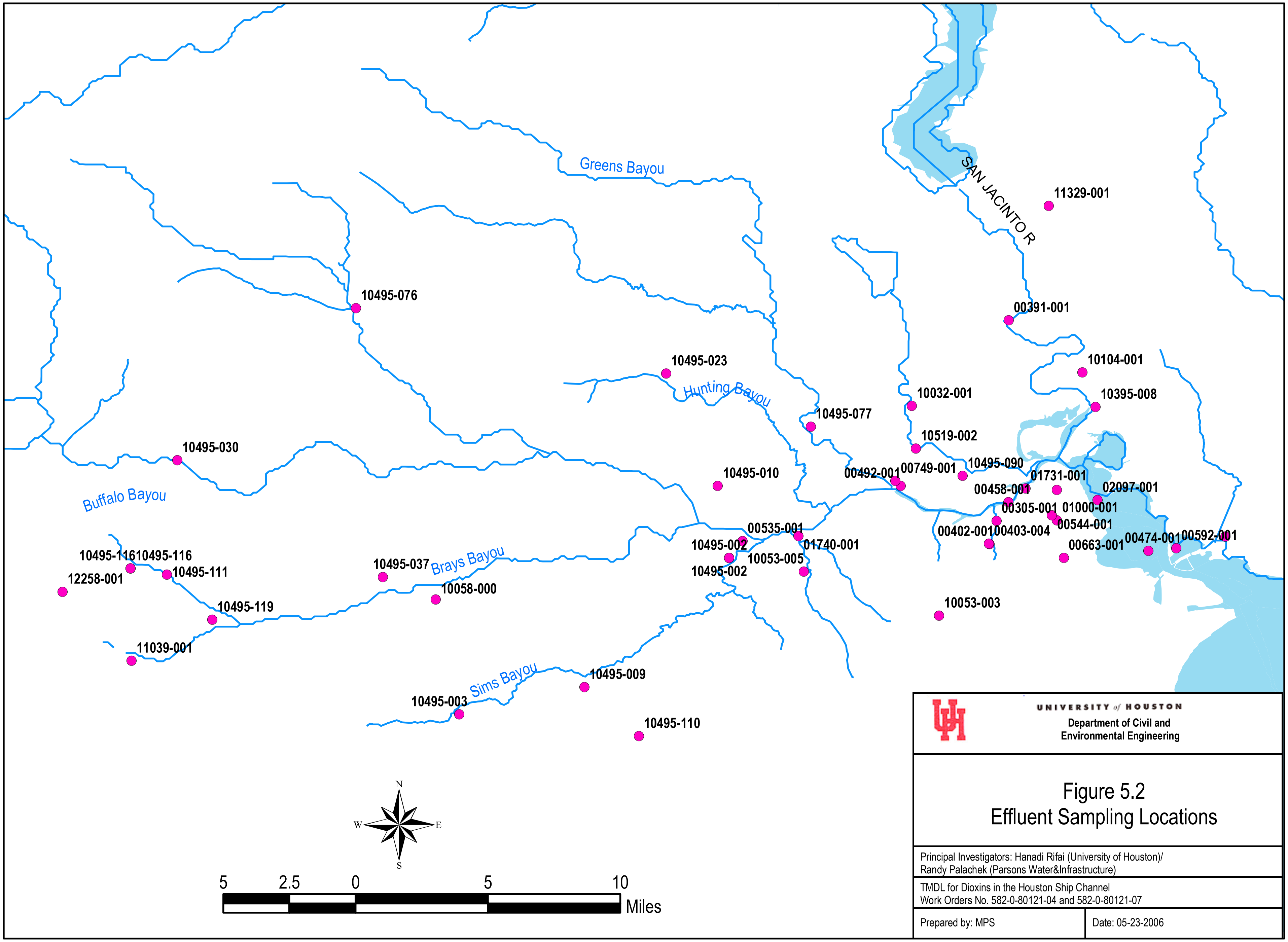
Segment	Site Description	Station ID/ Permit #	Reason for Not Sampling
1006	ELF ATOCHEM	00445-001	Now Atofina - no sludge (went to facility)
1007	HOLNAM, INC	00456-001	SIC code not among potential dioxin sources 50320 - home furnishings
1007	ARMCO INC.	00509-003	SIC code not among potential dioxin sources + only domestic and stormwater outfalls 6512 - NONRESIDENTIAL BUILDING OPERATORS
2427	EQUISTAR CHEMICALS	00534-002	outfall not active
1007	BAYER CORP	00587-001	SIC code not among potential dioxin sources 2822 - synthetic rubber
1007	MOBIL OIL CORP	00649-001	SIC code not among potential dioxin sources 2874 - Phosphatic Fertilizers
2430	HI-PORT INC.	01062-001	SIC code not among potential dioxin sources 2430-MILLWORK, PLYWOOD & STRUCTURAL
1006	PRAXAIR, INC.	01173-001	SIC code not among potential dioxin sources 28130 - industrial gases
2427	AIR PRODUCTS	01280-001	SIC code not among potential dioxin sources, 28130- industrial gases
2426	NATURAL GAS ODORIZING, INC.	01385-001	no sludge per letter
1006	ROLLINS ENVIRONMENTAL	01429-001	SIC code not among potential dioxin sources 49530 - refuse systems
1006	EMPAK, INC.	01731-001	SIC code not among potential dioxin sources 49530 - refuse systems, included for effluent sampling
1006	INTERCONTINENTAL TERMINALS	01984-002	SIC code not among potential dioxin sources 42260 - SPECIAL WAREHOUSING AND STORAGE
1006	SEQUA CORP	02160-001	minor industrial 0.03 mgd
1006	AIR PRODUCTS, INC.	02177-001	SIC code not among potential dioxin sources, 28130- industrial gases
2429	EXXON CHEMICAL ASSET	02184-001	not included for sludge sampling, included for effluent sampling
1005	METTON AMERICA	02406-001	no sludge - verbal
1006	JOHANN HALTERMANN	02458-001	SIC code not among potential dioxin sources 28990 - CHEMICAL PREPARATIONS, NEC
1005	TX SOUTHWEST SHIPYARD	02605-001	SIC code not among potential dioxin sources 37310 - SHIP BUILDING AND REPAIRING
1006	DICKSON WEATHERPROOF	02650-001	inactive
1007	ECONO-RAIL CORP.	02659-001	SIC code not among potential dioxin sources 50520 - COAL AND OTHER MINERALS AND ORES
2430	HOUSTON MARINE SERVICES	02842-002	SIC code not among potential dioxin sources 51710 - PETROLEUM BULK STATIONS & TERMINALS
1001	CO-GEN LYONDELL INC.	02845-002	SIC code not among potential dioxin sources 49310 - ELECTRIC AND OTHER SERVICES COMBINED
1006	STOLTHAVEN HOUSTON	03129-003	SIC code not among potential dioxin sources 42260 - SPECIAL WAREHOUSING AND STORAGE, NEC
1006	AIR LIQUIDE AMERICA	03167-001	SIC code not among potential dioxin sources, 28130- industrial gases
1007	NORTHWESTERN STEEL & WIRE	03272-001	SIC code not among potential dioxin sources 33120 - BLAST FURNACES AND STEEL MILLS
1006	KAW TRANSPORT CO.	03317-001	SIC code not among potential dioxin sources 76990 - REPAIR SERVICES, NEC
1006	GLOBAL OCTANES	03375-002	no sludge - verbal
1001	OTTO MARINE ENTERPRISE INC.	03445-001	SIC code not among potential dioxin sources 50930 - SCRAP AND WASTE MATERIALS
1001	TRUCK STOP CORP	03517-001	SIC code not among potential dioxin sources 54110 - GROCERY STORES
1007	AMERI-FORGE CORP	03767-001	SIC code not among potential dioxin sources 34620 - IRON AND STEEL FORGINGS
1006	ISK MAGNETICS INC	03834-001	SIC code not among potential dioxin sources 28160 - INORGANIC PIGMENTS
1006	DISPOSAL SYSTEMS INC.	03937-001	SIC code not among potential dioxin sources 49530 - refuse systems
1007	COOPER, JERRRY	03987-001	SIC code not among potential dioxin sources 49530 - refuse systems
1007	FKP, INC.	03999-001	SIC code not among potential dioxin sources 28190 - INDUSTRIAL INORGANIC CHEMICALS, NEC
2427	NOLTEX L.L.C.	04029-001	utility water only, no process wastewater discharge
1006	HARSCO CORP	04102-001	inactive
1006	PASADENA-DEEPWATER	10053-002	The outfall at Vince Bayou was sampled instead
1001	HARRIS CO WCID 001	10104-001	not included for sludge sampling, included for effluent sampling
1006	HARRIS CO WCID 021	10105-001	not included for sludge sampling, included for effluent sampling
1006	HARRIS CO FWSD 006	10184-001	minor domestic 0.4 mgd
1007	CITY OF SOUTH HOUSTON	10287-001	declined to participate
1001	HARRIS CO WCID 070	10530-001	minor domestic 0.17 mgd
1001	HARRIS CO FWSD 058	10668-001	minor domestic 0.35 mgd
1006	HARRIS CO FWSD 047	10794-001	minor domestic 0.52 mgd
1007	GALENA PARK	10831-001	minor domestic 0.95 mgd
1007	GALENA PARK	10831-002	minor domestic 0.1 mgd
2426	HARRIS CO FWSD 001A	11195-001	inactive
1001	NEWPORT MUD	11329-001	not included for sludge sampling, included for effluent sampling
2426	COUNTRY TERRACE WATER	11955-001	minor domestic 0.22 mgd
1006	CARGILL, INC.	12231-001	inactive
1006	QUARTERS	12318-001	minor domestic 0.005 mgd
1001	UTILITIES INVESTMENT CORP	12863-001	minor domestic 0.1 mgd
1006	COFLEXIP STENA	12874-001	minor domestic 0.0015 mgd
1006	HARRIS CO MUD 285	12928-001	minor domestic 0.25 mgd
1006	PORT OF HOUSTON AUTH	13203-001	minor domestic 0.005 mgd
1006	S.I. ENTERPRISES	13316-001	minor domestic 0.002 mgd
1001	CHAPMAN, PAT	13964-001	SIC code not among potential dioxin sources 65150 - MOBILE HOME SITE OPERATORS

This outfall will be sampled in Phase III

3. Select outfalls that ranked high based on both concentration and load (28 in total).
4. Identify facilities that were not selected using Steps 1-3 but that still had relatively high load, and add those to selected facilities in Step 3 (a total of 11).
5. Identify facilities that have not had their sludge sampled, and update status with respect to effluent sampling. Also, identify facilities with SIC codes that were left off previous lists/databases, and evaluate for effluent sampling; eight outfalls were added to the list in this step.

A total of 47 outfalls were identified for effluent sampling, and samples were collected at 44 of them. The location at Harris County WCID 021 was not sampled because access was denied. The Blue Ridge Municipal Utility District was not sampled due to their failure to respond to repeated contacts, and a sample from Oxy Vinyl's Deer Park Outfall 001 was not collected because the chlor-alkali portion of that facility has been idled since the end of December 2001. Thus, Outfall 001 from the mercury cell chlor-alkali plant is now carrying only intermittent treated storm water and a small amount of once-through non-contact cooling water. In addition to those 44 facilities, a sample at City of Baytown-West District was collected, even though more recent data indicate that the facility is not among the highest potential sources.

Figure 5.2 shows the location of the 45 outfalls sampled for effluent, and Table 5.3 includes a summary of the outfalls sampled for effluent.



UNIVERSITY of HOUSTON
Department of Civil and Environmental Engineering

Figure 5.2
Effluent Sampling Locations

Principal Investigators: Hanadi Rifai (University of Houston)/
Randy Palachek (Parsons Water&Infrastructure)

TMDL for Dioxins in the Houston Ship Channel
Work Orders No. 582-0-80121-04 and 582-0-80121-07

Prepared by: MPS

Date: 05-23-2006

5.1.3 Analytical Methods

PCDDs and PCDFs in sludge samples were quantified by high-resolution gas chromatography/high resolution mass spectrometry (HRGC/HRMS) using EPA Method 1613B at Pace Analytical. Sediment samples were homogenized, spiked with fifteen $^{13}C_{12}$-labeled PCDD/PCDF internal standards, and extracted using a Soxhlet extraction apparatus. The extracts were then spiked with 2378-TCDD-$^{37}C_{l4}$ enrichment efficiency standard and subjected to acid/base washes, multiplayer silica, alumina, and carbon column cleanup procedures to remove interferences from the extracts. After cleanup, the extracts were concentrated to near dryness and spiked with recovery standards (1234-TCDD-$^{13}C_{12}$ and 123789-HxCDD-$^{13}C_{12}$) immediately prior to injection. Chromatographic separation was achieved with a DB-5 capillary chromatography column (60 m, 0.25 mm i.d., 0.25 µm film thickness). A second column DB-225 (30 m, 0.25 mm i.d., 0.25 µm film thickness) was used for confirmation of TCDF identification.

PCDDs and PCDFs in effluent samples were quantified by high-resolution gas chromatography/high resolution mass spectrometry (HRGC/HRMS) using EPA Method 1613B at PSC/Maxxam Analytical. Resin and filters from effluent samples were homogenized, spiked with 15 $^{13}C_{12}$-labeled PCDD/PCDF internal standards, and mixed with sodium sulfate, allowing 12-24 hours to dry. Subsequently, the samples were extracted for 18-24 hours using methylene chloride, hexane (1:1) in a Soxhlet extractor, and the extract was evaporated to dryness. The extracts were then spiked with 2378-TCDD-$^{37}C_{l4}$ enrichment efficiency standard and were subjected to acid/base washes, multiplayer silica, alumina, and carbon column cleanup procedures to remove interferences from the extracts. After cleanup, the extracts were concentrated to near dryness and spiked with recovery standards (1234-TCDD-$^{13}C_{12}$ and 123789-HxCDD-$^{13}C_{12}$) immediately prior to injection. Chromatographic separation was achieved with a DB-5 capillary chromatography column (60 m, 0.25 mm i.d., 0.25 µm film thickness). A second column DB-225 (30 m, 0.25 mm i.d., 0.25 µm film thickness) was used for confirmation of TCDF identification.

Physical properties of sludge and effluent samples were analyzed at North Water District Laboratory Services (NWDLS) using standard methods (U.S. Environmental Protection Agency, 1983) as follows: organic content of sediments (TOC) Lloyd Kahn, total solids content EPA 160.3, TDS EPA 160.1, TSS EPA 160.2, TOC EPA 415.2, and DOC EPA 415.2. Standard field parameters (temperature, pH, salinity, and conductivity) were measured using a YSI multiparameter probe (model 6920 or 600XLM).

5.2 QUALITY CONTROL

Field duplicates for sludge samples were collected at a 7% frequency, while for effluent a field duplicate was collected at the City of Deer Park outfall. Field blanks were collected at a frequency of 5%. In addition, laboratory duplicates and blanks were run at a frequency of 5%. Overall, when detected, both field and laboratory blanks showed levels below 5% of the levels in the samples. Results obtained from the duplicate samples were consistent and in agreement with the method requirements for the different congeners. QC data are included in Appendix A. Non-detects were assumed to be equal to half of the detection limit for total equivalence quotient (TEQ) calculations.

5.3 RESULTS

Dioxin results from the sludge sampling effort conducted during Summer 2002 are summarized in Table 5.4. This table also includes the physical characteristics of sludge samples. Figure 5.3 depicts the total TEQ levels at each sampled location. Dioxin concentrations for sludge samples varied between 0.06 and 7,598 ng TEQ/kg-dry wt. with an average value of 154.04 ng TEQ/kg-dry wt. Dioxin levels in sludge associated with the organic carbon were within the range 0.8 - 37,428 ng TEQ/kg-oc, with a mean OC-normalized concentration of 1015 ng TEQ/kg-oc. Appendix B includes the results received from Pace Analytical Laboratory for the sludge samples.

Table 5.5 provides a summary of field parameters measured throughout effluent sampling activities during Spring 2003. The physical characteristics of effluent samples are summarized in Table 5.6. In addition, dioxin results from the effluent sampling are summarized in Table 5.7, and the calculated Texas TEQ concentrations are presented in Figure 5.4. Dioxin concentrations for effluent samples varied between 0.03 and 2.01 pg TEQ/L, with an average value of 0.21 pg TEQ/L (non-detects assumed to be half of the MDL). Appendix B includes the results received from PSC Philips Analytical Laboratory for the effluent samples.

Table 5.3 Summary of Effluent Locations and Volumes

Segment	Facility Name	Permit Number	Sample Date	Outfall ID	Volume Sampled (L)
1006	City of Pasadena- Golden Acres	WQ0010053-003	02/18/2003	OTFL 001	508
1007	City of Pasadena- Vince Bayou	WQ0010053-005	02/18/2003	OTFL 001	253
1006	Harris County- FWSD 051	WQ0010032-001	02/19/2003	OTFL 001	273
1007	City of Houston- Simms South	WQ0010495-002	02/19/2003	OTFL 002	501
1006	GB Biosciences	WQ0000749-001	02/20/2003	OTFL 101	256
1007	City of Houston- Simms North	WQ0010495-002	02/20/2003	OTFL 001	504
1007	City of Houston- Southwest Plant	WQ0010495-037	02/25/2003	OTFL 001	503
1007	City of Houston- Beltway	WQ0010495-111	02/25/2003	OTFL 001	502
1007	City of Houston- Homestead	WQ0010495-023	02/26/2003	OTFL 001	508
1007	City of Houston- 69th Street	WQ0010495-090	02/26/2003	OTFL 001	504
1007	City of Houston- FWSD-23	WQ0010495-116	02/27/2003	OTFL 001	503
1001	Equistar	WQ0000391-001	03/06/2003	OTFL 001	255
1006	Oxy Vinyls- LP - La Porte	WQ0002097-000	03/07/2003	OTFL 001	254
1007	Valero	WQ0000535-000	03/11/2003	OTFL 001	253
1005	Exxon Bayport Refinery	WQ0000592-000	03/11/2003	OTFL 001	501
1006	Shell Chemical	WQ0000402-000	03/12/2003	OTFL 001	252
1006	Albermarle	WQ000492-000	03/12/2003	OTFL 001	251
1001	City of Baytown- Baytown Central	WQ0010395-002	03/13/2003	OTFL 001	257
1001	City of Baytown- Baytown West	WQ0010395-008	03/13/2003	OTFL 001	259
1007	City of Houston- Keegans Bayou	WQ0010495-119	03/14/2003	OTFL 001	505
1005	Atofina	WQ001000-000	03/18/2003	OTFL 001	269
2427	Dow DP	WQ000663-000	03/19/2003	OTFL 001	260
1007	City of Houston- Almeda Sims	WQ0010495-003	03/20/2003	OTFL 001	502
1007	City of Houston- Chocolate Bayou	WQ0010495-009	03/20/2003	OTFL 001	259
1007	City of Houston- Upper Brays	WQ0010495-116	03/21/2003	OTFL 001	506
1007	City of Houston- Clinton Park	WQ0010495-010	03/25/2003	OTFL 001	255
1006	City of Houston- Northeast	WQ0010495-077	03/25/2003	OTFL 001	252
1006	Rohm & Haas	WQ0000458-001	03/26/2003	OTFL 007	264
1007	Gulf Coast Waste Disposal Authority	WQ0001740-001	03/27/2003	OTFL 002	500
1007	City of West University Place	WQ0010058-001	03/28/2003	OTFL 001	256
1007	City of Houston- Greenridge MUD	WQ0010495-110	03/28/2003	OTFL 110	253
1007	Beechnut MUD	WQ0012258-001	04/01/2003	OTFL 001	262
2427	E.I Du Pont De Nemours	WQ0000474-000	04/02/2003	OTFL 001	253
1006	City of Deer Park	WQ0010519-002	04/02/2003	OTFL 001	254
1006	Shell Refinery	WQ000403-000	04/10/2003	OTFL 001	258
1005	BP Solvay	WQ000544-001	04/28/2003	OTFL 001	257
1007	City of Meadows	WQ0011039-001	05/08/2003	OTFL 001	250
1001	Harris County MUD 019/ Newport M	WQ0011329-001	05/08/2003	OTFL 001	252
1006	Vopak	WQ001731-001	06/24/2003	OTFL 001	253
1014	City of Houston- West District	WQ0010495-030	06/25/2003	OTFL 001	251
1017	City of Houston- Northwest	WQ0010495-076	06/25/2003	OTFL 001	252
1006	Oxy Vinyls DP OF 005	WQ0000305-000	07/22/2003	OTFL 005	252
1006	Clean Harbors	WQ0001429-001	08/07/2003	OTFL 001	261
1005	Oxy Battleground	WQ001539-001	05/07/2003	OTFL 001	134
1001	Harris County WCID 1	WQ0010104-001	05/07/2003	OTFL 001	199

Notes:

Locations of duplicates are not included

Table 5.4 Dioxin Concentrations in Sludge (ng/kg-dry wt.)

Facility Name	Permit Number	Date	Segment	SIC Code	Matrix	% Solids	TOC (%)	2,3,7,8-TCDD	1,2,3,7,8-PeCDD	1,2,3,4,7,8-HxCDD	1,2,3,6,7,8-HxCDD	1,2,3,7,8,9-HxCDD	1,2,3,4,6,7,8-HpCDD	OCDD	2,3,7,8-TCDF	1,2,3,7,8-PeCDF	2,3,4,7,8-PeCDF	1,2,3,4,7,8-HxCDF	1,2,3,6,7,8-HxCDF	2,3,4,6,7,8-HxCDF	1,2,3,7,8,9-HxCDF	1,2,3,4,6,7,8-HpCDF	1,2,3,4,7,8,9-HpCDF	OCDF	Total TEQ	TEQ (ng/kg dry wt.)[a]	OC-normalized TEQ (ng/kg dry wt.)	Average TEQ (ng/kg dry wt.)[a,b]	Average OC-normalized TEQ (ng/kg)[b]
ADVANCED AROMATICS	WQ0001914-001	08/26/2002	2426	28690	Sludge	8.45	9.3	2	< 3.4	82	220	180	7500	57000	8.2	< 4	13	46	64	100	12	1400	78	2000	80.670	80.67	867.42	80.67	867.42
ALBERMARLE OF 001	WQ0000492-001	08/07/2002	1006	28690	Sludge	9.06	3.79	< 0.98	< 0.67	0.58	1.5	1.3	17	130	5.4	< 0.98	< 0.98	3.6	2.7	2.4	< 0.5	17	2.1	35	2.700	2.70	71.24	2.70	71.24
ARISTECH/SONOCO OF 001(ng/L)	WQ0002107-001	08/06/2002	2427	28210	Water	0.084	7.55	< 0.0016	< 0.0023	< 0.0022	< 0.002	< 0.0018	0.0028	< 0.0028	< 0.0013	< 0.0016	< 0.001	< 0.0013	< 0.00096	< 0.0019	< 0.0018	< 0.0032	< 0.0022	< 0.0019	0.002	2.77	36.71	2.77	36.71
ATOFINA LP OF 001(ng/L)	WQ0001000-001	08/13/2002	1005	28210	Water	3.01	3.88	0.25	< 0.007	< 0.06	< 0.067	< 0.074	1.1	13	0.97	< 0.031	< 0.048	0.1	< 0.052	< 0.059	< 0.084	< 0.14	< 0.13	0.95	0.391	13.00	335.07	13.00	335.07
BEECHNUT MUD (ng/L)	WQ0012258-001	08/29/2002	1007	49520	Water	0.29	15.3	< 0.0024	< 0.012	0.006	0.0051	< 0.0038	0.054	0.49	0.0047	< 0.0016	0.0019	< 0.004	< 0.0045	0.019	0.0029	0.071	< 0.017	0.13	0.010	3.30	21.58	3.30	21.58
BLUE RIDGE WEST MUD	WQ0011553-001	09/05/2002	1007	49520	Sludge	12.4	19.6	1.6	18	3.6	9.2	12	87	850	2.6	3.1	< 1	5.1	24	4	< 0.95	68	< 3.5	150	17.103	17.10	87.26	17.10	87.26
BP SOLVAY 1	WQ0000544-001	08/23/2002	1005	28210	Sludge	4.46	32.5	1.1	< 0.68	4.2	9.4	5.1	260	2300	7.2	< 0.51	4.8	11	7.6	6.4	4.5	74	7.2	170	9.223	9.22	28.38	17.20	40.36
BP SOLVAY 1 - SAMPLE 2	WQ0000544-001	04/28/2003	1005	28210	Sludge	16.60	48.1	3.44	4.81	7.77	21.6	18.4	805	7990	21.8	13	9.65	29.6	21.3	11.7	6.39	230	24.2	628	25.176	25.18	52.34		
BP SOLVAY 2	WQ0000544-001	08/23/2002	1005	28210	Sludge	2.52	13.7	< 0.25	< 0.68	< 0.25	< 1.2	< 0.6	5.4	110	0.22	< 0.51	0.28	1	0.77	< 0.42	< 0.51	3.1	< 0.47	8.9	0.796	0.80	5.81	0.80	5.81
CHELFORD CITY MUD	WQ0011599-001	09/05/2002	1007	49520	Water	1.16	21.4	< 0.0044	< 0.027	0.016	0.022	< 0.0086	0.3	3.1	< 0.0033	0.23	0.0093	< 0.0054	< 0.0067	0.015	0.0058	0.22	< 0.018	0.67	0.032	2.77	12.96	2.52	11.76
CHELFORD CITY MUD - dup	WQ0011599-001	09/05/2002	1007	49520	Water	1.16	21.4	< 0.0047	< 0.03	< 0.0098	0.02	< 0.013	0.29	3.3	< 0.0051	< 0.22	0.0087	< 0.0045	< 0.0055	0.015	0.011	< 0.2	< 0.026	0.65	0.026	2.26	10.55		
CHEVRON PHILLIPS	WQ0000815-001	08/20/2002	1007	28210	Sludge	72.2	0.60	0.38	< 0.68	< 0.32	2	1.3	100	1000	0.59	< 0.51	0.45	0.63	< 0.27	0.8	< 0.51	4.6	< 0.4	10	1.375	1.37	229.13	1.37	229.13
CITY OF BAYTOWN - WEST DISTRICT (ng/L)	WQ0010395-008	08/28/2002	1001	49520	Water	0.86	26.2	< 0.0088	< 0.071	< 0.013	< 0.02	< 0.01	0.37	8.7	< 0.0089	< 0.019	< 0.014	< 0.015	< 0.016	< 0.01	< 0.013	0.27	< 0.029	0.82	0.031	3.65	13.94	3.65	13.94
CITY OF BAYTOWN - WEST MAIN (ng/L)	WQ0010395-002	08/28/2002	2426	49520	Water	0.79	20.8	< 0.0035	< 0.013	< 0.0058	0.01	< 0.0048	0.17	2.3	0.1	< 0.0065	0.012	< 0.005	< 0.0037	< 0.0039	< 0.0033	0.075	< 0.012	0.17	0.023	2.97	14.29	2.97	14.29
CITY OF DEER PARK (ng/L)	WQ0010519-002	09/10/2002	1006	49520	Water	0.85	21.2	0.0041	< 0.036	0.019	0.028	< 0.01	0.36	3.2	0.0031	< 0.0077	< 0.0047	< 0.0047	< 0.0033	0.033	0.026	< 0.025	< 0.03	1.6	0.026	3.09	14.58	3.09	14.58
CITY OF HOUSTON - ALMEDA SIMS	WQ0010495-003	08/27/2002	1007	49520	Sludge	16.6	19.3	< 0.27	< 1.4	< 0.6	< 1.1	< 0.76	28	290	0.51	< 0.49	0.34	< 0.5	1.8	1.9	< 0.49	20	< 2.5	58	1.261	1.26	6.53	1.26	6.53
CITY OF HOUSTON - BELTWAY	WQ0010495-111	08/27/2002	1007	49520	Sludge	16.6	20.5	0.9	< 3.3	4	< 1.8	< 2.5	94	970	< 0.86	< 0.67	3.7	< 1.2	5.4	4.2	< 2.1	< 2	< 2.6	210	5.375	5.37	26.22	4.89	24.50
CITY OF HOUSTON - BELTWAY-dup	WQ0010495-111	08/27/2002	1007	49520	Sludge	15.8	19.3	< 0.25	< 3.6	6.8	7.9	2.4	65	600	1.2	< 0.5	1.8	< 0.52	2.1	3.7	< 0.5	59	< 2.4	150	4.399	4.40	22.79		
CITY OF HOUSTON - CH CLINTON PARK (ng/L)	WQ0010495-010	08/23/2002	1007	49520	Water	0.08	13.0	< 0.0039	< 0.014	< 0.0084	0.013	< 0.009	0.19	2.3	< 0.0037	< 0.0041	< 0.0043	< 0.0035	< 0.0029	< 0.005	< 0.0047	0.039	< 0.016	0.094	0.010	12.23	94.11	12.23	94.11
CITY OF HOUSTON - CHOCOLATE BAYOU	WQ0010495-009	08/27/2002	1007	49520	Sludge	20.2	15.0	1	12	7.3	< 1.6	2.7	100	1300	0.91	< 0.48	0.64	1.4	1.5	2.3	< 0.48	41	< 2.7	130	9.047	9.05	60.31	9.05	60.31
CITY OF HOUSTON - EASTHAVEN (ng/L)	WQ0010495-065	08/27/2002	1007	49520	Water	0.90	16.4	< 0.0038	< 0.03	< 0.0079	< 0.01	< 0.0089	0.25	2.1	< 0.01	< 0.0058	< 0.005	0.019	0.013	0.017	< 0.002	0.25	< 0.028	0.77	0.018	1.96	11.95	1.96	11.95
CITY OF HOUSTON - GREENRIDGE	WQ0010495-110	08/27/2002	1007	49520	Sludge	17.8	19.3	0.59	8	3.7	< 1.2	< 0.59	38	330	1.2	< 0.5	1.1	0.89	0.78	1.6	< 0.5	35	< 1.9	77	6.084	6.08	31.52	6.08	31.52
CITY OF HOUSTON - KEEGANS BAYOU	WQ0010495-119	08/27/2002	1007	49520	Sludge	13.1	24.3	0.4	< 1.7	1.7	< 1.2	< 0.58	25	230	0.5	< 0.5	0.6	< 0.52	1	1.6	< 0.82	24	< 1	58	1.774	1.77	7.30	1.77	7.30
CITY OF HOUSTON - SIMMS NORTH (ng/L)	WQ0010495-002	08/23/2002	1007	49520	Water	0.86	27.2	< 0.032	< 0.11	< 0.079	< 0.097	< 0.083	0.88	9.2	0.059	< 0.06	< 0.065	< 0.026	< 0.031	< 0.038	< 0.061	0.71	< 0.17	6.8	0.088	10.22	37.58	10.22	37.58
CITY OF HOUSTON - SIMMS SOUTH (ng/L)	WQ0010495-002	08/23/2002	1007	49520	Water	0.53	20.2	< 0.0093	< 0.028	< 0.0068	< 0.0088	< 0.0063	0.094	1.1	< 0.0079	< 0.0056	< 0.0071	< 0.0044	< 0.0044	< 0.0037	< 0.0047	0.044	< 0.02	0.13	0.016	3.00	14.87	3.00	14.87
CITY OF HOUSTON - SOUTHWEST (ng/L)	WQ0010495-037	08/27/2002	1007	49520	Water	0.66	35.5	< 0.0058	< 0.047	< 0.0087	< 0.011	< 0.0073	0.34	3.2	< 0.0057	< 0.0062	< 0.0062	< 0.0047	< 0.0071	0.011	< 0.005	0.17	< 0.03	0.61	0.020	3.02	8.51	3.02	8.51
CITY OF HOUSTON - UPPER BRAYS	WQ0010495-116	08/27/2002	1007	49520	Sludge	16.6	17.4	0.93	< 4.2	11	11	3.5	120	1200	2.8	< 0.51	2.9	< 0.53	4	8	< 0.51	110	< 3	320	7.525	7.52	43.25	7.52	43.25
CITY OF HOUSTON - WCID #47 (ng/L)	WQ0010495-050	08/27/2002	1007	49520	Water	0.25	27.1	< 0.0051	< 0.017	< 0.0023	< 0.0029	< 0.0034	0.12	1.1	< 0.005	< 0.0049	< 0.0036	0.025	0.0052	< 0.0036	< 0.0022	0.088	< 0.015	0.25	0.012	4.73	17.44	4.73	17.44
CITY OF HOUSTON FWSD #23 PLANT (ng/L)	WQ0010495-016	08/27/2002	1006	49520	Water	0.78	18.1	< 0.012	< 0.039	< 0.017	< 0.015	< 0.023	0.5	8	< 0.0084	0.11	< 0.016	< 0.013	< 0.014	< 0.013	< 0.0085	0.16	< 0.038	0.62	0.031	3.95	21.85	3.95	21.85
CITY OF HOUSTON HOMESTEADPLANT (ng/L)	WQ0010495-023	08/27/2002	1007	49520	Water	0.27	14.3	< 0.0049	< 0.021	< 0.011	0.017	< 0.0076	0.32	2.8	< 0.0035	0.0061	< 0.0066	< 0.0081	< 0.0055	< 0.0073	< 0.0061	0.086	< 0.026	0.24	0.014	5.11	35.77	5.11	35.77
CITY OF HOUSTON NE PLANT	WQ0010495-077	08/27/2002	1006	49520	Water	0.64	13.5	< 0.015	< 0.026	< 0.023	< 0.016	0.09	0.46	8.2	< 0.012	< 0.014	< 0.018	0.055	< 0.0082	< 0.028	< 0.041	< 0.024	< 0.036	1.9	0.040	6.21	46.02	6.21	46.02
CITY OF JACINTO CITY PW (ng/L)	WQ0010195-001	08/29/2002	1007	49520	Water	0.36	20.0	< 0.0085	< 0.029	< 0.017	< 0.015	< 0.026	0.019	3.6	0.00062	< 0.0089	< 0.0094	< 0.01	< 0.0094	< 0.007	< 0.009	0.055	< 0.041	0.3	0.019	5.22	26.12	5.22	26.12
CITY OF MEADOWS	WQ0011039-001	09/10/2002	1007	49520	Sludge	1.01	16.8	< 0.86	3.6	1.6	4.9	2.2	84	760	2.9	< 0.5	3.1	3.2	2.8	7	< 0.95	< 1.4	< 2.1	350	6.300	6.30	37.50	6.30	37.50
CITY OF PASADENA - GOLDEN ACRES	WQ0010053-003	08/28/2002	1006	49520	Sludge	17.2	16.5	0.46	< 3.6	< 0.98	8.7	2.7	140	2200	1.9	< 0.51	2.9	19	3.9	6.3	1.7	110	< 1.7	300	7.292	7.29	44.19	7.29	44.19
CITY OF PASADENA - VINCE BAYOU	WQ0010053-005	08/28/2002	1007	49520	Sludge	19.0	22.2	1.1	9.3	< 1.6	21	7.2	490	7200	3.8	< 0.48	2	9.1	4.7	4.4	< 1	97	< 3.7	290	11.912	11.91	53.66	9.57	47.81
CITY OF PASADENA - VINCE BAYOU-dup	WQ0010053-005	08/28/2002	1007	49520	Sludge	18.5	17.2	0.98	< 5.2	< 1.1	15	< 1.3	320	5300	3	< 0.6	3.1	5.8	3	5.3	< 0.86	88	< 6.9	270	7.218	7.22	41.97		
CITY OF WEST UNIVERSITY PLACE	WQ0010058-000	08/29/2002	1007	49520	Sludge	2.76	15.3	0.5	< 0.71	1.3	5.5	3.1	130	1500	1.8	< 0.51	2.9	3.1	2.2	6.1	< 0.51	< 0.53	< 1.8	460	4.476	4.48	29.25	4.48	29.25
CROSBY MUD (ng/L)	WQ0011388-001	08/30/2002	1001	49520	Water	0.54	20.7	< 0.0034	< 0.014	< 0.0066	< 0.0096	< 0.0054	0.25	14	0.0036	< 0.0037	0.0065	< 0.006	< 0.0047	0.011	< 0.0081	0.24	< 0.016	0.66	0.012	2.23	10.76	2.23	10.76
DONOHUE INDUSTRIES (ng/L)	WQ0001160-001	08/19/2002	1006	26210	Water	0.96	26.4	< 0.075	< 0.092	< 0.081	< 0.09	< 0.068	< 0.12	2.1	< 0.049	< 0.05	< 0.065	< 0.062	< 0.074	< 0.068	< 0.038	0.23	< 0.11	1	0.105	10.89	41.23	10.89	41.23
DOW-LA PORTE OF 001	WQ0000663-001	08/07/2002	2427	28210	Sludge	13.4	5.01	< 0.99	< 4.9	< 4.9	< 4.9	< 4.9	110	1100	2.8	< 4.9	< 4.9	26	< 4.9	< 4.9	< 4.9	< 4.9	7.7	97	7.418	7.42	148.05	7.42	148.05
DUPONT BELT PRESS	WQ0000474-001	08/14/2002	2427	28650	Sludge	38.3	5.29	< 0.27	< 0.67	0.77	1.5	1.4	42	380	4.8	< 0.5	1.7	1.8	0.73	1.1	< 0.5	6.4	< 0.55	17	2.400	2.40	45.37	2.40	45.37
EOTT ENERGY	WQ0000440-000	09/25/2002	2436	28690	Sludge	5.35	8.64	< 0.29	0.94	2.3	4	4.8	120	5300	0.85	0.9	1	2.3	3.3	2.9	0.93	16	1.4	12	3.298	3.30	38.17	3.30	38.17
EQUISTAR	WQ0000391-001	08/14/2002	1001	28690	Sludge	3.34	22.0	< 2.5	< 6.7	< 1.2	< 12	7.2	130	1600	18	13	39	16	18	21	< 5.1	57	< 4	47	32.010	32.01	145.50	32.01	145.50
EXXON BAYPORT REFINERY	WQ0000592-001	08/22/2002	1005	29110	Sludge	69.3	0.13	0.63	< 0.66	< 0.69	1.6	< 0.79	22	320	2.5	< 0.5	1.1	< 0.52	1	< 0.53	< 0.5	5.9	< 1.4	16	2.019	2.02	1553.08	2.02	1553.08
EXXON OLEFINS (ng/L)	WQ0000393-001	08/23/2002	1007	28690	Water	0.08	22.3	< 0.0092	< 0.052	< 0.02	< 0.023	< 0.02	0.2	3.4	< 0.011	< 0.027	< 0.021	< 0.027	< 0.0099	< 0.02	< 0.023	< 0.059	< 0.064	< 0.095	0.031	39.03	175.00	39.03	175.00
FALLBROOK MUD	WQ0010919-001	09/24/2002	1006	49520	Sludge	0.60	20.0	< 0.49	3.6	2	7.4	4.6	54	410	0.76	< 0.51	< 0.57	< 0.58	< 4.1	2	1.3	49	< 3.4	130	4.445	4.45	22.23	4.45	22.23
GB BIOSCIENCES 1	WQ0000749-001	09/05/2002	1006	28790	Sludge	6.68	24.7	110	92	140	480	210	3900	17000	13000	750	1200	1100	250	270	170	3600	370	160000	2355.500	2355.50	9536.44	4976.75	23482.50
GB BIOSCIENCES 1-dup	WQ0000749-001	09/05/2002	1006	28790	Sludge	6.68	20.3	270	330	490	1800	730	15000	78000	44000	2500	4200	< 20	870	850	630	13000	1300	530000	7598.000	7598.00	37428.57		
GB BIOSCIENCES 2	WQ0000749-001	09/05/2002	1006	28790	Sludge	29.7	16.4	< 4.9	< 13	170	460	300	2800	9600	< 3.4	< 10	< 5.3	2500	680	500	430	4200	1200	1000000	511.445	511.45	3118.57	511.45	3118.57
GCA BAYPORT	WQ0001054-001	08/16/2002	2438	95110	Sludge	15.7	24.4	< 0.83	< 0.97	0.95	2.6	1.1	22	250	1	< 0.51	0.69	2.8	< 0.74	1.3	< 1.4	25	< 3.1	80	2.097	2.10	8.60	2.10	8.60
GCA WASHBURN TUNNEL PRIMARY	WQ0001740-002	08/14/2002	1007	49520	Sludge	25.8	22.4	< 4.3	< 3.4	< 1.5	< 5.9	< 3	54	1500	6.8	< 2.6	< 2.4	< 2.6	1.9	< 2.5	< 2.5	11	< 3.8	27	5.435	5.44	24.26	5.44	24.26
GCA WASHBURN TUNNEL SECONDARY	WQ0001740-001	08/19/2002	1007	49520	Sludge	17.6	27.0	< 1.9	< 3.4	0.91	< 6	< 3	29	570	4	< 2.5	< 1.3	< 2.6	< 1.3	< 2.1	< 2.5	6	< 2	12	3.554	3.55	13.16	3.55	13.16
GEORGIA GULF SLUDGE (ng/L)	WQ0002067-004	08/28/2002	1006	28650	Water	0.24	20.8	< 0.0065	< 0.0096	< 0.0066	< 0.009	< 0.0081	0.042	0.39	< 0.01	< 0.0087	0.0081	< 0.0066	< 0.0071	< 0.0048	< 0.0071	< 0.011	< 0.018	0.07	0.013	5.37	25.81	5.37	25.81
GULF PERFORMANCE (ng/L)	WQ0001310-001	08/21/2002	1006	28210	Water	0.07	34.8	< 0.0069	< 0.015	< 0.0088	< 0.012	< 0.008	0.31	3.4	0.023	< 0.0066	< 0.0093	< 0.007	< 0.0053	< 0.0074	< 0.013	< 0.014	< 0.027	0.092	0.015	21.52	61.84	21.52	61.84
HAMPSHIRE (DOW) OF 001 (ng/L)	WQ0002558-001	08/12/2002	1006	28690	Water	1.34	7.95	< 0.0019	< 0.0023	0.0048	0.0099	0.0077	0.1	0.63	0.012	< 0.0015	0.0047	0.0041	0.005	0.0023	< 0.0017	0.02	< 0.0029	0.044	0.009	0.64	8.05	0.64	8.05
HARRIS COUNTY FWSD 051	WQ0010032-001	08/26/2002	1006	49520	Sludge	13.5	22.4	< 0.47	< 9.1	< 1.7	< 2.4	< 3.9	130	5200	1.9	< 0.96	1.4	28	1.7	4.5	< 1.2	100	< 5	270	7.304	7.30	32.61	7.30	32.61
HARRIS COUNTY WCID #84	WQ0010558-001	08/29/2002	1006	49520	Sludge	1.18	16.8	< 1.4	< 3.3	< 2	< 4.2	< 4.9	110	1600	1.1	< 1.1	1.8	1.5	< 1.1	< 1.1	< 0.76	< 9.3	< 3.8	140	3.416	3.42	20.33	15.07	70.35
KMCO	WQ0002712-001	08/26/2002	1001	28690	Sludge	4.26	22.2	8.6	< 6.8	< 3.9	< 12	7.4	68	430	83	11	9.9	< 5.3	< 2.7	4.3	< 5.1	12	< 4	< 24	26.720	26.72	120.36	26.89	121.38
KMCO-dup	WQ0002712-001	08/26/2002	1001	28690	Sludge	3.88	22.1	7.1	13	< 1.6	5.4	4.5	61	340	70	< 1.6	9.3	2.1	2.1	2.4	< 0.65	11	< 3.2	9.8	27.053	27.05	122.41		
LUBRIZOL OF 001	WQ0000639-001	08/13/2002	1006	28690	Sludge	7.84	7.01	< 0.25	< 0.68	< 0.2	< 1.2	< 0.6	1.5	9.7	< 0.17	< 0.51	< 0.27	< 0.53	< 0.27	< 0.42	< 0.51	< 0.24	< 0.4	< 2.4	0.570	0.57	8.13	0.57	8.13
LYONDELL	WQ0002927-001	08/14/2002	1001	28650	Sludge	4.04	30.6	< 2	< 3.4	< 1	< 5.9	< 3	5.3	73	< 1.6	< 2.5	< 1.3	< 2.6	< 1.3	< 2.1	< 2.5	< 1.7	< 2	< 12	3.238	3.24	10.58	3.24	10.58
MILLENIUM OF 001 (ng/L)	WQ0000534-001	08/06/2002	2427	28690	Water	1.16	5.64	< 0.0078	< 0.015	< 0.011	< 0.0099	< 0.0088	0.026	0.26	< 0.0039	< 0.0078	< 0.0049	< 0.023	< 0.0061	< 0.0093	< 0.0088	< 0.016	< 0.011	< 0.093	0.013	1.13	20.04	1.13	20.04
OXY BATTLEGROUND	WQ0001539-001	08/22/2002	1005	28120	Sludge	69.1	0.34	0.66	< 0.81	3.9	4.7	3	89	1000	11	30	13	89	39	14	9.8	130	28	200	26.303	26.30	7736.03	26.30	7736.03
OXY VINYLS DP OF 001	WQ0000305-001	08/08/2002	1006	28120	Sludge	63.1	1.36	6.1	< 4.5	< 4.5	< 4.5	< 4.5	50	720	72	24	19	170	37	5.9	< 4.5	280	75	1200	47.315	47.32	3479.04	47.32	3479.04
OXY VINYLS DP OF 005 (ng/L)	WQ0000305-001	08/12/2002	1006	28120	Water	0.65	6.64	< 0.0016	< 0.045	< 0.037	< 0.047	< 0.049	0.37	3.2	0.26	0.22	0.29	0.79	0.73	1.4	0.14	35	1.6	410	0.507	77.95	1174.00	77.95	1174.00
OXY VINYLS LP BIO RECYCLE	WQ0002097-001	08/12/2002	1005	28690	Sludge	2.04	5.45	< 0.26	< 0.67	< 0.29	1.8	1.4	32	440	54	330	73	630	< 0.45	140	150	6200	1800	160000	151.055	151.05	2771.64	151.05	2771.64
OXY VINYLS LP COPPER CLARIF	WQ0002097-001	08/12/2002	1005	28690	Sludge	3.40	3.01	< 0.25	< 0.67	1.4	2	1.3	34	190	1.2	6.1	5.2	25	< 0.27	22	9.2	200	62	670	9.421	9.42	312.99	9.42	312.99
OXY VINYLS PASADENA OF 001 (ng/L)	WQ0000002-001	08/08/2002	1006	28210	Water	0.51	7.37	< 0.018	< 0.057	< 0.057	< 0.057	< 0.057	0.11	0.76	< 0.015	< 0.057	< 0.057	< 0.057	< 0.057	< 0.057	< 0.057	< 0.057	< 0.057	< 0.11	0.060	11.69	158.63	11.69	158.63
REICHHOLD OF 001	WQ0000662-001	08/09/2002	1006	28210	Sludge	74.9	0.28	< 0.97	< 4.9	< 4.9	< 4.9	< 4.9	< 4.9	290	< 0.97	< 4.9	< 4.9	< 4.9	< 4.9	< 4.9	< 4.9	< 4.9	< 4.9	< 9.7	4.821	4.82	1721.79	4.82	1721.79
ROHM & HAAS OF 001	WQ0000458-001	08/05/2002	1006	28690	Sludge	4.97	6.43	< 8.5	< 42	< 42	< 42	< 42	490	5800	< 8.5	< 42	< 42	< 42	< 42	< 42	< 42	< 42	< 42	260	41.425	41.43	644.25	41.43	644.25
ROHM & HAAS OF 007	WQ0000458-007	08/05/2002	1006	28690	Sludge	3.64	7.58	< 1.2	< 6.1	< 6.1	< 6.1	< 6.1	< 6.1	14	< 1.2	< 6.1	< 6.1	< 6.1	< 6.1	< 6.1	< 6.1	< 6.1	< 6.1	< 12	5.998	6.00	79.12	6.00	79.12
SHELL DEER PARK REFINERY	WQ0000403-004	10/23/2002	1006	29110	Sludge	1.75	28.9	11	110	56	110	67	500	1500	160	380	410	620	470	200	250	1100	400	770	483.300	483.30	1672.32	483.30	1672.32
SHELL DP CHEM	WQ0000402-001	09/03/2002	1006	28650	Sludge	1.86	16.7	< 0.93	< 0.85	2.4	2.6	3.1	63	370	1.4	6.3	8.8	44	50	44	16	590	110	1600	21.743	21.74	130.19	21.74	130.19
TEXMARK	WQ0000786-001	08/20/2002	1007	28690	Sludge	1.45	16.2	0.91	< 0.68	1.8	5.7	2.6	160	1500	1.9	< 0.51	< 0.6	< 0.53	0.9	1.2	< 0.51	14	< 1.5	22	2.705	2.70	16.70	2.70	16.70
VALERO	WQ0000535-001	08/20/2002	1007	29110	Sludge	1.6	31.4	< 1.3	< 0.86	3	14	6.3	320	3600	2.4	3.1	6	13	9	12	< 1.5	77	10	120	10.065	10.07	32.05	10.07	32.05

