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Sampling, Chemical Analysis, and Bioassessment in Accordance with CWA Section 404

Houston Ship Channel Expansion Channel Improvement Project, North of Morgan's Point Houston Ship Channel, Texas

(Part 6 of 6: Appendices 8-9, CDFATE Modeling Report & USEPA R6 Validation Worksheets)

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Appendix 8: CDFATE Report

Houston Ship Channel Expansion Channel Improvement Project (HSC ECIP), North of Morgan's Point Sediments, 404 Sediment Characterization and Testing – Mixing Zone Modeling for Discharge in Upland Placement Areas

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1.0 Objectives

This report details the mixing zone modeling performed by the U.S. Army Engineer Research and Development Center (ERDC) to support a CWA Section 404 sediment testing characterization study for Houston Ship Channel Expansion Channel Improvement Project (HSC ECIP), North of Morgan's Point (NMP). Simulations of dredged material discharges into four upland placement areas (PAs) were run using the Fate of Continuous Discharge from Dredging Operations into Open Water (CDFATE) module, Windows version 1.0, (Havis 1994, Doneker and Jirka 1990, Akar and Jirka 1991, Jones 1990) of the ADDAMS model to establish compliance with water column toxicity criteria for the HSC sediment samples HSCNew-NMP-02, HSCNew-NMP-03, HSCNew-NMP-04, HSCNew-NMP-05, HSCNew-NMP-06, HSCNew-NMP-07, HSCNew-NMP-08, HSCNew-NMP-09, HSCNew-NMP-10, and HSCNew-NMP-11. Elutriate chemistry and elutriate bioassay data (Sections 4.5 and 4.6 of the HSC ECIP NMP Report) were evaluated and applied in the modeling.

2.0 Dredging and Placement Locations

The dredging and placement plan for NMP Segments 4, 5, and 6 is displayed below in Figure 1. Four upland placement sites are identified to receive dredged material from the project. Sediment from location HSCNew-NMP-01 from ship channel segment 1 (not shown on the map) is now not planned to be dredged and is therefore not included in the mixing zone analysis. Sediment from Segment 4 in the vicinity of locations HSCNew-NMP-02 and -NMP-03 will be placed in the New BW-8 PA. Segment 4 sediment from locations HSCNew-NMP-04 and -NMP-05 will be placed in the New E2-Clinton PA. Segment 5 sediment from location HSCNew-NMP-06 and Segment 6 sediment from locations -NMP-07, -NMP-08, -NMP-09 and -NMP-10 will be placed into the Glendale PA. Sediment from the vicinity of sample location HSCNew-NMP-11 will be placed in the Filter Bed PA.

Discharge locations and drainage paths to receiving waters for the four PAs are shown in Figure 2. The New BW-8 PA will discharge to existing and future onsite unnamed ditches (mostly grass lined ditches and some underground culverts) to Buffalo Bayou/HSC. New E2-Clinton PA will discharge to unnamed ditches and culverts to Turkey Run Gully, which is a mostly grass drainage ditch that discharges into Hunting Bayou. Glendale PA will also discharge to Turkey Run Gully, upstream of the New E2-Clinton PA discharge, flowing through a mix of underground culverts, mostly grass drainage ditch, concrete ditch from Mercury to Cheston Dr. 2 blocks E of Holland, then grass drainage ditch to Hunting Bayou. Hunting Bayou is considered the receiving water for both the New E2-Clinton and Glendale PAs. Filter Bed PA discharges to unnamed overgrown grass ditches to City of Houston (COH) underground storm water line to Buffalo Bayou. A mixing zone evaluation is needed to determine if the effluent discharged from these PAs will be sufficiently diluted within allowable mixing zones to comply with applicable water quality and toxicity criteria.

Figure 1. DMMP NW Dredging and Placement Locations

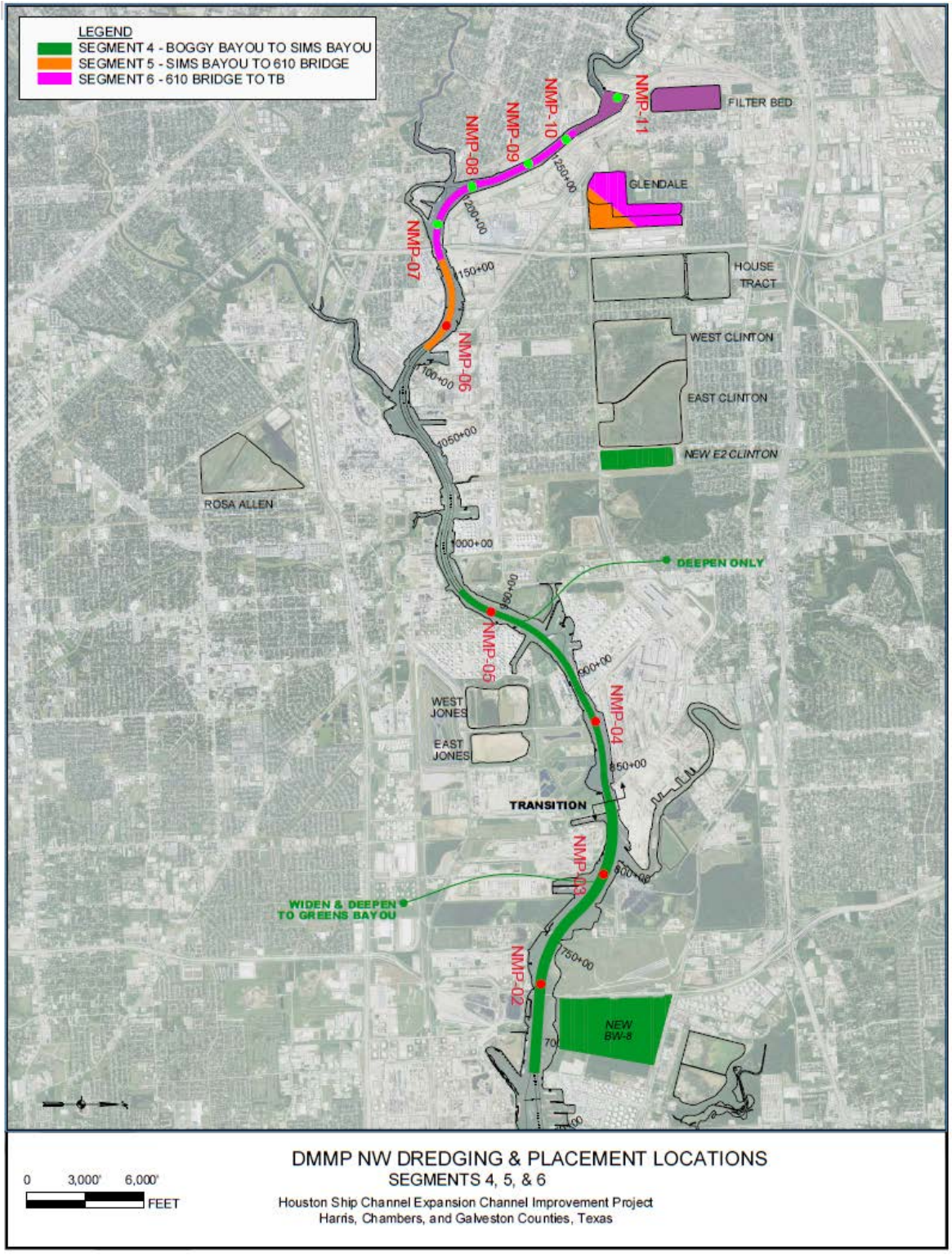
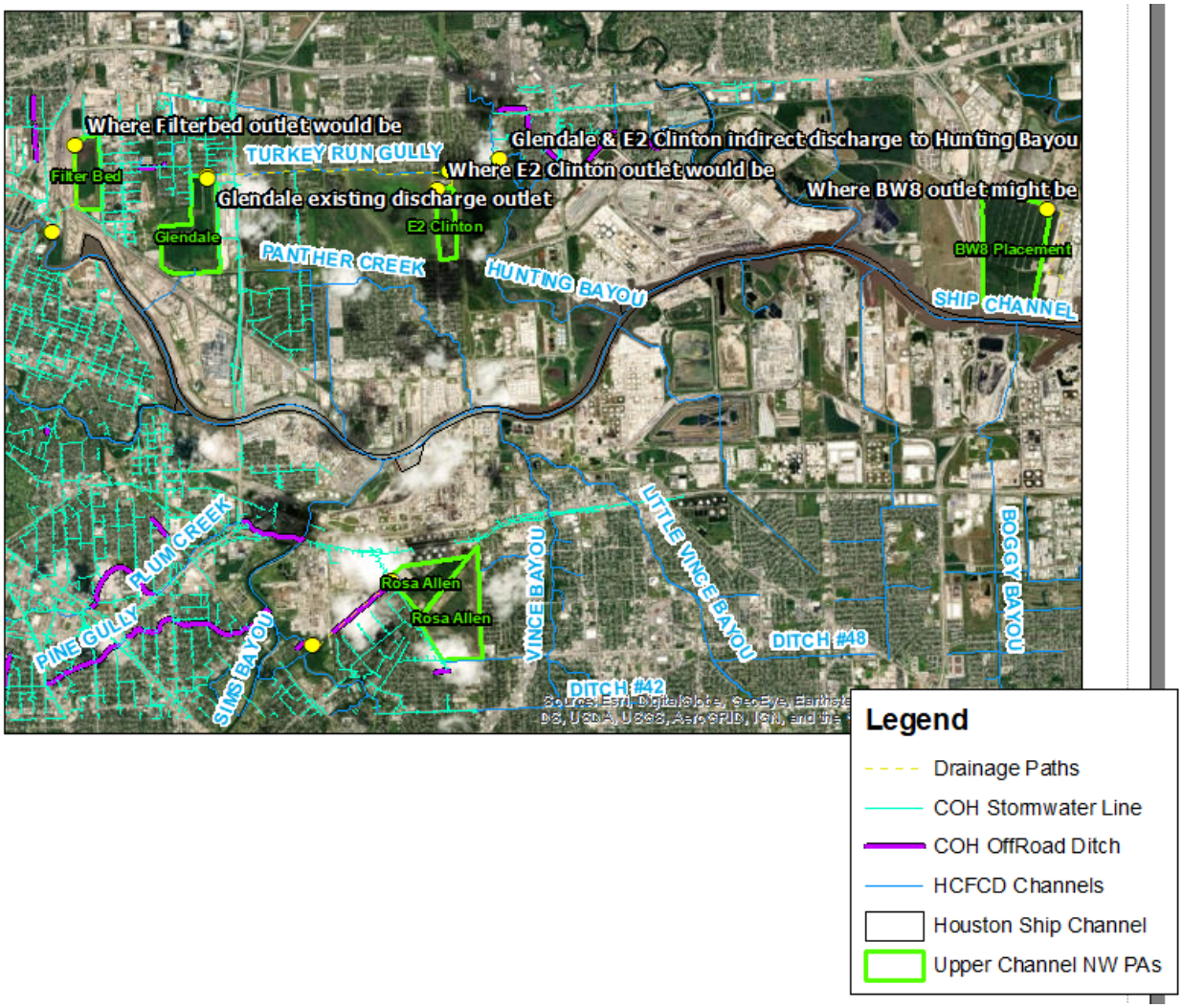


Figure 2. Upland Placement Area Discharge Locations and Drainage Paths to Receiving Water



3.0 Mixing Zone Evaluation Approach

Dilution of effluent from the dredged material placement area occurs when the effluent discharge mixes with the waters of the receiving stream. The extent to which the two streams (PA effluent and receiving stream) mix depends on physical characteristics of the flows such as density and flow rate (or velocity) of both streams, geometry of the receiving stream, and size and orientation of the effluent pipe (or channel). The CDFATE model is used here to evaluate the extent of mixing for effluent from each PA into their respective receiving streams.

The amount of dilution (D) that is required to meet water quality criteria is a function of the contaminant concentration in the effluent discharge (as represented by elutriate concentrations (C), the applicable water quality criteria (C_{wq}), and the background concentration of the receiving water (C_B). Required dilution is expressed in terms of how many parts of receiving water need to be mixed with one part of

effluent to reach the applicable criteria. Equations to calculate dilution requirements for both water quality ($D_{a\text{-}wq}$) and toxicity ($D_{a\text{-}tox}$) are provided below.

$$D_{a-wq} = \frac{C-C_{wq}}{C_{wq}-C_B} \quad (1)$$

where

$D_{a\text{-}wq}$ = dilution required to achieve concentration equivalent to water quality criteria
C = contaminant concentration in elutriate sample
C_{wq} = water quality criteria
C_B = background (receiving water) contaminant concentration

$$D_{a-tox} = \frac{100-LPC}{LPC} \quad (2)$$

where

$D_{a\text{-}tox}$ = dilution required to achieve LPC for toxicity
LPC = limiting permissible concentration based on elutriate toxicity evaluation

As shown in Equation 1, the quality of the receiving water affects dilution requirements. The higher the background concentration, the more water has to be mixed in to sufficiently dilute. The concentration of the mixture will necessarily fall between the concentration of the effluent and of the receiving water. If the background concentration is above the criteria, then it is impossible to demonstrate sufficient dilution to reach the criteria.

Texas surface water quality standards allow for application of a mixing zone (MZ) and zone of initial dilution (ZID). Acute toxicity is not allowed in a mixing zone, and chronic toxicity is not allowed beyond a mixing zone (TCEQ 2012). The ZID is a small area where initial dilution with receiving waters occurs and may not meet criteria applicable to the receiving water. Acute criteria may be exceeded within a ZID; thus acute criteria apply at the edge of the ZID. Chronic criteria apply at the edge of the mixing zone. Typically, the amount of mixing and dilution increases with distance from the discharge point. CDFATE modeling is necessary to determine the location (distance from the discharge point) at which dilution is sufficient to reach acute and chronic criteria and thus determine the dimensions needed for the ZID and mixing zones for each discharge location.

4.0 Elutriate Chemistry and Toxicity

Elutriate chemistry and toxicity were evaluated for comparison to water quality criteria to determine the need for a mixing zone evaluation for each PA. Sediment samples HSCNew-NMP-01-SD, HSCNew-NMP-02-SD, HSCNew-NMP-03-SD, HSCNew-NMP-04-SD, HSCNew-NMP-05-SD, HSCNew-NMP-06-SD, HSCNew-NMP-07-SD, HSCNew-NMP-08-SD, HSCNew-NMP-09-SD, HSCNew-NMP-10-SD and HSCNew-NMP-11-SD were collected during October 2018; corresponding water samples were also collected from the same locations in October, 2018 (Appendix 2 of the HSC ECIP NMP Report). Elutriate samples were prepared from the sediment samples as reported in Section 2.2.1 of the Tier III Biological Testing Report (Appendix

8 of the HSC ECIP NMP Report). The analytical results for the water and elutriate samples are provided in Sections 3.3 and 3.5, respectively, and Appendix 5 of the HSC ECIP NMP Report. Contaminants of concern (COCs) for which the elutriate concentration is shown to be below marine water screening criteria do not pose a problem for meeting criteria. Sixteen COCs were identified in which either the elutriate concentration exceeded the screening criteria (either acute or chronic), or the reporting limits (RLs) were above the screening criteria and therefore could not be verified as meeting the criteria. The elutriate results for the sixteen (16) COCs whose reported results exceed criteria are presented below in Table 1.