- Non-detects resported as "< MDL "
- TEQ Concentrations determined using TCEQ TEF
- Non-detects assumed to be 1/2 of the Method Detection Limit (MDL)

[a] Concentrations for the samples analyzed as a solid matrix are given on a dry-weight basis. For the samples analyzed as water, the concentrations were divided by the % solids to obtain a concentration on a dry-weight b

[b] Average of duplicate samples, otherwise concentration of a single sample

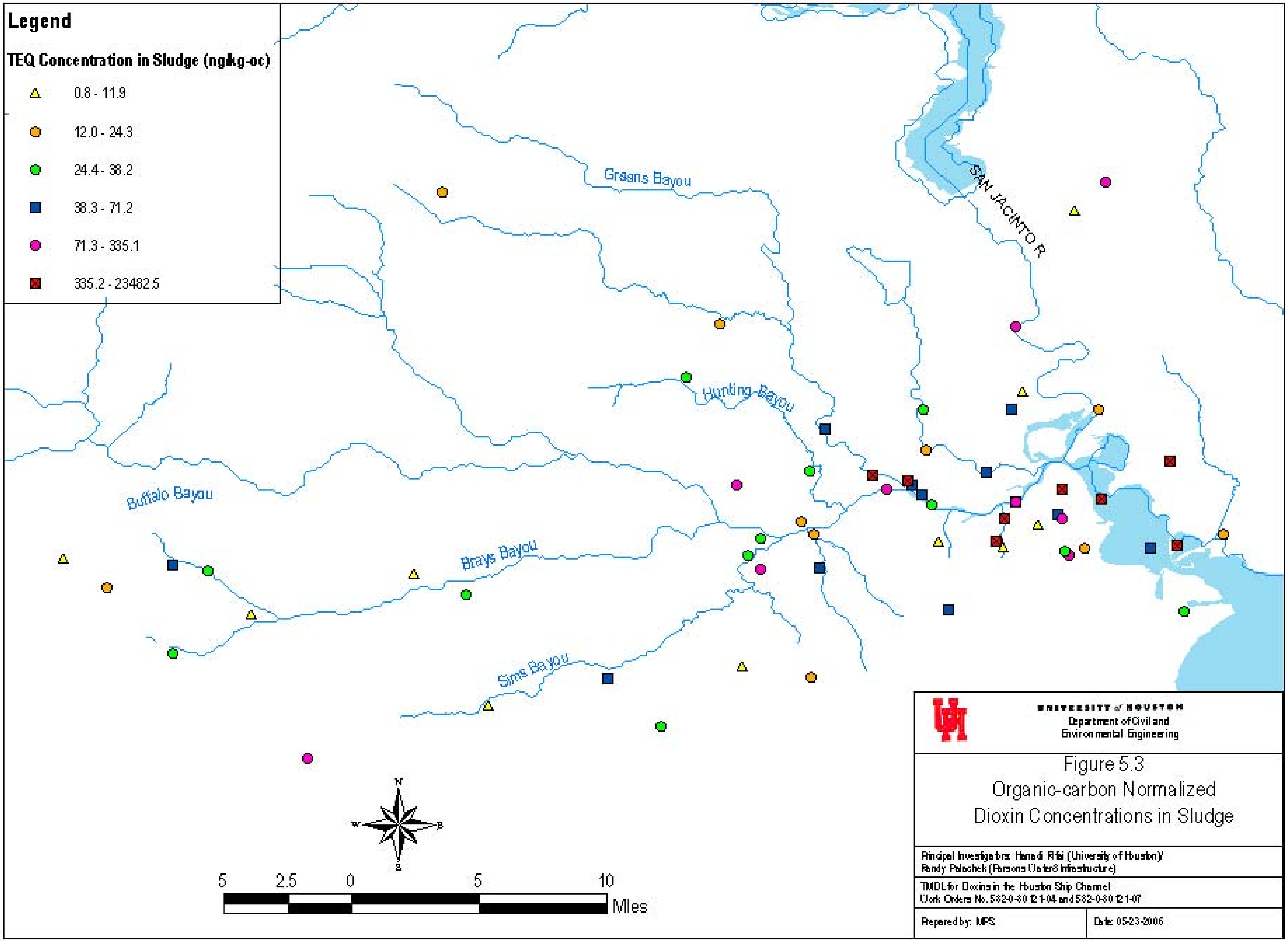


Figure 5.3
Organic-carbon Normalized
Dioxin Concentrations in Sludge

Principal Investigators: Hanadi Rifai (University of Houston)/
Randy Palachek (Parsons Water& Infrastructure)

TMDL for Dioxins in the Houston Ship Channel
Work Orders No. 582-0-80121-04 and 582-0-80121-07

Prepared by: MPS

Date: 05-23-2006

Table 5.5 Field Measurements during Effluent Sampling Spring 2003

Facility Name	Sample ID	Sample Date	Sample time	Temperature (^{o}C)	Conductivity (μ S/cm)	Salinity ($^{o}/_{oo}$)	DO %	DO (mg/L)	pH (SU)	Volume
City of Pasadena - Golden Acres	WQ10053-003-A	02/18/2003	9:00	18.99	1387	N/A	100.5	9.33	5.90	508
City of Pasadena - Golden Acres	WQ10053-003-B	02/18/2003	14:30	19.69	1391	N/A	97.0	8.81	7.19	
City of Pasadena - Vince Bayou	WQ10053-005-A	02/18/2003	10:30	20.54	1622	N/A	81.7	7.21	6.47	253
City of Pasadena - Vince Bayou	WQ10053-005-B	02/18/2003	12:30	20.83	1638	N/A	82.3	7.30	6.90	
Harris County - FWSD 051	WQ10032-001-A	02/19/2003	10:00	20.9	844	N/A	70.3	6.25	5.97	273
Harris County - FWSD 051	WQ10032-001-B	02/19/2003	12:45	21.19	843	N/A	71.4	6.27	6.30	
City of Houston - Simms South	WQ10495-002-outfall 2-A	02/19/2003	8:30	20.32	902	N/A	97.1	8.75	5.37	501
City of Houston - Simms South	WQ10495-002-outfall 2-B	02/19/2003	14:00	21.08	879	N/A	87.9	7.74	6.57	
GB Biosciences	WQ00749-001-A	02/20/2003	10:30	21.26	120	N/A	133.0	11.52	7.14	256
GB Biosciences	WQ00749-001-B	02/20/2003	13:00	21.45	N/A	N/A	126.3	10.68	7.34	
City of Houston - Simms North	WQ10495-002 outfall 1-A	02/20/2003	9:00	20.78	728	0.36	130.0	11.86	6.28	504
City of Houston - Simms North	WQ10495-002 outfall 1-B	02/20/2003	13:45	20.96	708	0.35	126.0	11.20	7.38	
City of Houston - Southwest	WQ10495-037-A	02/25/2003	9:00	20.66	712	N/A	182.0	16.07	6.10	503
City of Houston - Southwest	WQ10495-037-B	02/25/2003	15:00	27.23	707	0.25	148.3	13.36	7.30	
City of Houston - Beltway	WQ10495-111-A	02/25/2003	10:00	22.25	826	N/A	155.7	13.38	7.00	502
City of Houston - Beltway	WQ10495-111-B	02/25/2003	16:00	22.38	848	0.42	224.9	19.30	7.36	
City of Houston - Homestead	WQ10495-023-A	02/26/2003	8:30	14.21	805	N/A	145.1	14.64	6.21	508
City of Houston - Homestead	WQ10495-023-B	02/26/2003	14:10	14.59	899	N/A	165.2	16.29	6.85	
City of Houston - 69th Street	WQ10495-090-A	02/26/2003	9:15	18.75	1102	N/A	132.7	12.38	6.42	504
City of Houston - 69th Street	WQ10495-090-B	02/26/2003	14:15	19.42	1150	0.57	142.0	12.94	6.50	
City of Houston - FWSD- 23	WQ10495-016-A	02/27/2003	8:22	16.26	997	0.5	139.1	13.65	6.38	503
City of Houston - FWSD- 23	WQ10495-016-B	02/27/2003	13:45	16.57	1056	0.53	137.4	13.39	6.89	
Equistar	WQ00391-001-A	03/06/2003	9:07	23.45	2588	1.33	113.0	8.49	6.68	255
Equistar	WQ00391-001-B	03/06/2003	12:15	23.96	5485	2.95	147.0	11.79	7.02	
Oxy Vinyls - La Porte	WQ002097-A	03/07/2003	9:45	29.53	N/A	N/A	82.0	N/A	N/A	254
Oxy Vinyls - La Porte	WQ002097-B	03/07/2003	13:17	32.94	N/A	15.75	89.8	5.88	7.24	
Valero	WQ00535-000 outfall 001-A	03/11/2003	11:45	25.34	N/A	2.25	81.7	6.61	7.68	253
Valero	WQ00535-000 outfall 001-B	03/11/2003	14:15	25.79	N/A	2.28	73.7	5.95	7.62	
Exxon	WQ00592-001-A	03/11/2003	9:10	18.62	N/A	N/A	43.6	3.94	6.09	501
Exxon	WQ00592-001-B	03/11/2003	14:45	20.27	N/A	2.12	78.3	6.89	7.56	
Shell Chemical	WQ00402-A	03/12/2003	8:20	25.26	N/A	N/A	N/A	N/A	7.24	252
Shell Chemical	WQ00402-B	03/12/2003	11:00	25.33	N/A	N/A	N/A	N/A	7.26	
Albermarle	WQ00492-A	03/12/2003	12:00	23.75	N/A	N/A	N/A	N/A	7.26	251
Albermarle	WQ00492-B	03/12/2003	14:25	24.63	N/A	N/A	N/A	N/A	7.22	
City of Baytown - Central	WQ10395-002-A	03/13/2003	11:40	21.59	909	0.45	133.2	11.60	6.49	257
City of Baytown - Central	WQ10395-002-B	03/13/2003	14:00	21.66	914	0.45	142.6	12.14	6.60	
City of Baytown - West Main	WQ10395-008-A	03/13/2003	8:25	21.31	902	0.44	139.7	12.55	6.29	259
City of Baytown - West Main	WQ10395-008-B	03/13/2003	10:40	21.41	900	0.44	135.0	11.82	6.57	
City of Houston - Keegans Bayou	WQ10495-119-A	03/14/2003	8:40	25.3	907	0.44	116.2	9.59	7.02	505
City of Houston - Keegans Bayou	WQ10495-119-B	03/14/2003	13:45	26.22	897	0.44	106.3	8.50	6.90	
Atofina	WQ10000-000-A	03/18/2003	9:45	22.81	1104	0.55	88.5	7.79	6.88	269
Atofina	WQ10000-000-B	03/18/2003	12:45	22.98	1097	0.54	66.9	5.79	7.25	
Dow DP	WQ00663-000-outfall 1-A	03/19/2003	9:40	28.45	N/A	32.79	N/A	N/A	7.47	260
Dow DP	WQ00663-000-outfall 1-B	03/19/2003	12:20	28.66	N/A	31.79	88.9	5.79	7.60	
City of Houston - Almeda Simms	WQ10495-003-A	03/20/2003	8:15	21.9	838	0.41	95.7	8.34	6.05	502
City of Houston - Almeda Simms	WQ10495-003-B	03/20/2003	13:15	22.77	860	N/A	89.8	7.72	7.12	
City of Houston - Chocolate Bayou	WQ10495-009-A	03/20/2003	9:45	21.25	712	0.35	112.0	9.91	7.33	259
City of Houston - Chocolate Bayou	WQ10495-009-B	03/20/2003	12:20	21.5	712	0.35	107.4	9.47	7.46	

Table 5.5 Field Measurements during Effluent Sampling Spring 2003

Facility Name	Sample ID	Sample Date	Sample time	Temperature (^{o}C)	Conductivity (µ S/cm)	Salinity ($^{o}/_{oo}$)	DO %	DO (mg/L)	pH (SU)	Volume
City of Houston - Upper Brays	WQ10495-116-A	03/21/2003	8:50	24.46	1013	N/A	113.6	9.49	6.18	506
City of Houston - Upper Brays	WQ10495-116-B	03/21/2003	13:35	24.87	1001	N/A	111.1	9.15	7.28	
City of Houston - Clinton Park	WQ10495-010-A	03/25/2003	8:30	19.98	1038	0.52	128.9	11.67	7.02	255
City of Houston - Clinton Park	WQ10495-010-B	03/25/2003	10:40	20.13	1031	0.51	121.7	10.98	7.47	
City of Houston - Northeast	WQ10495-077-A	03/25/2003	11:30	22.22	844	0.47	115.9	10.08	7.32	252
City of Houston - Northeast	WQ10495-077-B	03/25/2003	13:45	22.82	862	0.47	107.4	9.22	7.26	
Rohm & Haas	WQ00458-001-A	03/26/2003	9:00	25.3	N/A	3.15	65.1	5.41	6.33	264
Rohm & Haas	WQ00458-001-B	03/26/2003	11:45	25.2	N/A	4.13	63.5	5.26	6.66	
Gulf Coast Waste Disposal Authority	WQ01740-001-A	03/27/2003	9:00	26.35	N/A	1.57	66.4	4.98	6.67	500
Gulf Coast Waste Disposal Authority	WQ01740-001-B	03/27/2003	14:30	27.38	N/A	1.59	27.3	2.15	6.85	
City of West University Place	WQ10058-001-A	03/28/2003	8:30	22.79	656	0.32	115.9	10.00	6.67	256
City of West University Place	WQ10058-001-B	03/28/2003	10:00	22.99	656	0.32	104.9	8.98	6.89	
City of Houston - Greenridge	WQ10495-110-A	03/28/2003	12:00	20.14	759	0.37	108.1	9.63	7.25	253
City of Houston - Greenridge	WQ10495-110-B	03/28/2003	15:15	19.72	770	0.38	73.8	7.51	7.38	
Beechnut MUD	WQ12258-001-A	04/01/2003	8:45	20.02	852	0.42	86.0	8.16	6.24	262
Beechnut MUD	WQ12258-001-B	04/01/2003	11:15	20.48	871	0.44	N/A	N/A	6.77	
Dupont	WQ00474-000-A	04/02/2003	9:00	24.35	3845	2.03	93.4	8.05	7.55	253
Dupont	WQ00474-000-B	04/02/2003	11:15	25	3736	1.98	127.9	10.93	8.20	
City of Deer Park	WQ10519-002-A	04/02/2003	13:20	22.39	687	0.33	114.0	9.89	7.19	254
City of Deer Park	WQ10519-002-B	04/02/2003	16:00	22.43	683	0.33	10.3	5.08	7.34	
Shell Refinery	WQ00403-000-A	04/10/2003	9:59	26.45	2251	1.15	37.6	4.10	6.20	258
Shell Refinery	WQ00403-000-B	04/10/2003	12:40	26.89	2308	1.18	96.7	7.61	6.83	
BP Solvay	WQ00544-001-A	04/28/2003	15:34	33.44	2640	1.35	152.6	10.83	6.44	257
BP Solvay	WQ00544-001-B	04/28/2003	18:12	33.07	2114	1.06	135.9	9.85	7.18	
Oxy Vinyls - Battleground	WQ01539-001-A	05/07/2003	10:40	32.57	N/A	N/A	97.2	5.91	5.92	134
Harris County WCID 1	WQ10104-001-A	05/07/2003	13:38	26.01	676	0.33	88.5	7.13	6.59	199
Harris County WCID 1	WQ10104-001-B	05/07/2003	15:40	26.46	663	0.32	78.6	0.30	6.19	
City of Meadows	WQ11039-000-A	05/08/2003	8:54	26.62	914	0.45	90.2	7.20	6.67	250
City of Meadows	WQ11039-000-B	05/08/2003	11:03	26.88	913	0.45	92.2	7.26	6.89	
Newport MUD	WQ11329-001-A	05/08/2003	13:28	26.05	616	0.31	101.0	8.19	7.12	202
Newport MUD	WQ11329-001-B	05/08/2003	16:10	26.77	635	0.31	101.5	8.11	9.28	
Vopak	0001731-001-A	06/24/2003	9:55	33.49	14270	N/A	14.5	0.99	6.41	253
Vopak	0001731-001-B	06/24/2003	12:00	34.06	14380	N/A	1.6	0.10	N/A	
City of Houston - West District	10495-030-A	06/25/2003	9:45	28.02	800	N/A	137.0	10.65	6.67	251
City of Houston - West District	10495-030-B	06/25/2003	11:35	29.29	772	N/A	134.8	10.50	6.40	
City of Houston - Northwest	10495-076-A	06/25/2003	12:45	29.92	735	N/A	92.4	6.94	6.31	252
City of Houston - Northwest	10495-076-B	06/25/2003	15:10	30.06	763	N/A	115.3	8.70	6.40	
Oxy Vinyls - Deer Park	Outfall 005-A	07/22/2003	N/A	N/A	N/A	N/A	N/A	N/A	N/A	252
Oxy Vinyls - Deer Park	Outfall 005-B	07/22/2003	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
Clean Harbors	Clean Harbors-A	08/07/2003	10:35	32.68	N/A	N/A	134.8	9.52	8.58	261
Clean Harbors	Clean Harbors-B	08/07/2003	12:45	33.14	N/A	N/A	N/A	9.37	8.54	

N/A - not measured, problems with the field probe

Table 5.6 Characteristics of Effluent Samples - Spring 2003 - NOT QC'd

Facility Name	Sample ID	Sample Date	Sample time	TSS (mg/L)	TDS (mg/L)	TOC (mg/L)	DOC (mg/L)
City of Pasadena - Golden Acres	10053-003-A	02/18/2003	9:00	15	417	7.6	N/A
City of Pasadena - Golden Acres	10053-003-B	02/18/2003	14:30	17	412	N/A	N/A
City of Pasadena - Vince Bayou	10053-005-A	02/18/2003	10:30	9	404	N/A	N/A
City of Pasadena - Vince Bayou	10053-005-B	02/18/2003	12:30	9	413	N/A	N/A
Harris County - FWSD 051	10032-001-A	02/19/2003	10:00	5	450	221	N/A
Harris County - FWSD 051	10032-001-B	02/19/2003	12:45	9	431	224	N/A
City of Houston - Simms South	10495-002-outfall 2-A	02/19/2003	8:30	3	504	197	186
City of Houston - Simms South	10495-002-outfall 2-B	02/19/2003	14:00	6	477	263	157
GB Biosciences	00749-001-A	02/20/2003	10:30	3	8711	101	N/A
GB Biosciences	00749-001-B	02/20/2003	13:00	6	9129	64.9	N/A
City of Houston - Simms North	10495-002 outfall 1-A	02/20/2003	9:00	6	501	103	N/A
City of Houston - Simms North	10495-002 outfall 1-B	02/20/2003	N/A	6	480	180	131
City of Houston - Southwest	10495-037-A	02/25/2003	9:00	10	452	104	N/A
City of Houston - Southwest	10495-037-B	02/25/2003	15:00	10	460	135	120
City of Houston - Beltway	10495-111-A	02/25/2003	10:00	6	495	114	N/A
City of Houston - Beltway	10495-111-B	02/25/2003	16:00	8	551	112	N/A
City of Houston - Homestead	10495-023-A	02/26/2003	8:30	29	447	83.7	N/A
City of Houston - Homestead	10495-023-B	02/26/2003	14:10	24	368	249	144
City of Houston - 69th Street	10495-090-A	02/26/2003	9:15	15	474	41.2	19.4
City of Houston - 69th Street	10495-090-B	02/26/2003	14:15	18	494	10.4	N/A
City of Houston - FWSD- 23	10495-016-A	02/27/2003	8:22	9	476	140	N/A
City of Houston - FWSD- 23	10495-016-B	02/27/2003	13:45	9	599	112	N/A
Equistar	00391-001-A	03/06/2003	9:07	12	1458	129	98.7
Equistar	00391-001-B	03/06/2003	12:15	13	3130	77.5	N/A
Oxy Vinyls - La Porte	002097-A	03/07/2003	9:45	9	13285	139	N/A
Oxy Vinyls - La Porte	002097-B	03/07/2003	13:17	7	12890	159	133
Valero	535-000 outfall 001-A	03/11/2003	11:45	19	2199	35.1	N/A
Valero	535-000 outfall 001-B	03/11/2003	14:15	17	2224	35.8	N/A
Exxon	592-000-001-A	03/11/2003	9:10	32	2452	190	178
Exxon	592-000-001-B	03/11/2003	14:45	36	2407	156	N/A
Shell Chemical	0000402-A	03/12/2003	8:20	22	8849	152	N/A
Shell Chemical	0000402-B	03/12/2003	11:00	25	9092	253	203
Albermarle	0000492-A	03/12/2003	12:00	48	1815	208	123
Albermarle	0000492-B	03/12/2003	14:25	18	1709	10.2	5.4
City of Baytown - Central	10395-002-A	03/13/2003	11:40	9	516	5.4	N/A
City of Baytown - Central	10395-002-B	03/13/2003	14:00	11	516	6.3	6.15
City of Baytown - West Main	10395-008-A	03/13/2003	8:25	10	527	47.2	N/A
City of Baytown - West Main	10395-008-B	03/13/2003	10:40	13	548	32	N/A
City of Houston - Keegans Bayou	10495-119-A	03/14/2003	8:40	10	506	2.47	2.44
City of Houston - Keegans Bayou	10495-119-B	03/14/2003	13:45	9	509	2.23	N/A
Atofina	00010000-000-A	03/18/2003	9:45	29	999	11	9.67
Atofina	00010000-000-B	03/18/2003	12:45	44	707	18.7	14.6
Dow DP	0000663-000-outfall 1-A	03/19/2003	9:40	16	34540	<25	<25
Dow DP	0000663-000-outfall 1-B	03/19/2003	12:20	23	34128	<25	<25
City of Houston - Almeda Simms	10495-003-A	03/20/2003	8:15	17	667	20.7	20.3
City of Houston - Almeda Simms	10495-003-B	03/20/2003	13:15	11	673	23.7	23.2
City of Houston - Chocolate Bayou	10495-009-A	03/20/2003	9:45	13	551	7.75	6.34
City of Houston - Chocolate Bayou	10495-009-B	03/20/2003	12:20	10	530	6.55	6.06
City of Houston - Upper Brays	10495-116-A	03/21/2003	8:50	11	533	5.2	4.72
City of Houston - Upper Brays	10495-116-B	03/21/2003	13:35	9	600	5.35	4.93
City of Houston - Clinton Park	10495-010-A	03/25/2003	8:30	8	671	3.01	3.19
City of Houston - Clinton Park	10495-010-B	03/25/2003	10:40	5	688	3.11	3.51
City of Houston - Northeast	10495-077-A	03/25/2003	11:30	8	619	5.43	5.2
City of Houston - Northeast	10495-077-B	03/25/2003	13:45	5	563	5.88	5.76
Rohm & Haas	0000458-001-A	03/26/2003	9:00	29	4771	14.8	8.36
Rohm & Haas	0000458-001-A-dup	03/26/2003	9:00	27	4778	13.6	7.64
Rohm & Haas	0000458-001-B	03/26/2003	11:45	33	5704	10.1	9.28
Rohm & Haas	0000458-001-B-dup	03/26/2003	11:45	55	5593	12	6.32
Gulf Coast Waste Disposal Authority	0001740-001-A	03/27/2003	9:00	21	2017	28.8	23.8
Gulf Coast Waste Disposal Authority	0001740-001-B	03/27/2003	14:30	19	2059	28.2	25
City of West University Place	10058-001-A	03/28/2003	8:30	6	396	9.31	8.48

Table 5.6 Characteristics of Effluent Samples - Spring 2003 - NOT QC'd

Facility Name	Sample ID	Sample Date	Sample time	TSS (mg/L)	TDS (mg/L)	TOC (mg/L)	DOC (mg/L)
City of West University Place	10058-001-B	03/28/2003	10:00	6	401	9.52	8.26
City of Houston - Greenridge	10495-110-A	03/28/2003	12:00	19	504	16.6	10.8
City of Houston - Greenridge	10495-110-B	03/28/2003	15:15	26	429	23.7	11.5
Beechnut MUD	0012258-001-A	04/01/2003	8:45	2	555	4.87	4.65
Beechnut MUD	0012258-001-B	04/01/2003	11:15	8	584	4.83	4.69
Dupont	0000474-000-A	04/02/2003	9:00	18	2354	31.4	30.1
Dupont	0000474-000-B	04/02/2003	11:15	18	2253	32.1	29.7
City of Deer Park	0010519-002-A	04/02/2003	13:20	13	561	10.6	10.1
City of Deer Park	0010519-002-B	04/02/2003	16:00	16	558	10.5	9.96
Shell Refinery	0000403-001-A	04/10/2003	10:00	9	1291	21.9	19.7
Shell Refinery	0000403-001-B	04/10/2003	12:30	16	1275	22.3	19.6
BP Solvay	WQ00544-000-A	04/28/2003	12:10	33	1724	28.3	28
BP Solvay	WQ00544-000-B	04/28/2003	18:10	42	1465	29.4	27.5
Oxy Vinyls - Battleground	1539-001-A	05/07/2003	11:00	16	32896	27.9	26.8
Oxy Vinyls - Battleground	1539-001-B	05/07/2003	12:05	16	43489	28.1	24.8
Harris County WCID 1	10104-001-A	05/07/2003	13:30	14	545	10.3	10.7
Harris County WCID 1	10104-001-B	05/07/2003	16:15	11	494	9.52	9.56
City of Meadows	011039-001-A	05/08/2003	9:00	3	530	6.5	6.45
City of Meadows	0011039-001-B	05/08/2003	11:30	5	516	6.66	6.58
Newport MUD	0011329-001-A	05/08/2003	13:28	8	434	10.5	9.29
Newport MUD	0011329-001-B	05/08/2003	16:10	9	419	10.4	9.04
Vopak	0001731-001-A	06/24/2003	9:30	13	10478	134	131
Vopak	0001731-001-B	06/24/2003	12:00	6	10390	136	132
City of Houston - West District	10495-030-A	06/25/2003	9:45	4	639	8.28	7.46
City of Houston - West District	10495-030-B	06/25/2003	11:30	4	580	7.81	7.01
City of Houston - Northwest	10495-076-A	06/25/2003	13:00	5	594	10.3	9.23
City of Houston - Northwest	10495-076-B	06/25/2003	15:15	7	652	9.08	9.03
Oxy Vinyls - Deer Park	Outfall 005-A	07/22/2003	9:20	8	711	12.8	12.5
Oxy Vinyls - Deer Park	Outfall 005-B	07/22/2003	11:50	6	709	12.8	12.4
Clean Harbors	Clean Harbors-A	08/07/2003	10:40	11	3775	20.6	18.3
Clean Harbors	Clean Harbors-B	08/07/2003	12:35	4	4824	19.7	18

N/A = not available

DOC higher than TOC

Table 5.7 Dioxin Concentrations in Effluent (pg/L)

Facility Name	Permit Number	Date	Segment	SIC Code	Volume (L)	2,3,7,8-TCDD	1,2,3,7,8-PeCDD	1,2,3,4,7,8-HxCDD	1,2,3,6,7,8-HxCDD	1,2,3,7,8,9-HxCDD	1,2,3,4,6,7,8-HpCDD	OCDD	2,3,7,8-TCDF	1,2,3,7,8-PeCDF	2,3,4,7,8-PeCDF	1,2,3,4,7,8-HxCDF	1,2,3,6,7,8-HxCDF	2,3,4,6,7,8-HxCDF	1,2,3,7,8,9-HxCDF	1,2,3,4,6,7,8-HpCDF	1,2,3,4,7,8,9-HpCDF	OCDF	Total TEQ	Average TEQ[a]
Albermarle	WQ0000492-001	03/12/2003	1006	28690	251	< 0.0295	< 0.0243	< 0.0371	< 0.0390	< 0.0546	0.6016	2.6693	< 0.6494	0.1263	0.2869	0.2876	0.1267	< 0.1825	< 0.0319	0.7012	< 0.0578	1.0757	0.2921	0.2921
Atofina	WQ0001000-001	03/18/2003	1005	28210	269	< 0.0212	< 0.0249	< 0.0309	< 0.0442	< 0.0494	1.1524	9.9071	< 0.0483	< 0.0290	< 0.0286	< 0.0680	< 0.0316	< 0.0316	< 0.0342	< 0.3428	< 0.0375	0.6543	0.0519	0.0519
Beechnut MUD	WQ0012258-001	04/01/2003	1007	49520	262	< 0.0237	< 0.0374	< 0.0366	< 0.0309	< 0.0344	0.1313	1.1527	0.1336	< 0.0240	< 0.0240	0.2080	< 0.0153	< 0.0210	< 0.0244	< 0.0962	< 0.0454	0.3244	0.0757	0.0757
BP Solvay	WQ0000544-001	04/28/2003	1005	28210	257	< 0.0584	< 0.0490	< 0.0840	< 0.0864	< 0.1665	4.0739	40.0000	< 0.1751	< 0.0735	< 0.0778	< 0.2747	< 0.0564	< 0.0626	< 0.0981	< 0.5268	< 0.1405	< 1.8623	0.1339	0.1339
City of Baytown - Central	WQ0010395-002	03/13/2003	2426	49520	257	< 0.0222	< 0.0455	< 0.0272	< 0.0393	< 0.0506	0.5914	10.6226	0.1362	< 0.0300	0.0529	0.0374	0.0323	0.0739	0.0307	< 0.3911	< 0.0658	0.8949	0.0960	0.0960
City of Baytown - West Main	WQ0010395-008	03/13/2003	1001	49520	259	< 0.0193	< 0.0421	0.0216	< 0.0286	< 0.0367	0.4903	18.3398	0.0714	< 0.0355	0.0571	< 0.0313	0.0347	0.0533	0.0324	< 0.2239	< 0.0649	0.7297	0.0839	0.0839
City of Deer Park	WQ0010519-002	04/02/2003	1006	49520	254	< 0.0610	< 0.0535	< 0.0906	< 0.0780	< 0.0898	0.8031	2.7953	< 0.0736	< 0.0835	< 0.0831	< 0.7677	< 0.0413	< 0.0579	< 0.0654	< 1.2598	< 0.0827	< 0.5984	0.1323	0.0950
City of Deer Park - dup	WQ0010519-002	04/02/2003	1006	49520	254	< 0.0252	< 0.0256	< 0.0382	< 0.0315	< 0.0366	0.2484	1.8543	< 0.0417	< 0.0551	< 0.0543	< 0.2063	< 0.0189	< 0.0433	< 0.0287	< 0.4252	< 0.0354	< 0.4862	0.0576	
City of Houston - 69th Street	WQ0010495-090	02/26/2003	1007	49520	504	< 0.0429	< 0.1000	< 0.0395	< 0.1056	< 0.0756	2.0437	30.1587	0.7679	0.1042	0.2183	< 0.6944	0.0542	< 0.0754	< 0.0506	< 0.8480	< 0.0919	< 2.0020	0.3266	0.3266
City of Houston - Almeda Simms	WQ0010495-003	03/20/2003	1007	49520	502	< 0.0215	< 0.0277	< 0.0291	< 0.0243	< 0.0279	0.2888	2.7709	< 0.0261	< 0.0263	< 0.0259	< 0.1004	< 0.0125	< 0.0193	< 0.0189	< 0.2090	< 0.0237	< 0.2829	0.0431	0.0431
City of Houston - Beltway	WQ0010495-111	02/25/2003	1007	49520	502	< 0.0327	< 0.0337	< 0.0321	< 0.0283	< 0.0315	0.2669	2.2908	< 0.0414	< 0.0345	< 0.0343	< 0.0960	< 0.0149	< 0.0187	< 0.0213	0.1793	< 0.0474	0.4661	0.0560	0.0560
City of Houston - Chocolate Bayou	WQ0010495-009	03/20/2003	1007	49520	259	< 0.0313	< 0.0996	< 0.0448	< 0.0444	< 0.0436	0.4286	4.5483	< 0.0367	< 0.0390	< 0.0386	< 0.0278	< 0.0224	< 0.0313	< 0.0344	< 0.2402	< 0.0305	< 0.4008	0.0858	0.0858
City of Houston - Clinton Park	WQ0010495-010	03/25/2003	1007	49520	255	< 0.0302	0.0431	< 0.0373	< 0.0310	< 0.0357	0.4000	3.9569	0.0933	< 0.0271	< 0.0318	< 0.0161	< 0.0129	< 0.0180	< 0.0235	< 0.1427	< 0.0357	< 0.2353	0.0668	0.0668
City of Houston - FWSD- 23	WQ0010495-016	02/27/2003	1006	49520	503	< 0.0268	0.0553	< 0.0209	0.0322	< 0.0219	0.7972	30.2386	< 0.0457	0.0239	0.0296	< 0.0294	0.0187	0.0332	< 0.0105	< 0.0256	< 0.0215	0.6421	0.0793	0.0793
City of Houston - Greenridge	WQ0010495-110	03/28/2003	1007	49520	253	< 0.0174	< 0.1063	< 0.0229	< 0.0387	< 0.0245	0.5648	4.4427	< 0.0395	< 0.0150	< 0.0166	< 0.0237	< 0.0142	< 0.0261	< 0.0158	< 1.0399	< 0.0379	1.1656	0.0870	0.0870
City of Houston - Homestead	WQ0010495-023	02/26/2003	1007	49520	508	< 0.0490	0.1364	0.0815	< 0.2041	0.2065	8.2087	116.5354	0.1339	< 0.0520	< 0.0581	< 0.3346	0.0760	< 0.0880	< 0.0671	< 1.8465	< 0.1138	3.8917	0.1935	0.1935
City of Houston - Keegans Bayou	WQ0010495-119	03/14/2003	1007	49520	505	< 0.0180	< 0.0792	< 0.0562	< 0.0535	< 0.0545	0.4436	3.4851	< 0.0574	0.0248	0.0358	0.0236	0.0166	0.0432	< 0.0216	< 0.4554	< 0.5248	0.5743	0.0717	0.0717
City of Houston - Northeast	WQ0010495-077	03/25/2003	1006	49520	252	< 0.0242	0.0524	< 0.0377	< 0.0317	< 0.0361	< 0.4206	10.9841	0.0524	< 0.0258	< 0.0254	< 0.0298	< 0.0179	< 0.0250	< 0.0278	< 0.2750	< 0.0583	< 0.5714	0.0619	0.0619
City of Houston - Northwest	WQ0010495-076	06/25/2003	1017	49520	252	< 0.0254	< 0.0274	< 0.0163	< 0.0163	< 0.0159	0.1111	0.9524	< 0.0325	< 0.0210	< 0.0246	< 0.0194	< 0.0131	< 0.0171	< 0.0171	< 0.0829	< 0.0171	< 0.0885	0.0411	0.0411
City of Houston - Simms North	WQ0010495-002	02/20/2003	1007	49520	501	< 0.0098	< 0.0283	< 0.0122	< 0.0277	< 0.0208	0.3613	3.4132	< 0.0818	< 0.0206	0.0375	< 0.0144	< 0.0146	0.0214	< 0.0106	< 0.1269	< 0.0234	0.3054	0.0497	0.0497
City of Houston - Simms South	WQ0010495-002	02/19/2003	1007	49520	504	< 0.0165	< 0.0478	< 0.0173	0.0556	0.0399	0.8671	11.8056	< 0.0595	0.0266	0.0325	0.0200	< 0.0181	0.0270	0.0224	< 0.3141	< 0.0310	1.2599	0.0703	0.0703
City of Houston - Southwest	WQ0010495-037	02/25/2003	1007	49520	503	< 0.0254	< 0.0300	< 0.0264	< 0.0280	< 0.0256	0.3579	3.1809	< 0.0284	< 0.0243	< 0.0239	< 0.2684	< 0.0262	< 0.0350	< 0.0416	0.2008	< 0.0477	< 0.4553	0.0508	0.0508
City of Houston - Upper Brays	WQ0010495-116	03/21/2003	1007	49520	506	< 0.0160	< 0.0532	< 0.0287	< 0.0283	< 0.0277	< 0.3291	2.6265	< 0.0336	< 0.0245	< 0.0241	< 0.3427	< 0.0093	< 0.0194	< 0.0140	< 0.3889	< 0.0229	< 0.7306	0.0661	0.0661
City of Houston - West District	WQ0010495-030	06/25/2003	1014	49520	251	< 0.0323	< 0.0343	< 0.0227	< 0.0223	< 0.0219	0.1514	1.0598	< 0.0382	< 0.0363	< 0.0355	< 0.0582	< 0.0191	< 0.0247	< 0.0247	< 0.1020	< 0.0263	0.1375	0.0461	0.0461
City of Meadows	WQ0011039-001	05/08/2003	1007	49520	250	< 0.0172	< 0.0196	< 0.0244	< 0.0240	< 0.0232	0.1440	1.2400	0.2600	< 0.0284	< 0.0304	< 0.0308	< 0.0136	< 0.0176	< 0.0176	< 0.0812	< 0.0216	< 0.0776	0.0610	0.0610
City of Pasadena - Golden Acres	WQ0010053-003	02/18/2003	1006	49520	508	< 0.0246	< 0.0841	< 0.0278	< 0.0195	< 0.0238	0.3484	3.2480	< 0.0650	< 0.0213	0.0386	< 0.0238	< 0.0195	< 0.0281	< 0.0272	< 0.0425	< 0.0504	0.4803	0.0717	0.0717
City of Pasadena - Vince Bayou	WQ0010053-005	02/18/2003	1007	49520	253	< 0.0312	< 0.0613	< 0.0427	< 0.0451	< 0.0530	0.7589	6.1660	< 0.1265	0.0542	< 0.0565	< 0.0470	< 0.0411	< 0.0625	< 0.0482	< 0.4051	< 0.0534	< 0.9043	0.1134	0.1134
City of West University Place	WQ0010058-000	03/28/2003	1007	49520	256	< 0.0180	< 0.0172	< 0.0297	< 0.0250	< 0.0289	0.2543	< 1.8320	< 0.0203	< 0.0242	< 0.0238	< 0.0852	< 0.0176	< 0.0246	< 0.0270	< 0.2801	< 0.0262	0.3945	0.0367	0.0367
Clean Harbors	WQ0001429-001	08/07/2003	1006	49530	261	< 0.0502	< 0.0345	< 0.0444	< 0.0579	< 0.0632	0.5249	3.0651	< 0.2874	< 0.0709	< 0.0920	0.1456	0.0613	0.0697	< 0.0513	0.4866	< 0.0966	0.6080	0.1205	0.1205
Dow DP	WQ0000663-001	03/19/2003	2427	28210	260	< 0.0412	< 0.0442	< 0.0619	< 0.1058	< 0.1038	7.1000	54.7692	< 0.4000	< 0.0442	< 0.1181	< 0.4385	< 0.0815	< 0.0673	< 0.0727	< 1.6135	< 0.0954	8.5731	0.1875	0.1875
Dupont	WQ0000474-001	04/02/2003	2427	28650	253	< 0.0621	< 0.0431	< 0.0743	< 0.1146	0.1170	6.2846	46.1660	< 0.2213	< 0.0431	< 0.0427	< 0.1332	< 0.0292	< 0.0411	< 0.0478	< 0.5743	< 0.0577	< 2.2292	0.1080	0.1080
Equistar	WQ0000391-001	03/06/2003	1001	28690	255	< 0.0373	< 0.0357	< 0.0812	< 0.1224	< 0.1702	3.9961	51.6078	0.5608	< 0.0557	< 0.1169	< 0.1953	< 0.0561	< 0.1145	< 2.1314	< 0.7992	< 0.0878	< 1.7141	0.4213	0.4213
Exxon	WQ0000592-001	03/11/2003	1005	29110	501	< 0.0279	< 0.0259	< 0.0148	< 0.0259	< 0.0347	< 0.4271	3.0339	0.0679	0.0208	< 0.0303	0.0236	< 0.0162	< 0.0240	< 0.0108	< 0.0575	< 0.0126	< 0.1577	0.0606	0.0606
GB Biosciences	WQ0000749-001	02/20/2003	1006	28790	256	< 0.0332	< 0.0262	< 0.0527	< 0.0371	< 0.0418	0.1914	1.0547	< 0.9961	< 0.1121	0.1078	< 0.0941	0.0801	< 0.0852	< 0.0551	2.2109	< 0.0762	78.5156	0.1824	0.1824
Gulf Coast Waste Disposal Authority	WQ0001740-001	03/27/2003	1007	49520	500	< 0.0132	< 0.0080	< 0.0112	< 0.0114	< 0.0172	0.3080	4.9300	< 0.0382	< 0.0082	0.0112	< 0.0192	< 0.0068	< 0.0078	< 0.0088	< 0.0602	< 0.0134	< 0.1170	0.0284	0.0284
Harris County - FWSD 051	WQ0010032-001	02/19/2003	1006	49520	273	< 0.0242	< 0.0502	< 0.0381	< 0.0348	< 0.0377	0.4579	14.4322	< 0.0842	0.0487	< 0.0421	< 0.1000	0.0505	0.0454	0.0363	< 0.5359	< 0.0850	< 8.8245	0.0867	0.0867
Harris County WCID 1	WQ0010104-001	05/07/2003	1001	49520	199	< 0.0407	< 0.0513	< 0.0392	< 0.0538	< 0.0377	0.7915	10.3618	0.0854	< 0.0558	< 0.0548	< 0.1191	< 0.0211	< 0.0276	< 0.0276	< 0.5874	< 0.0558	0.7402	0.0830	0.0830
Newport MUD	WQ0011329-001	05/08/2003	1001	49520	202	< 0.0257	0.5347	< 0.0990	< 0.0500	< 0.0401	0.8762	70.5941	0.1188	< 0.0386	< 0.0421	< 0.0921	< 0.0228	< 0.0312	< 0.0223	< 0.5198	< 0.0554	< 0.3891	0.3286	0.3286
Oxy Vinyls - Battleground	WQ0001539-001	05/07/2003	1005	28120	134	< 0.0239	< 0.0343	< 0.0500	< 0.0590	< 0.0866	1.7687	71.6418	0.3209	0.3313	0.2985	0.6090	0.5657	< 0.5231	< 0.0978	< 0.9104	0.5493	0.9328	0.4132	0.4132
Oxy Vinyls - Deer Park	WQ0000305-001	07/22/2003	1006	28120	254	< 0.0942	< 0.1619	< 0.1687	< 0.1544	< 0.1599	< 0.2504	0.9484	< 0.0904	< 0.1881	< 0.1806	< 0.2286	< 0.2107	0.4579	< 0.1500	8.6730	0.9004	157.0873	0.2575	0.2575
Oxy Vinyls - La Porte	WQ0002097-001	03/07/2003	1005	28690	252	< 0.0319	< 0.0496	< 0.0492	0.1102	< 0.0909	1.5000	12.8346	< 0.6614	1.8110	0.4094	3.3465	1.3858	0.5906	< 0.1610	< 31.0236	4.0157	632.6378	0.9267	0.9267
Rohm & Haas	WQ0000458-001	03/26/2003	1006	28690	264	< 0.0231	< 0.0394	< 0.0716	0.1587	< 0.1981	6.5530	62.3106	< 0.0390	< 0.0189	< 0.0227	0.0848	< 0.0307	< 0.0208	< 0.0231	< 0.7644	< 0.0587	< 1.7193	0.0980	0.0980
Shell Chemical	WQ0000402-001	03/12/2003	1006	28650	252	< 0.0933	< 0.0552	< 0.1060	0.1746	0.1980	3.4365	28.2540	< 0.6746	< 0.2619	0.3651	4.5437	2.5159	2.2659	< 0.1496	44.5635	6.8810	100.1587	1.2845	1.2845
Shell Refinery	WQ0000403-004	04/10/2003	1006	29110	258	< 0.0647	< 0.2946	< 0.2969	< 0.3864	< 0.6023	2.9612	12.4419	< 1.1434	< 1.5771	1.4702	4.6876	1.8725	< 0.8264	< 0.2112	< 5.0674	< 1.5612	3.2058	2.0048	2.0048
Valero	WQ0000535-001	03/11/2003	1007	29110	253	< 0.0316	< 0.0534	< 0.0723	0.1439	< 0.1719	3.9526	48.1028	0.0877	< 0.0561	< 0.0850	< 0.1478	0.0814	0.1213	< 0.0332	0.5344	< 0.0482	0.9059	0.1287	0.1287
Vopak	WQ0001731-001	06/24/2003	1006	49530	253	< 0.0427	< 0.0399	< 0.0186	< 0.0182	< 0.0249	< 0.1423	3.3202	0.0458	< 0.0292	< 0.0292	< 0.0162	< 0.0150	< 0.0194	< 0.0194	< 0.0664	< 0.0383	0.1561	0.0513	0.0513

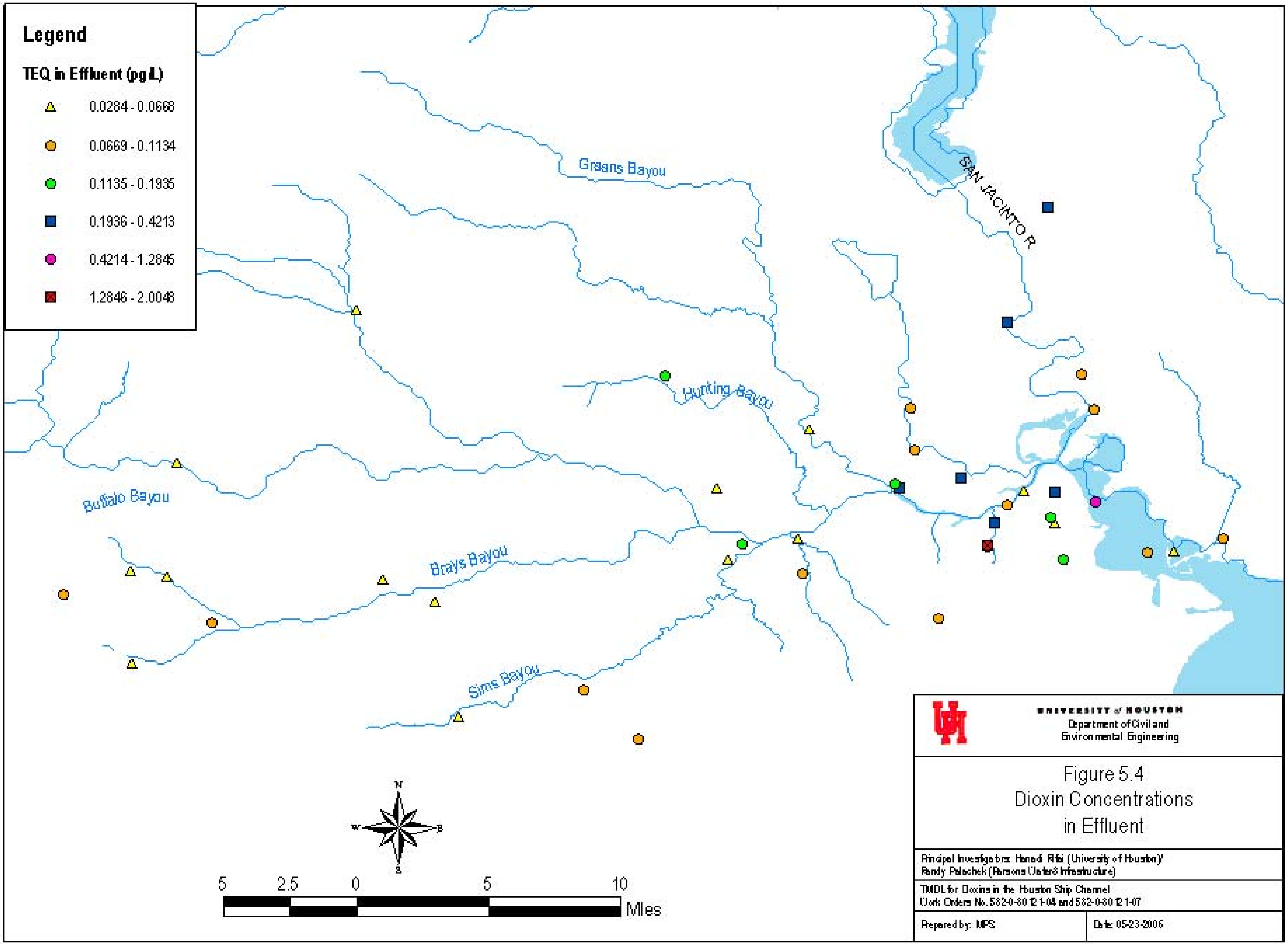
[a] Average of duplicate samples, otherwise concentration of a single sample

dup = duplicate

Values reported to the detection limit

phases

Total TEQ was calculated as the sum of the dissolved TEQ plus the suspended TEQ. Non-detects were assumed to be 1/2 detection limit



UNIVERSITY of HOUSTON
Department of Civil and
Environmental Engineering

Figure 5.4
Dioxin Concentrations
in Effluent

Principal Investigators: Hanadi Rifai (University of Houston)/
Randy Palachek (Parsons Water & Infrastructure)

TMDL for Dioxins in the Houston Ship Channel
Work Orders No. 582-0-80121-04 and 582-0-80121-07

Prepared by: MPS

Date: 05-23-2006

CHAPTER 6

DIOXIN IN AIR IN THE HOUSTON SHIP CHANNEL AREA

6.1 METHODS

6.1.1 Locations and Sampling

Dioxins and furans were monitored at five different air-sampling locations across the city of Houston. These air dioxin monitoring sites were chosen to represent different ambient air backgrounds around the city. The monitors at Clinton Drive (C403) (29° 44' 02"N, 95° 15' 27"W) and Haden Road (C603) (29° 45' 55"N, 95° 10' 52"W) are located in residential/industrial and industrial areas, respectively. While the Mont Belvieu (C610) (29° 52' 44"N, 95° 55" 17"W) site is located in a semi-rural area, Lang Road (C408) (29° 50' 3"N, 95° 29' 21"W) and Bayland Park (C53) (29° 41' 45" N, 95° 29' 57"W) are located in commercial/residential areas in proximity to major highways (Figure 6.1).

Ambient air sampling was initiated in September 2002 at the Clinton Drive and Lang Road sites, October 2002 at Haden Road and Mont Belvieu, and March 2003 at Bayland Park. The sampling was concluded in August 2003. Additional sampling was carried out at Lang Road from December 2003 to April 2004, and Clinton Drive from December 2003 to April 2004 and September 2004 to February 2005. Additionally, a composited 11-month ambient air sample was collected at Clinton Drive from June 2005 to May 2006. Co-located samplers were set up at Clinton Drive and Lang Road for quality control purposes. The five sampling locations are maintained by the City of Houston, the State of Texas, and the Houston Regional Monitoring Network (HRM).

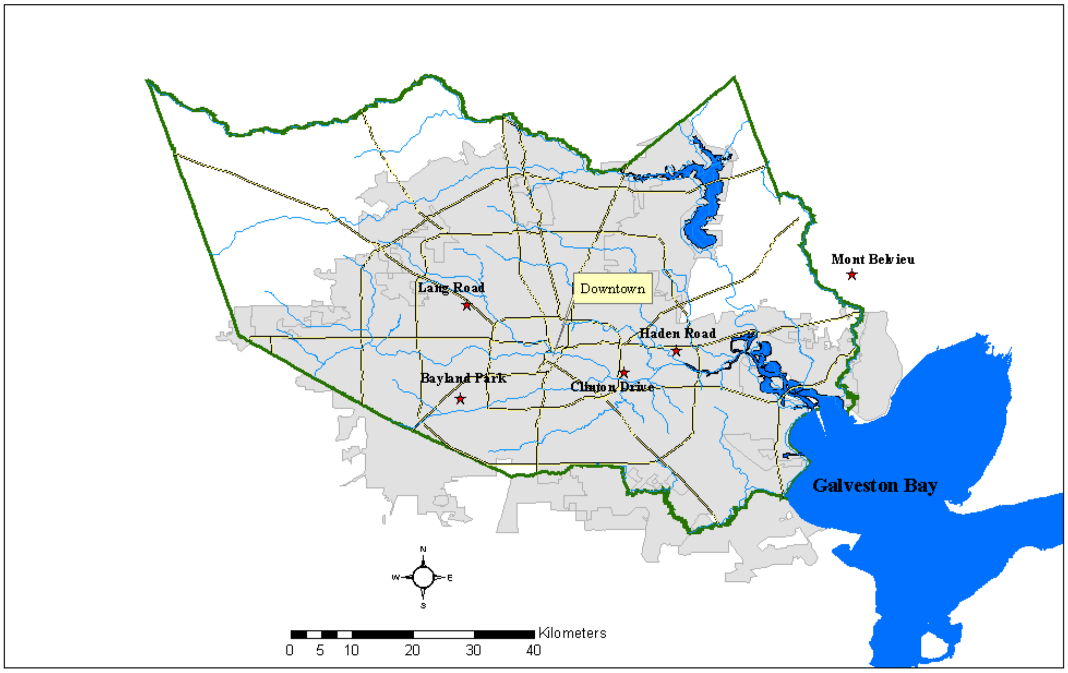


Figure 6.1 Air Sampling Locations.

Monthly, bi-monthly and an 11-month sampling events were planned to obtain enough sample volume for dioxin analysis due to the ultra trace levels of dioxins in the air. Wet and dry deposition was concurrently measured at Clinton Drive and Lang Road from December 2003 to April 2004 (first deposition experiment). Likewise, wet, dry and bulk deposition (second deposition experiment), and particle size distribution of associated dioxins was carried out at Clinton Drive from September 2004 to February 2005. Finally, an additional third wet, dry, and bulk deposition experiment was implemented at Clinton Drive from June 2005 to May 2006. In this particular deposition experiment, a modification that included the filtration of the collected rainwater with 150-mm filters (pore size 0.6 μm) was introduced. This modification was implemented to minimize the loss of sample from the XAD-2 resin columns used in the wet and bulk deposition experiments.

Ambient air samples were collected using high-volume samplers designed to collect both vapor and particle bound phases. In these samplers, air is first drawn through a quartz micro-fiber filter (QFF) where atmospheric particles of >0.1 μm in diameter are trapped. Air then passes through a polyurethane foam plug (PUF) used to remove the vapors from the air stream. Quartz filters were replaced on a weekly-basis to avoid significant pressure drops through the system. The airflow rate was calibrated to 0.25 m^3/min prior to initiation of the sampling event. At this flow rate, a minimum of 6000 m^3 of air was processed during the sampling period. The sampler motors are replaced every 500 hours of operation to avoid motor malfunctions that might cause loss of sample. QFFs are baked at 400°C for 5 hours and dried in a clean atmosphere prior to use. Likewise, the PUF adsorbent plugs are subjected to a 16-hour Soxhlet extraction with acetone at approximately 4 cycles per hour to ensure cleanliness. The PUF plugs are then air-dried in a clean atmosphere, placed in glass cartridges, and spiked with $^{37}Cl_4$-2,3,7,8-TCDD. The PUF plugs are wrapped in aluminum foil for protection from light prior to their use in the field.

Wet/Dry deposition samples were collected using modified automated precipitation collectors. Because these samplers are originally designed to collect only rain samples for wet deposition, they have been modified to include dry deposition sample collection. The modified sampler consists of two separate compartments where rainwater (wet event) and falling particles (dry event) are collected. The sampler is equipped with a rain sensor and a controller. The controller records the time corresponding to the total and dry events. The dry deposition compartment consists of an inverted translucent glass fiber Frisbee with a sharp edge (<10°) mounted on a mechanical actuator. The edge design minimizes abrupt interruptions of the wind path that might affect the deposition process. The face of the Frisbee exposed to the ambient air is covered with a one-foot diameter disk of Velcro-brand loop material to collect the falling particles. When raining, the sampler automatically retracts the dry deposition Frisbee, covers it with a lid, and expose the rain collector compartment. During dry periods, the sampler covers the rain collector and exposes the dry deposition disk to the environment. The rain collector compartment consists of an aluminum funnel with an area of 0.212 m^2 and a depth of 0.46 m. This funnel is connected to a XAD-2 resin column, wrapped in aluminum foil, where dioxins/furans are removed from the rainwater stream. To avoid losses and/or potential degradation of the sample, the dry deposition Velcro brand loop sampling material was replaced on a weekly basis.

Bulk (wet + dry) deposition sampler is an open-aluminum funnel with an area of 0.372 m^2. Similarly to the wet/dry deposition units, the funnel is connected to a XAD-2 resin column wrapped in aluminum foil. The columns are regularly replaced for fresh ones. The old columns are wrapped in aluminum foil and then stored at 4°C in darkness until analysis.

Particle size distribution of associated dioxins and OC/EC samples were taken with two high-volume TSP pumping systems equipped with five-stage cascade Impactors. Aerosol particles are separated into six size fractions on glass- and quartz-fiber filters according to the following equivalent cutoff diameters: first stage > 7.2 μm, second stage 7.2-3 μm, third stage 3.0-1.5 μm, fourth stage 1.5-0.95 μm, fifth stage 0.95-0.49 μm, and backup filter <0.49 μm. Slotted glass and quartz-fiber filters (SQFF) were used as collection substrates. Similarly to QFFs used in the collection of ambient air samples of dioxins, the filters were baked at 400°C for 5 hours and dried in a clean atmosphere prior to use and replaced on a weekly basis. The cascade impactors are adjusted to run at a flow rate of 1.13 m^3/min. Motors were also replaced every 500 hours of operation to avoid motor malfunctions that might cause loss of sample.

6.1.2 Analytical Methods

The 2,3,7,8-substituted congeners of dioxin/furans in ambient air, particle size distribution, and dry deposition samples were quantified by high-resolution gas chromatography/high resolution mass spectrometry (HRGC/HRMS) in compliance with the USEPA Method TO-9A[1]. After the QFF, PUF, SQFF, and Velcro samples were

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[1] USEPA, 1999

collected, they were spiked with 10 μL of a sample fortification solution containing $^{13}C_{12}$-chlorinated internal standards, and Soxhlet extracted with 275 ml of toluene for 16 hours. Then, the sample was subjected to an acid/base clean-up procedure. The resulting extract was spiked with 0.5 ng $^{13}C_{12}$-1,2,3,4-TCDD before HRGC-HRMS analysis to determine the recovery efficiencies achieved for the $^{13}C_{12}$-labeled internal standards and concentrated to 30μL using a stream of nitrogen before analysis.

The array of sample extracts was subjected to HRGC-HRMS selected ion monitoring analysis using a 60-m DB-5 fused silica capillary column. Helium was used as the gas carrier to separate PCDD/PCDFs at a flow rate of 1-2 ml/min. The GC injection port was maintained at a temperature of 200 °C. At the beginning of each day of analysis, the GC/MS system performance was verified for all labeled and unlabeled dioxins from different calibration solutions.

XAD-2 resin columns from the wet and bulk deposition experiments were analyzed according to USEPA method 1613B[2]. The XAD-2 columns were Soxhlet extract with dichloromethane and concentrated by rotary evaporation. After concentration, the extract was spiked with $^{37}Cl_4$-2,3,7,8-TCDD and subjected to a clean-up process. After the cleanup procedure was complete and prior to injection, the extract was concentrated to near dryness and an internal standard solution containing $^{13}C_{12}$-1,2,3,4-TCDD and $^{13}C_{12}$-1,2,3,7,8,9-HxCDD was added. An aliquot of 1.0 or 2.0 μl of the extract was injected into the gas chromatograph. The analytes were separated by the GC and detected by a high-resolution (>10,000) mass spectrometer. Congeners of dioxins and furans were separated using a DB-5, 60 m × 0.32 mm (i.d. 0.25 μm) 5%

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[2] USEPA, 1994

phenyl, 94% methyl, 1% vinyl silicone bonded-phase fused-silica capillary column. The injector and interface temperature were held at 270 and 290 °C, respectively.

Finally, organic (OC) and elemental (EC) carbon were analyzed by a thermal-optical method at a commercial lab (Method NIOSH 5040). The temperature and atmosphere controlled oven used in this method allows an OC/EC speciation. Carbon evolved during the analysis is initially oxidized to CO_2 and subsequently reduced to methane and detected by flame ionization method. The quantification limit for both OC and EC by the method was approximately 0.2 μg per square cm filter.

6.2 QUALITY CONTROL

This section of the report summarizes the quality assurance/quality control tasks undertaken to meet the data quality objective for the TMDL for dioxin in the Houston Ship Channel project. The following data verification cover total ambient air (T), particle (P) and gas (G) phases, dry (DD) and wet (WD), bulk (BD) deposition, and particle size distribution (PSD) for samples of dioxin/furans collected at different locations in the City of Houston from September 2002 to May 2006. The different samples were collected in the following ambient air sampling events (Table 6.1).