Table 1a Analytical Results for Houston Ship Chanel (HSC) Expansion Channel Improvement Project – Analytes of Interest for NMP Mixing Zone Analysis

	Hexachloro-butadiene µg/L	Hexachloro-cyclopentadiene µg/L	Anthracene µg/L	Pyrene µg/L	4,4'-DDT µg/L
Marine Water Screening Criteria:					
TSWQS (Acute)	-	-	-	-	0.13
EPA WQC (CMC)	-	-	-	-	0.13
NOAA (Marine Acute)	32	7	300	300	0.065
Region 6 (Marine Chronic)	0.32	0.07	0.18	0.24	0.001
Elutriate Samples:					
HSCNew-NMP-02-EL	**0.51 Ub**	**0.51 Ub**	0.079	**0.33**	**0.006 U**
HSCNew-NMP-03-EL	**0.50 Ub**	**0.50 Ub**	0.0045 Jb	0.017	**0.006 U**
HSCNew-NMP-03-EL-Field Dup	**0.50 Ub**	**0.50 Ub**	0.057	0.074	**0.006 U**
HSCNew-NMP-04-EL	**0.51 Ub**	**0.51 Ub**	0.15	0.20	**0.006 U**
HSCNew-NMP-05-EL	**0.50 Ub**	**0.50 Ub**	0.037	0.067	**0.006 U**
HSCNew-NMP-06-EL	**0.52 Ub**	**0.52 Ub**	0.013	0.092	**0.006 U**
HSCNew-NMP-07-EL	**0.50 Ub**	**0.50 Ub**	0.096	0.13	**0.006 U**
HSCNew-NMP-08-EL	**0.51 Ub**	**0.51 Ub**	**0.62**	**0.25**	**0.006 U**
HSCNew-NMP-09-EL	**0.51 Ub**	**0.51 Ub**	**0.85**	**0.28**	**0.006 U**
HSCNew-NMP-10-EL	**0.52 Ub**	**0.52 Ub**	0.10	0.10	**0.006 U**
HSCNew-NMP-11-EL	**0.47Ub**	**0.47Ub**	0.013	0.092	**0.006 U**
Site Water Samples:					
HSCNew-NMP-02-SW	**0.51 Ub**	**0.51 Ub**	0.010 Ub	0.0024 Jb	**0.006 U**
HSCNew-NMP-04-SW	**0.50 Ub**	**0.50 Ub**	0.010 Ub	0.0028 Jb	**0.006 U**
HSCNew-NMP-05-SW	**0.50 Ub**	**0.50 Ub**	0.010 Ub	0.0066 Jb	**0.006 U**
HSCNew-NMP-11-SW	**0.51 Ub**	**0.51 Ub**	0.010 Ub	0.0077 Jb	**0.006 U**

Footnotes:

(1) U/Ub = Analyte included in the analysis, but not detected (non-detect)

(2) J/Jb= Detected but below the Reporting Limit (Limit of Quantitation); therefore, result is an estimated concentration

(3) **Bold text** indicates samples that exceeded screening criteria

Table 1b **Analytical Results for Houston Ship Chanel (HSC) Expansion Channel Improvement Project – Analytes of Interest for NMP Mixing Zone Analysis**

	Dieldrin µg/L	Endrin µg/L	Endrin Aldehyde µg/L	Heptachlor µg/L	Heptachlor Epoxide µg/L
Marine Water Screening Criteria:					
TSWQS (Acute)	0.71	0.037	-	0.053	-
EPA WQC (CMC)	0.71	0.037	0.037	0.053	0.053
NOAA (Marine Acute)	0.355	0.0185	0.0185	0.0265	0.0265
Region 6 (Marine Chronic)	0.002	0.002	0.002	0.004	0.004
Elutriate Samples:					
HSCNew-NMP-02-EL	**0.006 U**	**0.006 U**	**0.006 U**	**0.006 U**	**0.006 U**
HSCNew-NMP-03-EL	**0.006 U**	**0.006 U**	**0.006 U**	**0.006 U**	**0.006 U**
HSCNew-NMP-03-EL-Field Dup	**0.006 U**	**0.006 U**	**0.006 U**	**0.006 U**	**0.006 U**
HSCNew-NMP-04-EL	**0.006 U**	**0.006 U**	**0.006 U**	**0.006 U**	**0.006 U**
HSCNew-NMP-05-EL	**0.006 U**	**0.006 U**	**0.006 U**	**0.006**	**0.006 U**
HSCNew-NMP-06-EL	**0.006 U**	**0.006 U**	**0.006 U**	**0.006 U**	**0.006 U**
HSCNew-NMP-07-EL	**0.006 U**	**0.006 U**	**0.006 U**	**0.006 U**	**0.006 U**
HSCNew-NMP-08-EL	**0.006 U**	**0.006 U**	**0.006 U**	**0.006 U**	**0.006 U**
HSCNew-NMP-09-EL	**0.006 U**	**0.006 U**	**0.006 U**	**0.006 U**	**0.006 U**
HSCNew-NMP-10-EL	**0.006 U**	**0.006 U**	**0.006 U**	**0.006 U**	**0.006 U**
HSCNew-NMP-11-EL	**0.006 U**	**0.006 U**	**0.006 U**	**0.006 U**	**0.006 U**
Site Water Samples:					
HSCNew-NMP-02-SW	**0.006 U**	**0.006 U**	**0.006 U**	**0.006 U**	**0.006 U**
HSCNew-NMP-04-SW	**0.006 U**	**0.006 U**	**0.006 U**	**0.006 U**	**0.006 U**
HSCNew-NMP-05-SW	**0.006 U**	**0.006 U**	**0.006 U**	**0.006 U**	**0.006 U**
HSCNew-NMP-11-SW	**0.006 U**	**0.006 U**	**0.006 U**	**0.006 U**	**0.006 U**

Footnotes:

(1) U/Ub = Analyte included in the analysis, but not detected

(2) J/Jb= Detected but below the Reporting Limit (Limit of Quantitation); therefore, result is an estimated concentration.

(3) **Bold text** indicates samples that exceeded screening criteria.

Table 1c **Analytical Results for Houston Ship Chanel (HSC) Expansion Channel Improvement Project – Analytes of Interest for NMP Mixing Zone Analysis**

	Toxaphene µg/L	Copper µg/L	Lead µg/L	Silver µg/L	Zinc µg/L	Cyanide µg/L
Marine Water Screening Criteria:						
TSWQS (Acute)	0.21	13.5	133	2	92.7	-
EPA WQC (CMC)	0.21	4.8	210	1.9	90	1
NOAA (Marine Acute)	0.21	4.8	210	0.95	90	1
Region 6 (Marine Chronic)	0.0002	3.6	5.3	-	84.2	5.6
Elutriate Samples:						
HSCNew-NMP-02-EL	**0.30U**	**5.0 U**	5.0 U	**1.4**	50	**10 Cl, U**
HSCNew-NMP-03-EL	**0.30U**	1.5 J	5.0 U	**5.0 U**	44	**10 Cl, U**
HSCNew-NMP-03-EL-Field Dup	**0.30U**	**5.0 U**	5.0 U	**1.1 J**	**184**	**10 Cl, U**
HSCNew-NMP-04-EL	**0.30U**	**5.0 U**	5.0 U	**5.0 U**	44	**10 Cl, U**
HSCNew-NMP-05-EL	**0.30U**	**5.0 U**	5.0 U	**5.0 U**	69	**10 Cl, U**
HSCNew-NMP-06-EL	**0.30U**	**5.0 U**	5.0 U	**5.0 U**	71	**10 Cl, U**
HSCNew-NMP-07-EL	**0.30U**	**5.0 U**	5.0 U	**5.0 U**	66	**10 Cl, U**
HSCNew-NMP-08-EL	**0.30U**	**5.0 U**	5.0 U	**5.0 U**	**162**	**10 Cl, U**
HSCNew-NMP-09-EL	**0.30U**	**5.0 U**	5.0 U	**3.2 J**	47	**10 Cl, U**
HSCNew-NMP-10-EL	**0.30U**	0.70 J	**16**	**1.2 J**	73	**10 Cl, U**
HSCNew-NMP-11-EL	**0.30U**	0.60 J	5.0 U	**5.0 U**	**149**	**10 Cl, U**
Site Water Samples:						
HSCNew-NMP-02-SW	**0.30U**	2.4 J	5.0 U	**1.3 J**	77	**10 Cl, U**
HSCNew-NMP-04-SW	**0.30U**	2.2 J	5.0 U	**5.0 U**	79	**10 Cl, U**
HSCNew-NMP-05-SW	**0.30U**	3.0 J	1.0 J	**5.0 U**	62	**10 Cl, U**
HSCNew-NMP-11-SW	**0.30U**	**4.6 J**	1.5 J	**5.0 U**	**86**	**10 Cl, U**

Footnotes:

(1) U/Ub = Analyte included in the analysis, but not detected

(2) J/Jb = Detected but below the Reporting Limit (Limit of Quantitation); therefore, result is an estimated concentration.

(3) Cl = Residual Chlorine or other oxidizing agent was detected in the container used to analyze this sample

(4) **Bold text** indicates samples that exceeded screening criteria.

The site water results for samples that represent receiving water are also provided in Table 1. Site water from the sample locations nearest the discharges to Buffalo Bayou/HSC (sample HSCNew-NMP-02-SW for New BW-8 PA, and sample HSCNew-NMP-11-SW for Filter Bed PA) represent background concentrations for the receiving water for those PAs. Site water data was not available for the receiving water location on Hunting Bayou from New E2-Clinton PA (receiving material from locations HSCNew-NMP-04 and -NMP-05) and Glendale PA (receiving material from sample locations HSCNew-NMP-06, -NMP-07, -NMP-08, -NMP-09 and -NMP-10). USGS Gauge data from 2000 were reviewed but determined to be unusable for this work as the data set was not a COC match and had several unreported or elevated reporting limits. As Hunting Bayou discharges into Buffalo Bayou/HSC between sample locations HSCNew-NMP-04 and -NMP-05, and representative data was unavailable, the site water data (conservative worst-case) from

these two locations were applied as the background concentrations for the discharges from Glendale and New E2-Clinton PAs into Hunting Bayou.

4.1 COCs with Reporting Limits above Criteria

For the following COCs in Table 1, analytical reporting limits (RLs) are above chronic criteria and qualified "U": hexachlorobutadiene, hexachlorocyclopentadiene, 4,4'-DDT, dieldrin, endrin, endrin aldehyde, heptachlor, heptachlor epoxide, toxaphene, copper and cyanide. The RLs are also above acute criteria for endrin, toxaphene, silver and cyanide. In cases where these contaminants are not detected in elutriate or receiving water, the RLs are (conservatively) assumed to be both the elutriate and the receiving water concentrations. Use of the RL in such circumstances makes it impossible to achieve dilution to meet either acute or chronic criteria concentrations, as it cannot be certain as to whether the criteria are exceeded.

The following COCs, were non-detect in any of the elutriate, site water and sediment samples: hexachlorocyclopentadiene, endrin, endrin aldehyde, heptachlor epoxide, toxaphene and cyanide. Given the lack of detections in sediment and surface water, there is no reason to believe these contaminants are present at concentrations of concern, and they are not evaluated further.

4.2 COCs above Criteria and Background

Several other COCs have limited evidence of their presence in the HSC sediment and waters. Heptachlor was shown as being detected at the reporting limit for one elutriate sample, but was not detected in any site water or sediment samples. Also, 4,4'-DDT was not detected in elutriate or site water and was only detected in sediment samples HSCNew-NMP-04-SD, HSCNew-NMP-05-SD and HSCNew-NMP-08-SD. Dieldrin was detected only in sediment of HSCNew-NMP-03-SD-Field Dup. Hexachlorobutadiene was only detected in sediment sample HSCNew-NMP-02-SD. The detection of these COCs suggests they are present, and they are therefore retained in the evaluation.

4.3 COCs with Background above Criteria

If background receiving water concentrations are already above criteria, then it is impossible to dilute the effluent to below the criteria (Section 3.0). In this case, a mixing zone evaluation is not necessary. Of the contaminants that were not eliminated from the evaluation in Section 4.1, the following contaminants have receiving water concentrations (either detected or RL applied) above chronic criteria: hexachlorobutadiene, 4,4'-DDT, dieldrin, heptachlor, and copper (HSCNew-NMP-11, Filter Bed PA only). As a result of both the finding that the receiving water concentrations (either detected or RL applied) are above chronic criteria for these COCs and that acute criteria were not exceeded for hexachlorobutadiene, 4,4'-DDT, dieldrin, and heptachlor, these COCS will not be further evaluated for mixing zone requirements. However, copper will continue to be evaluated as dilution can be achieved for three of the four PAs and it was the only COC where concentrations exceeded acute criteria.

Silver does not have an applicable chronic standard. However, since silver concentrations (either detected or RLs) in receiving waters (background) were above marine acute criteria, sufficient dilution cannot be achieved, and further evaluation with respect to a mixing zone is unnecessary.

Despite the inability to determine a mixing zone for these contaminants (hexachlorobutadiene, 4,4'-DDT, dieldrin, heptachlor and silver), compliance with water quality standards still needs to be demonstrated for each PA. Some alternatives to be considered to demonstrate compliance (in a follow-on evaluation) include: 1) reanalyzing elutriate and or receiving water chemistry with RLs below criteria; and 2) search for historical evaluation of receiving water chemistry that might have RLs below criteria. Furthermore, non-detect concentrations could potentially be handled in some manner other than assigning the RL as the concentration (USEPA 1991). If concentrations below criteria could justifiably be used as the receiving water concentrations, dilution requirements could then be determined for these COCs. Without that justification, however, these COCs will not be evaluated based on the inability to sufficiently dilute.

4.4 Bioassay Results

In 404 evaluations, it is recommended (but not required) that a multi-species testing approach be used to assess potential effects on the receiving waters. As reported in Section 3.6 and Appendix 8 of the HSC ECIP NMP Report, standard acute (96 hour) toxicity tests were conducted to assess toxicity of the elutriate samples. The tests subjected two species, *Menidia beryllina* and *Americamysis bahia*, to each elutriate sample. Elutriate bioassay test results are reported in Section 3.6 and Appendix 8 of the HSC ECIP NMP Report and presented below in Table 2.

Reported endpoints from the bioassay tests depends on the resulting mortality. If test mortality was high enough (50% effect was bracketed by dilution series and a no observed effects concentration (NOEC) was obtained), the end result of the effluent elutriate toxicity evaluation is the 96-hr median lethal concentration (LC50), expressed as a percentage of the suspended dredged material concentration (or 100% elutriate). However, if acute toxicity was demonstrated but mortality was not high enough to calculate a LC50, then the NOEC and lowest observed effects concentration (LOEC) were reported.

As shown in Table 2, there was no acute elutriate toxicity to four of the tested elutriates (HSCNew-NMP-02, -NMP-03, -NMP-05 and –NMP-09). Only material from HSCNew-NMP-02 and HSCNew-NMP-03 will be placed in New BW-8 PA, and since no acute toxicity was demonstrated for either material, mixing requirements on the basis of the bioassay testing are not needed for New BW-8 PA. However, the remaining elutriate samples (HSCNew-NMP-04, -NMP-06, -NMP-07, -NMP-08, -NMP-10 and –NMP-11) did display acute toxicity, and require the application of a mixing zone for New E2-Clinton PA, Glendale PA and Filter Bed PA.