The University of Houston collected all of the samples following the procedures described in the QAPP. While total ambient air, particle and gas phases, dry deposition, and particle size distribution samples were analyzed by Alta Analytical Lab using EPA Method TO-9A, wet and bulk deposition samples were analyzed by PSC Analytical services using EPA Method 1613B.

Table 6.1 Ambient Air sampling events

Event	Number of Locations	Sampling Dates	Type of samples collected	Blank
September/02	3	09/01/02-09/27/02	T (4)	T (1)
October/02	5	10/12/02-11/01/02	T (5), P (2), G (2)	T (1)
November/02	4	11/09/02-11/29/02	T (4), P (1), G (1)	T (1)
December/02	4	11/30/02-12/20/02	T (5)	P (1), G (1)
January/03	4	01/11/03-01/30/02	T (4), P (2), G (2)	T (1)
February/03	4	02/01/03-02/27/03	T (4), P (2), G (2)	T (1)
March/03	5	03/08/03-04/03/03	T (5), P (2), G (2)	T (1)
April/03	5	04/05/03-05/01/03	T (5), P (2), G (2)	T (1)
May/03	5	05/03/03-05/28/03	T (5), P (2), G (2)	T (1)
June/03	5	05/31/03-06/26/03	T (5), P (2), G (2)	T (1)
July/03	5	06/30/03-07/28/03	T (5), P (2), G (2)	T (1)
August/03	5	08/02/03-08/28/03	T (5), P (2), G (2)	T (1)
December/03-January/04	2	12/13/03-01/09/04	T (2), P (2), G (2), DD (2)	T (1), DD (1)
January/04-February/04	2	01/17/04-02/20/04	T (2), P (2), G (2), DD (1)	T (1), DD (1)
February/04-March/04	2	02/27/04-03/26/04	P (2), G (2), DD (2)	T (1)
March/04-April/04	2	03/26/04-04/23/04	P (2), G (2), DD (2), WD (1)	
September/04-October/04	1	09/07/04-11/02/04	P (1), G (1), DD (1), PSD (6)	
November/04-December/04	1	11/03/04-12/28/04	P (1), G (1), DD (1), PSD (6)	
January/05-February/05	1	12/28/04-02/22/05	P (1), G (1), DD (1), WD (1), BD (1), PSD (6)	T (1), PSD(3)
June/05-May/06	1	06/08/05-05/09/06	P (1), G (1), DD (1), WD (1), BD (1)	T(1)

Numbers in parenthesis correspond to the number of samples collected.

T - Total ambient air

P - Particle phase

G - Gas phase

DD - Dry deposition

WD - Wet deposition

BD - Bulk deposition

PSD - Particle size distribution

The results of the different analyses performed by the laboratories were reviewed and verified following the guidelines outline in the QAPP. Information reviewed in the data packages includes sample results, laboratory quality control results, instrument calibrations, blanks, and chain of custody forms.

6.2.1 Accuracy

Accuracy is a statistical measurement of correctness and includes components of systematic error. Accuracy is the degree of agreement between a measured value and the known value of an analyte's concentration in a spike sample, a certified reference material, or certain blank samples. Accuracy was quantitatively assessed using the percent of recovery (%R) as indicator. Samples, laboratory control samples (LCS)/ ongoing precision and recovery standards (OPR), blanks and labeled compound spikes were evaluated using the aforementioned indicator. With the exception of some cases (~11%), the range of acceptance for accuracy of 70-130% outlined in the QAPP was not met. Most of these cases corresponded to the analytes OCDD and OCDF. However, an analysis of the collected data using the acceptance control limit range of 50-120% for $^{13}C_{12}$-labeled tetra-, penta-, and hexa-CDD/CDFs, and 40-120% for $^{13}C_{12}$-labeled hepta- and octa-CDD/CDFs, established in the EPA Method TO-9A, showed that in a very few exceptions (<0.5%), the data were out of acceptance range. In those cases, although the data were flagged with an "H" indicating that signal-to-noise ratio was greater than 10:1, they were not flagged with an "R," meaning that the sample results were unusable. Therefore, these flagged data were integrated into the analysis.

Laboratory control samples (LCS)/ongoing precision and recovery standards (OPR) results were also employed to assess the accuracy of the lab in reporting results. OPR standard is a lab blank spiked with known quantities of analytes. The OPR is analyzed exactly like a sample. Its purpose is to assure that the results produced by the laboratory remain within the limit specified in the analytical method for precision and recovery. The recovery is calculated dividing the observed spiked concentration by the spike added. The recoveries were within 75-125% of the acceptable reference concentration.

6.2.2 Precision

Precision was evaluated through the use of field duplicate samples to assess the bias of field and laboratory conditions on the results. Precision expressed as Relative Percent Difference (RPD) was used as indicator. Data obtained from the co-located samplers at Clinton Drive and Lang Road was used to assess precision. In the QAPP, an allowable %RPD of 50% between field duplicates was set. In general, the congener-specific %RPDs were below 50%, with the exceptions of 1,2,3,7,8-PeCDD (79.25%) in the January/03 sample at Clinton Drive site, 2,3,7,8-TCDD (68.09%) in the November/02, and 1,2,3,7,8,9-HxCDF (56.45%), and 1,2,3,4,7,8,9-HpCDF (72.25%) in the May/03 at Lang Road site (Table 6.2). When the comparison was based on TEQ, the samples always met the acceptance criteria.

Table 6.2 Relative Percent Difference (RPD)

Event	2,3,7,8-TCDD	1,2,3,7,8-PeCDD	1,2,3,4,7,8-HxCDD	1,2,3,6,7,8-HxCDD	1,2,3,7,8,9-HxCDD	1,2,3,4,6,7,8-HpCDD	OCDD	2,3,7,8-TCDF	1,2,3,7,8-PeCDF	2,3,4,7,8-PeCDF	1,2,3,4,7,8-HxCDF	1,2,3,6,7,8-HxCDF	2,3,4,6,7,8-HxCDF	1,2,3,7,8,9-HxCDF	1,2,3,4,6,7,8-HpCDF	1,2,3,4,7,8,9-HpCDF	OCDF	TEQ
September/02																		
Lang Rd (C408)	31.8	2.1	6.9	0.4	8.9	1.1	8.1	2.2	4.9	0.9	14.5	6.1	4.8	19.6	4.4	3.8	6.5	1.4
October/02																		
Clinton Dr (C403)	36.8	28.3	13.2	18.2	8.5	10.6	5.9	5.7	23.6	20	12.2	13.2	11.4	27.2	9.6	38.8	4	18.6
Lang Rd (C408)	13	9.9	2	1.3	4.2	1	2.1	9.4	1.5	3.4	2.6	3.5	5.5	4.2	2.5	25.7	1.2	4.5
November/02																		
Lang Rd (C408)	**68.1**	21.1	13.3	8.9	12.4	8	8.8	2.7	5.6	1.9	4.2	0.1	0.4	2.8	3.9	1.7	3.2	9.9
December/02																		
Lang Rd (C408)	18.4	4.2	2.3	1.8	0.6	1.9	1.4	1	4.4	2.8	1.6	4	2.5	7.7	1.1	3.9	1	0.1
January/03																		
Clinton Dr (C403)	37.9	**79.2**	5.3	0.7	3.1	3	0.6	6.4	2.7	8.1	0.8	3.9	5	1.7	0.8	2.8	1.6	9.2
Lang Rd (C408)	39.3	5.8	1.7	3.2	5.2	4.1	2.9	1.2	1.7	3	4.8	4	6.4	6.1	5.6	19	1.7	6.6
February/03																		
Clinton Dr (C403)	NC	30.4	27.4	24.3	30.6	30.1	27	2.8	16.3	16.4	27.1	29.7	28.3	22.4	27.2	24.1	17.4	23.2
Lang Rd (C408)	19.6	1.5	3	13.2	11.3	10.7	4.9	0.2	2.4	6	11.8	6.6	12.6	13.3	11.3	5.8	11	8.3
March/03																		
Clinton Dr (C403)	6.6	7.2	4.9	8.1	11.1	5.7	3.3	9.3	13.4	11.1	9.7	15.9	17.8	21.4	9.7	15.2	14.9	9.8
Lang Rd (C408)	21.9	16.2	1.8	2.5	3.1	2.4	2.7	3.5	4.5	5.7	12.4	7.5	7	13.9	1	0.8	5.8	5
April/03																		
Clinton Dr (C403)	28.3	6.5	6.8	1.3	3.2	0.2	7.1	10.8	8.3	0.2	6.3	0.1	5.6	5.2	3	9.5	1.8	0.5
Lang Rd (C408)	12.8	19.4	8.3	6.8	4.5	2.6	4.8	2.2	0.5	4.6	1.4	3.8	0.4	6.6	2.6	8.3	3.7	0.9
May/03																		
Clinton Dr (C403)	18.8	4.5	0.9	NC	17.2	0.2	0.7	44.9	6.9	7	7.7	5	0.5	NC	2.9	NC	1.7	3.2
Lang Rd (C408)	6.9	33.4	7.5	1.5	11.1	8.8	2.9	5.8	4.1	23.6	2.1	1.9	20.5	**56.5**	5.2	**72.2**	18	12.2
June/03																		
Clinton Dr (C403)	1.4	28.4	4.2	0.6	5	2	3.5	5.1	0.1	1.5	5.5	2.6	4.5	18.7	0.3	6.4	0.5	5.2
Lang Rd (C408)	14.4	18.2	NC	7.8	33.9	2.4	5.2	4.1	16	7.3	11.2	1.6	15.3	2.7	1.7	10.4	5.9	2.7
July/03																		
Clinton Dr (C403)	21.8	7.7	7	2.2	4	2.7	10.8	1.2	19.1	37.1	5.9	4.3	10.6	NC	2	27.1	2.3	13
Lang Rd (C408)	NC	10.1	44.6	21.6	11.3	17.2	8.7	9.1	NC	27.1	0.3	16.2	9.9	47.9	1.1	NC	5.1	8.8
August/03																		
Clinton Dr (C403)	20.4	0.5	8.9	5	5.4	6	9.4	5.4	2.5	0.4	3.5	24.6	7.5	48.8	5.8	2.8	0.9	1
Lang Rd (C408)	7.7	4.5	5.8	0.5	1.3	0.6	0.2	2.3	7.9	5.6	5.8	6.8	11.1	5	7.8	7	11	3.5
December/03-January/04																		
Clinton Dr (C403)	18.6	25.7	29.8	31.8	23.2	32.1	21	22.1	32.8	38.1	33.2	30	42.7	41.6	44.8	28	22.6	29
Lang Rd (C408)	NC	17	7.9	12.1	21.4	15.3	13	12.7	1.5	14.8	22.7	21.8	38.1	42.8	29.9	9.3	4.4	18
January/04-February/04																		
Clinton Dr (C403)	1.5	3.3	4.4	1.6	5.8	0.4	2.1	1.4	2.2	2.3	1.9	1.2	5.1	1.8	1.3	5.7	2.7	1
Lang Rd (C408)	NC	27	27.2	13.5	13.2	0.6	1.2	6.4	11.9	22.7	16.9	1.7	0.7	41.9	29.5	42.5	33.3	8.2

Exceeds criteria

Only detected values were used to calculate RPD

NC, not calculated; one of the duplicate samples below MDL

%RPD = ABS(M1-M2)/((M1+M2)/2)*100

6.2.3 Collection frequency of duplicates, blanks, and LCS/OPR samples

The frequency of collection of duplicates, field and method blanks, and laboratory control standard samples are summarized in Table 6.3. In general, the frequency of the collection of the field duplicates and blanks was well above the minimum of 5% proposed for the present project.

6.2.4 Field blanks and reporting limits

A series of field blanks (quartz fiber filters and PUF plugs in ambient air, slotted quartz fiber filters in particle size distribution, and Velcro disks in dry deposition) were taken during the course of the sampling events. The blanks were processed in an identical manner to the actual samples. For ambient air samples, the blank was taken by installing the PUF and QFF in the sampler unit, except that no air was drawn through the media. Particle size distribution blanks were taken using the same procedure as the ambient air blanks. In the case of dry deposition, the blank consisted of a number of unexposed Velcro disks. The analytes found in the field blanks were 1,2,3,7,8,9-HxCDD, OCDD, 1,2,3,4,7,8-HxCDF, and OCDF (Table 6.4). Their concentrations were considerably lower than the actual samples (<4%), with the exception of OCDF in the October/02 sample, whose concentration was 6% of the lowest concentration of the actual samples. The most common congener detected in the blanks was OCDD. This individual congener encompassed approximately 60% of the analytes detected in the blanks. Finally, none of the lower chlorinated were detected in the blanks.

Laboratory reporting limits (RLs) were also assessed in this project. The RLs refer to the lowest concentration at which the laboratory will report quantitative data

Table 6.3 Frequency of collection of duplicates, field and method blanks, and LCS samples.

	Number of					% frequency of			
Matrix	**Samples**	**Duplicates**	**Field Blanks**	**Method Blanks**	**LCS**	**Duplicates**	**Field Blanks**	**Method Blanks**	**LCS**
Ambient Air	91[a]	25	17	20	20	27	19	22	22
Dry Deposition	11	0	2	-[b]	-[b]	0	2	-	-
Wet Deposition	3	0	0	3	3	0	0	100	100
Bulk Deposition	2	0	0	2	2	0	0	100	100
Particle Size Distr	18	0	3[c]	3	3	0	17	17	17

[a] Ambient air particle and gas phase samples analyzed separately were considered as one sample

[b] analyzed along with the set of ambient air samples

[c] Field blanks were only taken in three out of the six cascade impactor stages (>7.2 µm, 0.95-0.49 µm, and <0.49 µm)

Table 6.4 Field Blanks

	2,3,7,8- TCDD	1,2,3,7,8- PeCDD	1,2,3,4,7,8- HxCDD	1,2,3,6,7,8- HxCDD	1,2,3,7,8,9- HxCDD	1,2,3,4,6,7,8- HpCDD	OCDD	2,3,7,8- TCDF	1,2,3,7,8- PeCDF	2,3,4,7,8- PeCDF	1,2,3,4,7,8- HxCDF	1,2,3,6,7,8- HxCDF	2,3,4,6,7,8- HxCDF	1,2,3,7,8,9- HxCDF	1,2,3,4,6,7, 8-HpCDF	1,2,3,4,7,8,9 HpCDF	OCDF
Ambient Air																	
September/02	<2.00	<2.33	<5.10	<4.75	<4.71	<3.76	<14.1	<2.40	<3.47	<3.25	<1.56	<1.46	<1.65	<1.79	<1.46	<1.87	<11.3
October/02	<1.55	<2.33	<1.95	<1.72	<1.79	<3.55	6.26 (0.5%)	<0.70	<1.54	<1.31	<1.49	<0.60	<0.70	<0.80	<1.08	<1.20	4.19 (6.1%)
November/02	<1.34	<1.55	<2.70	<2.39	<2.48	2.07 (0.2%)	7.76 (0.2%)	<1.07	<1.68	<1.37	1.21 (3.8%)	<0.94	<1.14	<1.27	<2.89	<1.68	2.9 (1.8%)
December/02	<1.77	<1.49	<3.56	<3.11	<3.21	<3.22	6.99 (0.3%)	<2.46	<3.07	<2.68	<1.01	<0.87	<1.07	<1.24	<1.06	<1.21	<3.57
January/03	<1.74	<2.04	<3.19	<2.71	<2.83	3.84 (0.3%)	16.9 (0.4%)	<1.19	<1.63	<1.42	1.39 (3.2%)	<0.71	<0.85	<0.96	<1.10	<0.77	<5.70
February/03	<2.41	<2.49	<3.81	<3.33	<3.43	<6.50	15.2 (1.1%)	<2.07	<2.44	<2.13	<1.60	<1.39	<1.70	<1.98	<1.70	<1.96	<5.43
March/03	<1.26	<3.32	<2.50	<2.18	<2.25	<2.44	<4.03	<1.62	<2.59	<2.26	<1.81	<1.57	<1.92	<2.23	<1.74	<2.00	<3.47
April/03	<2.26	<6.71	<5.11	<4.33	<4.53	<2.30	<12.3	<3.31	<2.65	<2.30	<1.42	<1.19	<1.42	<1.62	<1.59	<1.79	<7.17
May/03	<1.76	<2.35	<3.65	<3.19	<3.29	<2.03	8.87 (0.5%)	<1.06	<1.74	<1.52	<1.14	<0.99	<1.22	<1.41	<0.90	<1.03	<5.04
June/03	<1.62	<4.28	<2.79	<2.44	<2.51	<5.52	<12.5	<1.23	<2.09	<1.82	<1.86	<1.62	<1.98	<2.30	<2.27	<2.61	<9.14
July/03	<2.65	<3.23	<6.97	<6.23	<6.57	<7.44	38.4 (2.0%)	<3.47	<5.24	<5.18	<2.95	<2.55	<3.12	<3.64	<5.01	<6.67	<8.57
August/03	<1.81	<1.55	<3.26	<3.27	<3.19	<4.10	19.7 (0.6%)	<1.51	<2.24	<2.25	<1.11	<1.11	<1.35	<1.56	<1.76	<2.20	<4.96
December/03-January/04	<1.44	<2.69	<4.98	<4.81	<4.71	<8.45	<6.82	<2.10	<2.98	<2.95	<1.45	<1.36	<1.48	<1.68	<1.71	<2.06	<8.06
January/04-February/04	<1.52	<3.48	<5.79	<5.29	<5.50	<2.70	<17.3	<2.09	<2.43	<2.33	<1.36	<1.19	<1.41	<1.70	<1.89	<2.54	<9.00
February/04-March/04	<2.71	<2.86	<4.45	<4.12	<4.20	<7.71	<14.1	<2.08	<5.04	<4.64	<1.74	<1.57	<1.87	<2.05	<2.51	<3.00	<9.54
January/05-February/05	<0.85	<0.34	<1.39	<1.10	<1.22	<1.74	<10.5	<0.83	<1.13	<1.03	<0.47	<0.37	<0.49	<0.59	<0.54	<0.75	<3.67
June/05-May/06	<1.67	<2.31	<3.91	<3.65	<3.69	5.69 (0.1%)	20.9 (0.3%)	<1.49	<6.51	<6.07	<1.68	<1.31	<1.63	<1.94	<2.16	<2.75	<5.94
Dry Deposition																	
December/03-January/04	<2.01	<2.12	<4.12	<3.98	<3.90	<6.52	<17.5	<1.59	<2.39	<2.37	<1.21	<1.13	<1.23	<1.40	<2.42	<2.92	<16.7
January/04-February/04	<2.69	<3.59	<5.98	<5.47	<5.69	<7.10	13.2 (2.4%)	<1.93	<3.36	<3.23	<2.03	<1.78	<2.09	<2.52	<3.10	<4.16	<12.7
Particle Size Distribution																	
January/05-February/05																	
1D-B (>7.2 μm)	<0.61	<1.05	<3.18	<2.52	<2.78	6.6 (1.3%)	32.8 (0.8%)	<0.83	<1.78	<1.63	<1.18	<0.93	<1.22	<1.47	<1.41	<1.11	<6.03
5D-B (0.95-0.49 μm)	<0.76	<0.71	<2.06	<1.64	<1.80	<5.00	40.4 (0.1%)	<0.74	<1.94	<1.78	<0.73	<0.58	<0.76	<0.91	<0.90	<1.24	4.3 (0.7%)
BF-B (<0.49 μm)	<0.96	<0.80	<0.88	<0.70	<0.77	5.02 (0.1%)	32.3 (0.1%)	<0.73	<2.07	<1.90	<0.58	<0.46	<0.60	<0.72	<0.98	<0.60	3.18 (0.2%)

The number in parenthesis represents the percent mass of dioxin congener detected in the blanks. That value was calculated dividing the mass detected in the blanks by the lowest concentration of that specific congener in the batch of samples.

within a specified recovery range. The acceptance criteria establish that the laboratory's reporting limit for each analyte should be at or below the AWRL listed in the QAPP. An RL equal to 0.25 pg/m^3 has been established in the QAPP for all dioxin and furan congeners. In this project, the laboratory reported values less than 0.01 pg/m3.

6.2.5 Completeness

This parameter was assessed by comparing the total number of samples collected with the number of samples collected that pass completely through the sampling, preparation, and analytical processes without significant data quality anomalies such as missed holding time, severe contamination of the field, method blanks, etc. None of the air samples analyzed were flagged with an "R." An "R" means the sample results are unusable. The acceptance criteria for this data quality indicator of >90% was achieved.

6.3 RESULTS

6.3.1 Ambient Air Concentrations

The ambient air concentrations (particle + vapor) of the 17 individual 2,3,7,8-substituted congeners of dioxin/furans at all air monitoring stations are given in Table 6.5. The individual concentrations were found fluctuating from non-detectable to 1718 fg/m^3. The higher chlorinated congeners such as 1,2,3,4,6,7,8-HpCDD, 1,2,3,4,6,7,8-HpCDF, OCDF, and particularly OCDD, exhibited the highest concentrations of all the 17 congeners analyzed at all stations during the period sampled. The congener 2,3,7,8-TCDD, the most toxic compound, was found at concentrations of up to 2 fg/m^3. The

Table 6.5 Total Ambient Concentrations (fg/m^3) of the 17 2,3,7,8-substituted congeners from September 2002 to February 2005.

	CLINTON DRIVE (C403)																			
	2002				**2003**															
	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Dec/03-Jan/04	Jan/04-Feb/04	Feb/04-Mar/04	Mar/04-Apr/04	Sep/04-Oct/04	Nov/04-Dec/04	Jan/05-Feb/05	Jun/05-May/06
2,3,7,8-TCDD	1.4	0.7	<0.6	0.7	1.3	0.6	0.9	1	0.8	0.9	1	1.1	1	1	1.6	<1.0	0.9	1.1	0.6	0.9
1,2,3,7,8-PeCDD	3	2	3	3	5	2	4	3	2	2	2	4	4	8	9	3	<4	5	3	3
1,2,3,4,7,8-HxCDD	3	3	5	4	7	4	8	5	3	3	3	4	7	11	10	3	4	8	5	5
1,2,3,6,7,8-HxCDD	7	6	10	8	13	7	13	8	<4	5	6	8	13	18	17	6	9	18	10	10
1,2,3,7,8,9-HxCDD	5	5	10	8	13	7	12	8	4	5	5	8	13	12	16	5	8	18	10	10
1,2,3,4,6,7,8-HpCDD	92	101	206	116	212	116	285	145	82	85	83	157	213	278	250	98	125	269	154	162
OCDD	443	431	943	473	786	479	1254	573	393	434	370	699	803	949	914	451	519	1022	600	696
2,3,7,8-TCDF	6	3	3	4	5	4	4	3	3	4	4	4	4	8	5	2	4	4	4	4
1,2,3,7,8-PeCDF	4	3	4	4	5	3	4	2	2	2	3	3	4	9	7	2	3	5	5	5
2,3,4,7,8-PeCDF	6	4	6	7	8	5	7	4	2	3	5	4	7	11	10	3	3	9	8	8
1,2,3,4,7,8-HxCDF	6	7	9	11	12	5	8	6	4	4	4	5	9	11	12	5	5	11	11	8
1,2,3,6,7,8-HxCDF	6	6	7	8	10	4	7	4	3	4	4	4	8	7	9	5	5	10	8	7
2,3,4,6,7,8-HxCDF	8	8	11	11	13	7	11	5	5	5	5	6	10	7	9	8	6	16	14	13
1,2,3,7,8,9-HxCDF	1	3	3	4	4	2	3	2	<4	2	2	2	4	8	3	2	1	5	4	4
1,2,3,4,6,7,8-HpCDF	35	41	49	44	51	21	43	28	21	25	22	29	37	23	32	32	28	55	46	64
1,2,3,4,7,8,9-HpCDF	3	7	6	6	5	3	4	3	<2	3	3	4	7	8	<4	5	<4	6	6	9
OCDF	36	45	42	47	52	26	43	37	22	30	24	33	38	35	76	37	54	56	62	85
Texas-TEQ[a]	10	8	11	12	16	8	13	9	6	7	8	9	14	19	20	7	8	17	13	13

	LANG ROAD (C408)															
	2002				**2003**											
	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Dec/03-Jan/04	Jan/04-Feb/04	Feb/04-Mar/04	Mar/04-Apr/04
2,3,7,8-TCDD	0.9	1	0.9	1	1.8	1	1	0.7	0.8	0.4	0.9	1.6	1.2	<1.0	<0.6	<1.0
1,2,3,7,8-PeCDD	3	4	8	6	6	4	5	3	3	1	2	3	6	6	3	2
1,2,3,4,7,8-HxCDD	5	6	12	11	8	8	9	4	4	<2	3	4	10	9	5	2
1,2,3,6,7,8-HxCDD	11	12	22	18	15	15	17	7	6	3	5	8	19	16	9	5
1,2,3,7,8,9-HxCDD	10	12	24	19	16	15	17	7	6	3	5	7	19	16	8	5
1,2,3,4,6,7,8-HpCDD	238	234	469	347	236	277	313	112	106	42	68	145	291	223	104	71
OCDD	859	945	1641	1375	841	969	1127	434	372	163	269	589	1024	815	382	300
2,3,7,8-TCDF	4	3	3	4	8	3	4	4	4	2	4	3	5	3	4	2
1,2,3,7,8-PeCDF	4	3	7	4	8	3	4	3	3	2	<2	2	6	4	4	2
2,3,4,7,8-PeCDF	6	5	8	7	13	5	7	4	5	3	5	3	12	7	8	3
1,2,3,4,7,8-HxCDF	6	7	22	11	14	8	9	7	6	4	5	3	14	5	10	6
1,2,3,6,7,8-HxCDF	6	6	12	9	12	6	8	6	5	4	4	4	12	6	7	4
2,3,4,6,7,8-HxCDF	8	9	15	14	17	10	13	8	7	4	5	5	18	7	13	7
1,2,3,7,8,9-HxCDF	2	3	6	5	5	3	4	2	2	1	2	1	6	3	4	2
1,2,3,4,6,7,8-HpCDF	39	42	81	52	58	36	52	32	23	19	24	19	60	39	43	32
1,2,3,4,7,8,9-HpCDF	5	6	12	7	6	5	5	4	3	2	3	3	9	6	*2*	4
OCDF	48	44	84	45	44	34	44	26	17	15	18	18	47	36	37	38
Texas-TEQ[a]	11	11	21	17	21	12	15	9	9	5	8	8	21	14	12	6

	HADEN ROAD (C603)											MONT BELVIEU (C610)											BAYLAND PARK (C53)					
	2002			**2003**								**2002**			**2003**								**2003**					
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Mar	Apr	May	Jun	Jul	Aug
2,3,7,8-TCDD	2	0.9	1.7	1.6	0.8	<0.4	1.1	0.9	1.1	1.7	1.8	<1.0	0.4	0.5	1.3	<0.4	<0.4	<0.4	0.4	<0.4	<0.4	<0.4	0.6	0.8	<0.4	0.7	<0.4	2
1,2,3,7,8-PeCDD	9	6	6	7	3	9	4	4	4	5	7	1	2	2	7	1	1	1	1	1	1	2	4	4	3	4	3	5
1,2,3,4,7,8-HxCDD	10	9	9	10	5	12	6	4	4	5	8	1	5	3	12	2	2	<4	2	2	2	3	6	5	4	5	4	6
1,2,3,6,7,8-HxCDD	29	16	19	18	11	24	13	7	9	12	23	2	8	6	23	3	4	3	3	3	3	6	11	9	7	8	8	11
1,2,3,7,8,9-HxCDD	26	16	17	19	9	24	13	6	8	12	19	3	9	6	24	4	4	3	3	3	3	5	11	8	6	7	6	9
1,2,3,4,6,7,8-HpCDD	373	338	225	298	135	380	163	83	94	126	253	46	196	97	454	52	65	57	63	73	68	124	235	137	91	83	98	139
OCDD	1381	1170	665	982	453	1110	546	331	359	462	881	203	728	308	1718	190	244	238	269	459	368	437	917	529	323	257	320	442
2,3,7,8-TCDF	8	5	13	8	4	4	6	4	4	7	7	1	2	33	3	1	1	1	1	1	2	2	3	3	2	4	3	3
1,2,3,7,8-PeCDF	7	5	20	9	4	5	4	2	3	4	5	1	2	12	3	1	2	1	2	1	1	1	3	3	2	3	2	2
2,3,4,7,8-PeCDF	11	9	29	14	7	7	5	3	3	6	8	1	3	33	5	2	2	1	2	1	2	2	4	5	2	4	3	3
1,2,3,4,7,8-HxCDF	16	13	59	19	10	11	8	4	5	6	9	2	5	14	7	2	3	2	4	2	2	3	7	6	4	6	5	5
1,2,3,6,7,8-HxCDF	13	11	81	15	7	9	6	4	5	6	8	1	4	9	6	2	3	2	3	<2	1	2	6	5	3	5	4	5
2,3,4,6,7,8-HxCDF	18	17	61	18	11	13	7	5	5	7	11	3	6	15	9	3	4	2	4	2	2	3	8	6	4	6	5	6
1,2,3,7,8,9-HxCDF	9	5	22	6	4	4	3	1	2	2	4	1	2	4	3	1	2	<4	1	1	<0.8	1	2	2	1	1	<2	2
1,2,3,4,6,7,8-HpCDF	85	72	291	77	39	57	35	20	26	28	51	10	26	27	35	11	18	11	16	8	8	15	38	29	26	33	30	40
1,2,3,4,7,8,9-HpCDF	12	8	39	9	6	5	5	2	3	4	9	1	3	4	4	2	2	1	2	1	1	2	4	4	2	2	2	3
OCDF	84	74	313	687	297	476	562	65	813	192	293	10	24	21	31	12	29	11	16	10	15	17	44	25	22	18	19	25
Texas-TEQ[a]	25	18	48	24	12	19	12	8	9	13	18	3	7	28	16	4	4	3	4	3	3	5	10	10	6	9	7	11

1 fg = 10^{-15} g.

[a] ½ MDL taken for calculations.

highest concentrations for this congener were monitored at the Haden Road site (the site in the industrial area) in the October/02 event.

In terms of Texas-TEQ concentrations, values were found fluctuating from 3 to 48 fg Texas-TEQ/m^3. The highest Texas-TEQ concentration was observed at the Haden Road site, the site in the industrialized area. Data collected at the sites Clinton Drive (C403), Lang Road (C408), Haden Road (C603), and Mont Belvieu (C610) for the period September 2002 to August 2003 showed annual mean Texas-TEQ concentrations (mean±std) of 11 ± 4, 13 ± 5, 19 ± 11, and 8 ± 7 fg Texas-TEQ/m^3, respectively. From these data, it is observed that after Haden Road (C603), the second highest concentration was obtained at the Lang Road site (C408). The Lang Road site is localized in a residential/commercial area characterized by having a large volume of traffic, a finding that suggests that traffic may be influencing the dioxin levels in Houston. The Bayland Park mean was not calculated because the sampling at this location started in Spring 2003 and was, therefore, not comparable. An annual mean I-TEQ concentration for the Houston area (September 2002-August 2003) was then found to be 12 ± 8 fg Texas-TEQ/m^3.

Among the TEQ of the individual congeners, 1,2,3,7,8-PeCDD and 2,3,4,7,8-PeCDF were consistently found as the major contributors to the Texas-TEQ concentration. Mean contributions of 1,2,3,7,8-PeCDD to the Texas-TEQ of 15±3, 16±3, 18±5, 15±5, and 21±3% were observed at Clinton Drive, Lang Road, Haden Road, Mont Belvieu, and Bayland Park, respectively. Similarly, mean contributions of 26±4, 25±5, 23±5, 25±10, and 20±4% were found for 2,3,4,7,8-PeCDF at the same sites, respectively.

The mean contributions of 2,3,7,8-TCDD to the Texas-TEQ of 10±4, 9±4, 8±4, 7±4, and 8±5% were observed at the aforementioned sites, respectively.

6.3.2 Particle Size Distribution

The dependence of the concentration of dioxin/furans with the particle size was studied. The concentrations determined in different particle size ranges (<0.49, 0.49-0.95, 0.95-1.5, 1.5-3.0, 3.0-7.2, and >7.2 μm) for the three bi-monthly sampling events (Sep/04-Oct/04, Nov/04-Dec/04, and Jan/05-Feb/05) at Clinton Drive are shown in Table 6.6. The concentrations of the higher chlorinated congeners were significantly higher than those of other less chlorinated congeners at all stages. OCDD was the most prevalent congener for the full size range analyzed in this research. The lower chlorinated and most toxic congeners were found more associated with particles with d_{ae}<0.95 μm. Particularly for 2,3,7,8-TCDD, this congener was detected associated with particles of d_{ae}<0.95 μm at a concentration of 0.3 fg/m^3 and to particles with d_{ae}<0.49 μm at a concentration of 0.1 fg/m^3 in the Nov/04-Dec/04 and Jan/05-Feb/05 events, respectively.

Texas-TEQ concentrations at each stage for the three events are also included in Table 6.6. The lowest particle sizes (0.95-0.49 and <0.49 μm) were characterized by carrying the highest toxicity values. It was observed that >86% of the Texas-TEQ concentration was associated with particles <0.95 μm. This finding is important since exposure to particles with d_{ae}< 2.5 μm are proven to generate adverse health effects on humans since particles at that range are transported and deposited in the lungs and cannot be removed by the respiratory system.

Table 6.6 Concentrations of dioxin/furans with respect to particle size (fg/m^3) at Clinton Dr (Jan/05-Feb/05).

	Sept/04-Oct/04						**Nov/04-Dec/04**						**Jan/05-Feb/05**					
	>7.2 µm	**7.2-3.0 µm**	**3.0-1.5 µm**	**1.5-0.95 µm**	**0.95-0.49 µm**	**<0.49 µm**	**>7.2 µm**	**7.2-3.0 µm**	**3.0-1.5 µm**	**1.5-0.95 µm**	**0.95-0.49 µm**	**<0.49 µm**	**>7.2 µm**	**7.2-3.0 µm**	**3.0-1.5 µm**	**1.5-0.95 µm**	**0.95-0.49 µm**	**<0.49 µm**
2,3,7,8-TCDD	<0.06	<0.04	<0.04	<0.04	<0.04	<0.06	<0.02	<0.02	<0.02	<0.02	0.09	0.2	<0.04	<0.02	<0.02	<0.02	<0.06	0.1
1,2,3,7,8-PeCDD	<0.2	<0.04	<0.04	<0.04	0.2	<0.6	0.1	<0.02	<0.02	0.03	0.7	2	<0.06	<0.02	<0.02	0.03	<0.4	<1
1,2,3,4,7,8-HxCDD	0.1	<0.04	<0.1	<0.1	0.6	1	0.1	<0.06	<0.04	0.07	1	6	0.1	<0.02	<0.04	<0.04	1	3
1,2,3,6,7,8-HxCDD	0.3	<0.04	<0.1	<0.1	2	3	0.3	0.1	0.1	0.16	2	12	0.2	<0.02	0.04	0.1	2	6
1,2,3,7,8,9-HxCDD	<0.2	<0.04	<0.1	<0.1	2	3	0.3	0.1	<0.06	0.13	3	13	0.2	<0.02	0.04	0.1	2	7
1,2,3,4,6,7,8-HpCDD	8	0.6	0.7	1	26	56	6	0.8	1	2	34	225	7	0.4	0.5	1	28	117
OCDD	62	3	3	5	99	285	51	3	3	8	114	848	59	2	2	5	101	452
2,3,7,8-TCDF	<0.08	<0.1	<0.06	<0.06	0.07	0.2	<0.2	<0.02	<0.04	<0.02	0.2	0.6	<0.2	<0.02	<0.02	<0.02	0.2	0.5
1,2,3,7,8-PeCDF	<0.06	<0.2	<0.06	<0.1	<0.1	0.3	0.2	<0.04	<0.04	0.02	0.4	1	0.1	<0.04	<0.02	0.03	0.5	1
2,3,4,7,8-PeCDF	0.1	<0.04	<0.06	<0.06	0.2	0.6	0.1	<0.04	<0.04	0.05	1	3	0.1	<0.04	<0.02	0.04	1	3
1,2,3,4,7,8-HxCDF	<0.2	<0.02	<0.02	<0.02	0.5	1	0.1	0.03	0.04	0.07	2	6	0.2	0.03	0.03	0.1	2	6
1,2,3,6,7,8-HxCDF	<0.2	<0.02	<0.02	<0.02	0.5	1	0.1	0.03	0.04	0.08	1	6	0.1	<0.02	0.04	0.1	2	4
2,3,4,6,7,8-HxCDF	<0.2	<0.02	0.02	0.03	1	2	0.2	0.1	0.1	0.13	3	11	0.2	0.03	0.04	0.1	3	9
1,2,3,7,8,9-HxCDF	<0.02	<0.02	<0.04	<0.02	0.3	0.6	0.1	<0.02	<0.02	0.04	1	3	0.1	<0.02	<0.02	0.04	1	3
1,2,3,4,6,7,8-HpCDF	1	0.1	0.1	0.2	5	11	1	0.2	0.2	0.45	9	44	1	0.1	0.15	0.4	12	31
1,2,3,4,7,8,9-HpCDF	<0.2	<0.02	<0.04	<0.04	0.7	2	0.2	<0.02	<0.02	0.1	1	6	0.2	<0.02	<0.02	<0.04	<1	4
OCDF	15	0.5	<0.2	0.6	9	24	4	0.2	0.3	0.53	8	45	8	0.2	0.24	0.53	15	38
Texas-TEQ[a]	0.22	0.06	0.07	0.07	0.92	1.68	0.25	0.07	0.06	0.12	2.28	8.51	0.21	0.04	0.04	0.10	1.98	5.75
OC (µg/m^3)	1.19	0.05	0.06	0.09	0.32	4.8	0.41	0.02	0.04	0.06	0.24	4.1	0.62	0.03	0.03	0.06	0.6	3.3
EC (µg/m^3)	0.14	0.005	0.01	0.01	0.03	0.93	0.04	0.002	0.003	0.005	0.02	1.1	0.05	0.002	0.002	0.003	0.07	0.98
Particle Conc. (µg/m^3)	23.2	3	2.1	1.8	8.1	28.7	15.1	1.5	1.3	1.3	4	23.1	20.1	3.2	2	1.7	4.6	31.5

[a] ½ MDL taken for calculations.