It should be noted, as pointed out in Section 3.6 and Appendix 8 of the HSC ECIP NMP Report, that concentrations of ammonia measured in all of the elutriates in which acute toxicity was observed were high enough to cause mortality to the test organisms based on literature reported values for ammonia toxicity. This suggests that ammonia was a factor in determining the observed toxicity in both test organisms. Ammonia is considered a non-persistent contaminant which often causes toxicity in elutriate tests (Kennedy et al. 2015). Being non-persistent, it is expected to dissipate rapidly and its presence is not expected to result in chronic effects.

As discussed previously, chronic criteria apply at the edge of the mixing zone and acute criteria at the edge of the ZID. The NOEC was applied as the acute criteria. The chronic criteria was determined as either the

LC50 multiplied by an application factor (AF) or (where a LC50 was not calculated) the LOEC multiplied by an AF. The AF generally represents the inverse of the acute-to-chronic ratio (ACR). An AF of 0.01 was used here as a conservative approach within this initial screening evaluation. The 0.01 AF was recommended by the National Academy of Science (NAS) and adopted in the MPRSA and USEPA/UACE dredged material testing guidance (Kennedy et al. 2015). There is precedent, however, for applying AFs other than 0.01 where ammonia is the driver of toxicity. Kennedy et al. (2105) suggests the use of a larger AF of 0.05 to 0.1 for dredging evaluations for nonpersistent contaminants. Although the conservative AF of 0.01 was used in this evaluation, it is recommended that a less conservative AF be considered in light of the ammonia toxicity and conservative nature of the 0.01 factor, and that the toxicity criteria be recalculated in subsequent evaluation.

Table 2 **Biological Testing Results for Houston Ship Chanel (HSC) Expansion Channel Improvement Project – Elutriate Bioassay Results of Interest for NMP Mixing Zone Analysis**

PA Assigned in DMMP	Sample	Endpoint	*96-h Americamysis bahia*			*96-h Menidia beryllina*		
			Endpoint Result	Acute criteria (1)	Chronic criteria (2)	Endpoint Result	Acute criteria (1)	Chronic criteria (2)
New BW-8	HSCNew-NMP-02	NOEC	100%	NA	NA	100%	NA	NA
		LOEC	NA (1)			NA (1)		
		LC50	NA (1)			NA (1)		
	HSCNew-NMP-03	NOEC	100%	NA	NA	100%	NA	NA
		LOEC	NA (1)			NA (1)		
		LC50	NA (1)			NA (1)		
New E2-Clinton	HSCNew-NMP-04	NOEC	50%	50%	1%	50%	50%	1%
		LOEC	100%			100%		
		LC50	NA (1)			NA (1)		
	HSCNew-NMP-05	NOEC	100%	NA	NA	100%	NA	NA
		LOEC	NA (1)			NA (1)		
		LC50	NA (1)			NA (1)		
Glendale	HSCNew-NMP-06	NOEC	100%	NA	NA	50%	50%	0.95%
		LOEC	NA (1)			100%		
		LC50	NA (1)			95 (78 – 117)		
	HSCNew-NMP-07	NOEC	50%	50%	0.79%	10%	10%	0.59%
		LOEC	100%			50%		
		LC50	79 (73 – 86)			59 (52 – 66)		
	HSCNew-NMP-08	NOEC	50%	50%	1%	50%	NA	NA
		LOEC	100%			100%		
		LC50	NA (1)			NA (1)		
	HSCNew-NMP-09	NOEC	100%	NA	NA	100%	NA	NA
		LOEC	NA (1)			NA (1)		
		LC50	NA (1)			NA (1)		

	HSCNew-NMP-10	NOEC	100%	NA	NA	50%	NA	NA
		LOEC	NA (1)			100%		
		LC50	NA (1)			NA (1)		
Filter Bed	HSCNew-NMP-11	NOEC	100%	NA	NA	50%	NA	NA
		LOEC	NA (1)			100%		
		LC50	NA (1)			NA (1)		

Footnotes:

(1) If no acute toxicity demonstrated, not applicable (NA); if acute toxicity predicted, then acute criteria (CMC) = NOEC

(2) If no acute toxicity demonstrated, not applicable (NA); if acute toxicity predicted, but LC50 cannot be calculated, then chronic criteria (CCC) = LOEC x AF; if acute toxicity predicted, and LC50 calculated, then CCC = LC50 x AF. AF = application factor (assumed to be 0.01).

4.5 Dilution Requirements

4.5.1 Water Quality

Table 3 presents the chemical concentrations (elutriate and background), water quality criteria and calculated dilution requirements to be applied in the CDFATE modeling for the COCs that were not previously eliminated from evaluation based on lack of detection (Section 4.1) and inability to dilute due to background concentrations above criteria (Section 4.3). The lowest of the acute criteria was applied to the dilution calculation using Equation 1.

For these COCs, the greatest dilution requirements to meet acute criteria are: 6.9 (Zn) for New BW-8 PA, 0.11 (Cu) for New E2-Clinton PA, 6.7 (Zn) for Glendale PA, and 13.4 (Zn) for Filter Bed PA. To meet chronic criteria, the greatest dilution requirements are 13.0 (Zn) for New BW-8 PA, 2.3 (Cu) for New E2-Clinton PA, 36 (Pb) for Glendale PA, and dilution is not possible for Filter Bed PA based on Zn receiving water (background) concentrations.

4.5.2 Toxicity

Based on the acute and chronic criteria determined from the bioassay evaluation (Section 4.4), dilution requirements were calculated for each elutriate and test species using Equation 2. The resulting dilution requirements are also presented in Table 3. The highest dilution required for any elutriate sample and species for a given PA is applied as the dilution requirement for that PA. With respect to the bioassay results, the highest dilution requirements to meet acute concentrations are 1.0 for New E2-Clinton PA, 1.0 for Glendale PA, and 1.0 for Filter Bed PA; where a 1.0 dilution means a 1:1 dilution (one part elutriate to one part receiving water), resulting in a concentration reduction of 50%. For chronic toxicity, dilution requirements are 99.0 for New E2-Clinton PA, 168.5 for Glendale PA, and 99.0 for Filter Bed PA. On the basis of bioassay testing, dilution requirements are not applicable for New BW-8 PA, as HSCNew-NMP-02 and HSCNew-NMP-03 did not display toxicity for either tested species.

4.5.3 Overall Dilution Requirements

Considering both COCs and bioassay results, the overall highest dilution requirements are 6.9 at New BW-8 PA, 1.0 (reduction of 50%) at New E2-Clinton PA, 6.7 at Glendale PA and 13.4 at Filter Bed PA to

meet acute criteria, and 13.0 at New BW-8 PA, 99.0 at New E2-Clinton PA, 168.5 at Glendale PA and 99.0 at Filter Bed PA to meet chronic criteria.

Table 3 Summary of Dredge Material Tier II Exceedances and Required Dilution

Parameter	Concentration (µg/L)									
	New BW-8 PA		New E2-Clinton PA		Glendale PA					Filter Bed PA
	HSC New-NMP-02	HSC New-NMP-03	HSC New-NMP-04	HSC New-NMP-05	HSC New-NMP-06	HSC New-NMP-07	HSC New-NMP-08	HSC New-NMP-09	HSC New-NMP-10	HSC New-NMP-11
Anthracene	0.079	0.057 (7)	0.015	0.037	0.013	0.096	0.62	0.85	0.10	0.013
Background	0.010 Ub	0.010 Ub	0.010 Ub	0.010 Ub	0.010 Ub	0.010 Ub	0.010 Ub	0.010 Ub	0.010 Ub	0.010 Ub
CMC (5)	300	300	300	300	300	300	300	300	300	300
CCC (6)	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
Dilution required to meet CMC(1)	0	0	0	0	0	0	0	0	0	0
Dilution required to meet CCC (1)	0	0	0	0	0	0	**2.600**	**3.959**	0	0
Pyrene	0.33	0.074 (8)	0.20	0.067	0.092	0.13	0.25	0.28	0.10	0.092
Background	0.0024 Jb	0.0024 Jb	0.0066 Jb (9)	0.0066 Jb (9)	0.0066 Jb (9)	0.0066 Jb (9)	0.0066 Jb (9)	0.0066 Jb (9)	0.0066 Jb (9)	0.0077 Jb
CMC (5)	300	300	300	300	300	300	300	300	300	300
CCC (6)	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24
Dilution required to meet CMC(1)	0	0	0	0	0	0	0	0	0	0
Dilution required to meet CCC (1)	**0.383**	0	0	0	0	0	**0.030**	**0.171**	0	0
Copper	5.0 U	5.0 U (10)	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	0.70 J	0.60 J
Background	2.4 J	2.4 J	3.0 J	3.0 J	3.0 J	3.0 J	3.0 J	3.0 J	3.0 J	4.6 J
CMC (5)	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8
CCC (6)	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6
Dilution required to meet CMC(1)	**0.083**	**0.083**	**0.111**	**0.111**	**0.111**	**0.111**	**0.111**	**0.111**	0	0
Dilution required to meet CCC (1)	**1.167**	**1.167**	**2.333**	**2.333**	**2.333**	**2.333**	**2.333**	**2.333**	0	0
Lead	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	16	5.0 U
Background	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	1.5 J
CMC (5)	133	133	133	133	133	133	133	133	133	133
CCC (6)	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3

Parameter	Concentration (µg/L)									
	New BW-8 PA		New E2-Clinton PA		Glendale PA					Filter Bed PA
	HSC New-NMP-02	HSC New-NMP-03	HSC New-NMP-04	HSC New-NMP-05	HSC New-NMP-06	HSC New-NMP-07	HSC New-NMP-08	HSC New-NMP-09	HSC New-NMP-10	HSC New-NMP-11
Dilution required to meet CMC(1)	0	0	0	0	0	0	0	0	0	0
Dilution required to meet CCC (1)	0	0	0	0	0	0	0	0	**36**	0
Zinc	50	184 (11)	44	69	71	66	162	47	73	149
Background	77	77	79	79	79	79	79	79	79	86
CMC (5)	90	90	90	90	90	90	90	90	90	90
CCC (6)	84.2	84.2	84.2	84.2	84.2	84.2	84.2	84.2	84.2	84.2
Dilution required to meet CMC(1)	0	**6.963**	0	0	0	0	**6.667**	0	0	**13.409**
Dilution required to meet CCC (1)	0	**12.961**	0	0	0	0	**15.560**	0	0	**TBD**
96-h *Americamysis bahia*										
NOEC (%)	100	100	50	100	100	50	50	100	100	100
LOEC (%)	NA	NA	100	NA	NA	100	100	NA	NA	NA
LC50 (%)	NA	NA	NA	NA	NA	79	NA	NA	NA	NA
CMC Concentration (3)	NA	NA	50	NA	NA	50	50	NA	NA	NA
Dilution required to meet CMC(2)	NA	NA	**1**	NA	NA	**1**	**1**	NA	NA	NA
CCC Concentration (4)	NA	NA	1	NA	NA	0.79	1	NA	NA	NA
Dilution required to meet CCC (2)	NA	NA	**99.0**	NA	NA	**125.6**	**99.0**	NA	NA	NA
96-h *Menidia beryllina*										
NOEC (%)	100	100	50	100	50	10	50	100	50	50
LOEC (%)	NA	NA	100	NA	100	50	100	NA	100	100
LC50 (%)	NA	NA	NA	NA	95	59	NA	NA	NA	NA

Parameter	Concentration (µg/L)									
	New BW-8 PA		New E2-Clinton PA		Glendale PA					Filter Bed PA
	HSC New-NMP-02	HSC New-NMP-03	HSC New-NMP-04	HSC New-NMP-05	HSC New-NMP-06	HSC New-NMP-07	HSC New-NMP-08	HSC New-NMP-09	HSC New-NMP-10	HSC New-NMP-11
CMC Concentration (3)	NA	NA	50	NA	50	50	50	NA	50	50
Dilution required to meet CMC(2)	NA	NA	**1**	NA	**1**	**1**	**1**	NA	**1**	**1**
CCC Concentration (4)	NA	NA	1	NA	0.95	0.59	1	NA	1	1
Dilution required to meet CCC (2)	NA	NA	**99.0**	NA	**104.3**	**168.5**	**99**	NA	**99**	**99**
Maximum dilution required for CMC (17)	**0.083**	**6.963**	**1**	**0.111**	**1**	**1**	**6.667**	**0.111**	**1**	**13.409**
Maximum dilution required for CCC (17)	**1.167**	**12.961**	**99**	**2.333**	**104.3**	**168.5**	**99**	**3.959**	**99**	**TBD**

Footnotes:

(1) Dilution ($D_{a\text{-}wq}$) = $(C - C_{WQ})/(C_{WQ} - C_{Background})$
- $D_{a\text{-}wq}$ = dilution required to achieve concentration equivalent to water quality criteria
- C = contaminant concentration in elutriate sample
- C_{WQ} = water quality criteria (lesser of TSWQS (Acute) or EPA WQC (CMC))
- $C_{Background}$ = background (ODMDS) contaminant concentration (HSCNEW-SMP-ODMDS-SW)

(2) Dilution ($D_{a\text{-}tox}$) = (100 – LPC)/LPC
- $D_{a\text{-}tox}$ = dilution required to achieve LPC for toxicity
- LPC = limiting permissible concentration based on elutriate toxicity evaluation

(3) If no acute toxicity demonstrated, not applicable (NA); if acute toxicity predicted, then CMC = NOEC

(4) If no acute toxicity demonstrated, not applicable (NA); if acute toxicity predicted, but LC50 cannot be calculated, then CCC = LOEC x AF; if acute toxicity predicted, and LC50 calculated, then CCC = LC50 x AF. AF = application factor (assumed to be 0.01).

(5) CMC = lowest of TSWQS (acute), EPA WQC (CMC), and NOAA (marine acute). This was NOAA (marine acute) for all COCs except lead (TSWQS (acute)).

(6) Region 6 (marine chronic)
(7) NMP03 was 0.0045 Jb; NMP-03-EL-Field Dup was 0.057. Used higher of the two values.
(8) NMP03 was 0.017; NMP-03-EL-Field Dup was 0.074. Used higher of the two values.
(9) HSCNew-NMP-04-SW is 0.0028 Jb; HSCNew-NMP-05-SW is 0.0066 Jb. Used HSCNew-NMP-05-SW as worst case.
(10) HSCNew-NMP-03-EL was 1.5 J; HSCNew-NMP-03-EL-Field Dup was 5.0 U. Used HSCNew-NMP-03-EL-Field Dup as worst case.
(11) HSCNew-NMP-03-EL was 44; HSCNew-NMP-03-EL-Field Dup was 184. Used HSCNew-NMP-03-EL-Field Dup as worst case.
(12) U = analyte included in the analysis, but not detected; set equal to the RL
(13) Ub = compound was analyzed for but was not detected (non-detect)
(14) J = Detected but below the Reporting Limit (Limit of Quantitation); therefore, result is an estimated concentration.
(15) Jb = estimated value less than RL
(16) Cl = Residual Chlorine or other oxidizing agent was detected in the container used to analyze this sample
(17) TBD = To be determined. It is impossible to meet acute or chronic criteria based on background concentrations above criteria. COC will be reviewed to better refine receiving water concentrations.

5.0 Dredged Material and Site Water Properties

The dredged slurry entering the PAs will consist of a mixture of the dredged material and entrained site water. Most of the solid particulates are expected to settle within the PA, so that the effluent will consist primarily of site water with some fraction (primarily fines) of suspended solids that did not settle. As discussed in Section 3.0, physical properties of both the effluent and receiving water, such as density as a function of salinity and temperature, affect the mixing behavior between the effluent and receiving water. Water samples were taken at mid-depth. Properties of the collected site water are shown in Table 5.

Grain size distributions and other physical properties of the sediment samples were collected as part of the sampling event. Although they are not used directly in the CDFATE modeling, the physical properties of the dredged material are always useful in interpreting the results. These are provided in Section 3.2.1 and Appendix 4 of the HSC ECIP NMP Report and Table 4 below.

Table 4 Results of Physical Analyses for Composited Dredge Material Samples (1)

	HSC New NMP -02- SD	HSC New NMP -03- SD	HSC New NMP- 03-SD- DUP	HSC New NMP -04 - SD	HSC New NMP -05- SD	HSC New NMP -06- SD	HSC New NMP -07- SD	HSC New NMP -08- SD	HSC New NMP -09- SD	HSC New- NMP -10- SD	HSC New- NMP -11- SD
Grain Size Percentages											
Gravel	0	0	0	0	0	0	0	0	0	0	0
Sand Coarse	0.4	0.7	0.6	0.4	2.8	0.1	0.2	0.1	0.4	0.2	0.4
Sand Medium	1.4	0.8	1.1	0.9	3.3	1.3	1.7	0.6	0.5	0.4	0.6
Sand Fine	19.7	39.6	48.8	11.6	28.3	16.7	28.4	13.5	7.7	12.4	41.4
Sand Total	21.5	41.1	50.5	12.9	34.4	18.1	30.3	14.2	8.6	13	42.4
Silt	38.7	29.6	23.4	28.7	25.8	38.1	30.6	17.7	18.3	23	23
Clay	39.8	28	26.1	58.2	39.5	42.3	39.1	68	73.1	63.9	34.7
Solids, %	65.1	81.3	54.9	65.5	67.5	68.1	69.1	69.3	66.1	72.3	79.6
Specific Gravity (g/cc)	2.67	2.64	2.69	2.65	2.67	2.65	2.66	2.64	2.65	2.69	2.66
Atterberg Liquid Limit (%)	44	23	25	70	47	42	45	57	55	56	32
Atterberg Plastic Limit (%)	17	12	11	23	16	17	16	19	21	20	14

Footnotes:

(1) Full particle size distribution report provided in Appendix 4 of the HSC ECIP NMP Report

Table 5 Results of In Situ Site Water Parameters (1)

	HSC New NMP -02- SW	HSC New NMP -03- SW	HSC New NMP -04 - SW	HSC New NMP -05- SW	HSC New NMP -06- SW	HSC New NMP -07- SW	HSC New NMP -08- SW	HSC New NMP -09- SW	HSC New- NMP -10- SW	HSC New- NMP -11- SW
Water Depth (ft)	7.9	30.2	25.3	31	10.3	20.2	40.2	40.1	32.6	40.3
Sample Depth (ft)	3.5	15	12.5	15.5	5.1	10	20.1	20	16	20.1
Water Temperature(^{o}C)	22.84	19.93	22.74	19.68	22.87	19.43	23.08	20.24	23.09	19.5
Salinity (ppt)	4.59	3.93	3.61	2.84	1.76	1.18	1.81	2.32	1.8	1.13
Turbidity (NTU)	8.0	8.2	8.4	8.6	9.8	9.5	7.6	12.1	12.9	26.3

Footnotes:

(1) Full site water analysis report provided in Appendix 5 of the HSC ECIP NMP Report

6.0 CDFATE Input

Mixing zone calculations are made using the CDFATE model (Havis 1994, Doneker and Jirka 1990, Akar and Jirka 1991, Jones 1990). CDFATE uses four categories of input parameters for these calculations: 1) discharge parameters; 2) site receiving water conditions, 3) effluent density modeling and 4) mixing zone data. Each of these are discussed below:

6.1 Discharge Parameters

Table 6 describes the discharge parameters for each of the PAs. A 24-inch hydraulic cutterhead dredge is planned for use. Assuming a typical pipeline velocity of 15 fps and a conservative assumption of 20% downtime, yields a flow rate of 37.7 cfs (1.07 m^3/s) into the PAs. It was assumed the discharge rate from the PAs would be equal to the inflow rate. Each candidate PA is discussed further below.

Table 6 CDFATE Input – Discharge Parameters

Parameter	New BW-8 PA	New E2-Clinton PA	Glendale PA	Filter Bed PA
Type Discharge	CDF Discharge from Partially Full Pipe	CDF Discharge from Side Stream Channel	CDF Discharge from Side Stream Channel	CDF Discharge from Partially Full Pipe
Water Depth at Discharge Point (m) (1)	5.02 m	2.10	2.10	3.50/4.40 (2)
Angle of Receiving Water Side (deg)	3.00	26.0	26.0	40.0
Horizontal Discharge Angle (deg)	90.0	90.0	90.0	90.0
Discharge Rate (m^3/s)	1.07	1.07	1.07	1.07
Width of Channel/Pipe Carrying Effluent (m) (3)	1.83	5.18	5.18	1.83
Depth of Flow in Channel/Pipe (m)	0.38	1.07	1.07	0.38

Protruding Distance (m) (2)	45.72 / 60.00	4.10	4.10	2.2/15.24

Footnotes:

(1) Estimated water depth 2-3 m from end of protruding distance
(2) Actual protruding distance unknown. Two distances were evaluated at New BW-8 PA and Filter Bed PA.
(3) Actual culvert dimensions unknown but assumed as 6 ft for New BW-8 PA and Filter Bed PA discharges. Turkey Run Gully appeared to have a width of 17 ft (5.18 m)

6.1.1 Placement Area - New BW-8 PA

New BW-8 PA discharges to Buffalo Bayou/HSC just east of the PA through an underground culvert (HSC-PDT Email from C. Sepulveda 3/27/19). Although the actual size and orientation of the culvert is not known, the culvert size was assumed to be 6 ft (1.83 m). Using Manning's equation, and assuming a slope of 0.01 (vertical:horizontal) and roughness value of 0.014 for concrete pipe, yields a flow depth of 1.25 ft (0.38 m). The pipe is assumed to extend perpendicular to the channel. Mixing is affected by the location the pipe discharges within the channel cross section, yet the actual pipe length is not known. Therefore, two separate model runs were performed assuming the pipe protrudes 150 ft (45.72 m) and 196 ft (60 m) into the channel. Bathymetry for Buffalo Bayou/HSC at the discharge location was obtained from USACE hydrographic surveys (eHydro). A recent survey of the Boggy Bayou to Greens Bayou section, dated 05 March 2019 provided bathymetry of the navigation channel; an older survey dated 12 March 2013 of the Carpenters Bayou to Boggy Bayou reach provided some additional depth information outside the navigation channel, although bathymetry was not available between the north bank (discharge point) and the navigation channel. A cross section was developed based on the bathymetry, for which an average depth was calculated as 24.7 ft (7.51 m). The channel width in that vicinity is approximately 1238 ft (377.5m). The water depth at the end of the pipe was estimated as 5.02 m, although the actual bathymetry was not known outside the channel. It was estimated that the angle between the bank and the horizontal culvert was 3.00 degrees based on the bank slope.

6.1.2 Placement Area – Filter Bed PA

The Filter Bed PA discharges to Buffalo Bayou/HSC through an underground culvert approximately 0.75 mi north of the turning basin (Figure 2). As with New BW-8 PA, the actual size and orientation of the culvert is not known, the culvert size was assumed to be 6 ft (1.83 m), with a flow depth of 0.38 m. Bathymetry of the Buffalo Bayou/HSC channel at the Filter Bed PA discharge location was obtained from USACE hydrographic surveys (eHydro), and a cross section delineated with an average channel depth of 14.8 ft (4.512 m). The channel width in that vicinity is approximately 305 ft (93 m). Two model runs were performed because the actual pipe distance was not known; one assumed the pipe protruded 2.2 m and one 15.24 m into the channel where the water depth is 3.5 m or 4.40 m, respectively. Side slope at the discharge location was estimated as 40 degrees.

6.1.3 Placement Area – New E2-Clinton PA and Glendale PA

Although New E2-Clinton and Glendale PAs are not located proximate to each other (Figure 2), they are discussed together because both New E2-Clinton PA and Glendale PA discharge into Hunting Bayou from Turkey Run Gulley, and their discharge parameters are the same. Bathymetry of neither Hunting Bayou nor Turkey Run Gulley was located. The depth of Hunting Bayou at the discharge location was provided as 7.5 – 8 ft (email Carl Sepulveda 3/27/19). From Google Earth, it appears the channel width at this

location is 50 ft (15.24 m). A trapezoidal cross section was assumed with a depth of 7.75 ft (2.36 m) and 2:1 (horizontal:vertical) side slopes (an angle of 26 degrees), which yields an average depth of 5.35 ft (1.63 m). Turkey Run Gulley was estimated from Google Earth to have a channel width of 17 ft (5.18 m), and an estimated water depth of 3.5 ft (1.07 m) and to extend perpendicularly into Hunting Bayou 4.1 m at a water depth of 2.1 m.

6.2 Site Receiving Water Conditions

Data input for the receiving water for each PA is provided in Table 7. Receiving water widths and depths were provided based on bathymetry or assumptions discussed above. For each PA, the channel was assumed to be narrow (bounded), as a conservative assumption, even though the channel width at the New BW-8 PA discharge is rather wide. Receiving water density was calculated based on temperature and salinity. It is important to note that the salinities measured at mid-depth (Table 5) may not be representative of the salinity of the dredge slurry from a cutterhead dredge operating at the sediment surface. According to City of Houston and PBS&J (2003), there is significant density stratification within the artificially deepened Buffalo Bayou/HSC. Salinity/conductivity profiles with depth, taken during several years, shows a steep increase in salinity with depth in some years, and less stratification in drier years when overall salinity is higher. Plots of conductivity with depth from the City of Houston and PBS&J (2003) report were used to estimate bottom salinities at the Buffalo Bayou locations in the report as: 9 ppt at Main Turning Basin (near Filter Bed PA discharge and location HSCNew-NMP-11), 12 ppt at Sims Bayou (downstream of HSCNew-NMP-06), and 15 ppt at Beltway 8 (near the New BW-8 PA discharge and HSCNew-NMP-02). As expected, salinity decreases with distance upstream. For the purpose of the CDFATE model, the receiving waters near the Filter Bed PA and New BW-8 PA discharges were assumed to have linear stratification. As it is shallower, the Hunting Bayou receiving water is expected to be less stratified. The conductivity plots from City of Houston and PBS&J (2003) were used to provide estimates of bottom salinity for Buffalo Bayou/HSC at the New BW-8 PA discharge (15 ppt) and Filter Bed PA discharge (9 ppt). Water temperatures and surface salinity were obtained from the collected water samples (Table 5), location HSCNew-NMP-11 for the Filter Bed PA outfall, and NMP-02 for the New BW-8 PA outfall. Salinity or density data was not located for Hunting Bayou at the discharge. It was assumed the receiving water at Hunting Bayou would be uniformly mixed, and might resemble the surface water of Buffalo Bayou/HSC at about the same distance from the mouth of Hunting Bayou, which would be between sample locations HSCNew-NMP-05 and HSCNew-NMP-06. Thus the salinity and temperature of those samples (Table 5) were averaged to estimate that of Hunting Bayou.

Table 7 CDFATE Input – Receiving Water Data – Site Conditions

Parameter	New BW-8 PA	New E2-Clinton PA	Glendale PA	Filter Bed PA
Receiving Water	Buffalo Bayou/HSC	Hunting Bayou	Hunting Bayou	Buffalo Bayou/HSC
Receiving Water Depth (m) (3)	7.51	1.63	1.63	4.51
Is Stream Narrow (Bounded)?	Yes	Yes	Yes	Yes
Receiving Water Density				
Stratification	Linear	Uniform	Uniform	Linear
Surface Temperature (°C)	22.84	21.3 (2)	21.3 (2)	19.5

Surface Salinity (ppt)	4.59	2.3 (2)	2.3 (2)	1.1
Surface Density (kg/m^3) (1)	1001.21	999.78	999.78	999.23
Bottom Temperature (^{o}C)	22.84	-	-	19.5
Bottom Salinity (ppt)	15	-	-	9
Bottom Density (kg/m^3) (1)	1009.21	-	-	1005.32
Channel Geometry	Straight	Moderately meandering	Moderately meandering	Winding
Channel Width (m)	377.5	15.24	15.24	93.0
Channel velocity (m/s)	0.022	0.055	0.055	0.136
Bottom Roughness (Manning's)	0.0177	0.055	0.055	0.0177
Wind Speed	Medium (1.0 – 6.0 m/s)	Medium (1.0 – 6.0 m/s)	Medium (1.0 – 6.0 m/s)	Medium (1.0 – 6.0 m/s)

Footnotes:

(1) Calculated based on temperature and salinity

(2) Average of HSC New NMP-05-SW and HSC New NMP-06-SW (Table 6)

(3) Average channel depth across channel cross-section

Stream gauges with discharge or velocity data were not in the vicinity of any discharge locations. The nearest stream location for Filter Bed PA discharge on Buffalo Bayou/HSC is USGS 008074000 Buffalo Bayou at Houston, approximately 8 mi upstream. The closest gauge located for the New BW-8 PA outfall on Buffalo Bayou/HSC is the NOAA g08010 gauge approximately 10.4 mi downstream at Fred Hartman Bridge. The nearest gauge for Hunting Bayou is the USGS sta 08075770 for Hunting Bayou at IH 610, approximately 5.5 mi upstream of the Turkey Run Gulley discharge. Summer stream flow data was located for Buffalo Bayou in a technical memorandum by Brown & Root, Inc. (1998), with a figure showing volume and velocity as a function of distance from river mouth. Based on the figure, it appears the New BW-8 PA discharge location has a discharge of approximately 2,200 cfs or a velocity of 0.07 ft/s (0.022 m/s). The Filter Bed PA discharge location appears to be approximately 2,000 cfs velocity 0.44 ft/s (0.136 m/s). For Hunting Bayou, discharge data was acquired for the upstream gauge at IH610. The median daily mean discharge between 1965 and 2019 was 7.66 cfs. It was assumed velocity would be similar between the gauge and discharge locations. Bathymetry was not available for either location. The channel width at the gauge was estimated as 20 ft (Google Earth), and a cross sectional area estimated as 43 ft^2. This yields a mean channel velocity of 0.18 ft/s (0.055 m/s). Manning's roughness values were obtained for Buffalo Bayou/HSC as 0.0177 from Guthrie and Schoenbaechler (2012), and for Hunting Bayou as 0.055 from AECOM Technical Services, Inc. (2014). Hourly wind speeds at the NOAA 8770777 station at Manchester, TX averaged 2.5 m/s during the year 2018.

6.3 Effluent Density Modeling

Table 8 provides CDFATE input data for the effluent discharged from the PAs and entering the receiving streams. The suspended solids (TSS) content of the effluent was estimated as 0.1 kg/m^3, and was assumed to consist mostly of clay with some fine silt. A column settling test (USACE 2015, Palermo et al. 1978, Palermo and Thackston 1988, Thackston et al., 1988) would be needed to predict the settling behavior of the dredged material in the PA and resulting TSS, which is also a function of the PA design and weir

operation. The assumed concentration of TSS is likely sufficient for modeling purposes, however, as density is controlled more so by the salinity than the solids content. The effluent densities were calculated based on temperature and salinity at the corresponding sample locations on Buffalo Bayou/HSC. Due to the discussed stratification (Section 5.0), it was assumed the salinity of the dredge slurry and effluent would be best represented by the bottom salinity in the channel. The salinity of the effluent from the Filter Bed PA was assumed to be represented by the bottom salinity near HSCNew-NMP-11 (9 ppt); New BW-8 PA discharge was assumed to have a salinity of 15 ppt. The salinity of discharges into New E2-Clinton would range between that of the bottom salinities of Buffalo Bayou/HSC at Beltway 8 and Sims Bayou, estimated as 13.5 ppt, and that of the Glendale PA discharge would range between that of the bottom salinities of Buffalo Bayou/HSC at Turning Basin and Sims Bayou, estimated as 11.5 ppt. A maximum distance of 2000 m and 100 reporting periods (locations at which concentration is reported) were used to fully delineate mixing zone requirements and provide sufficient resolution.