It has been noted that OC and EC concentrations were also associated with particles with $d_{ae} < 0.95$ μm, analogous to what was observed for the Texas-TEQ concentrations. The Texas-TEQ was correlated with OC and EC concentrations by multiple linear regression. A significant regression (p-value = 2×10^{-6} and $r^2 = 0.83$) was obtained with the expression

$$\text{Texas-TEQ } (\text{fg/m}^3) = 13.69\text{EC } (\mu\text{g/m}^3) - 2.18\text{OC } (\mu\text{g/m}^3) + 0.59 \qquad (7)$$

EC, sometimes termed soot, is usually produced by incomplete combustion of organic gases and particles. Soot is an important constituent of diesel engine emissions although other sources such as power plants may release it. This result shows the potential relationship between dioxin data and traffic as suggested earlier in Section 6.3.1.

6.3.3 Atmospheric Deposition

There are two routes for which dioxin congeners can be removed from the atmosphere: photochemical reactions and deposition. This section reports the characteristics that govern the dry, wet, and bulk deposition of dioxin/furans in the Houston area. Wet and dry deposition processes were evaluated as independent pathways. Their relative contribution to the total deposition was also assessed.

Dry deposition fluxes of dioxin/furans were experimentally measured at the Clinton Drive and Lang Road sites on a monthly basis from December 2003 to April 2004). A second dry deposition experiment was undertaken at Clinton Drive on a bi-monthly basis from September 2004 to February 2005. Finally, a third deposition experiment (11-month sample) was also carried at Clinton Drive from June 2005 to May 2006. The second and third dry deposition experiments were implemented using two co-located wet/dry deposition samplers in order to maximize the collection of sample. The results are summarized in Table 6.7. Houston dry deposition fluxes fluctuating from 1 to 4 pg Texas-TEQ/m^{2}day were measured at both sites (taking non-detects as one-half of the method detection limit). It was observed that the congener 2,3,7,8-TCDD was not detected in any of the collected dry deposition samples.

The wet deposition flux was measured at the Clinton Drive site between Dec/03 and Apr/04, Sept/04 and Feb/05, and Jun/05 and May/06 (Table 6.8). While the first wet deposition experiment was planned to be a five-month sample, the second and third consisted of a six-month and an 11-month co-located samples, respectively. This modification allowed minimizing non-detects. The results show that for the case of wet deposition, more congeners were detected in precipitation in contrast with dry deposition. Wet deposition fluxes were found to fluctuate between 10 and 23 pg Texas-TEQ/m^{2}day. In the second and third experiment, the congener 2,3,4,7,8-PeCDF accounted for 25 and 22% of the Texas-TEQ wet deposition flux, respectively, being the major contributor. Also in these experiments, the congener 2,3,7,8-TCDD was observed to contribute with about 2%. It is noted that the congener 2,3,4,7,8-PeCDF was also observed as the major contributor to the Texas-TEQ in ambient air.

Additionally, it has been observed also from the wet deposition results that congeners like 2,3,7,8-TCDF, a lower chlorinated congener, were being removed from the atmosphere by rain. These results demonstrate that precipitation, while sporadic, still removes a relatively significant amount of atmospheric dioxins.

A general trend was found when comparing the congeners detected in wet versus dry deposition: wet deposition includes a combination of Cl_4-Cl_8 congeners while dry

Table 6.7 Dry deposition fluxes of dioxin/furan congeners (pg/m^{2}day).

	First Deposition Experiment (monthly)							**Second Deposition Experiment (bi-monthly)**			**Third Depo Exp (11-month sample)**
	Clinton Drive (C403)				**Lang Road (C408)**			**Clinton Drive (C403)**			**Clinton Drive (C403)**
	Dec/03-Jan/04	**Jan/04-Feb/04**	**Feb/04-Mar/04**	**Mar/04-Apr/04**	**Dec/03-Jan/04**	**Feb/04-Mar/04**	**Mar/04-Apr/04**	**Sep/04-Oct/04**	**Nov/04-Dec/04**	**Jan/05-Feb/05**	**Jun/05-May/06**
2,3,7,8-TCDD	<1	<2	<1	<2	<2	<1	<2	<1	<0.2	<0.2	<0.3
1,2,3,7,8-PeCDD	<2	<3	<2	<2	<3	<2	<2	<1	<2	<0.4	<0.9
1,2,3,4,7,8-HxCDD	<4	<4	<3	<4	<4	<3	<2	<2	<2	<2	1
1,2,3,6,7,8-HxCDD	<4	<4	<3	<4	<4	<3	<4	<1	2	2	3
1,2,3,7,8,9-HxCDD	<4	<4	<3	<4	<4	<3	<4	<2	<4	<4	2
1,2,3,4,6,7,8-HpCDD	31	35	34	32	14	15	8	80	52	66	83
OCDD	241	289	280	306	89	124	68	751	395	597	750
2,3,7,8-TCDF	<1	<1	<2	<1	<3	<1	<1	<2	<1	<1	<0.5
1,2,3,7,8-PeCDF	<2	<1	<2	<2	<3	<2	<2	<1	<1	<1	<0.6
2,3,4,7,8-PeCDF	<2	<2	<2	<2	<3	<2	<2	<1	<1	<1	0.7
1,2,3,4,7,8-HxCDF	<1	<2	<1	<1	<1	<1	<1	<0.2	<1	<2	1
1,2,3,6,7,8-HxCDF	<1	<2	<1	<1	<1	<1	<1	<2	<1	<2	1
2,3,4,6,7,8-HxCDF	<1	<2	<1	<1	<1	<1	<1	<1	<2	<2	1
1,2,3,7,8,9-HxCDF	<1	<3	<2	<1	<2	<1	<1	<0.4	<0.6	<0.1	<0.3
1,2,3,4,6,7,8-HpCDF	5	6	7	7	<3	3	<5	12	7	9	12
1,2,3,4,7,8,9-HpCDF	<1	<2	<1	<2	<1	<1	<1	<0.6	<0.2	<1	<0.8
OCDF	14	18	24	17	6	2	4	58	20	33	39
Texas-TEQ[a]	2	3	2	3	4	2	3	2	2	1	2

[a] ½ MDL taken for calculations.

Table 6.8 Wet Deposition.

	First Experiment (Dec/03-Apr/04)		Second Experiment (Sep/04-Feb/04)		Third Experiment (Jun/05-May/06)	
	Rain Conc. (fg/L)	Wet Flux (pg/m^2day)	Rain Conc. (fg/L)	Wet Flux (pg/m^2day)	Rain Conc. (fg/L)	Wet Flux (pg/m^2day)
2,3,7,8-TCDD	<46	<4	<4	<0.4	<14	<1
1,2,3,7,8-PeCDD	<98	<8	<7	<0.6	66	5
1,2,3,4,7,8-HxCDD	99	9	95	8	157	11
1,2,3,6,7,8-HxCDD	153	14	138	12	291	21
1,2,3,7,8,9-HxCDD	<206	<18	178	16	458	33
1,2,3,4,6,7,8-HpCDD	3678	329	3405	300	8669	631
OCDD	26018	2329	26012	2290	51381	3742
2,3,7,8-TCDF	99	9	59	5	176	13
1,2,3,7,8-PeCDF	<134	<12	45	4	83	6
2,3,4,7,8-PeCDF	<126	<12	52	5	140	10
1,2,3,4,7,8-HxCDF	135	12	145	13	477	35
1,2,3,6,7,8-HxCDF	90	8	99	9	221	16
2,3,4,6,7,8-HxCDF	75	7	58	5	224	16
1,2,3,7,8,9-HxCDF	<58	<6	<2	<1	<32	<2
1,2,3,4,6,7,8-HpCDF	<592	<52	297	26	161	12
1,2,3,4,7,8,9-HpCDF	<78	<8	56	5	<33	<2
OCDF	1077	96	1274	112	4089	298
Texas-TEQ[a]	161	14	109	10	318	23
Volume collected (L)	111.5		251.9		363.5	

[a] ½ MDL taken for calculations.

favors the deposition of the Cl_7-Cl_8 congeners. This trend of finding a range of chlorination extending to lower numbers in wet deposition and not in dry deposition is consistent with the expectation that lower chlorinated congeners (e.g., 2,3,7,8-TCDF) would exist mostly in the vapor phase, and, therefore, they would more likely be deposited during washout than by sorbing to particles and dry depositing.

In order to estimate a total (wet + dry) deposition flux of dioxin/furans for the Houston area, the wet and dry deposition fluxes were adjusted by accounting for the fraction of time during the sampling period with precipitation. This adjustment allowed accounting for the individual contributions of both deposition mechanisms. An analysis of the collected data showed that precipitation occurred approximately 7% of the time for the first deposition experiment, and 4% for the second and third experiment. Therefore, total deposition of 3.6, 1.9, and 2.4 pg Texas-TEQ/m^2day were estimated for the three deposition experiments, respectively (taking non-detects as one-half of the detection limit) (Table 6.9). These TEQ fluxes, in terms of loadings, are equivalent to 0.017, 0.009 and 0.011 g TEQ/day, respectively for the Harris County area (1778 square miles). The congener 2,3,4,7,8-PeCDF was observed as the major contributor to the total Texas-TEQ deposition in the three deposition experiments (percentage contribution to the total Texas-TEQ deposition flux of approximately 20%).

In addition to experimentally measuring dry and wet deposition of dioxin congeners as independent processes, the bulk (dry + wet) deposition was also measured experimentally (second and third deposition experiments) and compared to the weighted total deposition flux obtained earlier in this section. Total bulk deposition fluxes of 0.8 and 1.1 pg Texas-TEQ/m^2day were determined, respectively (Table 6.10). These bulk

Table 6.9 Total (wet + dry) deposition flux (pg/m^{2}day).

	First Experiment (Dec/03-Apr/04)	Second Experiment (Sep/04-Feb/05)	Third Experiment (Jun/05-May/06)
2,3,7,8-TCDD	0.8	0.2	0.2
1,2,3,7,8-PeCDD	1	0.6	0.6
1,2,3,4,7,8-HxCDD	2	1	1
1,2,3,6,7,8-HxCDD	3	2	4
1,2,3,7,8,9-HxCDD	2	2	3
1,2,3,4,6,7,8-HpCDD	54	76	103
OCDD	423	654	859
2,3,7,8-TCDF	1	1	0.7
1,2,3,7,8-PeCDF	1	0.7	0.5
2,3,4,7,8-PeCDF	1	0.7	1
1,2,3,4,7,8-HxCDF	1	1	2
1,2,3,6,7,8-HxCDF	1	1	2
2,3,4,6,7,8-HxCDF	1	1	2
1,2,3,7,8,9-HxCDF	1	0.2	0.2
1,2,3,4,6,7,8-HpCDF	8	10	12
1,2,3,4,7,8,9-HpCDF	1	0.5	0.4
OCDF	24	40	48
Texas-TEQ	3.6	1.9	2.4

½ MDL taken for calculations.

Table 6.10 Bulk deposition flux at Clinton Drive (C403) (Sept/04-Feb/05) (pg/m^{2}day).

	Sep/04-Feb/05	Jun/05-May/06
2,3,7,8-TCDD	<0.1	<0.1
1,2,3,7,8-PeCDD	0.3	0.3
1,2,3,4,7,8-HxCDD	0.6	0.7
1,2,3,6,7,8-HxCDD	0.8	1
1,2,3,7,8,9-HxCDD	1	2
1,2,3,4,6,7,8-HpCDD	27	29
OCDD	207	200
2,3,7,8-TCDF	0.6	0.6
1,2,3,7,8-PeCDF	0.2	0.3
2,3,4,7,8-PeCDF	0.2	0.5
1,2,3,4,7,8-HxCDF	0.6	1
1,2,3,6,7,8-HxCDF	0.6	0.5
2,3,4,6,7,8-HxCDF	0.3	0.6
1,2,3,7,8,9-HxCDF	<0.04	<0.06
1,2,3,4,6,7,8-HpCDF	4	7
1,2,3,4,7,8,9-HpCDF	0.2	0.7
OCDF	11	15
Texas-TEQ[a]	0.8	1.1

[a] ½ MDL taken for calculations.

fluxes are relatively smaller than from those estimated earlier with wet and dry deposition measurements (1.9, and 2.4 pg Texas-TEQ/m^{2}day, respectively). This disagreement may be attributed to the differences in the configuration of the samplers used for the collection of the deposition samples. For example, in the case of the bulk deposition sampler that is designed to be open to the environment for the duration of the sampling, this configuration may promote losses of sample by particle blowout and evaporation during dry and wet conditions. Evaporation may be particularly important for the lower and mid chlorinated dioxin/furan congeners. It is possible that the bulk deposition sampler may not be suitable to collect dioxin/furans due to the long sampling periods and large volumes of rain required to minimize non-detects.

6.4 ANALYSIS

6.4.1 Vapor to Particle Partitioning

The vapor-particle partitioning of dioxin/furans was assessed at Clinton Drive (C403) and Lang Road (C408). Quartz fiber filters and PUF plugs were analyzed separately. Particle-bound and vapor phase concentrations of the 2,3,7,8-substituted congeners are summarized in Table 6.11 at the two sites, respectively. A consistent trend of increasing percentage in the particle phase, with increasing level of chlorination, was observed at both sites in all sampling events. Thus, tetra-chlorinated congeners were primarily present in the vapor phase; the penta- and hexa-chlorinated congeners were found distributed in both phases, and the hepta- and octa-chlorinated ones were found mostly sorbed in the particle bound phase.

Table 6.11 Particle and vapor concentrations (fg/m^3) of dioxin/furan congeners at Clinton Dr. and Lang Rd.

CLINTON DR (C403)	October/02		January/03		February/03		March/03		April/03		May/03		June/03		July/03		August/03		Dec/03-Jan/04		Jan/04-Feb/04		Feb/04-Mar/04		Mar/04-Apr/04		Sept/04-Oct/04		Nov/04-Dec/04		Jan/05-Feb/05		June/05-May/06	
	P	**V**	**P**	**V**	**P**	**V**	**P**	**V**	**P**	**V**	**P**	**V**	**P**	**V**	**P**	**V**	**P**	**V**	**P**	**V**	**P**	**V**	**P**	**V**	**P**	**V**	**P**	**V**	**P**	**V**	**P**	**V**	**P**	**V**
2,3,7,8-TCDD	<0.8	0.5	<0.6	0.9	<0.4	<0.4	<0.4	0.8	<0.4	0.7	<0.4	0.6	<0.4	0.9	<0.6	0.8	<0.4	1.3	<0.6	0.7	<0.6	0.9	<0.4	1.3	<0.4	<0.6	<0.4	0.7	0.3	0.8	<0.2	0.6	0.2	0.8
PeCDD	0.5	1.1	2.1	<2.6	1.3	1.8	1.4	2.5	1.2	2	0.4	1.6	<0.6	1.8	<1.2	2.2	0.9	2.7	3.7	2	4.1	3.8	2	7.1	1.2	1.4	<0.8	<2.2	3.2	2.1	1.8	<1.2	1.6	1.0
HxCDD	1.7	0.9	5.8	1.7	3.6	1.6	4.9	3.3	2.7	2.3	1	1.6	1.4	1.5	1.3	1.4	2.4	2.2	8.6	0.9	5.6	5.2	4.9	4.8	2.5	<1.0	2.2	2.1	7	1.2	4.5	0.8	4.1	1.3
HxCDD	3.1	1.7	10.3	2.5	6.4	2.4	9.4	4.9	4.1	3.9	2.1	3.2	2.7	2.7	2.9	3.1	4.2	4.3	16.6	1.9	9.6	7.9	9	7.8	4.7	1.5	4.9	3.8	15.4	2.3	8.3	1.3	7.6	2.3
HxCDD	3.5	1.3	10.6	1.9	7.2	2.2	9.7	4.1	5.2	3.2	2.4	2.5	2.5	2.1	3.2	2.3	4.7	3.5	15.1	1.3	8.8	3.1	9.9	6.1	4.3	<1.2	5.4	2.9	16	1.7	9.2	1.2	8.3	1.9
HpCDD	84.8	6.3	213.5	4.4	151.3	6.1	282.5	19.2	114.2	30.5	58.8	23.4	65.8	17.7	61.6	18.7	135.2	32	291	3	273.7	3.9	229	20.8	90	7.7	104.6	20.4	264.1	5.3	150.4	3.2	151.1	10.4
OCDD	402	4.3	788	3	626.6	2.2	1286	9	587.2	28.5	360.5	29.3	393.7	25.6	316.7	16	733.2	35.1	990.7	<2	946.8	2.9	906.8	7.7	445.1	5.5	497.2	21.4	1019	2.6	598.4	1.8	687.9	8.2
2,3,7,8-TCDF	0.4	2.5	<0.8	4.6	0.7	3.7	0.7	3.3	0.6	2.7	<0.4	2.1	0.4	4.3	<0.8	3.8	0.3	3.6	<1.2	3.2	0.8	7.3	0.5	4.9	0.5	1.8	0.3	3.3	0.8	3.4	0.8	2.8	1.1	3.0
PeCDF	0.6	1.6	1.8	3.8	1.1	2.2	1.1	3.4	0.9	1.8	<1.4	1.8	0.4	2	<1.2	2.1	0.6	2.2	3	2.9	3.9	4.7	1.3	5.5	0.8	1.4	0.5	2.2	1.7	2.9	2	2.5	1.8	2.9
PeCDF	1.2	2.1	3.8	4.6	2.3	3.2	2	5.3	1.3	2.3	0.5	1.9	0.7	2.7	<1.2	3.3	1.2	3.2	7.2	3.6	4.2	7.4	2.1	8.3	1.5	1.8	<0.8	2.9	4.4	4.3	4.2	3.8	4.0	4.3
HxCDF	3.8	2.5	7.9	3.7	4	2.7	4.3	4.8	3.3	2.6	1.4	2.6	1.6	2.9	1.6	2.8	2.1	2.6	11.1	1.8	7	2.6	3.1	8.8	4.3	<2.2	1.8	2.9	7.9	2.6	8.4	2.2	8.0	0.3
HxCDF	2.9	2.1	6.9	3.2	3.5	2.1	3.8	4.4	2.3	2.1	1.3	2.3	1.3	2.2	1.7	2.6	<1.8	2.5	9.6	1.3	5.1	2	3.1	5.8	3.7	1.6	1.9	2.7	7.8	2.4	6.5	1.7	6.6	0.3
HxCDF	5.1	1.8	11.2	2.4	6.8	1.9	8	4.8	3.6	2	2.3	2.4	2.3	2.8	2.7	2.6	3.5	2.6	15.1	1	6.3	0.8	5	4.1	6.3	1.3	3	2.9	14	2	12.4	1.5	13.1	0.2
HxCDF	1.9	0.5	3	0.6	2	0.7	2.3	1.5	1.2	0.7	1.9	0.7	0.6	0.8	<0.6	<0.6	<1.2	0.8	5.6	<0.4	5.1	3.1	1.6	1.5	1.7	<0.4	1	<0.6	4.1	0.7	3.6	0.5	3.7	0.1
HpCDF	32.6	4.6	48.2	2.6	25.4	2.7	38.8	9.1	21.2	6.5	13.3	7.2	15.4	9.5	13.4	7.9	19.5	8.2	57	1.2	17.4	5.6	23.5	8.4	28.3	3.4	18.6	9.7	52.2	3.2	43.5	2.4	58.4	6.0
HpCDF	4.7	<0.6	4.9	<0.2	3.6	<2.6	4.9	<2.8	3	<2.6	<2.6	0.5	1.8	0.8	1.9	<0.8	3.3	0.7	9.2	<0.2	7.9	<0.6	<3.4	<0.6	4.5	<0.6	<2.4	<0.8	6	0.2	6	<0.2	8.6	0.5
OCDF	41.7	1.2	52.5	<1.0	30.8	<5.2	50.2	<5.4	34.7	1.5	19.6	2.1	26.6	3.6	21.9	2.1	30.7	2.2	47.5	<1.0	33.7	<1.2	75	<1.2	36.4	<1.8	51.8	2.6	55.6	0.4	62.1	0.4	84.5	0.8
Texas-TEQ[a]	3.5	3.5	9.0	6.1	5.5	4.5	6.3	8.0	3.8	4.9	1.9	4.2	2.0	5.2	2.3	5.5	3.2	6.6	14.1	4.8	9.5	9.9	6.0	13.7	4.4	2.8	2.7	4.9	11.5	5.8	8.6	4.1	8.3	4.5
(°C)		19.3		10.6		12.3		17.4		21.3		26.3		27.7		27.9		28		13.2		11.7		19.3		21.9		25.9		16.1		15.3		22.6
PM$_{2.5}$ (μg/m^3)		9.5		10.7		8.8		12.6		12.7		21.5		12.8		15.4		14.6		11.9		10.3		11.3		12		15.2		9.8		11.8		15.9

[a] ½ MDL taken for calculations

LANG RD (C408)	October/02		November/02		January/03		February/03		March/03		April/03		May/03		June/03		July/03		August/03		Dec/03-Jan/04		Jan/04-Feb/04		Feb/04-Mar/04		Mar/04-Apr/04	
	P	**V**	**P**	**V**	**P**	**V**	**P**	**V**	**P**	**V**	**P**	**V**	**P**	**V**	**P**	**V**	**P**	**V**	**P**	**V**	**P**	**V**	**P**	**V**	**P**	**V**	**P**	**V**
2,3,7,8-TCDD	<0.6	0.9	<0.6	0.4	<0.6	1.2	<0.4	0.8	<0.4	0.8	<0.4	0.6	<0.4	0.7	<0.2	0.5	<0.6	<0.6	<0.4	1.6	<0.6	<0.6	<0.4	<0.6	<0.2	<0.4	<0.2	<0.6
PeCDD	1.4	2.4	4	2.1	2.3	3.7	1.8	2.5	1.1	4.6	<3.2	2.3	<3.2	1.9	<0.2	1.2	0.7	1.5	1	2.2	3	2.2	1.4	3.4	<0.6	2.2	0.7	1.2
HxCDD	4.2	2.1	9.3	1.6	6	2.1	5.5	2.4	3.5	5	1.6	2.4	0.9	2.4	0.6	1	<1.8	1.9	2.5	1.7	7.5	1.6	5.1	1.9	2.2	2.3	1.4	<0.8
HxCDD	7.8	3.6	16.9	3.3	11	3.4	9.2	4	6.6	9.7	3	4.1	1.8	4.4	1.3	2	2.6	3.6	4.2	3.4	13.9	2.7	10.4	3.4	4.9	4.2	3.5	1.9
HxCDD	9.1	3.1	18.4	2.4	12.1	2.7	10.4	3.3	8.1	9.1	3.4	3.4	2	3.6	1.2	<1.4	2.9	2.7	4.8	2.5	13.1	1.9	11.3	2.9	4.4	3.2	3.5	1
HpCDD	213.2	18.7	427.3	6.2	219	7.3	236.8	11.9	275.1	45.5	84.4	30.1	51.3	45.4	30	13.5	59.3	21.2	117.4	28.5	244.1	5.8	207.4	6	89	14.9	62.9	7.7
OCDD	953.1	12.6	1500	3.6	812	4.8	918	4.9	1139	17.7	431.1	24.8	290.3	71.1	153.5	18.5	270.5	22.9	549	41.4	896.4	2.6	802.2	3.1	374.1	8	293.9	5.9
2,3,7,8-TCDF	0.5	2.5	0.7	2.9	1	7.3	0.7	2.5	0.3	3.5	0.5	3.2	0.6	3.2	<0.2	2.6	<0.8	3.4	<0.2	2.6	1.3	4.2	0.5	2.5	0.5	3.7	<0.4	2.1
PeCDF	0.9	2.3	1.6	4.5	2.3	5.8	1	2.3	0.7	3.7	<1.4	2.7	0.7	2.3	0.3	2	<1.2	2.4	0.3	1.9	2.1	3.6	1	2.1	<1.0	3.4	0.7	1.5
PeCDF	1.6	2.9	3	5	5.1	7.1	2.3	2.8	1.5	5.6	1.2	3.5	1.2	2.5	0.5	2.5	<1.0	3.6	0.6	2.6	5.4	4.9	2.1	3.3	1.9	6.1	1.4	1.9
HxCDF	3.7	3.4	9.5	11.7	9.4	4.3	4.5	2.5	3.3	7.1	2.5	4.4	2.2	3.3	1.2	3	2.1	3.2	1	2.5	8.1	2.7	4	2.4	3.6	6.6	3.3	2.4
HxCDF	3	2.7	6.3	5.7	7.7	3.6	3.8	2	2.9	5.6	2.1	3.8	2.1	2.9	0.8	2.6	2.1	2.8	1.1	2.7	7.3	2.3	3.9	2.1	<3.4	5.2	2.7	1.7
HxCDF	6.3	2.4	11.4	4.1	13	2.7	7	1.6	6.9	7.4	4.1	4	5	3.1	1.7	2.9	3	2.9	2.2	2.9	10.6	1.4	6.9	<1.4	6.9	6	5.4	1.7
HxCDF	2.2	0.8	4.1	1.9	3.8	0.7	2.3	0.6	1.9	2.2	1.3	1.2	<3.6	0.9	0.7	0.8	0.9	<0.6	0.8	0.7	3.9	<0.6	2.2	<0.4	2.2	1.9	1.6	<0.8
HpCDF	34.7	6.5	69.2	8.7	51.6	3.6	29.3	2.9	36.2	15.4	21.4	11.3	12	9.6	9.9	9	15.4	8.9	11.2	9.4	41.8	2.3	26.8	2	30.8	11.9	26.7	5.2
HpCDF	4.7	<0.6	11.3	0.8	5.1	<0.2	4.3	<2.6	4.9	<2.6	3.3	0.7	<2.6	<2.6	1.5	0.7	<1.8	<0.8	1.7	0.7	8.1	<0.4	4	<0.4	2.1	<0.6	4.1	<0.8
OCDF	41.9	1.4	80.8	0.6	43.5	<0.8	30	<5.0	44.6	1.7	24.9	1.9	14.6	3.2	13.9	2.5	17.6	1.8	16.6	3	45.1	<0.2	26	<0.8	36.4	<0.8	37	<2.6
Texas-TEQ[a]	5.5	5.7	11.5	7.5	10.5	9.6	6.6	5.5	4.9	11.0	3.5	6.3	3.3	5.4	1.2	4.0	2.4	5.1	2.7	6.0	11.2	5.7	6.4	5.4	3.9	7.8	3.3	3.1
(°C)		18.6		14.9		10		10.5		16.9		20.9		26.1		27.3		27.2		28.2		12.3		11.2		19.1		21.3
PM$_{2.5}$ (μg/m^3)		8		8.6		9.9		7.6		10.9		11.7		18.5		10.6		12.8		11.6		9		8.7		8		8.8

[a] ½ MDL taken for calculations

The mass percentage of each congener associated with the particle phase was correlated to ambient air temperature by linear regression at both sites (Table 6.12). The analysis showed an existing negative correlation between the mass percentage associated with the particle phase with temperature was observed at both sites (at $\alpha = 0.05$). As the temperature increases, the percentage associated with particles decreases. This finding shows that the partitioning of a given congener in the vapor and particle phases in ambient air is a process strongly dependent on temperature.

A theoretically based model by Junge (1977) and Pankow (1987) and two experimentally defined models by Yamasaki et al, (1982), and Finzio et al, (1997) were used to describe the particle-vapor partitioning of the Houston data. These models use the subcooled liquid vapor pressure ($P_L°$) and the octanol-air partitioning coefficient (K_{oa}) as descriptors of the partitioning process.

The theoretical model, based on work by Junge (1977) and Pankow (1987) is given by the Equation

$$\phi = \frac{c\theta}{P_L^{\circ} + c\theta}, \tag{1}$$

where ϕ is the fraction of a compound that is associated with particles, θ is the total suspended particulate surface area concentration per volume of air, and c is a constant that generally is assumed to be 0.172 Pa m for high molecular weights organics. However, it is uncertain if this value is appropriate for describing dioxins since this constant depends on the heat of condensation of the chemical and surface properties. Particle surface areas (θ) often used in the literature are in the range of 4.2×10^{-5} (clean continental background), 1.5×10^{-4} (rural conditions), 3.5×10^{-4} (background plus local

Table 6.12 Particulate percentage (PP) versus ambient temperature correlation results.

	Clinton Dr (C403)				**Lang Road (C408)**			
	Slope	r^2	p-value	Mean PP	Slope	r^2	p- value	Mean PP
2,3,7,8-TCDD	-	-	-	0.28[a]	-	-	-	-
1,2,3,7,8-PeCDD	-1.91	0.5	0.02	0.4	-0.7	0.12	0.35	0.39
1,2,3,4,7,8-HxCDD	-1.81	0.51	0.003	0.62	-1.98	0.44	0.01	0.6
1,2,3,6,7,8-HxCDD	-1.84	0.5	0.002	0.64	-2.09	0.58	0.002	0.59
1,2,3,7,8,9-HxCDD	-18.2	0.7	0.0001	0.7	-1.77	0.44	0.01	0.67
1,2,3,4,6,7,8-HpCDD	-1.33	0.8	$3x10^{-6}$	0.89	-1.68	0.67	0.0003	0.85
OCDD	-0.38	0.74	$4x10^{-5}$	0.98	-0.65	0.56	0.002	0.96
2,3,7,8-TCDF	-0.52	0.28	0.07	0.15	-0.31	0.13	0.31	0.16
1,2,3,7,8-PeCDF	-1.27	0.48	0.006	0.31	-0.81	0.5	0.02	0.26
2,3,4,7,8-PeCDF	-1.5	0.41	0.01	0.38	-1.27	0.52	0.005	0.33
1,2,3,4,7,8-HxCDF	-2.28	0.59	0.0009	0.55	-1.84	0.6	0.001	0.48
1,2,3,6,7,8-HxCDF	-2.24	0.57	0.001	0.58	-1.95	0.64	0.001	0.5
2,3,4,6,7,8-HxCDF	-2.26	0.7	$6x10^{-5}$	0.7	-2.09	0.62	0.002	0.63
1,2,3,7,8,9-HxCDF	-1.85	0.4	0.01	0.69	-1.73	0.6	0.0148	0.62
1,2,3,4,6,7,8-HpCDF	-1.67	0.66	0.0001	0.8	-2.21	0.84	$4.4x10^{-6}$	0.76
1,2,3,4,7,8,9-HpCDF	-1.76	0.66	0.34	0.82	-1.95	0.97	0.01	0.78
OCDF	-0.68	0.73	0.001	0.94	-1.07	0.8	0.003	0.91
Texas-TEQ	-1.88	0.58	0.001	0.47	-1.55	0.59	0.001	0.44

[a] This value corresponds to the Nov/04-Dec/04 event where particle-bound concentration was detected.

sources), and 1.1 x 10^{-3} m^2/m^3 (urban). Subcooled liquid vapor pressures of dioxin/furans were determined using the relationship given by Hung et al, (2002):

$$\log P_L^{\circ} = \frac{-1.34(RI)}{T} + 1.67x10^{-3}(RI) - \frac{1320}{T} + 8.087. \qquad (2)$$

The theoretical values of θ were used to generate curves of ϕ versus $\log P_L^{\circ}$, as shown in Figure 6.2 and compared with the Houston data. In general, it can be seen that the data are located in the area delineated by the rural and urban theoretical curves at both sites. Moreover, the data seem to be evenly distributed along the background plus local sources curve. The curve corresponding to urban conditions in the Junge-Pankow model consistently overpredicts the Houston data. Differences between the experimental and predicted data may be the result of complex processes of sorption of the chemical in the particulate phase and/or sampling artifacts. Also, two limitations of the model are the inherent uncertainty in the values of c and θ and the inability to consider the kinetics of sorption/desorption.

Yamasaki et al, (1982), following the theory of adsorption, proposed the following Equation:

$$\log\left(\frac{C_P}{C_G(TSP)}\right) = \log K_p = m \log P_L^{\circ} + b, \qquad (3)$$

where K_p is known as the particle-gas partition coefficient. The parameters m and b are the slope and y-intercept of the linear regression. It has been established that for the equilibrium partitioning, a slope value near -1 in Equation (3) is to be expected.

In this study, $PM_{2.5}$ is proposed for use instead of TSP in Equations (3) since TSP is no longer routinely measured. Therefore in this research, the particle-gas partitioning coefficient was redefined as

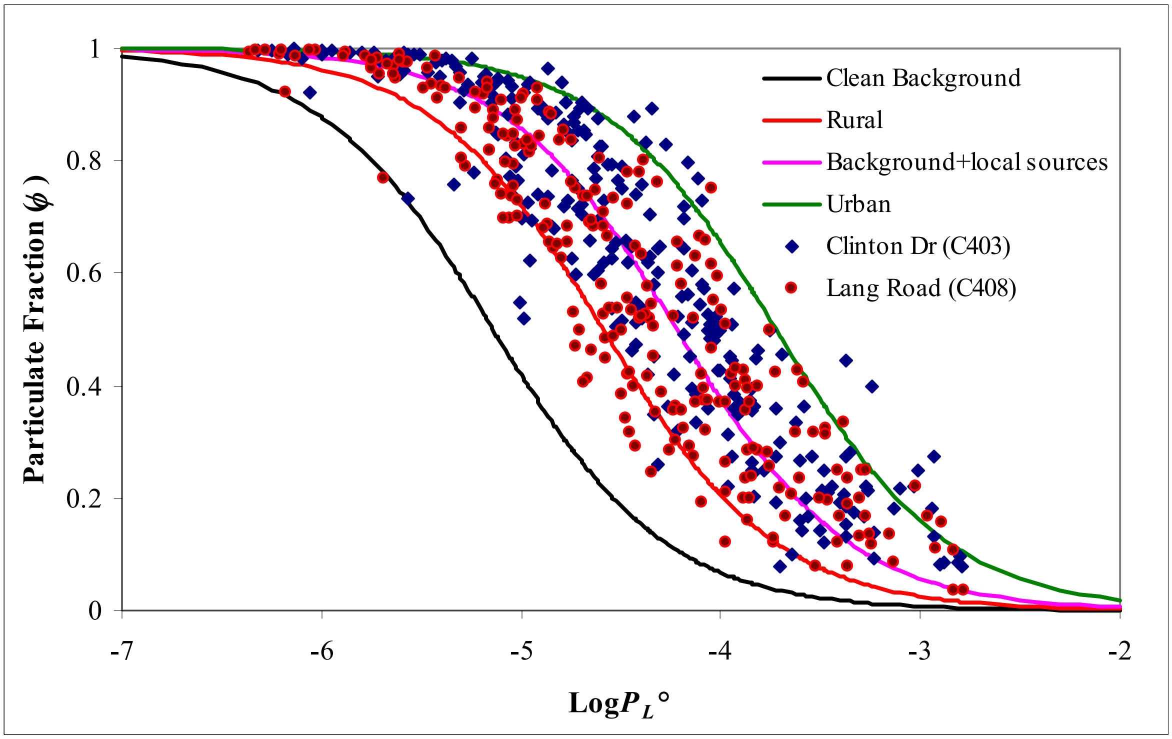


Figure 6.2 Partitioning of dioxins and furans based on the Junge-Pankow model at Clinton Dr. and Lang Rd. sites

$$\log\left(\frac{C_P}{C_G(PM_{2.5})}\right) = \log K_p = m \log P_L^{\circ} + b. \tag{4}$$

For the Houston data, $\log K_p$ was calculated and plotted against $\log P_L$°. $PM_{2.5}$ data was obtained from the Houston air-monitoring network. While $PM_{2.5}$ is currently monitored at Clinton Drive (C403), $PM_{2.5}$ data from site Houston Aldine (C8), a site in the proximity of Lang Road (C408) and with similar background conditions, was used in the partitioning analysis at Lang Road (C408). Results of Equation (4) applied at Clinton Drive and Lang Road sites are shown in Figure 6.3. Correlations of $\log K_p$ versus $\log P_L$° were in general highly significant ($P<0.001$). Little variation in the partitioning between the sites was observed. Values of the slope *m* and the y-intercept *b* for dioxin/furans in the Houston area were –1.02 and –0.95, and –5.2 and –5.0 at Clinton Drive and Lang Road, respectively, in agreement with theory of partitioning and experimental values obtained for other urban areas.