Table 8 CDFATE Input – Effluent Density and Modeling Parameters

Parameter	New BW-8 PA	New E2-Clinton PA	Glendale PA	Filter Bed PA
Effluent Clearwater Density (1)	1009.21	1008.31	1006.88	1005.32
Temperature (^oC)	22.84	21.7	21.2	19.5
Salinity (ppt)	15	13.5	11.5	9
Effluent concentration of solids (kg/m^3)	0.1	0.1	0.1	0.1
Percent Clumps (Specific gravity = 2.7)	0	0	0	0
Percent Sand (Specific gravity = 2.7)	0	0	0	0
Percent Fine Silt (Specific gravity = 2.65)	10	10	10	10
Percent Clay (Specific gravity = 2.65)	90	90	90	90
Effluent Density (kg/m^3) (2)	1009.27	1008.37	1006.94	1005.38
Modeling Parameters				
Max Distance of the Plume Model (m)	2000	2000	2000	2000
Number of Reporting Periods	100	100	100	100

Footnotes:

1) Calculated based on temperature and salinity
2) Calculated based on effluent clearwater density and solids concentration and specific gravity

6.4 Mixing Zone Data

Mixing zone input is provided in Table 9. CDFATE modeling was performed to delineate dilution with distance using a generic pollutant X with concentration of 100 and zero background concentration. These concentrations do not affect the physical degree of mixing and dilution and were merely used for easy calculation. Though a mixing zone distance and criterion were supplied as input, these values were also not used in determination of dilution with distance.

Table 9 CDFATE Input – Mixing Zone Data

Parameter	New BW-8 PA	New E2-Clinton PA	Glendale PA	Filter Bed PA
Name of Pollutant	X	X	X	X
Concentration of Pollutant above Background	100	100	100	100

Background Concentration	0	0	0	0
First Order Reaction Rate (sec^{-1})	0	0	0	0
Surface Heat Exchange Coefficient	0	0	0	0
Criterion Maximum Concentration (CMC)	10	10	10	10
Criterion Continuous Concentration (CCC)	1	1	1	1
Mixing Zone Distance (m)	500	500	500	500

These input parameters were used in Section 7.0 for the mixing zone/CDFATE calculations for each PA.

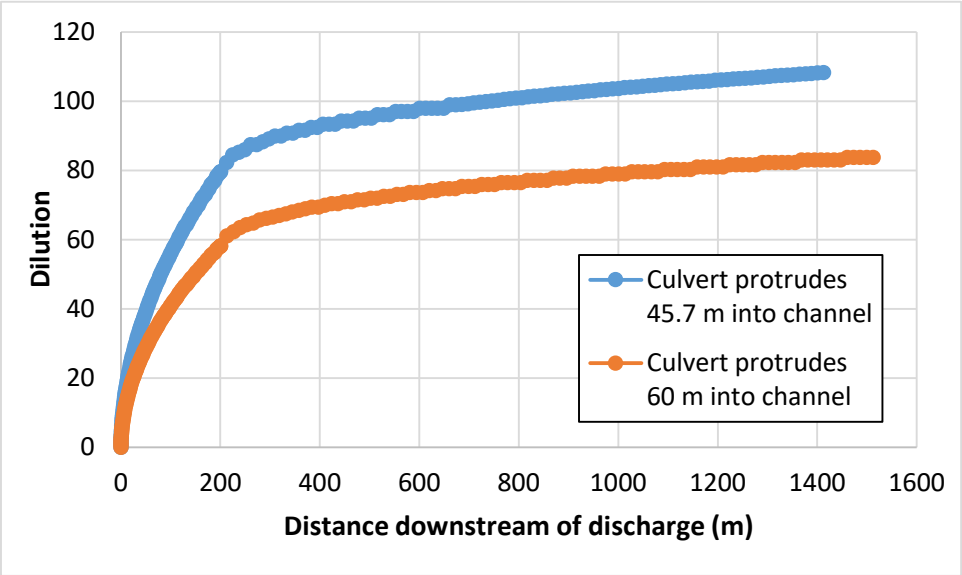
7.0 Mixing Zone Results

Six CDFATE model runs were performed using the input outlined in Section 6. Results are provided below for New BW-8 PA, Filter Bed PA, and New E2-Clinton and Glendale PA. For each PA, the dilution/mixing achieved within a given distance downstream from the discharge is compared to the dilutions required to achieve acute and chronic concentrations of COCs to determine distance required for the ZID and mixing zone. These evaluations do not include COCs which were excluded from the evaluation (Sections 4.1 – 4.3). The final mixing zone distances required for each PA are provided in Table 10.

7.1 Placement Area - New BW-8

The model results for discharges from New BW-8 PA into Buffalo Bayou/HSC are displayed in Figure 3, which shows dilution achieved with distance downstream from the discharge point. Two separate model runs were performed with different assumptions as to the length that the culvert extends into the channel, as the actual distance is unknown. It appears the shorter length of the culvert provides greater dilution. The dilution values are sufficient to provide mixing to dilute the concentrations to within acute and chronic criteria. Ignoring COCs where detection limits exceeded criteria (Section 4.1), and COCs for which background concentrations are above criteria (Section 4.2), the greatest dilution requirements for the New BW-8 PA are for zinc which requires a dilution factor of 6.9 for acute and 13.0 for chronic criteria. These dilution values can be met within 3.4 m (acute) and 11.0 m (chronic) for the longer culvert. Plume widths at these lengths are approximately 7 m and 13 m.

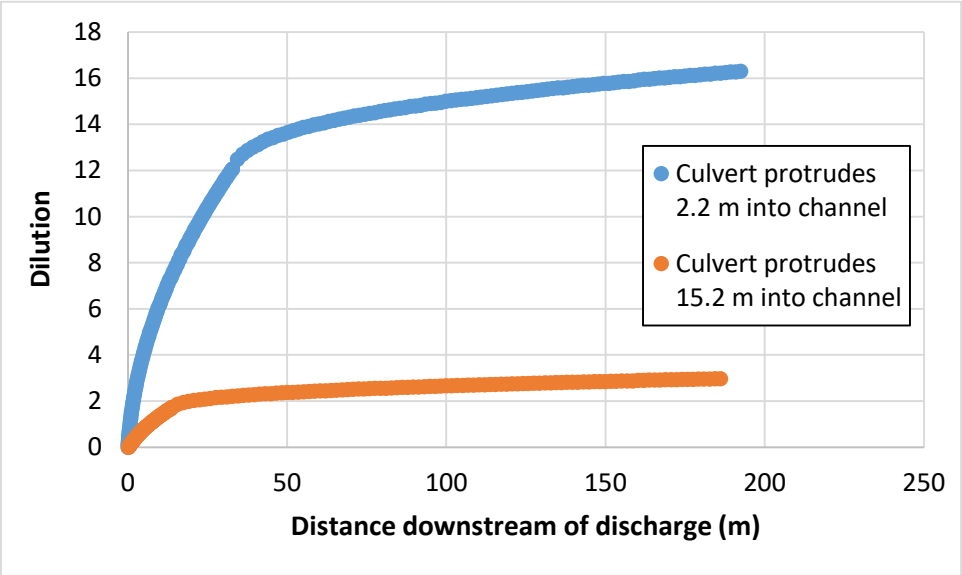
Figure 3. Dilution vs. Distance New BW-8 PA Discharge into Buffalo Bayou/HSC



7.2 Placement Area – Filter Bed

Figure 4 shows the dilution that is achieved with distance for the two scenarios which were modeled assuming two pipe extensions for the Filter Bed PA discharge into Buffalo Bayou/HSC since the actual discharge pipe length is not known. One curve shows the results if the culvert protrudes 2.2 m into the channel, and the other shows results with the culvert protruding 15.2 m. Extending the pipe farther into the channel achieved less dilution as it pushes the plume against the opposite bank. A mixing zone is not possible for meeting chronic requirements because the receiving water concentration of zinc is above the chronic criteria. To meet acute requirements for determination of a ZID, the greatest dilution required is for zinc, with a dilution factor of 13.4, which could be met within approximately 45 m if the culvert protrudes only 2.2 m. The plume width at 45 m would be approximately 23 m. Dilution could not be achieved with the longer pipe length which reaches a maximum dilution of approximately 3.0.

Figure 4. Dilution vs. Distance Filter Bed PA Discharge into Buffalo Bayou/HSC



7.3 Placement Areas New E2-Clinton and Glendale

Figure 5 and Figure 6 show the dilution achieved with distance downstream of the discharge into Hunting Bayou for effluent from New E2-Clinton PA and Glendale PA, respectively; note that the figures are identical. The only difference in input was a higher salinity assumption for New E2-Clinton PA, which did not impact the results. As can be seen from the figures, very little dilution is achieved over approximately 18 m. Beyond 18.8 m, the plume interacts with the bottom and both banks. Additional dilution is not expected to occur. Therefore the maximum dilution expected to occur within Hunting Bayou is 0.4.

As shown in Table 3, the greatest dilution requirements for New E-2 Clinton PA are 1 for acute conditions and 99 for chronic conditions, which are well above the predicted dilution in Hunting Bayou. For Glendale PA, the greatest dilution requirements are 6.7 for acute conditions and 168.5 for chronic criteria, which are also above that predicted. The predicted dilution of 0.4 is not sufficient to achieve concentrations below acute criteria for zinc or acute toxicity criteria based on bioassay results (Table 3). Dilution of 0.4 is also insufficient to achieve concentrations below chronic criteria for anthracene, copper, lead, zinc, and chronic toxicity criteria from bioassay results (Table 3).

As previously discussed, COCs with detection limits above criteria could not be evaluated. The uncertainty within the input parameters should be evaluated and the model refined accordingly to determine if discharge to Hunting Bayou is a feasible alternative.

Figure 5. Dilution vs. Distance for New E2-Clinton PA Discharge into Hunting Bayou

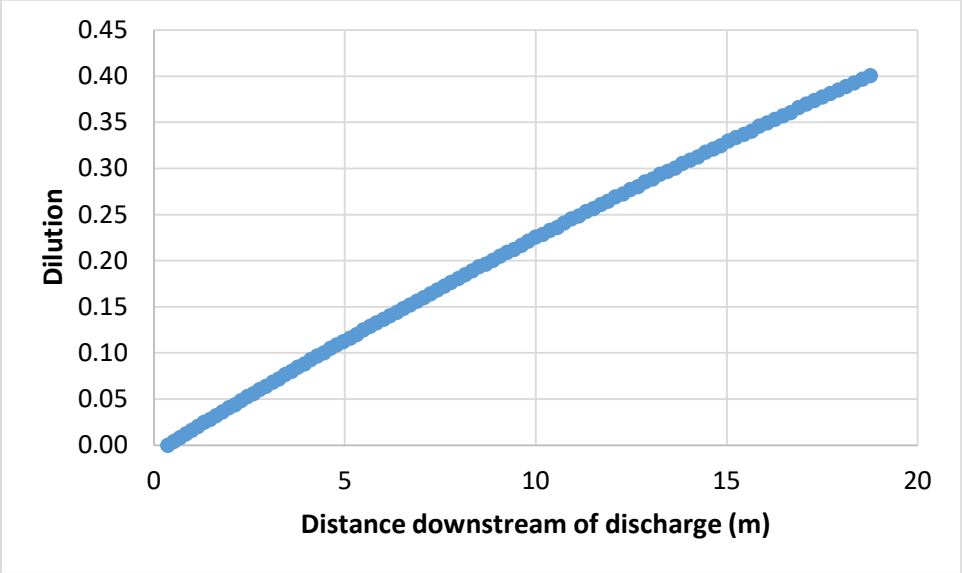


Figure 6. Dilution vs. Distance for Glendale PA Discharge into Hunting Bayou

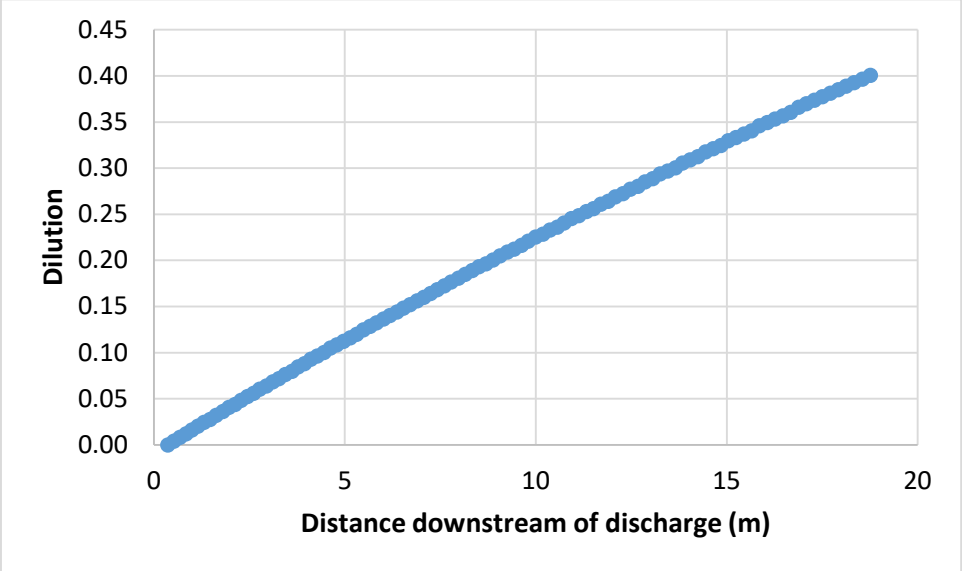


Table 10 Distances Required for ZID and Mixing Zones for Each PA

Placement Area	Greatest Dilution Required to Meet Acute Criteria (1)	Greatest Dilution Required to Meet Chronic Criteria (1)	Distance Required for ZID (m)	Distance Required for Mixing Zone (m)
New BW-8 PA	6.9	13.0	2.0-3.4 (2)	5.9-11.0 (2)
New E2-Clinton PA	1	99	TBD	TBD
Glendale PA	6.7	168.5	TBD	TBD
Filter Bed PA (3)	13.4	TBD	45	TBD

Footnotes:

(1) Greatest dilution required considering bioassay toxicity and COCs without detection limits above criteria.

(2) For culvert protruding between 45.7m and 60 m into the channel.

(3) Assuming pipe protrudes 2.2 m into channel.
(4) TBD = To Be Determined. It is impossible to meet acute or chronic criteria based on background concentrations above criteria. Model input and chemistry will be reviewed to better refine receiving water concentrations and model output.

The CDFATE modeling exercise showed that a ZID and mixing zone could be applied to meet acute and chronic criteria for the New BW-8 PA discharge. A rather large ZID (45 m) would be required to meet acute toxicity at the Filter Bed PA discharge location, assuming the discharge pipe is near the shore. Otherwise dilution is not possible, and dilution is not possible to meet chronic conditions due to zinc background concentrations. Modeling showed dilution to be insufficient for the New E2-Clinton and Glendale PAs to meet either chronic or acute conditions.