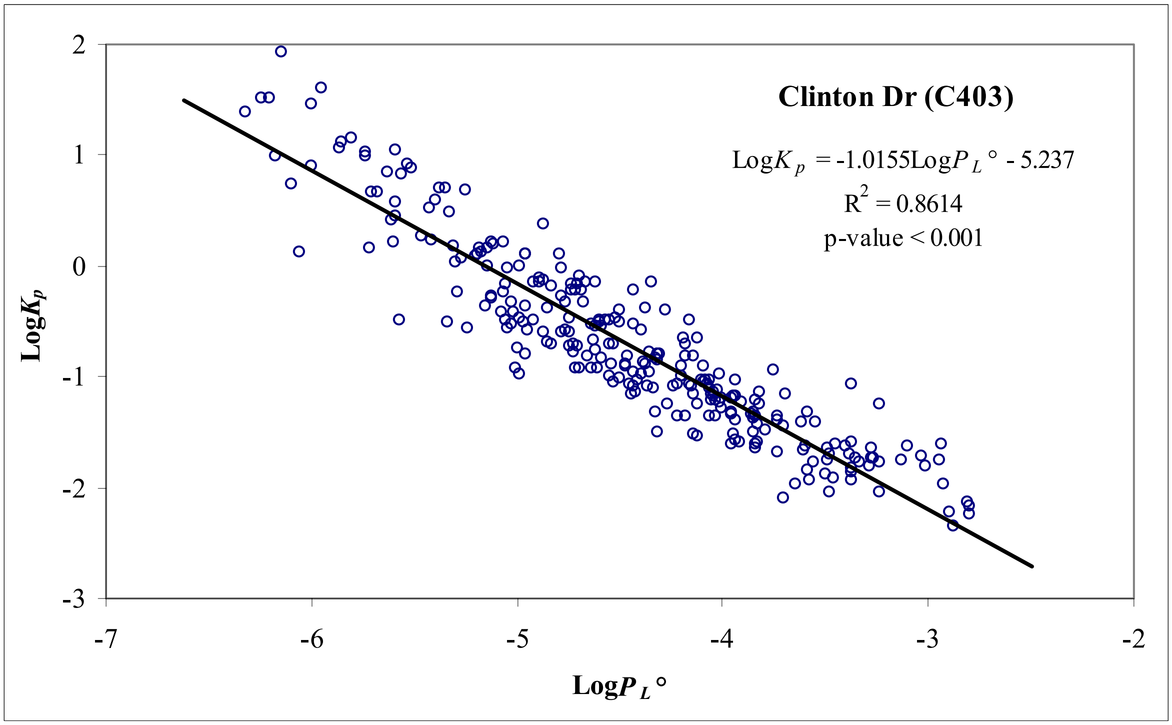
Finzio et al, (1997) proposed the octanol-air partition coefficient (K_{oa}) as a predictor of the partitioning and developed the relationship

$$\log\left(\frac{C_P}{C_G(TSP)}\right) = \log K_p = m \log K_{oa} + b. \tag{5}$$

K_{oa} can be estimated from octanol-water partition coefficient (K_{ow}) and Henry's law constant using

$$K_{oa} = \frac{K_{ow} RT}{H}. \tag{6}$$

Finzio et al (1997) established that a log-log plot of K_p and K_{oa} should be linear with a slope of +1 (equilibrium partitioning). Similarly to the $\log K_p$-$\log P_L$° model, the K_p in the



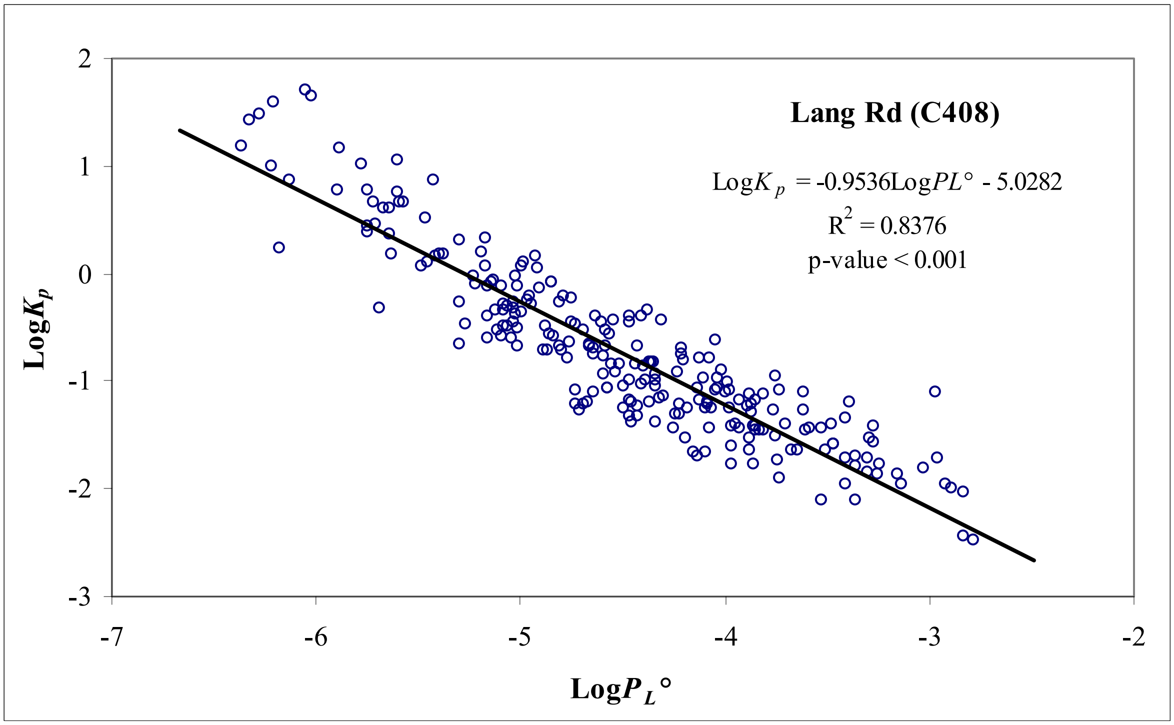


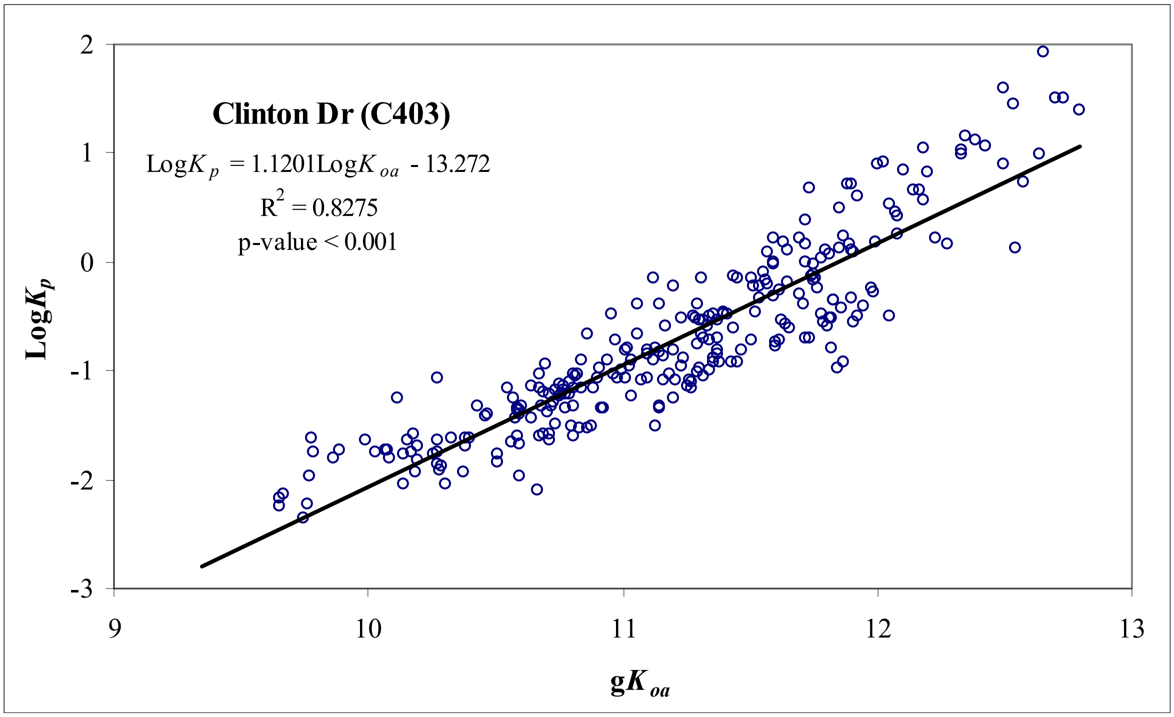
Figure 6.3 LogK_p – logP_L° model for dioxins and furans at Clinton Drive and Lang Road sites

$\log K_p$-$\log K_{oa}$ model was calculated using $PM_{2.5}$ instead of TSP in Equation (5). Results for the Houston data are depicted in Figure 6.4. Significant and similar correlations were obtained at both sites. Values of the slope *m* and the y-intercept *b* for dioxin/furans in the Houston area using this model were 1.12 and 1.05, and –13.27 and –12.52 at Clinton Drive and Lang Road, respectively.

It is important to point out that both the subcooled liquid vapor pressure ($P_L°$) and the (K_{oa}) octanol-air partition coefficient were observed as good descriptors of the particle-to-gas partitioning of dioxin/furans in the Houston area. In both models and sites, significant correlations with r^2's of about 0.8 were obtained. Higher regression coefficients were obtained with $P_L°$. Parameters such as the slope *m* and the y-intercept *b* were observed to follow the general theory of partitioning.

6.4.2 Temporal/Spatial Variability

An initial assessment of the collected data suggests that the concentration distribution varies over time, likely depending upon the chlorination level, the type of congener and ambient temperature (ultimately related to the time of the year). The typical temporal trend for each individual congener is shown in Figure 6.5 for the Lang Road site. As observed in Figure 6.5, ambient air concentrations of dioxin/furans tended to peak between the months of December and March, for which the colder temperatures are met at all of the sites in the Houston area. Therefore, the effect of seasonal effects in the Houston data was explored. The Mann-Kendall test for trend was applied to the Texas-TEQ concentration to determine if there was a statistically significant trend of increasing concentration with decreasing temperature. The results of the test indicated



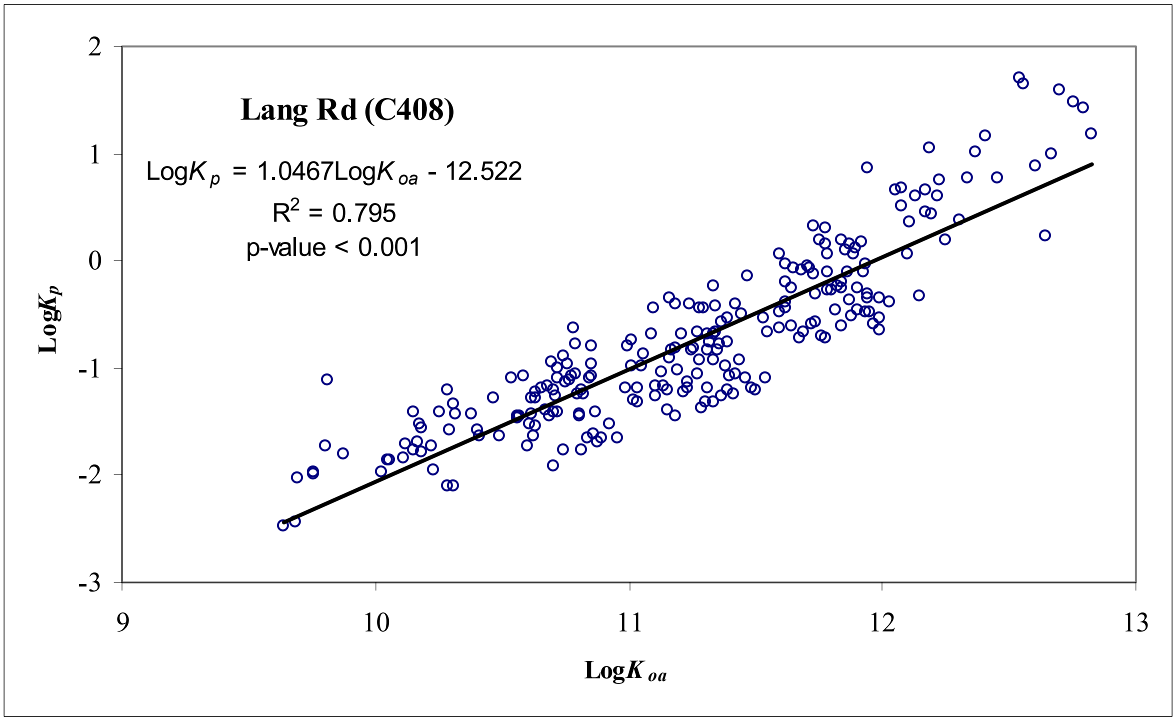
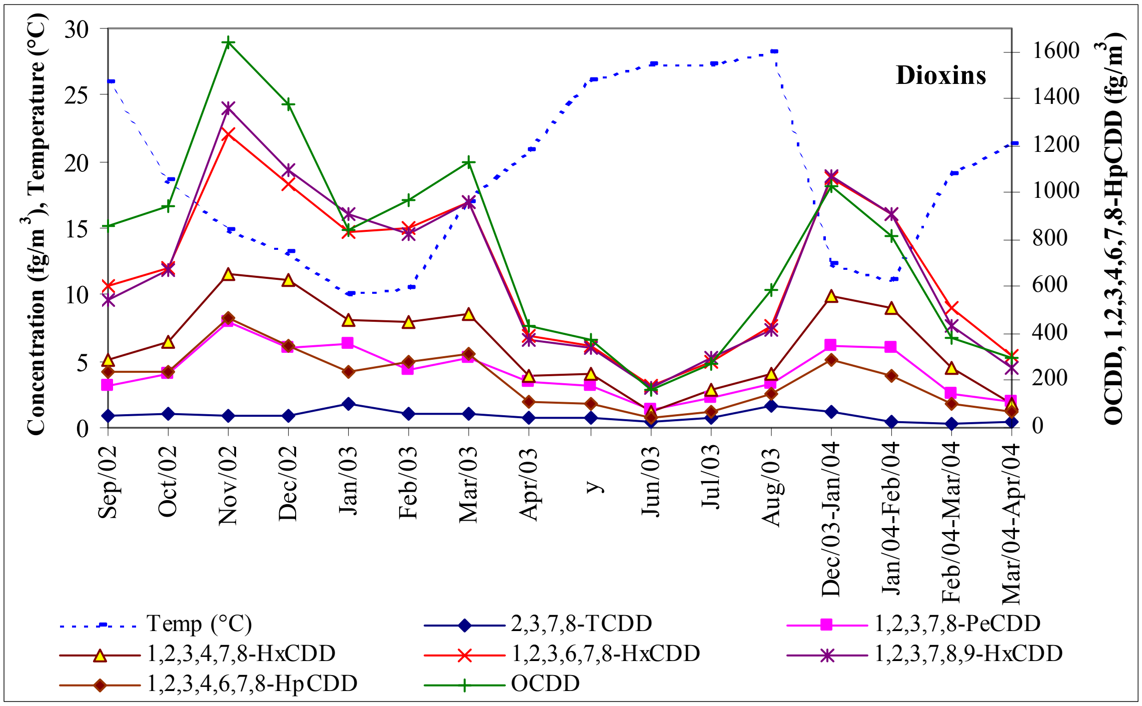


Figure 6.4 LogK_p – logK_{oa} model for dioxins and furans at Clinton Dr and Lang Rd sites.



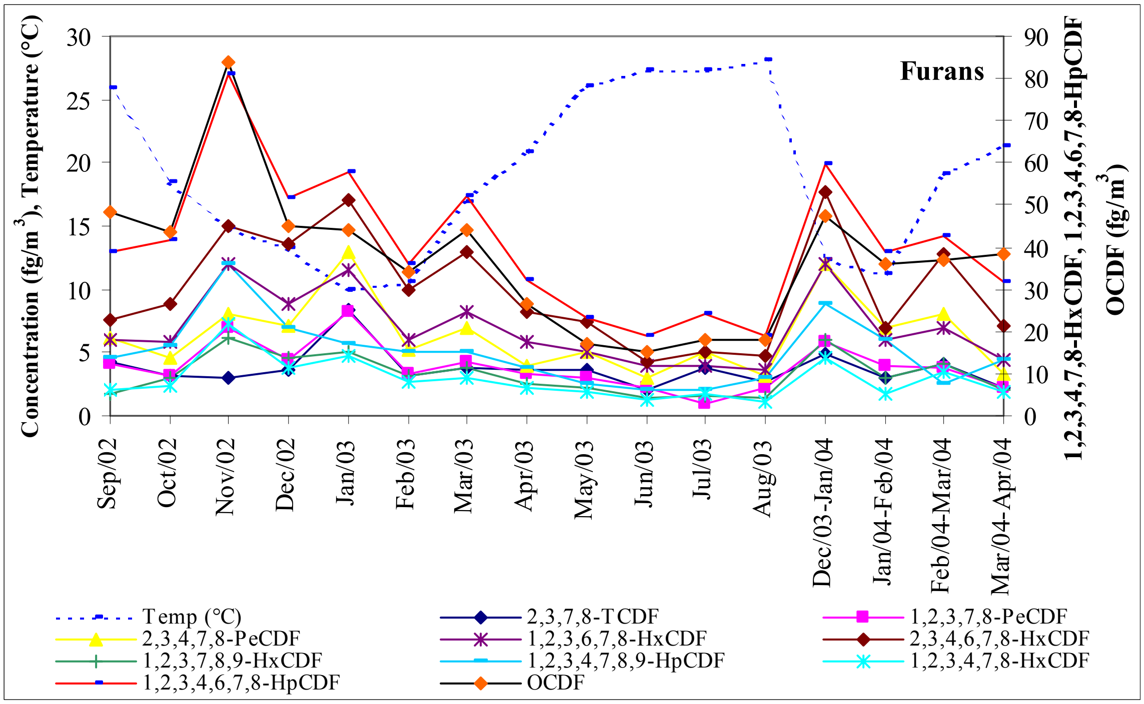


Figure 6.5 Monthly/bi-monthly ambient air concentrations of dioxins and furan congeners at Lang Road

statistically significant trends (at $\alpha = 0.05$) of increasing concentration with decreasing temperature. The analysis also included 2,3,7,8-TCDD, but this congener did not exhibit any significant temporal trend. The homogeneity of stations trend test was also applied to the Texas-TEQ concentration dataset in order to establish a region/study-wide statement about the temporal trend. The test indicated a statistically significant overall homogeneous trend of increasing concentration with decreasing temperature at an experimental wise error rate of 0.05.

Ambient air concentration data on dioxins and furans collected at the Clinton Drive, Lang Road, Haden Road, and Mont Belvieu sites were used to assess spatial variability. Pairs of sites were arranged and the t-test applied to determine any statistical difference in the concentrations values. The p-values of the pairs of monitoring sites were analyzed at a 0.05 significance level, and the results are summarized in Table 6.13. Overall, significant statistical spatial differences were observed among the congeners and Texas-TEQ concentrations. For example, 2,3,7,8-TCDD was found to fluctuate among the air monitoring pairs C403-C603, C403-C610, C408-C610, and C603-C610. Similarly, Texas-TEQ concentrations showed significant differences among the pairs C403-C603, C408-C603, C408-C610, and C603-C610. From these results, it is concluded that the Houston data exhibit spatial variability based on the observed differences between the sampled sites.

The overall spatial variability in the Houston data was further confirmed by applying the Kruskall-Wallis non-parametric comparison test to the Texas-TEQ concentrations at an alpha value of 0.05. This test indicated that statistically significant differences in Texas-TEQ concentrations exist spatially. These spatial variations may be

Table 6.13 Spatial variability results (September 2002 – August 2003).

	Pairs of monitoring sites (p-values)					
	C403-C408	C403-C603	C403-C610	C408-C603	C408-C610	C603-C610
2,3,7,8-TCDD	0.44	*0.03*	*0.0015*	0.11	*6.38E-05*	*0.0002*
1,2,3,7,8-PeCDD	0.10	*0.0003*	*0.0142*	*0.03*	*0.004*	*8.63E-05*
1,2,3,4,7,8-HxCDD	0.09	*0.0006*	0.16	0.20	*0.02*	*0.003*
1,2,3,6,7,8-HxCDD	0.06	*0.0007*	0.19	*0.05*	*0.02*	*0.001*
1,2,3,7,8,9-HxCDD	0.05	*0.001*	0.27	0.13	*0.02*	*0.003*
1,2,3,4,6,7,8-HpCDD	0.08	*0.007*	0.43	0.73	0.07	*0.04*
OCDD	0.22	0.16	0.29	0.76	0.11	0.11
2,3,7,8-TCDF	0.87	*0.008*	0.83	*0.01*	0.85	0.51
1,2,3,7,8-PeCDF	0.53	0.05	0.44	0.11	0.28	*0.05*
2,3,4,7,8-PeCDF	0.38	*0.05*	0.97	0.12	0.72	0.24
1,2,3,4,7,8-HxCDF	0.31	0.09	*0.005*	0.22	*0.01*	*0.04*
1,2,3,6,7,8-HxCDF	0.24	0.17	*0.0009*	0.24	*0.0002*	0.09
2,3,4,6,7,8-HxCDF	0.28	0.10	*0.005*	0.18	*0.0006*	*0.04*
1,2,3,7,8,9-HxCDF	0.37	0.09	*0.0003*	0.13	*0.0029*	0.05
1,2,3,4,6,7,8-HpCDF	0.38	0.11	*1.18E-05*	0.17	*0.0003*	*0.03*
1,2,3,4,7,8,9-HpCDF	0.25	0.10	*0.003*	0.18	*0.002*	*0.03*
OCDF	1.00	*0.02*	*2.16E-05*	*0.003*	*0.008*	*0.0003*
Texas-TEQ	0.16	*0.01*	0.24	*0.05*	*0.02*	*0.01*

Values in italics correspond to p-values $< \alpha=0.05$

the result of differences in air mass movement across the airshed, meteorology, and type of sources involved.

It is interesting to observe that there is no statistically significant difference between the Lang Road (C408) and Clinton Drive (C403) sites. While the Clinton Drive site is located in an area dominated by petrochemical facilities and the Port of Houston entrance, the Lang Road site is located in a commercial/residential area in proximity to major highways. This finding would suggest that traffic is a potential significant source of dioxins in the Houston area.

6.4.3 Relationships between Air Quality and Pollutants

The relationships between the ambient air concentrations of the 17 dioxin/furan congeners and Texas-TEQ collected at the different locations; the routinely measured air pollutants, NO_X, O_3, CO, $PM_{2.5}$, and SO_2; and the meteorological parameter of relative humidity (RH) were assessed using coefficient of correlation (ρ) as indicator. This parameter quantifies the degree of linear association between two given parameters. This analysis is important since field measurements of congener concentrations of dioxins and furans are expensive and difficult. The ability to indirectly model dioxin and furans congeners using other routinely monitored air data would provide a simple, cost-effective approach to predicting congener concentrations and assessing sources, controls, and the relevant importance of factors that affect the atmospheric levels of dioxin/furans.

To make the analysis comparable, the monthly mean levels of the mentioned pollutants/meteorological parameters were calculated. The correlation coefficients of the congeners and the selected parameters are presented in Table 6.14.

Table 6.14 Correlation coefficients (ρ) between dioxin/furan congeners and selected routinely parameters.

	Clinton Drive (C403) (n=19)						Lang Road (C408) (n=16)					ont Belvieu (C610) (n=1				aden Road (C603) (n=1				Bayland Park (C53)	
	NO_x	CO	SO_2	O_3	$PM_{2.5}$	RH	NO_x	CO	O_3	$_5^a$	RH^a	^{b}	O_3^b	^{b}	RH^b	NO_x	SO_2^c	O_3^d	$_5^d$	NO_x	O_3
2,3,7,8-TCDD	-0.1	-0.05	0.19	0.2	0.23	0.03	0.20	0.26	-0.22	0.10	-0.2	0.33	-0.33	-0.11	-0.42	0.02	*-0.63*	-0.32	-0.2	0.06	-0.1
1,2,3,7,8-PeCDD	0.35	-0.20	0.34	-0.16	-0.3	-0.4	**0.87**	0.16	**-0.63**	-0.3	-0.2	0.39	-0.32	-0.16	-0.55	0.35	-0.43	-0.42	-0.3	0.33	-0.1
1,2,3,4,7,8-	*0.5*	-0.09	0.45	-0.27	-0.39	*-0.5*	**0.87**	0.09	**-0.69**	-0.4	-0.1	0.44	-0.30	-0.14	*-0.7*	*0.7*	-0.25	-0.54	-0.5	0.69	-0.2
HxCDD	*0.6*	-0.17	0.41	-0.44	*-0.50*	**-0.6**	**0.87**	0.10	**-0.71**	-0.4	-0.1	0.44	-0.31	-0.16	*-0.6*	0.40	-0.51	-0.5	-0.5	0.70	-0.3
HxCDD	*0.6*	-0.06	*0.5*	-0.43	*-0.5*	**-0.6**	**0.89**	0.14	**-0.71**	-0.4	-0.1	0.46	-0.35	-0.20	-0.58	0.46	-0.40	-0.51	-0.5	*0.87*	-0.2
1,2,3,4,6,7,8-	*0.5*	0.01	0.39	-0.34	-0.43	*-0.5*	**0.79**	0.22	**-0.63**	-0.3	-0	0.40	-0.32	-0.15	*-0.6*	0.56	-0.39	-0.57	-0.5	*0.90*	-0.2
OCDD	*0.5*	0.08	0.31	-0.28	-0.37	-0.5	**0.78**	0.22	**-0.64**	-0.3	0.03	0.33	-0.30	-0.11	*-0.6*	0.48	-0.52	-0.57	-0.5	*0.91*	-0.1
2,3,7,8-TCDF	0.15	-0.17	0.09	-0.17	-0.09	-0.1	0.33	0.06	-0.18	0.20	-0.5	0.59	-0.32	-0.27	0.16	0.60	-0.37	-0.45	-0.4	0.32	-0.5
1,2,3,7,8-PeCDF	*0.5*	-0.30	0.21	-0.43	-0.39	-0.4	**0.78**	0.24	-0.46	-0.1	*-0.5*	*0.6*	-0.29	-0.22	0.04	**0.81**	-0.22	-0.52	-0.5	0.69	0.09
2,3,4,7,8-PeCDF	**0.60**	-0.19	0.24	*-0.5*	*-0.5*	-0.4	**0.73**	0.12	*-0.6*	-0.1	-0.4	*0.6*	-0.33	-0.26	0.12	**0.83**	-0.28	-0.58	-0.5	0.60	-0.1
HxCDF	**0.73**	0.19	0.16	**-0.57**	**-0.58**	*-0.6*	**0.81**	0.31	*-0.5*	-0.3	-0.4	*0.7*	-0.32	-0.20	-0.17	**0.82**	-0.21	-0.49	-0.5	**0.93**	-0.3
HxCDF	**0.73**	-0.18	0.17	**-0.59**	*-0.6*	**-0.6**	**0.85**	0.26	*-0.6*	-0.2	-0.4	**0.75**	-0.27	-0.21	-0.31	**0.76**	-0.18	-0.40	-0.4	*0.88*	-0.4
HxCDF	**0.68**	-0.17	0.11	**-0.6**	*-0.5*	*-0.6*	**0.83**	0.05	*-0.6*	-0.3	-0.4	**0.73**	-0.39	-0.28	-0.17	**0.84**	-0.26	-0.52	-0.5	**0.96**	-0.4
HxCDF	*0.6*	-0.18	0.26	*-0.5*	*-0.5*	-0.4	**0.91**	0.13	*-0.7*	-0.4	-0.3	**0.8**	-0.22	-0.36	-0.26	**0.81**	-0.32	-0.53	-0.5	0.61	0.05
HpCDF	**0.64**	-0.07	-0.1	*-0.5*	*-0.5*	-0.4	**0.9**	0.18	**-0.65**	-0.4	-0.2	*0.7*	-0.29	-0.19	-0.60	**0.82**	-0.26	-0.48	-0.5	0.57	-0.5
HpCDF	**0.62**	-0.16	-0.1	**-0.7**	**-0.66**	-0.3	**0.84**	0.32	*-0.60*	-0.3	-0.2	**0.75**	-0.36	-0.24	-0.46	**0.77**	-0.31	-0.47	-0.5	*0.75*	0.11
OCDF	0.24	*-0.47*	0.17	-0.30	-0.39	**-0.6**	**0.82**	0.17	*-0.6*	-0.3	-0.1	0.58	-0.22	-0.10	-0.58	-0	0.57	0.15	-0.2	**0.88**	-0.1
Texas-TEQ	**0.58**	-0.18	0.33	-0.43	-0.46	*-0.5*	**0.88**	0.20	**-0.65**	-0.3	-0.3	**0.71**	0.40	-0.29	-0.13	**0.83**	-0.34	-0.58	-0.5	0.58	-0.2

Numbers in italics significant at P≤0.05 and bold at P≤0.01; Routinely monitored air data taken from site [a] C8, [b] C15, [c] C405, [d] C01.

In general, 2,3,7,8-TCDD and 2,3,7,8-TCDF were not correlated with the same parameters as the other congeners, and their correlations were not as strong and significant as the other dioxin/furans. As a group, with the exception of 2,3,7,8-TCDD and 2,3,7,8-TCDF, the other dioxin/furan congeners exhibit similarities and differences in correlation results at all of the sites.

Dioxins and furans appear to be negatively correlated with ozone. Significant statistical correlations were only observed at the Clinton Drive (C403) and Lang Road (C408) sites. Between these two sites, however, it was seen that while the furan congeners were found to be better correlated with ozone at C403, dioxin congeners were found to be better correlated with the same parameter at C408. Texas-TEQ concentrations were found statistically correlated with ozone (at $p \leq 0.01$) only at C408 ($\rho=-0.65$).

Both dioxins and furans were found to be mainly negatively correlated with relative humidity, although no apparently consistent trend was observed among the sites. Overall, the Clinton Drive site presented higher correlation coefficients as compared to the other sites analyzed. Similar results were observed correlating $PM_{2.5}$ with dioxin/furan data.

Houston data were also correlated to CO and SO_2 at Clinton Drive, Lang Road, and Haden Road. In both cases (CO and SO_2), and with very few exceptions, poor and inconsistent correlations were observed. For example, while dioxin/furans and Texas-TEQ were negatively correlated with CO at Clinton Drive, they correlated positively with the same parameter at Lang Road. Likewise, while the congeners and Texas-TEQ were found positively correlated with SO_2 at Clinton Drive, they correlated negatively with SO_2 at Haden Road.

Dioxin and furan congeners (with the exception of 2,3,7,8-TCDD and 2,3,7,8-TCDF) were found positively and consistently correlated with mean NO_x at all of the sites. The results also showed furans having stronger correlation coefficients than dioxins. In general, high correlation coefficients were found for 2,3,4,7,8-PeCDF, which was one of the major contributors to the Texas-TEQ, in addition to being the majority of the remaining dioxin/furan congeners and Texas-TEQ at all of the sites. This apparent trend, along with the significance of the relationship between dioxin/furan data and the NO_x observed at all sites, suggests the potential for predictive model development. This finding also potentially offers using NO_x as a surrogate to predict dioxin pollution in the ambient air of Houston.

6.4.4 Dry Deposition Velocities and Scavenging Ratios

In modeling the dry and wet deposition of semi volatile organic compounds such as dioxins, two empirical parameters were calculated: the dry deposition velocity and the scavenging ratio. The dry deposition velocities of the 17 dioxin congeners was obtained dividing the observed dry deposition flux (F_{DRY}) by the particle-phase ambient air concentration (C_p):

$$v_d = \frac{F_{DRY}}{C_P}. \tag{7}$$

Deposition velocity values can be used to model the transfer of atmospheric pollutants to surfaces from ambient air concentrations.

In this project, dry deposition fluxes were concurrently measured with ambient air concentrations, so fluxes and air concentrations could be related. Calculated dry deposition velocities for particle-phase dioxin/furans and Texas-TEQ are summarized in

Table 6.15. With the exception of the lower chlorinated congeners 2,3,7,8-TCDD and 2,3,7,8-TCDF, dry deposition velocities <1 cm/s were essentially observed for the remaining congeners. Texas-TEQ dry deposition velocities fluctuated between 0.17 and 0.97 cm/s.

The wet deposition flux (F_{WET}) of a given pollutant can be calculated as

$$F_{WET} = IC_R , \tag{8}$$

where I is the precipitation rate (m/h), and C_R is the concentration of the pollutant in rain (fg/m^3). For modeling purposes, the applicability of Equation (8), in most cases, is limited because the rain concentrations of the pollutant are not available. To overcome this limitation, the scavenging ratio (W), a parameter that relates the concentration of the pollutant in rain to that in ambient air (C_A in units of fg/m^3) was calculated as

$$W = \frac{C_R}{C_A} . \tag{9}$$

Therefore, Equation (8) can be redefined as

$$F_{WET} = IWC_A . \tag{10}$$

Scavenging ratios for the Houston data are summarized in Table 6.16. As observed in Table 6.16, W values on the order of 10^4 were found for the Houston data, in agreement with the literature. Scavenging ratios for the Texas-TEQ were found fluctuating from about 1 x 10^4 and 2.4x 10^4.

Table 6.15 Dry deposition velocities (cm/s)

	First Deposition Experiment									**Second Deposition Experiment**				**Third Depo Exp**
	Clinton Drive (C403)					**Land Road (C408)**				**Clinton Drive (C403)**				**Clinton Drive (C403)**
	Dec/03-Jan/04	**Jan/04-Feb/04**	**Feb/04-Mar/04**	**Mar/04-Apr/04**	**Mean**	**Dec/03-Jan/04**	**Feb/04-Mar/04**	**Mar/04-Apr/04**	**Mean**	**Sep/04-Oct/04**	**Nov/04-Dec/04**	**Jan/05-Feb/05**	**Mean**	**Jun/05-May/06**
2,3,7,8-TCDD	*1.93*	*3.86*	*2.89*	*5.79*	*3.62*	*3.86*	*5.78*	*11.6*	*7.07*	*2.89*	*0.39*	*1.16*	*1.48*	*1.13*
1,2,3,7,8-PeCDD	*0.31*	*0.42*	*0.58*	*0.96*	*0.57*	*0.58*	*3.86*	*1.65*	*2.03*	*1.45*	*0.36*	*0.13*	*0.65*	*0.33*
1,2,3,4,7,8-HxCDD	*0.27*	*0.41*	*0.35*	*0.93*	*0.49*	*0.31*	*0.79*	*0.83*	*0.64*	*0.53*	*0.17*	*0.26*	*0.32*	0.28
1,2,3,6,7,8-HxCDD	*0.14*	*0.24*	*0.19*	*0.49*	*0.27*	*0.17*	*0.35*	*0.66*	*0.39*	*0.12*	0.15	0.28	0.18	0.46
1,2,3,7,8,9-HxCDD	*0.15*	*0.26*	*0.18*	*0.54*	*0.28*	*0.18*	*0.39*	*0.66*	*0.41*	*0.21*	*0.14*	*0.25*	*0.2*	0.30
1,2,3,4,6,7,8-HpCDD	0.12	0.15	0.17	0.41	0.21	0.07	0.2	0.15	0.14	0.89	0.23	0.51	0.54	0.64
OCDD	0.28	0.35	0.36	0.8	0.45	0.12	0.38	0.27	0.26	1.75	0.45	1.15	1.12	1.26
2,3,7,8-TCDF	*0.96*	*0.72*	*2.31*	*1.16*	*1.29*	*1.33*	*1.16*	*2.89*	*1.8*	*3.86*	*0.72*	*0.72*	*1.77*	*0.51*
1,2,3,7,8-PeCDF	*0.39*	*0.15*	*0.89*	*1.45*	*0.72*	*0.83*	*2.31*	*1.65*	*1.6*	*1.16*	*0.34*	*0.29*	*0.6*	*0.32*
2,3,4,7,8-PeCDF	*0.16*	*0.28*	*0.55*	*0.77*	*0.44*	*0.32*	*0.61*	*0.83*	*0.59*	*1.45*	*0.13*	*0.14*	*0.57*	0.20
1,2,3,4,7,8-HxCDF	*0.05*	*0.17*	*0.19*	*0.13*	*0.13*	*0.07*	*0.16*	*0.18*	*0.14*	*0.06*	*0.07*	*0.14*	*0.09*	0.15
1,2,3,6,7,8-HxCDF	*0.06*	*0.23*	*0.19*	*0.16*	*0.16*	*0.08*	*0.34*	*0.21*	*0.21*	*0.61*	*0.07*	*0.18*	*0.29*	0.17
2,3,4,6,7,8-HxCDF	*0.04*	*0.18*	*0.12*	*0.09*	*0.11*	*0.05*	*0.08*	*0.11*	*0.08*	*0.19*	*0.08*	*0.09*	*0.12*	0.09
1,2,3,7,8,9-HxCDF	*0.1*	*0.34*	*0.72*	*0.34*	*0.38*	*0.3*	*0.26*	*0.36*	*0.31*	*0.23*	*0.08*	*0.02*	*0.11*	*0.03*
1,2,3,4,6,7,8-HpCDF	0.1	0.4	0.34	0.29	0.28	*0.04*	0.12	*0.11*	0.12[a]	0.75	0.16	0.24	0.38	0.24
1,2,3,4,7,8,9-HpCDF	*0.06*	*0.15*	*0.34*	*0.26*	*0.2*	*0.07*	*0.28*	*0.14*	*0.16*	*0.29*	*0.02*	*0.1*	*0.14*	*0.07*
OCDF	0.34	0.62	0.37	0.54	0.47	0.15	0.06	0.11	0.11	1.3	0.42	0.62	0.78	0.53
Texas-TEQ	0.20	0.41	0.45	0.76	0.46	0.37	0.67	0.97	0.67	0.67	0.17	0.18	0.34	0.28

Numbers in italics correspond to deposition velocities calculated with a half of the detection limit of the dry deposition flux.

[a] This value correspond to the dry deposition flux observed in event Feb/04-Mar/04.

Table 6.16 Scavenging ratios (W)

	First Experiment	Second Experiment	Third Experiment
	(Dec/03-Apr/04) x10^4	(Sep/04-Feb/05) x10^4	(Jun/05-May/06) x10^4
2,3,7,8-TCDD	2.24	0.23	0.76
1,2,3,7,8-PeCDD	0.76	0.11	2.51
1,2,3,4,7,8-HxCDD	1.18	1.68	2.9
1,2,3,6,7,8-HxCDD	1.03	1.02	2.93
1,2,3,7,8,9-HxCDD	0.84	1.48	4.48
1,2,3,4,6,7,8-HpCDD	1.60	1.86	5.37
OCDD	3.15	3.64	7.38
2,3,7,8-TCDF	2.13	1.50	4.31
1,2,3,7,8-PeCDF	1.12	1.04	1.77
2,3,4,7,8-PeCDF	0.72	0.78	1.69
1,2,3,4,7,8-HxCDF	1.31	1.61	5.73
1,2,3,6,7,8-HxCDF	1.14	1.29	3.21
2,3,4,6,7,8-HxCDF	0.75	0.48	1.68
1,2,3,7,8,9-HxCDF	0.62	0.30	0.43
1,2,3,4,6,7,8-HpCDF	0.82	0.69	0.25
1,2,3,4,7,8,9-HpCDF	0.64	1.20	0.18
OCDF	2.20	2.22	4.79
Texas-TEQ	0.99	0.87	2.45

CHAPTER 7

DIOXIN IN RUNOFF FROM THE HOUSTON SHIP CHANNEL WATERSHED

7.1 METHODS

7.1.1 Locations and Sampling

Twenty-five candidate sampling sites were selected using Harris County Flood Control District watershed boundaries, channel system maps, and TCEQ wastewater permit database outfall coordinates. Sites were identified at road crossings for safe access. Sampling sites were selected so that no dry weather flows (wastewater treatment plant effluent) would be present.

Ten sites were selected for runoff sampling in 2002-2003 (Figure 7.1). A second round of runoff sampling was conducted in 2005 at ten locations, seven of which had been sampled in 2002-2003 (Figure 7.1).

For the duration of the storm event, dioxins and furans in runoff were directly sampled using a high-volume sampler, Infiltrex 300 sampler (Axys Environmental Systems, Inc). Water stream during runoff conditions was passed through the system in the following arrangement: first through the pre-filter, then through a 40-μm filter, and finally through a 1 μm filter before being discharged. The 1- and 40-μm filter arrangement allowed the quantification of dioxins associated with suspended particulate matter. The sampler was run at a flow rate not exceeding the 1.6 L/min. To increase the levels of detection, a minimum volume of 700 L of runoff water was processed. Figure 7.2 shows the amount of rain and flow rate during each sampling event. Concurrently with the collection of the dioxin samples, composited TSS, TDS, TOC, and DOC samples were taken at each station and preserved at 4°C in the dark until lab analysis. The results for these parameters are summarized in Table 7.1. Table 7.2 provides a summary of the field parameters during the runoff sampling activities.

Finally, dioxins in watershed sediment and soil (forest, grass, urban, residential, and transitional) were collected concurrently with runoff sampling at different locations across the city of Houston from December 2004 to October 2005 sampling.

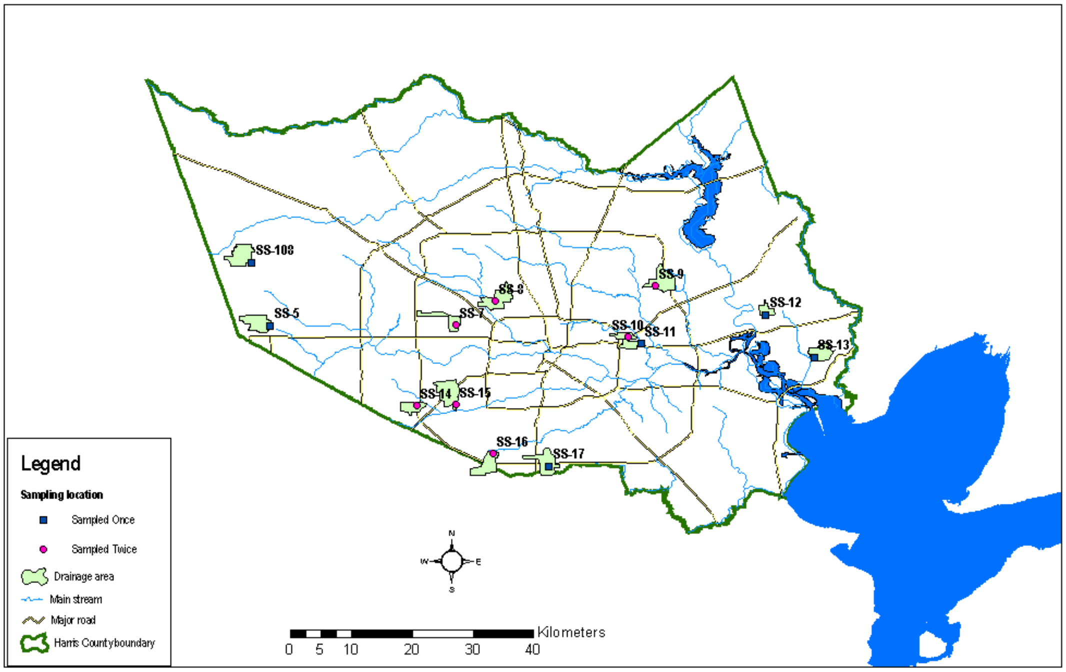


Figure 7.1 Runoff sampling locations and drainage areas

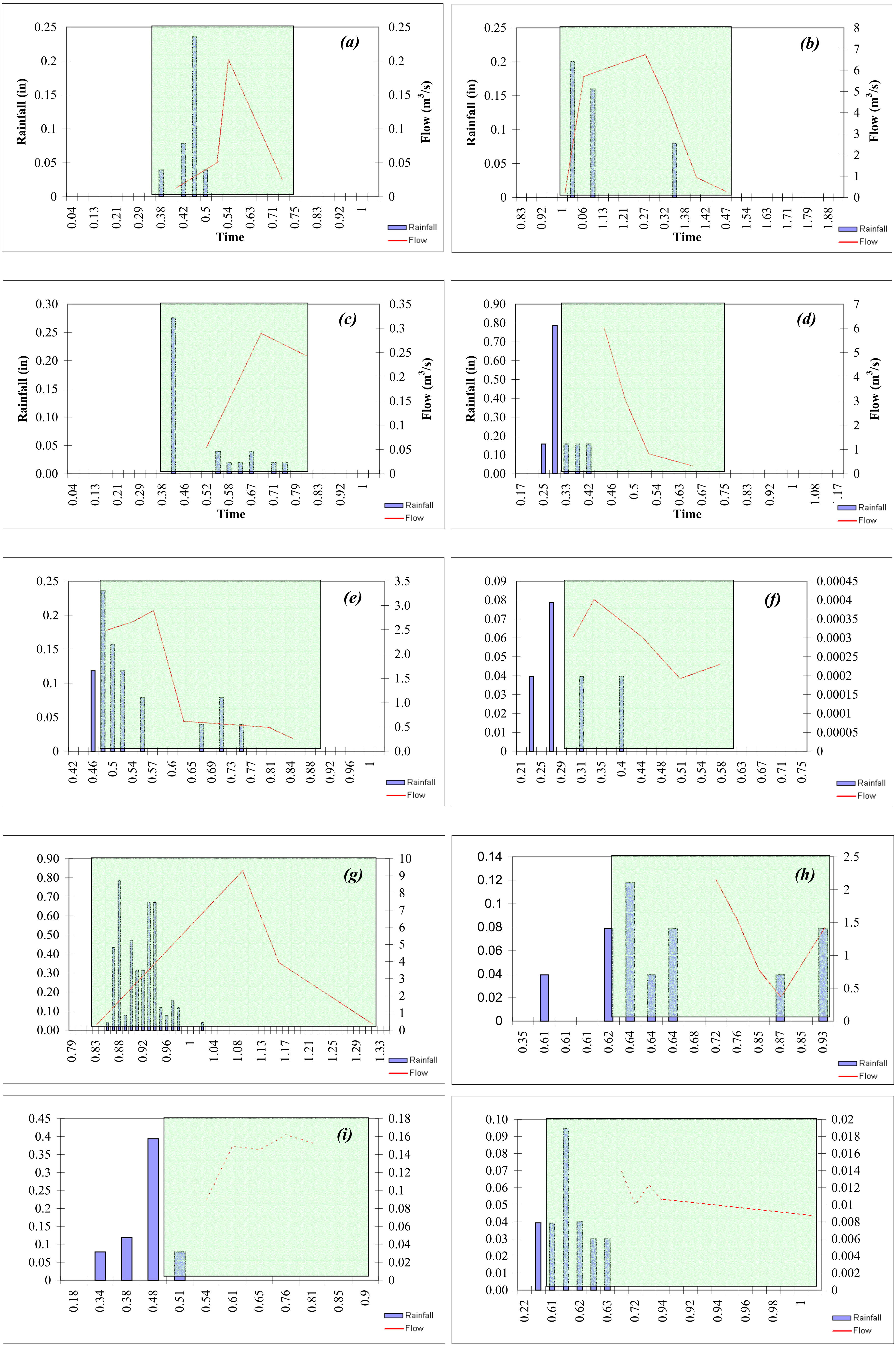


Figure 7.2 Rainfall Hyetograph from Harris County OEM Gages

(a) Sample Station SS-10 (HCOEM Gage 0830) - 16 December 2004
(b) Sample Station SS-13 (HCOEM Gage 1520) - 13 January 2005
(c) Sample Station SS-9 (HCOEM Gage 1620) - 7 February 2005
(d) Sample Station SS-15 (HCOEM Gage 0460) - 24 February 2005
(e) Sample Station SS-14 (HCOEM Gage 0475) - 3 March 2005
(f) Sample Station SS-16 (HCOEM Gage 0380) - 16 March 2005
(g) Sample Station SS-8 (HCOEM Gage 0535) - 29 May 2005
(h) Sample Station SS-7 (HCOEM Gage 2250) - 14 July 2005
(i) Sample Station SS-5 (HCOEM Gage 2040) - 10 October 2005
(j) Sample Station SS-108 (HCOEM Gage 1180) - 11 November 2005

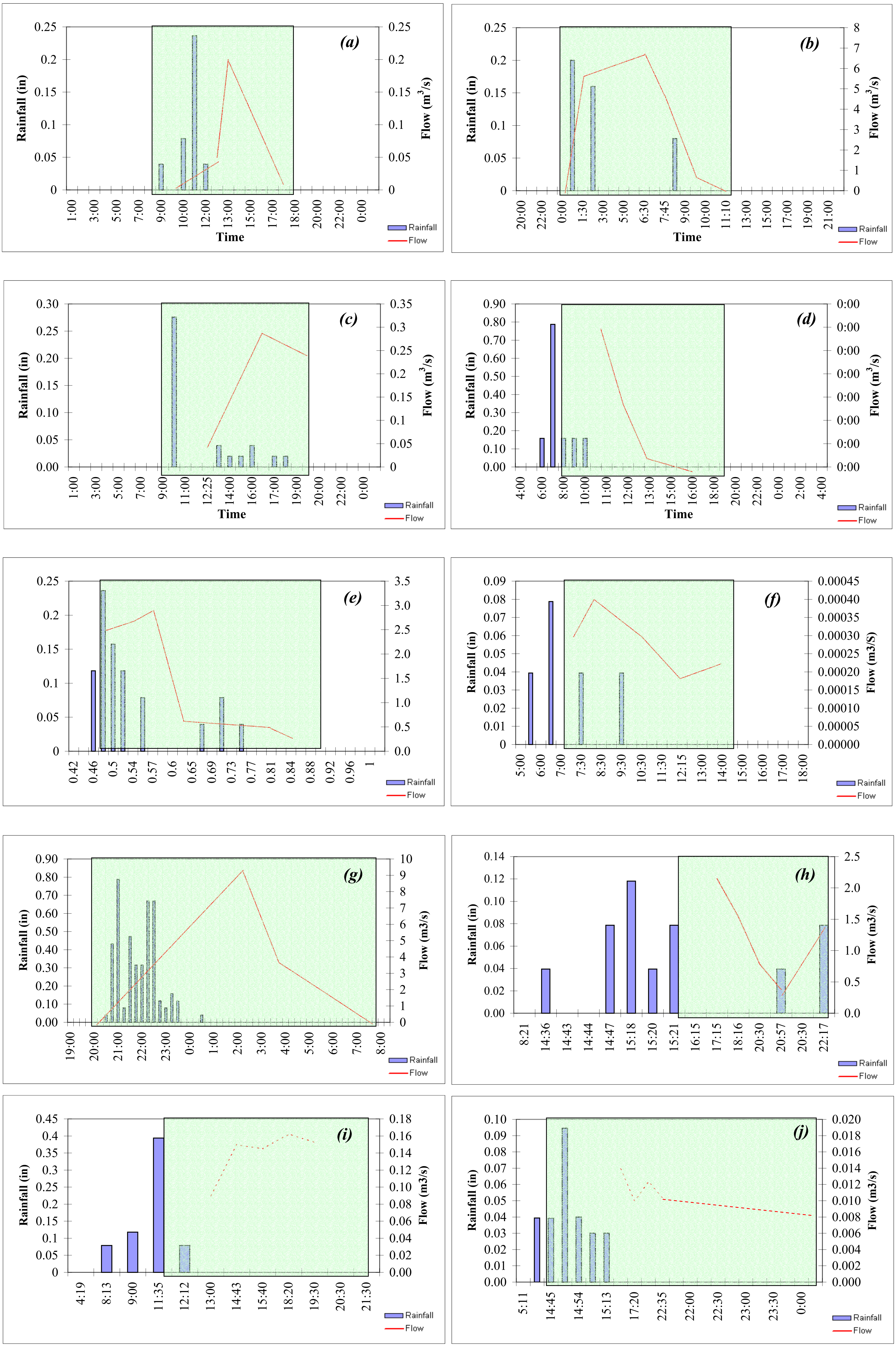


Figure 7.2b Rainfall Hyetograph from Harris County OEM Gages (2004-2005 Samples)

(a) Sample Station SS-10 (HCOEM Gage 0830) - 16 December 2004 *(b) Sample Station SS-13 (HCOEM Gage 1520) - 13 January 2005*

(c) Sample Station SS-9 (HCOEM Gage 1620) - 7 February 2005 *(d) Sample Station SS-15 (HCOEM Gage 0460) - 24 February 2005*

Table 7.1

TSS, TDS, TOC, and DOC concentrations (mg/L) in the Houston urban runoff.

Sampling Site	Date	TSS	TDS	TOC	DOC
SS-10	12/16/2004	66	NA	10.9	10.4
SS-13	1/13/2005	70.4	276	9.12	8.04
SS-9	2/7/2005	39.2	288	16.8	16.2
SS-15	2/24/2005	74.8	NA	9.19	9.04
SS-14	3/2/2005	122	214	8.1	7.22
SS-16	3/16/2005	<4.0	391	8.79	8.54
SS-8	5/29/2005	244	145	8.56	8.48
SS-7	7/14/2005	27.6	97	8.64	8.15
SS-5	10/10/2005	96	183	8.58	8.34
SS-108A	11/15/2005	146	452	7.31	9.76
SS-108B	11/15/2005	182	441	7.22	9.6
%RPD		21.95	2.46	1.24	1.65

NA= Not available, sample volume not sufficient for analysis.

Table 7.2 Field Measurements during Runoff Sampling Activities

StationID	Date	Time	Depth (m)	Temperature (^{o}C)	Conductivity (μ S/cm)	Salinity ($^{o}/_{oo}$)	pH (SU)	DO (mg/L)	Sample Volume (L)	Antecedant Dry Period^{a} (day)	Total Rainfall^{a} (in)
SS-10	12/16/2004	10:41	0.05	9.51	612	0.30	7.16		707	10	0.39
		13:00	0.43	10.07	1116		7.48	0.67			
		14:00	0.61	10.61	582	0.28	7.65				
		15:00	0.59	11.66	467		7.62	0.66			
		17:00	0.48	11.42	374		7.59	0.64			
		19:08	0.36	11.31	349	0.17	7.69				
SS-13	01/13/2005	02:10	0.91	NA	NA	NA	NA	NA	709	8	1.22
SS-9	02/07/2005	12:45	0.07	16.40	341	0.16	5.59	4.65	697	2	0.04
		20:05	0.49	16.18	314	0.14	6.42	2.25			
SS-15	02/24/2005	12:30	1.02	NA	NA	NA	NA	NA	674	11	1.42
SS-14	03/02/2005	17:00	0.14	14.19	162		7.73	18.51	700	3	0.87
		19:00	0.18	14.26	186		7.67	18.72			
		21:00	0.14	14.22	205		7.60	17.98			
		23:00	0.11	14.11	237		7.58	16.98			
SS-16	03/16/2005	07:15	0.16	13.35	864	0.43	8.00		700	9	0.2
		14:49	0.13	16.39	714	0.35	8.22				
SS-8	05/29/2005	20:00	0.18	28.38	573		14.00	3.90	708	21	4.37
		22:00	0.42	23.12	217		14.00	6.66			
		00:00	0.50	22.58	77		14.00	6.27			
		02:00	0.46	22.29	81		14.00	5.71			
		04:00	0.56	22.28	96		14.00	5.02			
		06:00	1.02	22.26	107		14.00	4.33			
		08:00	1.20	22.25	120		14.00	3.55			
SS-7	07/14/2005	15:30	0.04	26.91	99	0.05	8.58	4.78	617	1	4.09
		16:15	0.05	27.07	60	0.03	8.21	5.25			
		17:30	0.21	27.43	94	0.04	7.79	4.49			
		18:15	0.08	27.46	100	0.05	7.71	4.25			
		19:15	0.07	27.39	122	0.06	7.67	3.88			
		20:00	0.05	27.33	133	0.06	7.63	3.85			
		21:00	0.05	27.30	174	0.08	7.69	3.91			
		21:45	0.07	27.26	150	0.07	7.81	4.00			
		22:15	0.1	27.30	175	0.08	7.72	4.12			
		22:45	0.15	27.39	188	0.09	7.97	4.09			
SS-5	10/10/2005	13:30	0.49	21.54	408	0.20	6.81	1.31	701	17	0.79
SS-108A/	11/15/2005	15:10	0.26	22.75	898	0.44	7.81	3.95	703/718	7	0.28
		15:47	0.27	22.61	903	0.44	7.98				
		17:16	0.27	22.24	895	0.47	7.90	3.18			
		20:00	0.27	20.33	936	0.46	7.83	2.46			
		22:30	0.28	18.70	912	0.45	7.83	2.51			
		1:40	0.30	15.86	626	0.31	7.65	2.44			

NA= not available due to a failure of the YSI recording device

[a] Using data from the closest HCOEM rain gage

7.2 Quality Control

Runoff field duplicates and blanks were collected and analyzed as part of the QC/QA protocol. The precision of the Texas-TEQ field duplicates, quantified as the relative percentage difference (%RPD) of 44.7, 2.0 and 2.4% for the dissolved 1- and 40-μm suspended phases, respectively, were obtained, and were found to be lower than the allowable 50% RPD set in the QC/QA protocol.

Quality control/quality assurance procedures were also applied to the parameters TSS, TDS, TOC, and DOC. Field duplicate samples were used to assess precision, expressed as %RPD (Table 7.3). TSS showed the highest %RPD compared to the remaining parameters (21.9%). Fields duplicates were collected at a frequency of 10%. The %RPD was also calculated for the laboratory duplicates. The data quality objective (DQO) guideline for the laboratory duplicates establishes that a %RPD lower than 10% should be met for TSS/TDS higher than 100 mg/l, lower than 20% for TSS/TDS between 10-100 mg/l, and lower than 30% for TSS/TDS less than 10 mg/l. A %RPD for TOC and DOC not exceeding 20% has also been established. The %RPDs for the laboratory duplicates are summarized in Table 7.3. As observed in Table 7.3, all samples met the acceptance criteria for precision outlined in QAPP.

Similarly to the runoff section, during the sampling conducted at site SS-108, watershed sediment and soil field duplicates and blanks were processed as part of the QC/QA procedure. The %RPDs for the Texas-TEQ watershed sediment and soil were lower than the allowable %RPD of 50% set in the sampling protocol. Table 7.4 summarizes the physical characteristics of the watershed sediment/soil samples collected during the runoff sampling.

Table 7.3

%RPDs of laboratory duplicates for TSS, TDS, TOC, and DOC analysis

Sampling Site	**Date**	TSS				TDS				TOC				DOC			
		X1	X2	%RPD	Met DOQ	X1	X2	%RPD	Met DOQ	X1	X2	%RPD	Met DOQ	X1	X2	%RPD	Met DOQ
SS-10	12/16/2004	4.8	4.8	0	Y	[a]	[a]	-	-	28.9	29.1	1	Y	28.9	29.1	1	Y
SS-13	1/13/2005	8.8	9.2	4	Y	195	195	0	Y	6.07	5.89	3	Y	6.07	5.89	3	Y
SS-9	2/7/2005	<4.0	<4.0	0	Y	288	289	0.3	Y	26.2	26	1	Y	26.2	26	1	Y
SS-15	2/24/2005	12	11.6	4	Y	[a]	[a]	-	-	4	4.21	5	Y	4	4.21	5	Y
SS-14	3/2/2005	10.4	10.8	2	Y	441	451	2	Y	7.78	8.14	5	Y	7.78	8.14	5	Y
SS-16	3/16/2005	19.2	18.8	-	Y	716	723	1	Y	6.33	6.38	1	Y	6.33	6.38	1	Y
SS-8	5/29/2005	<4.0	<4.0	-	Y	145	151	4	Y	6.74	6.8	1	Y	6.74	6.8	1	Y
SS-7	7/14/2005	<4.0	<4.1	-	Y	406	400	1	Y	4.1	4.09	0	Y	4.1	4.09	0	Y
SS-5	10/10/2005	<4.0	<4.2	-	Y	499	489	2	Y	5.59	5.44	3	Y	5.59	5.44	3	Y
SS-108A	11/15/2005	<4.0	<4.3	-	Y	688	697	1	Y	7.31	7.33	0	Y	7.31	7.33	0	Y

a Sample volume not sufficient for analysis

%RPD = ABS(X1-X2)/((X1+X2))/2

Table 7.4 Physical Characteristics of Soil/Sediment Samples collected during Runoff Sampling

Station ID	Date	Type	Solids Content %	TOC %	Gravel %	Coarse Sand %	Medium Sand %	Fine Sand %	Silt %	Clay %	Silt and Clay %
SS-10	12/16/2004	Residential	72.0	2.68	0.00	0.00	0.00	0.00	40.60	59.40	
		Urban	81.0	3.62	10.13	10.82	18.91	42.40	[a]	[a]	17.74
		Grass	74.6	3.59	0.00	0.00	7.01	31.38	40.90	20.71	
		Forest	56.4	3.77	0.00	0.00	0.00	0.00	50.94	49.06	
		Transitional	84.4	0.77	0.00	0.00	40.92	39.98	8.70	10.40	
		Sediment	53.8	3.42	0.00	0.00	0.00	0.00	33.01	66.99	
SS-13	01/13/2005	Woodland	67.6	3.24	0.00	0.00	0.00	0.00	44.08	55.92	
		Grass	76.6	3.99	0.00	0.00	0.00	27.70	48.94	23.37	
		Transitional	74.2	2.53	0.00	0.00	0.00	0.00	43.28	56.72	
		Urban/Road	75.2	2.06	0.00	0.00	0.00	0.00	40.51	59.49	
		Sediment	72.7	3.94	26.18	21.11	21.41	16.90	[a]	[a]	14.39
SS-9	01/27/2005	Forest	72.3	1.49	0.00	0.00	7.30	40.98	42.87	8.86	
		Grass	80.1	2.05	0.00	0.13	14.06	73.10	[a]	[a]	12.72
		Transitional	95.5	1.78	0.00	0.38	16.69	57.85	[a]	[a]	25.07
		Urban	98.9	5.66	21.53	17.30	21.65	31.09	[a]	[a]	8.43
		Residential	90.9	0.90	0.00	0.19	17.67	61.80	[a]	[a]	20.35
		Sediment	61.8	0.44	0.00	0.00	0.02	61.92	32.20	5.86	
SS-15[b]	02/24/2005	Urban/Residential	72.9	5.09	0.00	0.00	5.24	48.99	39.66	6.11	
		Urban	85.3	1.89	0.00	0.00	3.90	50.44	34.36	11.30	
		Grass	73.1	3.61	0	0	6.1	34.75	40.48	18.67	
		Forest	72.9	5.70	0	0	5.96	29.42	49.52	15.11	
		Transitional	79.7	1.77	0	0	5.52	37.84	48.89	7.74	
SS-14	03/02/2005	Sediment	63.4	0.92	0	0	0.02	33.48	55.54	10.96	
		Residential	77.9	2.84	0	0	2.55	43.14	48.01	6.29	
		Urban	70.7	2.70	0	0	2.61	38.62	47.64	11.13	
		Grass	68.9	2.56	0	0	5.51	36.3	46.7	11.48	
		Forest	66.5	4.24	0	0	2.96	37.51	43.01	16.53	
		Transitional	73.3	1.34	0	0	0.28	35.25	51.45	13.03	
SS-16	03/15/2005	Forest	76.6	3.56	0	0	0	38.69	52.45	8.86	
		Grass	74.2	4.24	3.43	13.37	38.13	27.71	[a]	[a]	17.35
		Urban	93.8	3.45	0	0	5.8	39.86	47.3	7.04	
		Urban/Residential	79.5	3.92	0	0	0	0	69.93	30.07	
		Transitional	83.0	1.88	0	0	5.05	42.64	43.94	8.37	
		Sediment	73.7	0.94	0	0	0.1	81.35	14.03	4.52	
SS-8	05/29/2005	Forest	82.2	1.82	0	0	0.6	25.6	59.6	14.3	
		Grass	80.9	2.62	0	0.2	1.4	18.2	63.70	16.50	
		Urban/Residential	80.9	1.90	0	0.1	2.7	24.7	58.7	13.8	
		Transitional	77.2	2.00	0	0	3.4	34.0	51.1	11.5	
		Sediment	81.5	1.78	0	0	5.3	39.0	42.8	13.0	
SS-7	07/14/2005	Urban/Residential	83.4	1.43	0	0.1	2.4	20.9	62.4	14.1	
		Sediment	79.9	1.75	34.6	25.4	15.4	14.9	7.8	2.0	
SS-5	10/10/2005	Forest	84.9	0.88	0	0.1	2.4	23.5	55.6	18.4	
		Grass	84.5	4.87	0	0	1.6	25.2	58.6	14.5	
		Sediment	67	0.85	0	0	0.5	18.1	63.9	17.5	
		Urban/Residential	76.4	1.76	0	0	1.7	27.7	60	10.7	
		Transitional	91.8	0.28	0	0	0.5	29.8	49.2	20.5	
SS-108A	11/15/2005	Sediment	76.1	0.53	0	0.6	17.3	35	22.8	5	
		Grass	83.5	3.38	0	0	0.8	3.3	69.6	15	
SS-108B	11/15/2005	Sediment	74.4	0.69	0	0.5	14.1	32.3	24.9	5.3	
		Grass	86	1.47	0	0	3.2	13.1	50.7	12.3	

[a] Dry sieve data do not differentiate silt/clay fractions

[b] Sediment was not collected at this site because the ditch is concrete-lined

7.2.1 Results

Results for dioxins in Houston urban runoff samples in both dissolved and suspended (1 and 40 μm) phases collected at different locations are summarized in Table 7.5. Both phases were dominated by the higher and less toxic chlorinated congeners, particularly OCDD all the runoff samples. 2,3,7,8-TCDD was above the detection limit only in the 1- and 40-μm suspended phases, with the exception of the sample collected at SS-9 in 2002 that showed detectable levels of 2,3,7,8-TCDD in the dissolved phase. This finding was unexpected since this congener is predominantly found in the vapor phase in the atmosphere and may have the potential to be dissolved in the rain. Concentrations of up to 0.036 pg/L were measured for 2,3,7,8-TCDD in the suspended phase (40 μm, SS-7, 2005). The Texas-TEQ distribution between the dissolved and suspended phases is illustrated in Figure 7.3. On average, approximately 87% of the total Texas-TEQ (suspended + dissolved) was found associated with particulate matter.

Total Texas-TEQ concentrations (dissolved + suspended) in Houston runoff was found ranging from 0.019 (SS-16, March 2005) to 0.567 (SS-15, March 2003) pg Texas-TEQ/L. It was noted that all but four samples exceeded the water quality standard of 0.093 pg Texas-TEQ/L. Observed Texas-TEQ in runoff was correlated to undeveloped land use percentage. Although a negative correlation was observed--as undeveloped land percentage increased, Texas-TEQ decreased--this correlation was found not to be significant (p-value >0.05).

Tables 7.6 through 7.9 provide a summary of the dioxin concentrations found in watershed sediment and soil. The congener 2,3,7,8-TCDD was found below the detection limit in all of the watershed sediment samples collected. Regarding the soil

Table 7.5 Dissolved-phase concentrations (pg/L) of dioxins in runoff

	SS-10	**SS-13**	**SS-9**	**SS-15**	**SS-14**	**SS-16**	**SS-8**	**SS-7**	**SS-5**	**SS-108A**	**SS-108B**
2,3,7,8-TCDD	<0.002	<0.004	<0.003	<0.002	<0.002	<0.002	<0.005	<0.020	<0.004	<0.003	<0.004
1,2,3,7,8-PeCDD	<0.007	0.014	0.012	<0.005	0.005	<0.002	0.008	<0.015	0.004	0.004	0.005
1,2,3,4,7,8-HxCDD	0.009	0.038	0.020	0.005	0.006	0.002	0.012	<0.009	<0.004	0.006	0.008
1,2,3,6,7,8-HxCDD	0.017	0.062	0.030	0.013	0.016	0.004	0.037	0.018	0.005	0.026	0.039
1,2,3,7,8,9-HxCDD	0.020	0.068	0.047	0.013	0.014	0.004	0.030	<0.016	0.008	0.016	0.018
1,2,3,4,6,7,8-HpCDD	0.424	3.526	1.576	0.357	0.400	0.067	1.102	0.410	0.074	0.740	1.030
OCDD	5.374	26.798	108.882	4.000	3.714	0.643	15.537	5.186	1.012	5.121	7.938
2,3,7,8-TCDF	0.031	0.008	<0.016	<0.016	0.020	<0.011	0.038	0.030	<0.014	0.053	0.086
1,2,3,7,8-PeCDF	0.007	<0.003	0.004	0.002	0.003	<0.002	0.005	<0.020	<0.004	<0.008	0.015
2,3,4,7,8-PeCDF	0.012	0.005	0.005	0.006	0.007	0.004	0.013	<0.018	0.008	0.009	0.017
1,2,3,4,7,8-HxCDF	0.018	0.010	0.006	0.008	0.009	0.004	0.017	0.020	<0.003	0.008	0.017
1,2,3,6,7,8-HxCDF	0.010	0.004	0.054	0.008	0.007	0.003	0.020	<0.024	<0.011	<0.131	<0.196
2,3,4,6,7,8-HxCDF	0.010	0.007	0.003	0.004	0.005	0.002	0.010	0.013	<0.003	0.007	0.008
1,2,3,7,8,9-HxCDF	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.010	<0.003	0.004	0.004
1,2,3,4,6,7,8-HpCDF	<0.095	<0.225	<0.026	<0.053	<0.043	<0.012	<0.099	<0.041	<0.026	<0.077	<0.117
1,2,3,4,7,8,9-HpCDF	<0.006	<0.013	<0.002	<0.005	<0.004	<0.002	0.010	0.015	<0.004	<0.006	<0.008
OCDF	0.126	0.959	0.037	0.134	0.081	0.027	0.198	0.080	0.021	0.185	0.251
Texas-TEQ[a]	0.021	0.031	0.027	0.011	0.015	0.006	0.030	0.029	0.011	0.026	0.041

[a] Non-detects assumed as½ MDL for calculations.