8.0 Uncertainty Evaluation

There was a great deal of uncertainty associated with numerous assumptions that were made for various input parameters in this preliminary mixing zone evaluation. The uncertainty associated with these parameters should be addressed to further refine the model as discussed below.

8.1 Chemistry, Toxicity and Elutriate Uncertainty

A mixing zone evaluation was performed to determine the ZID and mixing zone lengths needed to meet the greatest dilution requirements for each PA based on conservative assumptions regarding chemistry and toxicity results.

There is uncertainty regarding both the chemistry and toxicity evaluations. Sources of uncertainty include:

1) Elutriate and site water RLs above criteria. Instances where reporting limits exceed criteria force the use of overly conservative assumptions for background concentrations
2) Lack of receiving water chemistry and characterization for Hunting Bayou (New E2-Clinton PA and Glendale PA receiving water); use of alternate data from Buffalo Bayou may not be appropriate
3) Conservative AF used to calculate chronic criteria for bioassays
4) Consideration of impacts of ammonia on bioassay results. A toxicity reduction evaluation (TRE) could potentially be performed to evaluate the effect that ammonia had on the resulting toxicity. Even without a TRE, application of a higher AF might be justifiable in light of the ammonia effects and the highly conservative nature of the selected AF
5) Determination of whether chronic criteria are applicable based on the length of time that discharge is expected to occur at each PA
6) There were a number of COCs excluded from the evaluation because background concentrations were either above criteria or the RLs were above criteria (Section 4.2). It is currently not possible to show that water quality criteria can be met for these COCs

The uncertainties from (1) through (5) above were addressed in this preliminary mixing zone evaluation by making conservative assumptions; however, additional data collection or evaluation would allow refinements to the evaluation to produce more site-specific results and reduce uncertainty for all six factors listed above.

8.2 Modeling Uncertainty

In the preliminary CDFATE modeling, several non-site specific conservative initial assumptions were made that would influence the model output and could be refined:

1) Details pertaining to many of the CDFATE model input parameters were not available, requiring numerous assumptions for which the introduced bias (positive or negative) is not fully understood
2) Discharge/velocity data was not available in the near vicinity of any of the discharge locations and had to be extrapolated from distant gauges or report figures
3) The size and orientation of the culverts leading from New BW-8 PA and Filter Bed PA to Buffalo Bayou/HSC were not known, requiring assumptions to be made for water depth, culvert width, depth, slope and protruding distance into the channel
4) Bathymetry data for Hunting Bayou and geometry of Turkey Run Gulley where it discharges to Hunting Bayou were also largely assumed
5) Site receiving water conditions were in many instances assumed and should be refined
6) Salinity gradients within Buffalo Bayou were estimated based on a published figure of conductivity gradients for several years; salinity data for Hunting Bayou was not available, which could be important because there is significant density stratification within the artificially deepened Buffalo Bayou/HSC (City of Houston and PBS&J, 2003). Salinity/conductivity profiles with depth, taken during several years, showed a steep increase in salinity with depth in some years, and less stratification in drier years when overall salinity was higher

In order to provide greater confidence in results, additional site specific data should be collected to refine the mixing zone modeling and evaluation.

9.0 Summary, Conclusion and Recommendations

9.1 Summary

Elutriate and site water chemistry was evaluated for ten sediment samples along Segments 4 – 6 of the HSC-NMP. Some of the site waters also represented receiving water for the four proposed PAs. COCs that were detected in at least one of the media were retained for evaluation. Several COCs were eliminated from the evaluation because their RLs were above criteria and they were not detected in any of the elutriate, site water or sediment samples. For instances when the background concentration exceeded criteria, dilution could not be evaluated. The contaminants that could not be fully evaluated for a mixing zone for this reason included hexachlorobutadiene, 4,4'-DDT, dieldrin, heptachlor, and silver, therefore, it cannot be demonstrated that they will not violate water quality criteria. Required dilutions to meet chronic and acute water quality criteria were calculated for the contaminants remaining after these other COCs were excluded. These COCs were anthracene, pyrene, copper, lead and zinc.

The CDFATE model was used to complete a preliminary mixing evaluation of each PA effluent into the receiving waters. Model runs were performed for two scenarios each with different protruding pipe distances for New BW-8 PA and Filter Bed PA. Two model runs with different salinity assumptions were also done for the PAs discharging to Hunting Bayou (New E2-Clinton and Glendale).

The resulting data was compared to dilution requirements at each PA to estimate required ZID and mixing zone lengths for each PA. For New BW-8 PA, results showed that for the evaluated COCs and toxicity requirements, a ZID of 2.0 m – 3.4 m (depending on the actual pipe protruding distance) was required for and a mixing zone length between 5.9 m and 11.0 m would be required. For Filter Bed PA, modeling showed that a ZID of 45 m would be required to achieve acute criteria if the pipe was near the shore; dilution would not be possible if the culvert extended 15 m into the channel and it would not be possible to meet chronic criteria because zinc concentrations in the receiving water exceed chronic criteria. Modeling results for E2-Clinton PA and Glendale PA discharges into Hunting Bayou showed that a maximum dilution of 0.4 would be reached before the channel is completely mixed. This was not sufficient to meet acute or chronic criteria for the COCs or toxicity requirements for either PA.

9.2 Conclusions

Using both site-specific data when available, and conservative worst-case assumptions when it was not, the results of the CDFATE modeling showed the following:

- sufficient mixing can be achieved in Buffalo Bayou/HSC to dilute the effluent from dredged material placement into the New BW-8 PA to within acute and chronic criteria, requiring a ZID of up 2.0 – 3.4 m and a mixing zone length of 5.9 to 11.0 m
- based on the modeling at Hunting Bayou, sufficient dilution is not available to achieve either acute or chronic criteria for effluent discharging from either the New E2-Clinton PA or the Glendale PA
- mixing is insufficient and it is not possible to dilute effluent discharges from the Filter Bed PA to chronic criteria for zinc as receiving water (background) concentrations were shown to be above criteria. CDFATE modeling suggested that a ZID of 45 m would be required for sufficient mixing to achieve acute criteria for zinc
- verification of the ability to meet water quality for several COCs (hexachlorobutadiene, 4,4'-DDT, dieldrin, heptachlor, and silver) that were dropped from the evaluation due to background concentrations above criteria was not possible with the available data

Due to the uncertainty regarding the analytical data and model input parameters, additional data collection and evaluation is recommended to refine the mixing zone evaluation.

9.3 Recommendations

Numerous assumptions were made within the CDFATE modeling parameters and analytical results were unable to fully characterize the chemistry and toxicity of the effluent and receiving waters. In order to provide greater confidence in results, the mixing zone evaluation should be refined by additional data collection. Areas where data collection would be particularly helpful include:

- bathymetry and flow data at Hunting Bayou
- geometry of Turkey Run Gulley where it discharges to Hunting Bayou
- flow data at New BW-8 and Filter Bed discharge locations
- culvert geometries and orientation

- salinity distributions within each channel
- receiving water contaminant concentrations at Hunting Bayou
- alternate data for Buffalo Bayou receiving water COCs with RLs > criteria, and
- seek acceptance of alternate AF for chronic criteria

The CDFATE modeling effort should be repeated using refined data input for each PA with site-specific elutriate and receiving water concentrations for the COCs requiring the greatest dilution in order to delineate mixing zone requirements for the discharges associated with the HSC ECIP-NMP.

10.0 References

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Appendix A

CDFATE Model Output

Appendix A

CDFATE Model Output

APPENDIX A - TABLE OF CONTENTS

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CORMIX3 PREDICTION FILE:
3333333333333333333333333333333333333333333333333333333333333333333333333333333333
                    CORNELL MIXING ZONE EXPERT SYSTEM
Subsystem CORMIX3:                                          Subsystem version:
 Buoyant Surface Discharges
------------------------------------------------------------------------------
------------------------------------------------------------------------------
CASE DESCRIPTION
 Site name/label:         BW8 PA Discharge at Buffalo Bayou
 Design case:
 FILE NAME:               cormix\sim\        .cx3
 Time of Fortran run:

ENVIRONMENT PARAMETERS (metric units)
 Bounded section
 BS    =    377.50  AS    =   2835.03  QA    =     62.37
 HA    =      7.51  HD    =      5.02
 UA    =     0.022 F     =     0.013 USTAR =0.8720E-03
 UW    =     5.000 UWSTAR=0.5520E-02
 Density stratified environment
 STRCND=  A         RHOAM = 1005.0000
 RHOAS = 1001.0000  RHOAB = 1009.0000  RHOAEF= 1005.0000  E     =0.0000E+00

DISCHARGE PARAMETERS (metric units)
 BANK  =  RIGHT     DISTB =     45.72  Configuration:
 Circular discharge pipe:
 D0    =     1.830 A0    =     0.145
 Dimensions of equivalent rectangular discharge:
 B0    =     0.381 H0    =     0.380 A0    =0.1446E+00  AR    =      0.998
 SIGMA =     90.00  SLOPE =     3.00
 U0    =     7.398 Q0    =     1.070       =0.1070E+01
 RHO0  = 1005.0000  DRHO0 =0.0000E+00  GP0   =0.0000E+00
 C0    =0.1000E+03  CUNITS=  X
 IPOLL =  1         KS    =0.0000E+00  KD    =0.0000E+00

FLUX VARIABLES (metric units)
 Q0    =0.1070E+01  M0    =0.7916E+01  J0    =0.0000E+00
 Associated length scales (meters)
 LQ    =     0.38  LM    =  99999.00  Lm    =    127.89  Lb    =      0.00

NON-DIMENSIONAL PARAMETERS
 FR0   =  99999.00  FRCH  =  99999.00  R     =    336.26

FLOW CLASSIFICATION
 33333333333333333333333333333333333333
 3  Flow class (CORMIX3)      =    SA1    3
 3  Applicable layer depth HS =     5.02  3
 33333333333333333333333333333333333333

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
 C0    =0.1000E+03  CUNITS=  X
 NTOX  =  1         CMC   =0.1000E+02  CCC   =  CSTD
 NSTD  =  1         CSTD  =0.1000E+01
 REGMZ =  1
 REGSPC=  1         XREG  =    500.00  WREG  =      0.00  AREG  =      0.00
 XINT  =   2000.00  XMAX  =   2000.00

X-Y-Z COORDINATE SYSTEM:
    ORIGIN is located at the WATER SURFACE and at center of discharge
      channel/outlet:     45.72 m  from the RIGHT bank/shore.
    X-axis points downstream
    Y-axis points to left as seen by an observer looking downstream
    Z-axis points vertically upward (in CORMIX3, all values Z = 0.00)
NSTEP =100 display intervals per module
------------------------------------------------------------------------------
------------------------------------------------------------------------------
BEGIN MOD301: DISCHARGE MODULE (FLOW ESTABLISHMENT)

Profile definitions:
   BV = Gaussian 1/e (37%) vertical thickness
   BH = Gaussian 1/e (37%) horizontal half-width, normal to trajectory
   S = hydrodynamic centerline dilution
   C = centerline concentration (includes reaction effects, if any)

       X        Y       Z        S       C       BV       BH
      0.00     1.51    0.00     1.0 0.100E+03   0.44     0.28
 Cumulative travel time =           0. sec

END OF MOD301: DISCHARGE MODULE (FLOW ESTABLISHMENT)
```

BEGIN MOD317: WEAKLY DEFLECTED JET (3-D) WITH LEESIDE RECIRCULATION ZONE

Surface JET into a crossflow

Profile definitions:
BV = Gaussian 1/e (37%) vertical thickness
BH = Gaussian 1/e (37%) horizontal half-width, normal to trajectory
S = hydrodynamic centerline dilution
C = centerline concentration (includes reaction effects, if any)

X	Y	Z	S	C	BV	BH
0.00	1.51	0.00	1.0	0.100E+03	0.44	0.28
0.08	4.03	0.00	1.8	0.556E+02	0.72	0.56
0.19	6.56	0.00	2.6	0.385E+02	1.00	0.84
0.35	9.09	0.00	3.4	0.295E+02	1.28	1.11
0.54	11.61	0.00	4.2	0.239E+02	1.55	1.39
0.77	14.14	0.00	5.0	0.201E+02	1.83	1.67
1.04	16.66	0.00	5.8	0.173E+02	2.11	1.95
1.35	19.19	0.00	6.6	0.152E+02	2.39	2.23
1.70	21.72	0.00	7.4	0.136E+02	2.67	2.50
2.09	24.24	0.00	8.2	0.122E+02	2.94	2.78
2.51	26.77	0.00	9.0	0.111E+02	3.22	3.06
2.98	29.29	0.00	9.8	0.102E+02	3.50	3.34

** CMC HAS BEEN FOUND **
The pollutant concentration in the plume falls below CMC value of 0.100E+02
in the current prediction interval.
This is the extent of the TOXIC DILUTION ZONE.

3.48	31.82	0.00	10.6	0.947E+01	3.78	3.62
4.03	34.35	0.00	11.4	0.880E+01	4.06	3.89
4.61	36.87	0.00	12.2	0.822E+01	4.33	4.17
5.23	39.40	0.00	13.0	0.772E+01	4.61	4.45
5.89	41.92	0.00	13.8	0.727E+01	4.89	4.73
6.59	44.45	0.00	14.5	0.687E+01	5.17	5.00
7.33	46.98	0.00	15.3	0.652E+01	5.44	5.28
8.10	49.50	0.00	16.1	0.619E+01	5.72	5.56
8.92	52.03	0.00	16.9	0.590E+01	6.00	5.84
9.77	54.55	0.00	17.7	0.564E+01	6.28	6.12
10.67	57.08	0.00	18.5	0.540E+01	6.56	6.39
11.60	59.61	0.00	19.3	0.517E+01	6.83	6.67
12.57	62.13	0.00	20.1	0.497E+01	7.11	6.95
13.58	64.66	0.00	20.9	0.478E+01	7.39	7.23
14.63	67.18	0.00	21.7	0.460E+01	7.67	7.51
15.72	69.71	0.00	22.5	0.444E+01	7.94	7.78
16.85	72.24	0.00	23.3	0.429E+01	8.22	8.06
18.02	74.76	0.00	24.1	0.415E+01	8.50	8.34
19.22	77.29	0.00	24.9	0.401E+01	8.78	8.62
20.47	79.81	0.00	25.7	0.389E+01	9.05	8.89
21.75	82.34	0.00	26.5	0.377E+01	9.33	9.17
23.08	84.87	0.00	27.3	0.366E+01	9.61	9.45
24.44	87.39	0.00	28.1	0.356E+01	9.89	9.73
25.84	89.92	0.00	28.9	0.346E+01	10.16	10.01
27.28	92.44	0.00	29.7	0.337E+01	10.44	10.28
28.76	94.97	0.00	30.5	0.328E+01	10.72	10.56
30.27	97.50	0.00	31.3	0.320E+01	11.00	10.84
31.83	100.02	0.00	32.1	0.312E+01	11.27	11.12
33.43	102.55	0.00	32.9	0.304E+01	11.55	11.40
35.06	105.07	0.00	33.7	0.297E+01	11.83	11.67
36.74	107.60	0.00	34.5	0.290E+01	12.11	11.95
38.45	110.13	0.00	35.3	0.284E+01	12.38	12.23
40.20	112.65	0.00	36.1	0.277E+01	12.66	12.51
41.99	115.18	0.00	36.9	0.271E+01	12.94	12.78
43.82	117.70	0.00	37.7	0.266E+01	13.22	13.06
45.69	120.23	0.00	38.5	0.260E+01	13.49	13.34
47.60	122.76	0.00	39.3	0.255E+01	13.77	13.62
49.54	125.28	0.00	40.1	0.250E+01	14.05	13.90
51.53	127.81	0.00	40.9	0.245E+01	14.32	14.17
53.55	130.33	0.00	41.6	0.240E+01	14.60	14.45
55.62	132.86	0.00	42.4	0.236E+01	14.88	14.73
57.72	135.39	0.00	43.2	0.231E+01	15.16	15.01
59.86	137.91	0.00	44.0	0.227E+01	15.43	15.29
62.04	140.44	0.00	44.8	0.223E+01	15.71	15.56
64.26	142.96	0.00	45.6	0.219E+01	15.99	15.84
66.52	145.49	0.00	46.4	0.215E+01	16.27	16.12
68.82	148.02	0.00	47.2	0.212E+01	16.54	16.40
71.15	150.54	0.00	48.0	0.208E+01	16.82	16.67
73.53	153.07	0.00	48.8	0.205E+01	17.10	16.95
75.94	155.59	0.00	49.6	0.202E+01	17.37	17.23

78.39	158.12	0.00	50.4	0.198E+01	17.65	17.51
80.89	160.65	0.00	51.2	0.195E+01	17.93	17.79
83.42	163.17	0.00	52.0	0.192E+01	18.21	18.06
85.99	165.70	0.00	52.8	0.189E+01	18.48	18.34
88.60	168.22	0.00	53.6	0.187E+01	18.76	18.62
91.24	170.75	0.00	54.4	0.184E+01	19.04	18.90
93.93	173.28	0.00	55.2	0.181E+01	19.31	19.18
96.66	175.80	0.00	56.0	0.179E+01	19.59	19.45
99.42	178.33	0.00	56.8	0.176E+01	19.87	19.73
102.23	180.85	0.00	57.6	0.174E+01	20.14	20.01
105.07	183.38	0.00	58.4	0.171E+01	20.42	20.29
107.95	185.91	0.00	59.2	0.169E+01	20.70	20.57
110.87	188.43	0.00	60.0	0.167E+01	20.98	20.84
113.83	190.96	0.00	60.8	0.165E+01	21.25	21.12
116.83	193.48	0.00	61.6	0.162E+01	21.53	21.40
119.87	196.01	0.00	62.4	0.160E+01	21.81	21.68
122.95	198.54	0.00	63.2	0.158E+01	22.08	21.96
126.06	201.06	0.00	64.0	0.156E+01	22.36	22.24
129.22	203.59	0.00	64.8	0.154E+01	22.64	22.52
132.41	206.11	0.00	65.6	0.153E+01	22.91	22.80
135.64	208.64	0.00	66.4	0.151E+01	23.19	23.07
138.92	211.17	0.00	67.2	0.149E+01	23.47	23.35
142.23	213.69	0.00	68.0	0.147E+01	23.75	23.63
145.58	216.22	0.00	68.7	0.145E+01	24.02	23.91
148.97	218.74	0.00	69.5	0.144E+01	24.30	24.19
152.39	221.27	0.00	70.3	0.142E+01	24.58	24.47
155.86	223.80	0.00	71.1	0.141E+01	24.85	24.75
159.37	226.32	0.00	71.9	0.139E+01	25.13	25.03
162.91	228.85	0.00	72.7	0.137E+01	25.41	25.31
166.49	231.37	0.00	73.5	0.136E+01	25.68	25.58
170.12	233.90	0.00	74.3	0.135E+01	25.96	25.86
173.78	236.43	0.00	75.1	0.133E+01	26.24	26.14
177.48	238.95	0.00	75.9	0.132E+01	26.51	26.42
181.22	241.48	0.00	76.7	0.130E+01	26.79	26.70
185.00	244.00	0.00	77.5	0.129E+01	27.07	26.98
188.81	246.53	0.00	78.3	0.128E+01	27.34	27.26
192.67	249.06	0.00	79.1	0.126E+01	27.62	27.54
196.57	251.58	0.00	79.9	0.125E+01	27.90	27.82
200.50	254.11	0.00	80.7	0.124E+01	28.17	28.10

Cumulative travel time = 1116. sec

Some concentration build-up near bank/shore due to recirculation effects.
Find concentration and thickness values for the RECIRCULATION REGION
at end of MOD329!

END OF MOD317: WEAKLY DEFLECTED JET (3-D) WITH LEESIDE RECIRCULATION ZONE

BEGIN MOD327: STRONGLY DEFLECTED JET (3-D) WITH LEESIDE RECIRCULATION ZONE

Profile definitions:
BV = Gaussian 1/e (37%) vertical thickness
BH = Gaussian 1/e (37%) horizontal half-width, normal to trajectory
S = hydrodynamic centerline dilution
C = centerline concentration (includes reaction effects, if any)

X	Y	Z	S	C	BV	BH
200.50	254.11	0.00	80.7	0.124E+01	68.73	68.53
212.62	258.26	0.00	83.7	0.120E+01	69.97	69.78
224.74	260.43	0.00	85.2	0.117E+01	70.62	70.43
236.87	262.02	0.00	86.4	0.116E+01	71.10	70.91
248.99	263.31	0.00	87.3	0.115E+01	71.49	71.30
261.11	264.41	0.00	88.1	0.113E+01	71.82	71.63
273.23	265.38	0.00	88.9	0.113E+01	72.11	71.92
285.35	266.26	0.00	89.5	0.112E+01	72.37	72.18
297.47	267.05	0.00	90.1	0.111E+01	72.61	72.42
309.59	267.78	0.00	90.6	0.110E+01	72.83	72.64
321.72	268.46	0.00	91.2	0.110E+01	73.03	72.84
333.84	269.10	0.00	91.6	0.109E+01	73.23	73.03
345.96	269.70	0.00	92.1	0.109E+01	73.41	73.21
358.08	270.27	0.00	92.5	0.108E+01	73.58	73.38
370.20	270.82	0.00	92.9	0.108E+01	73.74	73.55
382.32	271.33	0.00	93.3	0.107E+01	73.89	73.70
394.44	271.83	0.00	93.7	0.107E+01	74.04	73.85
406.57	272.30	0.00	94.1	0.106E+01	74.19	73.99
418.69	272.76	0.00	94.4	0.106E+01	74.32	74.13
430.81	273.20	0.00	94.7	0.106E+01	74.45	74.26
442.93	273.63	0.00	95.1	0.105E+01	74.58	74.39
455.05	274.04	0.00	95.4	0.105E+01	74.71	74.51

467.17	274.44	0.00	95.7	0.105E+01	74.83	74.63
479.29	274.82	0.00	96.0	0.104E+01	74.94	74.75
491.42	275.20	0.00	96.3	0.104E+01	75.05	74.86

** REGULATORY MIXING ZONE BOUNDARY is within the Near-Field Region (NFR) **

503.54	275.57	0.00	96.6	0.104E+01	75.16	74.97
515.66	275.92	0.00	96.8	0.103E+01	75.27	75.08
527.78	276.27	0.00	97.1	0.103E+01	75.38	75.18
539.90	276.61	0.00	97.4	0.103E+01	75.48	75.29
552.02	276.94	0.00	97.6	0.102E+01	75.58	75.38
564.14	277.27	0.00	97.9	0.102E+01	75.67	75.48
576.27	277.58	0.00	98.1	0.102E+01	75.77	75.58
588.39	277.89	0.00	98.4	0.102E+01	75.86	75.67
600.51	278.20	0.00	98.6	0.101E+01	75.95	75.76
612.63	278.49	0.00	98.8	0.101E+01	76.04	75.85
624.75	278.79	0.00	99.1	0.101E+01	76.13	75.94
636.87	279.07	0.00	99.3	0.101E+01	76.22	76.02
648.99	279.35	0.00	99.5	0.101E+01	76.30	76.11
661.12	279.63	0.00	99.7	0.100E+01	76.38	76.19
673.24	279.90	0.00	99.9	0.100E+01	76.46	76.27

** WATER QUALITY STANDARD OR CCC HAS BEEN FOUND **

The pollutant concentration in the plume falls below water quality standard or CCC value of 0.100E+01 in the current prediction interval.

This is the spatial extent of concentrations exceeding the water quality standard or CCC value.

685.36	280.17	0.00	100.1	0.999E+00	76.54	76.35
697.48	280.43	0.00	100.3	0.997E+00	76.62	76.43
709.60	280.69	0.00	100.5	0.995E+00	76.70	76.51
721.72	280.94	0.00	100.7	0.993E+00	76.78	76.59
733.85	281.19	0.00	100.9	0.991E+00	76.85	76.66
745.97	281.44	0.00	101.1	0.989E+00	76.93	76.73
758.09	281.68	0.00	101.3	0.987E+00	77.00	76.81
770.21	281.92	0.00	101.5	0.985E+00	77.07	76.88
782.33	282.16	0.00	101.7	0.983E+00	77.14	76.95
794.45	282.39	0.00	101.9	0.981E+00	77.21	77.02
806.57	282.62	0.00	102.1	0.980E+00	77.28	77.09
818.70	282.85	0.00	102.3	0.978E+00	77.35	77.16
830.82	283.07	0.00	102.4	0.976E+00	77.42	77.22
842.94	283.30	0.00	102.6	0.975E+00	77.48	77.29
855.06	283.51	0.00	102.8	0.973E+00	77.55	77.36
867.18	283.73	0.00	103.0	0.971E+00	77.61	77.42
879.30	283.94	0.00	103.1	0.970E+00	77.68	77.49
891.42	284.15	0.00	103.3	0.968E+00	77.74	77.55
903.55	284.36	0.00	103.5	0.967E+00	77.80	77.61
915.67	284.57	0.00	103.6	0.965E+00	77.86	77.67
927.79	284.77	0.00	103.8	0.964E+00	77.92	77.73
939.91	284.97	0.00	103.9	0.962E+00	77.99	77.79
952.03	285.17	0.00	104.1	0.961E+00	78.05	77.85
964.15	285.37	0.00	104.3	0.959E+00	78.10	77.91
976.27	285.56	0.00	104.4	0.958E+00	78.16	77.97
988.40	285.76	0.00	104.6	0.956E+00	78.22	78.03
1000.52	285.95	0.00	104.7	0.955E+00	78.28	78.09
1012.64	286.14	0.00	104.9	0.953E+00	78.33	78.14
1024.76	286.32	0.00	105.0	0.952E+00	78.39	78.20
1036.88	286.51	0.00	105.2	0.951E+00	78.45	78.25
1049.00	286.69	0.00	105.3	0.949E+00	78.50	78.31
1061.12	286.87	0.00	105.5	0.948E+00	78.56	78.36
1073.25	287.05	0.00	105.6	0.947E+00	78.61	78.42
1085.37	287.23	0.00	105.8	0.945E+00	78.66	78.47
1097.49	287.41	0.00	105.9	0.944E+00	78.72	78.53
1109.61	287.58	0.00	106.0	0.943E+00	78.77	78.58
1121.73	287.76	0.00	106.2	0.942E+00	78.82	78.63
1133.85	287.93	0.00	106.3	0.940E+00	78.87	78.68
1145.97	288.10	0.00	106.5	0.939E+00	78.92	78.73
1158.10	288.27	0.00	106.6	0.938E+00	78.97	78.78
1170.22	288.44	0.00	106.7	0.937E+00	79.02	78.83
1182.34	288.60	0.00	106.9	0.936E+00	79.07	78.88
1194.46	288.77	0.00	107.0	0.934E+00	79.12	78.93
1206.58	288.93	0.00	107.1	0.933E+00	79.17	78.98
1218.70	289.09	0.00	107.3	0.932E+00	79.22	79.03
1230.83	289.26	0.00	107.4	0.931E+00	79.27	79.08
1242.95	289.42	0.00	107.5	0.930E+00	79.32	79.13
1255.07	289.57	0.00	107.7	0.929E+00	79.37	79.18
1267.19	289.73	0.00	107.8	0.928E+00	79.41	79.22
1279.31	289.89	0.00	107.9	0.927E+00	79.46	79.27
1291.43	290.04	0.00	108.0	0.926E+00	79.51	79.32
1303.55	290.20	0.00	108.2	0.924E+00	79.55	79.36
1315.68	290.35	0.00	108.3	0.923E+00	79.60	79.41
1327.80	290.50	0.00	108.4	0.922E+00	79.64	79.45
1339.92	290.65	0.00	108.5	0.921E+00	79.69	79.50

```
   1352.04   290.80    0.00   108.7 0.920E+00  79.73    79.54
   1364.16   290.95    0.00   108.8 0.919E+00  79.78    79.59
   1376.28   291.10    0.00   108.9 0.918E+00  79.82    79.63
   1388.40   291.25    0.00   109.0 0.917E+00  79.87    79.68
   1400.53   291.39    0.00   109.2 0.916E+00  79.91    79.72
   1412.65   291.54    0.00   109.3 0.915E+00  79.95    79.76
 Cumulative travel time =       56214. sec

 Some concentration build-up near bank/shore due to recirculation effects.
   Find concentration and thickness values for the RECIRCULATION REGION
   at end of MOD329!

END OF MOD327: STRONGLY DEFLECTED JET (3-D) WITH LEESIDE RECIRCULATION ZONE
------------------------------------------------------------------------------
------------------------------------------------------------------------------
BEGIN MOD329: STRONGLY DEFLECTED PLUME WITH LEESIDE RECIRCULATION ZONE

 This flow region is INSIGNIFICANT in spatial extent and will be by-passed.

 The near-shore RECIRCULATION REGION extends back to the discharge location:
    Concentration C within that region:        0.458E+00
    Layer thickness BV within that region:    79.95

END OF MOD329: STRONGLY DEFLECTED PLUME WITH LEESIDE RECIRCULATION ZONE
------------------------------------------------------------------------------
------------------------------------------------------------------------------
** End of NEAR-FIELD REGION (NFR) **
------------------------------------------------------------------------------

The initial plume WIDTH values in the next far-field module will be
  CORRECTED by a factor  0.65 to conserve the mass flux in the far-field!

 The LIMITING DILUTION (given by ambient flow/discharge ratio) is:    59.3
   This value is below the computed dilution of   109.3 at the end
   of the NFR.
 Mixing for this discharge configuration is constrained by LOW AMBIENT FLOW!

 The previous module predictions are unreliable since the limiting dilution
   cannot be exceeded for this discharge into a deep unstratified layer.

 A subsequent module (MOD381) will predict the properties of the
   cross-sectionally fully mixed plume with limiting dilution and will
   compute a POSSIBLE UPSTREAM WEDGE INTRUSION.
------------------------------------------------------------------------------
BEGIN MOD381: MIXED PLUME/BOUNDED CHANNEL/POSSIBLE UPSTREAM WEDGE INTRUSION

 The DOWNSTREAM flow field for this unstable shallow water discharge is
     VERTICALLY FULLY MIXED.
 The mixing is controlled by the limiting dilution =     59.3

 NO UPSTREAM INTRUSION will occur since the discharge is NON-BUOYANT.

       X        Y       Z        S       C       BV       BH
   1412.65   -45.72    0.00    59.3 0.169E+01   7.51   377.50
 Cumulative travel time =       56214. sec

 Vertically and laterally fully mixed over layer depth: END OF SIMULATION!