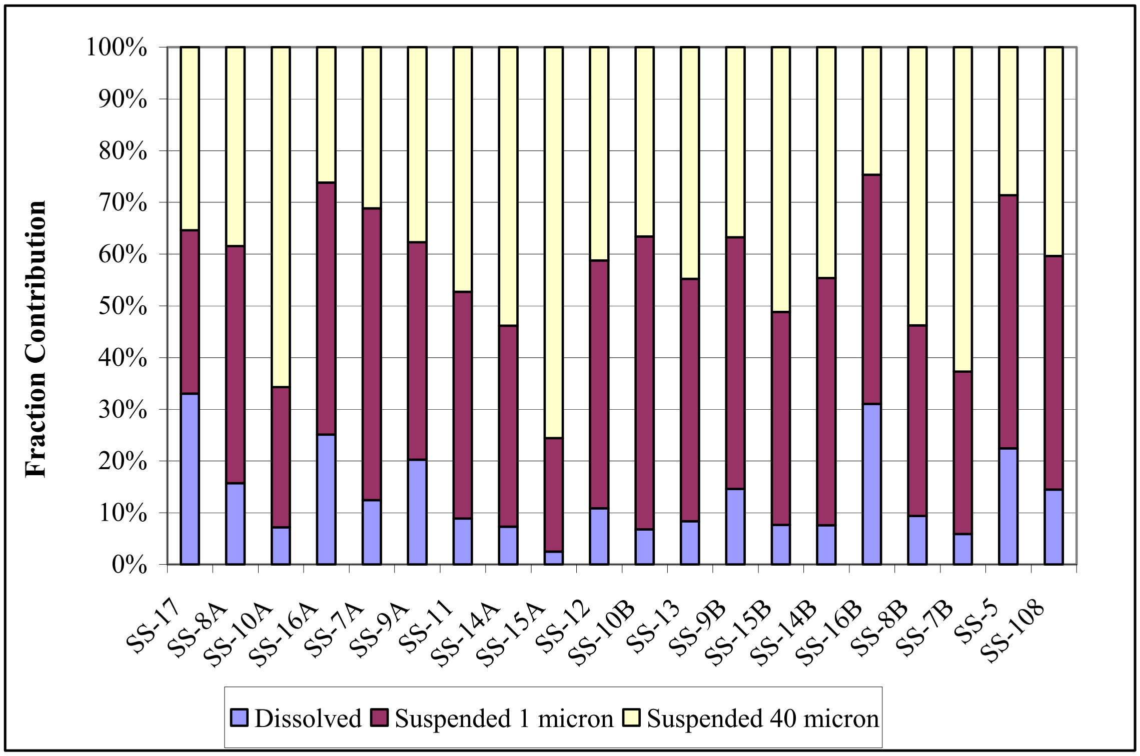


Figure 7.3 Texas-TEQ distribution in suspended and dissolved phases in the Houston runoff

Table 7.6 Dioxins in Houston watershed sediment during runoff conditions (ng/kg)

	SS-10	**SS-13**	**SS-9**	**SS-14**	**SS-16**	**SS-8**	**SS-7**	**SS-5**	**SS-108A**	**SS-108B**
2,3,7,8-TCDD	<0.54	<0.16	<0.16	<0.16	<0.16	<0.16	<0.17	<0.16	<0.42	<0.29
1,2,3,7,8-PeCDD	<1.20	<0.42	0.57	0.69	<0.18	<0.18	0.66	<0.18	<0.43	<0.38
1,2,3,4,7,8-HxCDD	1.6	1	1.2	1.1	<0.23	<0.23	1.1	<0.28	<0.50	<0.52
1,2,3,6,7,8-HxCDD	4.4	2.4	2.2	2.3	<0.18	0.32	8	<0.24	0.71	1.6
1,2,3,7,8,9-HxCDD	3.6	2	2.7	2	<0.2	0.25	5.2	<0.24	<0.48	0.68
1,2,3,4,6,7,8-HpCDD	85	58	110	53	2.6	9.8	310	3.3	10	22
OCDD	1000	670	4800	800	30	560	3900	54	86	180
2,3,7,8-TCDF	1.4	<0.24	<0.24	0.5	<0.23	<0.24	0.38	<0.21	<0.52	<0.45
1,2,3,7,8-PeCDF	<1.00	<0.2	<0.2	0.3	<0.20	<0.2	<0.25	<0.13	<0.36	<0.43
2,3,4,7,8-PeCDF	1.2	<0.23	<0.23	0.41	<0.23	<0.23	0.4	<0.16	<0.36	0.5
1,2,3,4,7,8-HxCDF	1.1	<0.6	0.42	0.8	<0.18	0.24	1.6	<0.14	<0.28	<0.28
1,2,3,6,7,8-HxCDF	0.8	<0.99	0.26	<0.23	<0.23	<0.23	<7.2	<0.12	<0.23	<0.36
2,3,4,6,7,8-HxCDF	2.1	<1.3	0.3	<0.26	<0.25	<0.26	<0.93	0.17	<0.30	<0.27
1,2,3,7,8,9-HxCDF	<1.10	<0.21	<0.21	<0.21	<0.21	<0.21	0.38	<0.11	0.45	<0.31
1,2,3,4,6,7,8-HpCDF	15	<18	2.4	9.3	0.54	1.4	<6.1	0.81	4.7	4.8
1,2,3,4,7,8,9-HpCDF	<3.50	<0.96	0.24	0.93	<0.20	<0.20	6.5	<0.22	0.51	0.58
OCDF	34	21	5.2	23	1.5	3.3	400	2.1	3.2	11
Texas-TEQ[a]	2.75	0.95	1.16	1.35	0.27	0.33	2.69	0.25	0.65	0.84
TOC %	3.42	3.94	0.444	0.916	0.936	1.78	1.75	0.851	0.527	0.693
Texas-TEQ[a, b]	80.41	25.88	260.81	147.38	29.17	18.37	153.93	29.38	123.34	121.212
Date	12/16/2004	1/13/2005	2/7/2005	3/2/2005	3/16/2005	5/29/2005	7/14/2006	10/10/2005	11/15/2005	11/15/2005

[a] Non-detects assumed as½ MDL for calculations.

[b] Normalized by TOC content (concentrations in ng/Kg-oc)

Sediment was not collected at SS-15 because the ditch is concrete-lined.

Table 7.7 Suspended-phase (40μm) concentrations (pg/L) of dioxins in runoff

	SS-10	**SS-13**	**SS-9**	**SS-15**	**SS-14**	**SS-16**	**SS-8**	**SS-7**	**SS-5**	**SS-108A**	**SS-108B**
2,3,7,8-TCDD	<0.006	0.01	0.004	0.009	0.005	<0.002	0.01	0.036	<0.003	<0.008	<0.004
1,2,3,7,8-PeCDD	0.03	0.078	0.029	0.027	0.031	<0.002	0.051	0.112	0.006	0.012	0.012
1,2,3,4,7,8-HxCDD	<0.044	0.24	0.073	0.034	0.05	<0.002	0.099	0.151	0.008	0.027	0.022
1,2,3,6,7,8-HxCDD	0.105	0.409	0.116	0.081	0.129	0.003	0.254	0.324	0.013	0.142	0.139
1,2,3,7,8,9-HxCDD	0.13	0.437	0.215	0.114	0.143	0.004	0.268	0.357	0.021	0.071	0.071
1,2,3,4,6,7,8-HpCDD	2.687	21.157	7.45	2.286	3.857	0.079	7.91	9.724	0.271	3.841	3.621
OCDD	35.361	211.566	702.006	25.714	40.000	0.800	197.74	124.797	5.419	29.874	30.636
2,3,7,8-TCDF	0.11	0.012	0.013	0.036	<0.049	<0.003	0.096	<0.110	<0.009	0.053	0.060
1,2,3,7,8-PeCDF	0.034	0.009	0.004	0.01	0.014	<0.002	0.03	0.034	<0.003	0.020	0.022
2,3,4,7,8-PeCDF	0.055	<0.006	0.006	0.016	0.021	0.002	0.044	0.039	0.007	0.020	0.017
1,2,3,4,7,8-HxCDF	0.156	0.038	0.021	0.067	0.077	0.003	0.169	0.162	0.005	0.057	0.052
1,2,3,6,7,8-HxCDF	0.072	<0.003	0.011	0.059	0.091	0.003	0.138	0.729	0.005	<0.426	<0.487
2,3,4,6,7,8-HxCDF	0.074	0.023	0.009	0.031	0.043	<0.002	0.086	0.102	0.005	0.040	0.033
1,2,3,7,8,9-HxCDF	<0.004	<0.004	0.003	<0.002	0.003	<0.002	0.007	<0.034	<0.004	0.018	0.018
1,2,3,4,6,7,8-HpCDF	<0.792	<1.693	<0.103	<0.471	<0.614	<0.019	1.384	2.27	<0.053	<0.583	<0.613
1,2,3,4,7,8,9-HpCDF	<0.044	<0.056	<0.103	<0.024	<0.039	<0.003	0.079	0.112	<0.004	0.038	0.046
OCDF	1.117	8.322	0.244	1.114	1.386	0.04	3.107	5.348	0.103	1.849	1.950
Texas-TEQ[a]	0.114	0.167	0.067	0.073	0.088	0.005	0.171	0.303	0.014	0.083	0.081

[a] Non-detects assumed as½ MDL for calculations.

Table 7.8 Dioxins in Houston watershed sediment during runoff conditions (ng/kg)

	SS-10	**SS-13**	**SS-9**	**SS-14**	**SS-16**	**SS-8**	**SS-7**	**SS-5**	**SS-108A**	**SS-108B**
2,3,7,8-TCDD	<0.54	<0.16	<0.16	<0.16	<0.16	<0.16	<0.17	<0.16	<0.42	<0.29
1,2,3,7,8-PeCDD	<1.20	<0.42	0.57	0.69	<0.18	<0.18	0.66	<0.18	<0.43	<0.38
1,2,3,4,7,8-HxCDD	1.6	1	1.2	1.1	<0.23	<0.23	1.1	<0.28	<0.50	<0.52
1,2,3,6,7,8-HxCDD	4.4	2.4	2.2	2.3	<0.18	0.32	8	<0.24	0.71	1.6
1,2,3,7,8,9-HxCDD	3.6	2	2.7	2	<0.2	0.25	5.2	<0.24	<0.48	0.68
1,2,3,4,6,7,8-HpCDD	85	58	110	53	2.6	9.8	310	3.3	10	22
OCDD	1000	670	4800	800	30	560	3900	54	86	180
2,3,7,8-TCDF	1.4	<0.24	<0.24	0.5	<0.23	<0.24	0.38	<0.21	<0.52	<0.45
1,2,3,7,8-PeCDF	<1.00	<0.2	<0.2	0.3	<0.20	<0.2	<0.25	<0.13	<0.36	<0.43
2,3,4,7,8-PeCDF	1.2	<0.23	<0.23	0.41	<0.23	<0.23	0.4	<0.16	<0.36	0.5
1,2,3,4,7,8-HxCDF	1.1	<0.6	0.42	0.8	<0.18	0.24	1.6	<0.14	<0.28	<0.28
1,2,3,6,7,8-HxCDF	0.8	<0.99	0.26	<0.23	<0.23	<0.23	<7.2	<0.12	<0.23	<0.36
2,3,4,6,7,8-HxCDF	2.1	<1.3	0.3	<0.26	<0.25	<0.26	<0.93	0.17	<0.30	<0.27
1,2,3,7,8,9-HxCDF	<1.10	<0.21	<0.21	<0.21	<0.21	<0.21	0.38	<0.11	0.45	<0.31
1,2,3,4,6,7,8-HpCDF	15	<18	2.4	9.3	0.54	1.4	<6.1	0.81	4.7	4.8
1,2,3,4,7,8,9-HpCDF	<3.50	<0.96	0.24	0.93	<0.20	<0.20	6.5	<0.22	0.51	0.58
OCDF	34	21	5.2	23	1.5	3.3	400	2.1	3.2	11
Texas-TEQ[a]	2.75	0.95	1.16	1.35	0.27	0.33	2.69	0.25	0.65	0.84
TOC %	3.42	3.94	0.444	0.916	0.936	1.78	1.75	0.851	0.527	0.693
Texas-TEQ[a, b]	80.41	25.88	260.81	147.38	29.17	18.37	153.93	29.38	123.34	121.212
Date	12/16/2004	1/13/2005	2/7/2005	3/2/2005	3/16/2005	5/29/2005	7/14/2006	10/10/2005	11/15/2005	11/15/2005

[a] Non-detects assumed as½ MDL for calculations.

[b] Normalized by TOC content (concentrations in ng/Kg-oc)

Sediment was not collected at SS-15 because the ditch is concrete-lined.

Table 7.9 Dioxins in Houston forest and grass soil during runoff conditions (ng/kg)

	Forest								**Grass**									
	SS-10	**SS-13**	**SS-9**	**SS-15**	**SS-14**	**SS-16**	**SS-8**	**SS-5**	**SS-10**	**SS-13**	**SS-9**	**SS-15**	**SS-14**	**SS-16**	**SS-8**	**SS-5**	**SS-108A**	**SS-108B**
2,3,7,8-TCDD	<0.16	<0.17	<0.16	<0.16	<0.16	<0.16	<0.54	<0.21	<0.16	<0.23	<0.16	<0.15	<0.16	<0.16	0.94	<0.28	<0.52	<0.47
1,2,3,7,8-PeCDD	<0.18	0.18	0.41	<0.25	<0.18	<0.18	1.2	<0.28	0.22	<0.33	<0.18	0.53	<0.18	<0.18	0.83	<0.25	<0.41	<0.36
1,2,3,4,7,8-HxCDD	0.25	0.25	0.95	0.66	<0.23	<0.23	1.1	<0.32	0.28	<0.94	0.97	0.78	<0.23	<0.22	1.9	0.18	<0.40	<0.54
1,2,3,6,7,8-HxCDD	0.47	0.28	1.3	1.9	0.23	<0.18	7.8	<0.56	0.57	2.3	1	2.7	0.66	0.28	6	0.44	<0.38	<0.28
1,2,3,7,8,9-HxCDD	0.51	0.68	1.5	<0.2	0.21	<0.2	3.1	<0.32	0.52	1.2	1.4	1.6	0.45	<0.20	2.9	0.48	<0.40	<0.33
1,2,3,4,6,7,8-HpCDD	6.4	8.5	54	73	4.3	4.1	320	2.5	10	88	49	56	14	9.2	230	5.8	5.3	3
OCDD	59	280	3600	740	43	36	4200	120	100	1300	3400	620	200	83	2300	140	49	29
2,3,7,8-TCDF	0.37	<0.24	<0.24	<0.24	<0.24	<0.24	<0.44	<0.26	0.25	<0.40	<0.24	0.58	<0.24	<0.23	3.7	<0.31	<0.54	<0.50
1,2,3,7,8-PeCDF	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.51	<0.25	<0.19	<0.52	<0.20	<0.21	<0.20	<0.20	1	<0.29	<0.56	<0.44
2,3,4,7,8-PeCDF	0.23	<0.23	0.26	0.38	<0.23	<0.23	0.42	<0.20	<0.22	<0.45	<0.23	0.72	<0.23	<0.22	1.2	<0.17	<0.34	<0.31
1,2,3,4,7,8-HxCDF	0.46	0.18	0.38	0.53	0.28	<0.18	1.5	<0.17	0.38	<0.54	0.33	<0.17	0.28	0.24	<0.18	0.26	<0.32	<0.17
1,2,3,6,7,8-HxCDF	<0.23	<0.23	0.25	0.29	<0.23	<0.23	0.66	<0.13	<0.31	<0.84	<0.23	0.84	<0.23	<0.22	2.7	0.18	<0.28	<0.19
2,3,4,6,7,8-HxCDF	0.27	<0.26	0.32	0.4	<0.26	<0.26	<0.25	<0.19	<0.25	<0.25	0.28	1.5	0.26	<0.25	3.1	<0.13	<0.23	<0.21
1,2,3,7,8,9-HxCDF	<0.21	<0.21	0.28	<0.21	<0.21	<0.21	<0.21	<0.19	<0.20	<0.23	<0.21	<0.20	<0.21	<0.20	0.45	<0.13	1.3	0.77
1,2,3,4,6,7,8-HpCDF	1.5	0.31	2	6.2	1.2	1.1	37	0.38	1.7	7	2.9	24	3.8	2.3	42	0.97	1.6	1.3
1,2,3,4,7,8,9-HpCDF	<0.38	<0.26	<0.20	0.4	0.34	0.35	2.6	<0.30	<0.40	<0.39	0.2	1.4	<0.42	0.21	3.1	<0.22	<0.42	<0.36
OCDF	4.5	1.4	5.8	18	2.5	1.9	160	1.7	3.8	25	7.9	81	10	5.2	92	1.9	2	1.4
Texas-TEQ[a]	0.5	0.42	0.93	0.75	0.32	0.27	2.55	0.34	0.49	0.83	0.62	1.52	0.4	0.3	4.09	0.43	0.72	0.60
TOC %	3.77	3.24	1.49	5.7	4.24	3.56	1.82	0.879	3.59	3.99	2.05	3.61	2.56	4.24	2.62	4.87	3.38	1.47
Texas-TEQ[a,b]	13.26	13.07	62.42	13.12	7.5	7.7	140.32	38.68	13.59	20.88	30.22	42.21	15.55	7.15	156.07	8.83	21.30	40.82
Date	12/16/2004	1/13/2005	1/27/2005	2/24/2005	3/2/2005	3/15/2005	5/29/2005	10/10/2005	12/16/2004	1/13/2005	1/27/2005	2/24/2005	3/2/2005	3/15/2005	5/29/2005	10/10/2005	11/15/2005	11/15/2005

[a] Non-detects assumed as½ MDL for calculations.

[b] Normalized by TOC content (concentrations in ng/Kg-oc).

samples, this congener was detected at a few sampling locations and soils at concentrations of up to 0.94 ng/Kg (Grass soil). Figure 7.4 depicts the contribution of each congener to the Texas-TEQ in watershed sediment. No apparent contribution trend of a specific congener to the Texas-TEQ was found in watershed sediment.

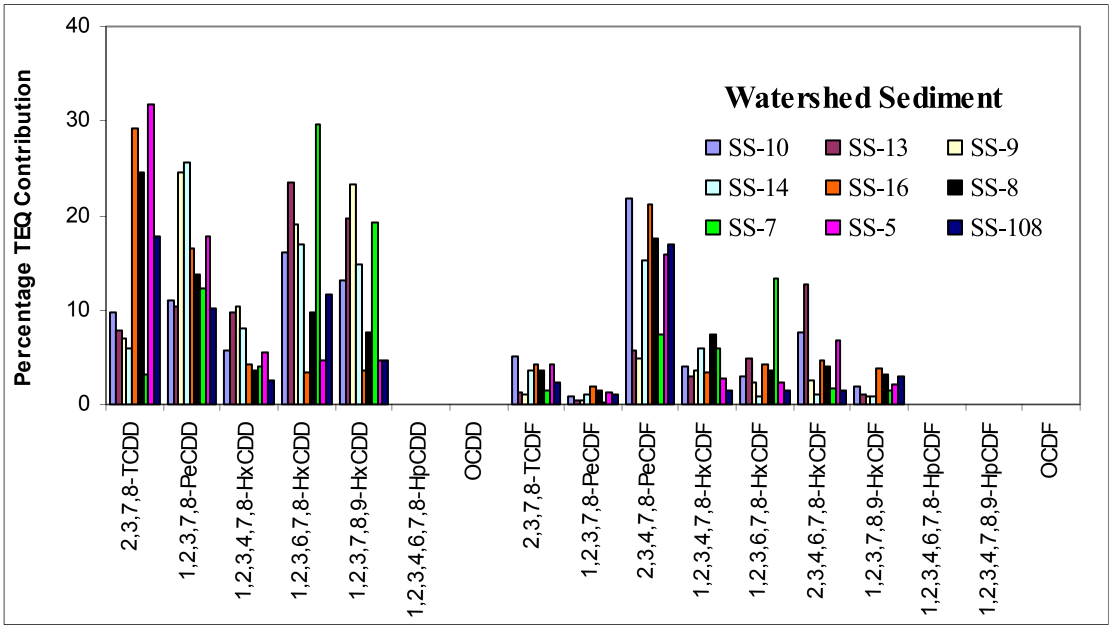


Figure 7.4 Percentage contribution of the 17-dioxin congeners to the Texas-TEQ during runoff conditions

7.2.2 Analysis

Texas-TEQ concentrations in runoff were correlated to TSS and TOC by linear regression. The purpose of this analysis is to determine if these parameters, which are much easier to quantify, can be used to indirectly measure the TEQ concentrations in the Houston runoff. During runoff conditions, TSS may be indicative of the ease at which soil and particulate matter is disassociated with nearby surfaces and suspended within the water. Depending upon the contaminant type, the concentration of TSS may be directly correlated to the concentrations of other pollutants present in the water column. A robust positive correlation between TSS and dioxins would help to estimate loads or determine an efficient and feasible reduction plan. The results of the analysis, however, showed no significant correlations between the Texas-TEQ concentrations and TSS and TOC, as observed in Figures 7.5 and 7.6. 2,3,7,8-TCDD data was also correlated to the same parameters, but no significant trend was found. Additionally, the Texas-TEQ concentrations in the suspended and dissolved phases were correlated to each other by linear regression. In this case, a weak but significant correlation between these two phases was found ($r^2 = 0.198$; *p*-value = 0.05) (Figure 7.7).

Total TEQ concentrations (suspended + dissolved phases) were multiplied by the observed time-averaged flow rates (Figure 7.2) at each site to obtain the dioxin loading rates for the event. The results are summarized in Table 7.10. A dioxin load rate of up to 320 μg Texas-TEQ/day (SS-15) was observed among the collected runoff samples.

The experimental watershed sediment data were correlated to solid and clay content, and to TOC by multiple linear regression. A no significant correlation (at an alpha value of

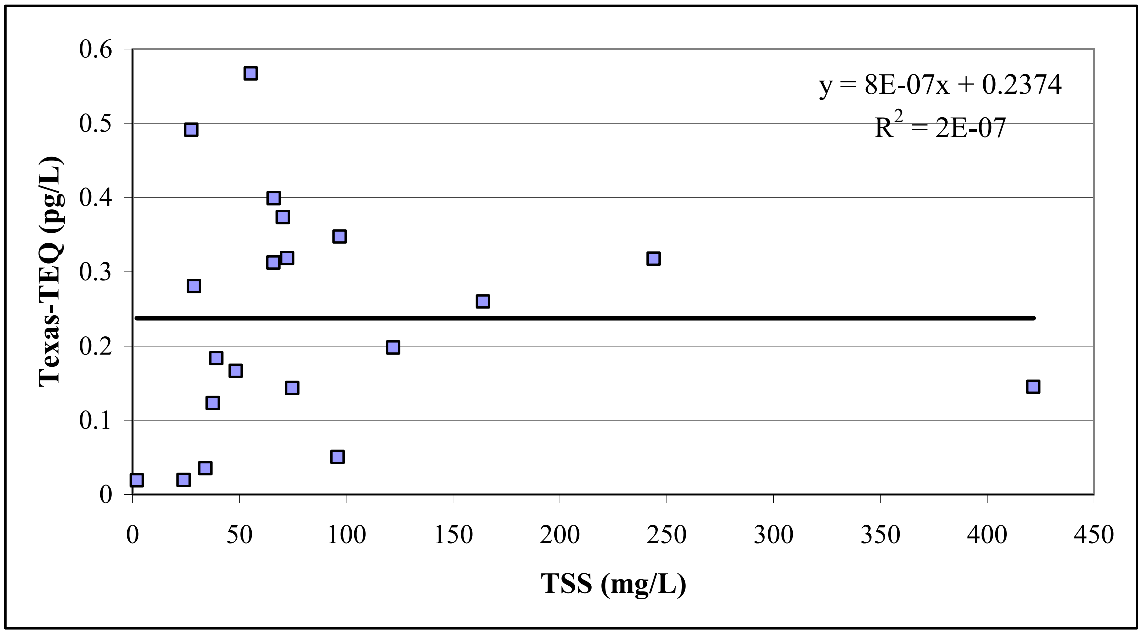


Figure 7.5 Texas-TEQ concentration versus TSS in runoff samples

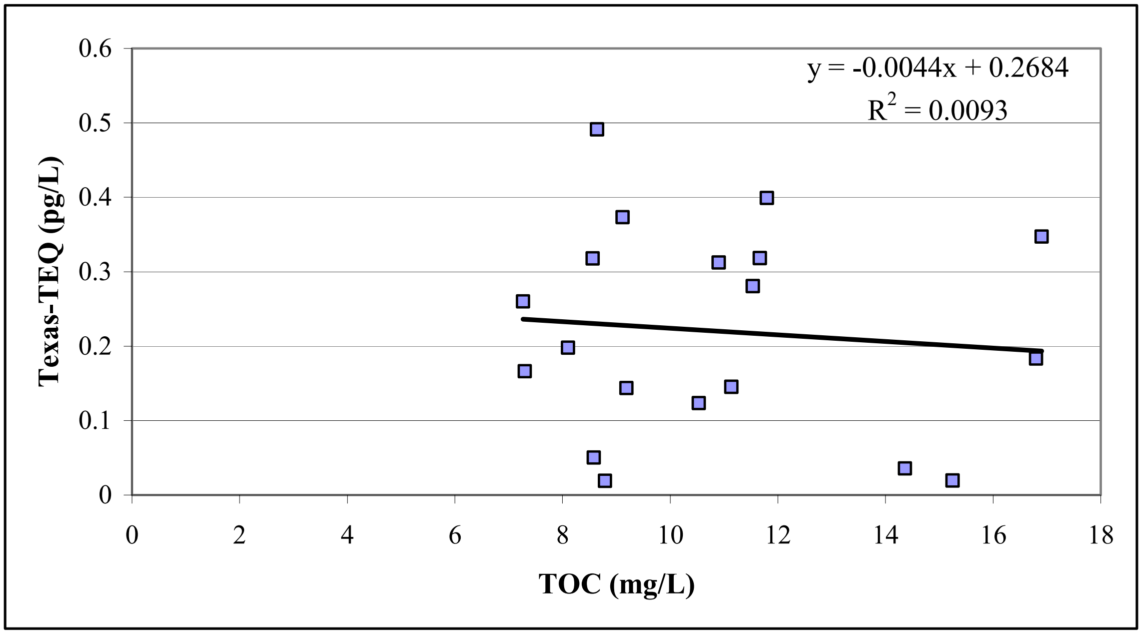


Figure 7.6 Combined Texas-TEQ concentration versus TOC

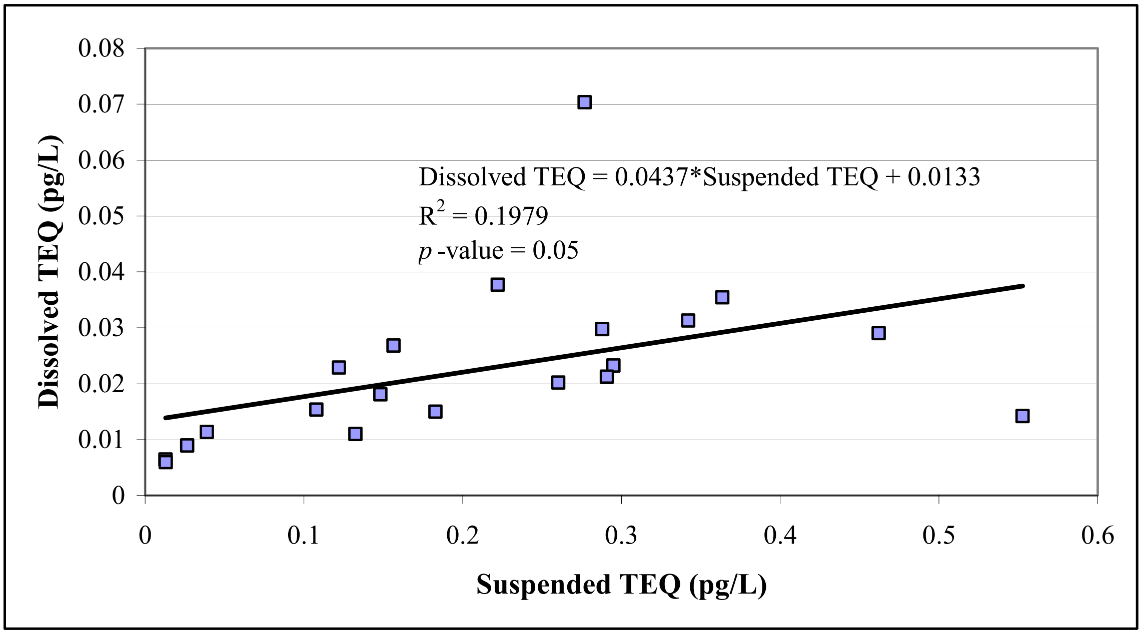


Figure 7.7 Texas-TEQ suspended-phase concentration versus Texas-TEQ dissolved-phase concentration

Table 7.10 Dioxins in Houston residential and urban soil during runoff conditions (ng/kg)

	Residential								Urban						
	SS-10	**SS-9**	**SS-15**	**SS-14**	**SS-16**	**SS-8**	**SS-7**	**SS-5**	**SS-10**	**SS-13**	**SS-9**	**SS-15**	**SS-14**	**SS-16**	**SS-5**
2,3,7,8-TCDD	<0.16	<0.16	<0.21	<0.16	0.51	<0.16	<0.14	<0.24	<0.24	<0.22	<0.16	0.19	<0.16	<0.16	<0.20
1,2,3,7,8-PeCDD	<0.18	0.53	1.2	0.29	0.32	0.23	0.33	<0.19	<0.30	0.37	0.68	<0.20	<0.18	<0.18	<0.23
1,2,3,4,7,8-HxCDD	0.25	1.3	<0.22	0.47	<0.23	<0.23	0.42	<0.29	<1	0.79	<0.23	1.2	<0.23	0.7	<0.31
1,2,3,6,7,8-HxCDD	<0.18	1.7	4.2	1	0.98	0.49	2.8	<0.23	1.7	1.2	<0.18	2.2	0.35	2.9	<0.19
1,2,3,7,8,9-HxCDD	<0.19	2.2	4.7	0.67	0.79	0.3	1.1	0.41	2.5	1.5	2.3	2.4	<0.20	1.6	<0.30
1,2,3,4,6,7,8-HpCDD	6.8	81	100	20	20	12	61	3.8	45	33	64	43	7.8	82	2.7
OCDD	140	4300	1200	210	200	110	550	47	720	840	2400	420	88	880	230
2,3,7,8-TCDF	<0.23	<0.24	0.78	<0.23	2	<0.24	0.22	<0.21	0.7	<0.30	<0.24	0.3	<0.24	0.24	<0.21
1,2,3,7,8-PeCDF	<0.19	<0.20	0.37	0.25	0.92	<0.2	0.21	<0.13	<0.53	<0.19	<0.20	0.29	<0.2	0.26	<0.22
2,3,4,7,8-PeCDF	<0.22	<0.23	1.1	0.36	0.71	<0.23	0.35	<0.16	0.49	<0.22	<0.23	0.44	<0.23	0.36	<0.16
1,2,3,4,7,8-HxCDF	<0.18	0.41	2.4	0.57	2.1	0.28	0.52	0.15	<0.34	0.19	0.31	0.94	0.3	0.89	<0.22
1,2,3,6,7,8-HxCDF	<0.22	<0.23	1.9	0.41	0.68	<0.23	0.59	<0.12	<0.37	0.35	<0.23	0.65	<0.23	0.44	<0.20
2,3,4,6,7,8-HxCDF	<0.25	<0.26	2.1	0.52	0.65	<0.25	0.37	<0.13	0.76	0.28	<0.26	1.1	<0.26	0.79	<0.16
1,2,3,7,8,9-HxCDF	<0.20	<0.21	0.61	<0.21	0.33	<0.21	<0.14	<0.13	<0.39	<0.20	<0.21	0.24	<0.21	0.25	<0.18
1,2,3,4,6,7,8-HpCDF	0.97	2.8	29	4.6	5.2	2.4	<4.9	0.66	6.2	3.3	2.9	9.3	1.9	12	0.41
1,2,3,4,7,8,9-HpCDF	<0.22	<0.20	1.8	0.49	0.59	<0.20	<0.49	<0.22	<1.20	0.5	<0.42	0.63	0.3	1.2	<0.22
OCDF	2.7	7.5	56	10	10	4.3	10	1.6	15	9	7.2	18	4.1	36	1.4
Texas-TEQ[a]	0.28	1.02	2.95	0.8	1.84	0.42	1.03	0.32	1.12	0.81	0.811	1.38	0.321	1.09	0.29
TOC %	2.68	0.898	5.09	2.84	3.92	1.9	1.43	1.76	3.62	2.06	5.66	1.89	2.7	3.45	0.32
Texas-TEQ[a,b]	10.53	113.08	58.03	28.29	46.82	22.24	31.06	18.18	39.36	14.33	72.88	11.89	31.86	31.06	90.63
Date	12/16/2004	1/27/2005	2/24/2005	3/2/2005	3/15/2005	5/29/2005	7/14/2005	10/10/2005	12/16/2004	1/12/2005	1/27/2005	2/27/2005	3/2/2005	3/15/2005	10/10/2005

[a] Non-detects assumed as½ MDL for calculations.

[b] Normalized by TOC content (concentrations in ng/Kg-oc).

0.05) was observed for the dioxin/furan congeners and Texas-TEQ with those parameters. Sediment was also correlated to undeveloped land use percentage by linear regression. Although a negative correlation was observed, this one was not significant (p-value > 0.05). Finally, a significant correlation between the watershed sediment data and composition (%gravel, %sand, %silt, and %clay) was not observed. Regarding dioxin content in soil, the Texas-TEQ concentrations for all of the soils were linearly correlated with TOC measurements but no significant correlation was found at an alpha value of 0.05.

Similarities and differences between the runoff dissolved and suspended phases and watershed sediment profiles were evaluated by PCA (Figure 7.8). From Figure 7.8, it was observed that (i) with the exception of sites SS-13 and SS-5, the runoff phases (dissolved, 1 μm, and 40 μm) were correlated to each other (in close proximity); (ii) with the exception of sites SS-7 and SS-5, the remaining sites showed a correlation between runoff and watershed sediment profiles, suggesting that watershed dioxin-contaminated sediment may be acting as a potential source; and (iii) runoff suspended phases were found more correlated to watershed sediment than the runoff dissolved phase.

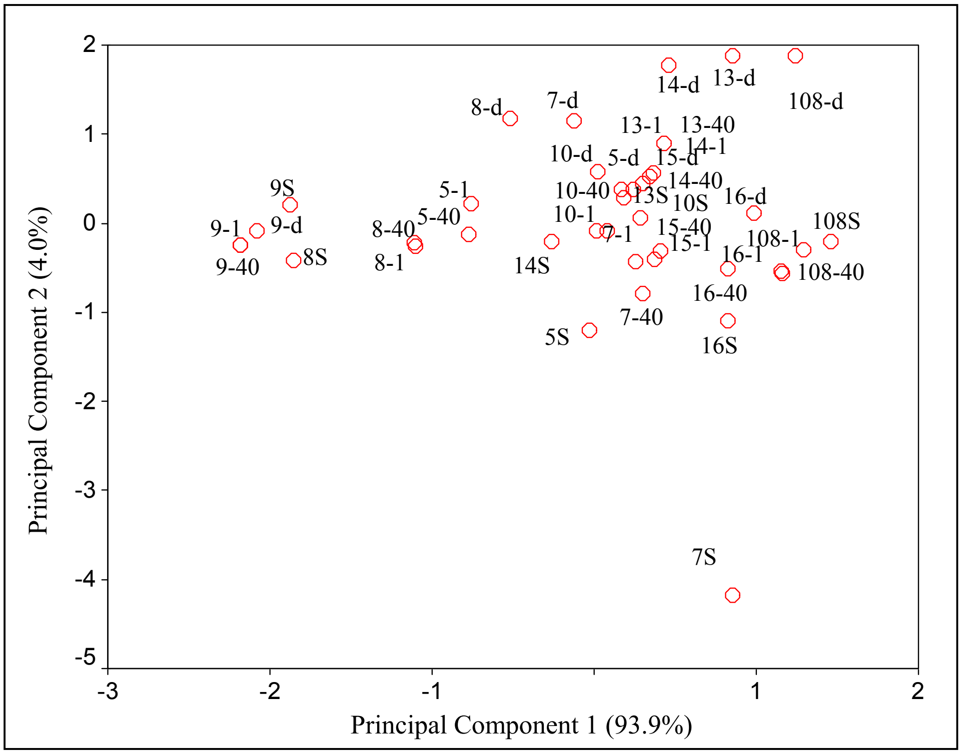


Figure 7.8 Two-dimensional score plot from PCA comparing runoff phases (dissolved (d), 1 µm (1), and 40 µm (40)) and watershed sediment (S) profiles. The numbers in the figure represent the runoff sample sites.

APPENDIX A

QC DATA

APPENDIX B

RESULTS RECEIVED FROM PSC/MAXXAM ANALYTICAL LABORATORY FOR THE SLUDGE SAMPLES

APPENDIX C

SUMMARY OF PROCEDURES TO COMPUTE S VALUES

APPENDIX D

SITE SELECTION MATRIX