END OF MOD381: MIXED PLUME/BOUNDED CHANNEL/POSSIBLE UPSTREAM WEDGE INTRUSION
------------------------------------------------------------------------------
------------------------------------------------------------------------------
CORMIX3: Buoyant Surface Discharges                    End of Prediction File
3333333333333333333333333333333333333333333333333333333333333333333333333333
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CORMIX3 PREDICTION FILE:
3333333333333333333333333333333333333333333333333333333333333333333333333333333333
                    CORNELL MIXING ZONE EXPERT SYSTEM
Subsystem CORMIX3:                                          Subsystem version:
 Buoyant Surface Discharges
------------------------------------------------------------------------------
------------------------------------------------------------------------------
CASE DESCRIPTION
 Site name/label:         BW8 PA Discharge at Buffalo Bayou
 Design case:
 FILE NAME:               cormix\sim\        .cx3
 Time of Fortran run:

ENVIRONMENT PARAMETERS (metric units)
 Bounded section
 BS    =    377.50  AS    =   2835.03  QA    =     62.37
 HA    =      7.51  HD    =      5.02
 UA    =     0.022 F     =     0.013 USTAR =0.8720E-03
 UW    =     5.000 UWSTAR=0.5520E-02
 Density stratified environment
 STRCND=  A         RHOAM = 1005.0000
 RHOAS = 1001.0000  RHOAB = 1009.0000  RHOAEF= 1005.0000  E     =0.0000E+00

DISCHARGE PARAMETERS (metric units)
 BANK  =  RIGHT     DISTB =     60.00  Configuration:
 Circular discharge pipe:
 D0    =     1.830 A0    =     0.145
 Dimensions of equivalent rectangular discharge:
 B0    =     0.381 H0    =     0.380 A0    =0.1446E+00  AR    =      0.998
 SIGMA =     90.00  SLOPE =     3.00
 U0    =     7.398 Q0    =     1.070       =0.1070E+01
 RHO0  = 1005.0000  DRHO0 =0.0000E+00  GP0   =0.0000E+00
 C0    =0.1000E+03  CUNITS=  X
 IPOLL =  1         KS    =0.0000E+00  KD    =0.0000E+00

FLUX VARIABLES (metric units)
 Q0    =0.1070E+01  M0    =0.7916E+01  J0    =0.0000E+00
 Associated length scales (meters)
 LQ    =     0.38  LM    =  99999.00  Lm    =    127.89  Lb    =      0.00

NON-DIMENSIONAL PARAMETERS
 FR0   =  99999.00  FRCH  =  99999.00  R     =    336.26

FLOW CLASSIFICATION
 33333333333333333333333333333333333333
 3  Flow class (CORMIX3)      =    SA1    3
 3  Applicable layer depth HS =     5.02  3
 33333333333333333333333333333333333333

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
 C0    =0.1000E+03  CUNITS=  X
 NTOX  =  1         CMC   =0.1000E+02  CCC   =  CSTD
 NSTD  =  1         CSTD  =0.1000E+01
 REGMZ =  1
 REGSPC=  1         XREG  =    500.00  WREG  =      0.00  AREG  =      0.00
 XINT  =   2000.00  XMAX  =   2000.00

X-Y-Z COORDINATE SYSTEM:
    ORIGIN is located at the WATER SURFACE and at center of discharge
      channel/outlet:     60.00 m  from the RIGHT bank/shore.
    X-axis points downstream
    Y-axis points to left as seen by an observer looking downstream
    Z-axis points vertically upward (in CORMIX3, all values Z = 0.00)
NSTEP =100 display intervals per module
------------------------------------------------------------------------------
------------------------------------------------------------------------------
BEGIN MOD301: DISCHARGE MODULE (FLOW ESTABLISHMENT)

Profile definitions:
   BV = Gaussian 1/e (37%) vertical thickness
   BH = Gaussian 1/e (37%) horizontal half-width, normal to trajectory
   S = hydrodynamic centerline dilution
   C = centerline concentration (includes reaction effects, if any)

       X        Y       Z        S       C       BV       BH
      0.00     1.51    0.00     1.0 0.100E+03   0.44     0.28
 Cumulative travel time =           0. sec

END OF MOD301: DISCHARGE MODULE (FLOW ESTABLISHMENT)
```

BEGIN MOD317: WEAKLY DEFLECTED JET (3-D) WITH LEESIDE RECIRCULATION ZONE

Surface JET into a crossflow

Near-field limitation in bounded channel.
Profile definitions:
BV = Gaussian 1/e (37%) vertical thickness
BH = Gaussian 1/e (37%) horizontal half-width, normal to trajectory
S = hydrodynamic centerline dilution
C = centerline concentration (includes reaction effects, if any)

X	Y	Z	S	C	BV	BH
0.00	1.51	0.00	1.0	0.100E+03	0.44	0.28
0.08	4.03	0.00	1.8	0.557E+02	0.72	0.56
0.19	6.56	0.00	2.6	0.386E+02	1.00	0.84
0.35	9.08	0.00	3.4	0.295E+02	1.28	1.11
0.54	11.61	0.00	4.2	0.239E+02	1.55	1.39
0.77	14.13	0.00	5.0	0.201E+02	1.83	1.67
1.04	16.66	0.00	5.8	0.173E+02	2.11	1.95
1.35	19.18	0.00	6.6	0.152E+02	2.39	2.23
1.70	21.71	0.00	7.4	0.136E+02	2.67	2.50
2.09	24.23	0.00	8.2	0.122E+02	2.94	2.78
2.51	26.76	0.00	9.0	0.112E+02	3.22	3.06
2.98	29.28	0.00	9.8	0.102E+02	3.50	3.34

** CMC HAS BEEN FOUND **
The pollutant concentration in the plume falls below CMC value of 0.100E+02
in the current prediction interval.
This is the extent of the TOXIC DILUTION ZONE.

3.48	31.81	0.00	10.6	0.947E+01	3.78	3.61
4.02	34.33	0.00	11.4	0.881E+01	4.05	3.89
4.60	36.86	0.00	12.2	0.823E+01	4.33	4.17
5.23	39.38	0.00	13.0	0.772E+01	4.61	4.45
5.88	41.91	0.00	13.7	0.727E+01	4.89	4.72
6.58	44.43	0.00	14.5	0.688E+01	5.17	5.00
7.32	46.96	0.00	15.3	0.652E+01	5.44	5.28
8.10	49.48	0.00	16.1	0.620E+01	5.72	5.56
8.91	52.01	0.00	16.9	0.591E+01	6.00	5.84
9.77	54.53	0.00	17.7	0.564E+01	6.28	6.11
10.66	57.06	0.00	18.5	0.540E+01	6.55	6.39
11.59	59.58	0.00	19.3	0.517E+01	6.83	6.67
12.56	62.11	0.00	20.1	0.497E+01	7.11	6.95
13.57	64.63	0.00	20.9	0.478E+01	7.39	7.22
14.62	67.16	0.00	21.7	0.461E+01	7.66	7.50
15.71	69.68	0.00	22.5	0.444E+01	7.94	7.78
16.84	72.21	0.00	23.3	0.429E+01	8.22	8.06
18.00	74.73	0.00	24.1	0.415E+01	8.50	8.34
19.21	77.26	0.00	24.9	0.402E+01	8.77	8.61
20.45	79.78	0.00	25.7	0.389E+01	9.05	8.89
21.74	82.31	0.00	26.5	0.377E+01	9.33	9.17
23.06	84.83	0.00	27.3	0.366E+01	9.60	9.45
24.42	87.36	0.00	28.1	0.356E+01	9.88	9.72
25.82	89.88	0.00	28.9	0.346E+01	10.16	10.00
27.26	92.40	0.00	29.7	0.337E+01	10.44	10.28
28.73	94.93	0.00	30.5	0.328E+01	10.71	10.56
30.25	97.45	0.00	31.3	0.320E+01	10.99	10.84
31.81	99.98	0.00	32.1	0.312E+01	11.27	11.11
33.40	102.50	0.00	32.9	0.304E+01	11.55	11.39
35.03	105.03	0.00	33.7	0.297E+01	11.82	11.67
36.71	107.55	0.00	34.5	0.290E+01	12.10	11.95
38.42	110.08	0.00	35.3	0.284E+01	12.38	12.22
40.17	112.60	0.00	36.1	0.277E+01	12.66	12.50
41.96	115.13	0.00	36.9	0.271E+01	12.93	12.78
43.78	117.65	0.00	37.6	0.266E+01	13.21	13.06
45.65	120.18	0.00	38.4	0.260E+01	13.49	13.33
47.56	122.70	0.00	39.2	0.255E+01	13.76	13.61
49.50	125.23	0.00	40.0	0.250E+01	14.04	13.89
51.49	127.75	0.00	40.8	0.245E+01	14.32	14.17
53.51	130.28	0.00	41.6	0.240E+01	14.60	14.45
55.57	132.80	0.00	42.4	0.236E+01	14.87	14.72
57.67	135.33	0.00	43.2	0.231E+01	15.15	15.00
59.81	137.85	0.00	44.0	0.227E+01	15.43	15.28
61.99	140.38	0.00	44.8	0.223E+01	15.70	15.56
64.21	142.90	0.00	45.6	0.219E+01	15.98	15.83
66.46	145.43	0.00	46.4	0.215E+01	16.26	16.11
68.76	147.95	0.00	47.2	0.212E+01	16.54	16.39
71.09	150.48	0.00	48.0	0.208E+01	16.81	16.67
73.47	153.00	0.00	48.8	0.205E+01	17.09	16.95

75.88	155.53	0.00	49.6	0.202E+01	17.37	17.22
78.33	158.05	0.00	50.4	0.198E+01	17.64	17.50
80.82	160.58	0.00	51.2	0.195E+01	17.92	17.78
83.35	163.10	0.00	52.0	0.192E+01	18.20	18.06
85.92	165.63	0.00	52.8	0.189E+01	18.47	18.33
88.52	168.15	0.00	53.6	0.187E+01	18.75	18.61
91.17	170.68	0.00	54.4	0.184E+01	19.03	18.89
93.85	173.20	0.00	55.2	0.181E+01	19.31	19.17
96.58	175.73	0.00	56.0	0.179E+01	19.58	19.45
99.34	178.25	0.00	56.8	0.176E+01	19.86	19.72
102.14	180.78	0.00	57.6	0.174E+01	20.14	20.00
104.98	183.30	0.00	58.4	0.171E+01	20.41	20.28
107.86	185.83	0.00	59.2	0.169E+01	20.69	20.56
110.78	188.35	0.00	60.0	0.167E+01	20.97	20.84
113.74	190.88	0.00	60.8	0.165E+01	21.24	21.11
116.73	193.40	0.00	61.5	0.162E+01	21.52	21.39
119.77	195.93	0.00	62.3	0.160E+01	21.80	21.67
122.84	198.45	0.00	63.1	0.158E+01	22.07	21.95
125.96	200.98	0.00	63.9	0.156E+01	22.35	22.23
129.11	203.50	0.00	64.7	0.154E+01	22.63	22.51
132.30	206.03	0.00	65.5	0.153E+01	22.91	22.79
135.53	208.55	0.00	66.3	0.151E+01	23.18	23.07
138.80	211.08	0.00	67.1	0.149E+01	23.46	23.34
142.11	213.60	0.00	67.9	0.147E+01	23.74	23.62
145.45	216.13	0.00	68.7	0.146E+01	24.01	23.90
148.84	218.65	0.00	69.5	0.144E+01	24.29	24.18
152.27	221.18	0.00	70.3	0.142E+01	24.57	24.46
155.73	223.70	0.00	71.1	0.141E+01	24.84	24.74
159.23	226.23	0.00	71.9	0.139E+01	25.12	25.02
162.77	228.75	0.00	72.7	0.138E+01	25.40	25.30
166.35	231.28	0.00	73.5	0.136E+01	25.67	25.57
169.97	233.80	0.00	74.3	0.135E+01	25.95	25.85
173.63	236.33	0.00	75.1	0.133E+01	26.23	26.13
177.33	238.85	0.00	75.9	0.132E+01	26.50	26.41
181.07	241.38	0.00	76.7	0.130E+01	26.78	26.69
184.84	243.90	0.00	77.5	0.129E+01	27.06	26.97
188.66	246.43	0.00	78.3	0.128E+01	27.33	27.25
192.51	248.95	0.00	79.1	0.126E+01	27.61	27.53
196.40	251.47	0.00	79.9	0.125E+01	27.89	27.80
200.33	254.00	0.00	80.7	0.124E+01	28.16	28.08

Cumulative travel time = 1115. sec

Some concentration build-up near bank/shore due to recirculation effects.
Find concentration and thickness values for the RECIRCULATION REGION
at end of MOD329!

END OF MOD317: WEAKLY DEFLECTED JET (3-D) WITH LEESIDE RECIRCULATION ZONE

The LIMITING DILUTION (given by ambient flow/discharge ratio) is: 59.3
This value is below the computed dilution of 80.7 at the end
of the NFR.
Mixing for this discharge configuration is constrained by LOW AMBIENT FLOW!

The previous module predictions are unreliable since the limiting dilution
cannot be exceeded for this discharge into a deep unstratified layer.

A subsequent module (MOD381) will predict the properties of the
cross-sectionally fully mixed plume with limiting dilution and will
compute a POSSIBLE UPSTREAM WEDGE INTRUSION.

BEGIN MOD381: MIXED PLUME/BOUNDED CHANNEL/POSSIBLE UPSTREAM WEDGE INTRUSION

The DOWNSTREAM flow field for this unstable shallow water discharge is
VERTICALLY FULLY MIXED.
The mixing is controlled by the limiting dilution = 59.3

NO UPSTREAM INTRUSION will occur since the discharge is NON-BUOYANT.

X	Y	Z	S	C	BV	BH
200.33	-60.00	0.00	59.3	0.169E+01	5.02	377.50

Cumulative travel time = 1115. sec

Vertically and laterally fully mixed over layer depth: END OF SIMULATION!

END OF MOD381: MIXED PLUME/BOUNDED CHANNEL/POSSIBLE UPSTREAM WEDGE INTRUSION

BEGIN MOD327: STRONGLY DEFLECTED JET (3-D) WITH LEESIDE RECIRCULATION ZONE

Profile definitions:
BV = Gaussian 1/e (37%) vertical thickness
BH = Gaussian 1/e (37%) horizontal half-width, normal to trajectory
S = hydrodynamic centerline dilution
C = centerline concentration (includes reaction effects, if any)

X	Y	Z	S	C	BV	BH
200.33	254.00	0.00	59.3	0.169E+01	58.91	58.74
213.45	258.37	0.00	62.0	0.161E+01	60.22	60.05
226.57	260.61	0.00	63.4	0.158E+01	60.89	60.73
239.69	262.26	0.00	64.4	0.155E+01	61.38	61.22
252.82	263.59	0.00	65.2	0.153E+01	61.78	61.62
265.94	264.72	0.00	66.0	0.152E+01	62.12	61.96
279.06	265.72	0.00	66.6	0.150E+01	62.42	62.26
292.18	266.62	0.00	67.2	0.149E+01	62.69	62.53
305.30	267.43	0.00	67.7	0.148E+01	62.94	62.77
318.42	268.19	0.00	68.2	0.147E+01	63.16	63.00
331.54	268.89	0.00	68.6	0.146E+01	63.37	63.21
344.66	269.54	0.00	69.1	0.145E+01	63.57	63.41
357.78	270.16	0.00	69.5	0.144E+01	63.76	63.59
370.91	270.75	0.00	69.9	0.143E+01	63.93	63.77
384.03	271.30	0.00	70.2	0.142E+01	64.10	63.93
397.15	271.84	0.00	70.6	0.142E+01	64.26	64.09
410.27	272.34	0.00	70.9	0.141E+01	64.41	64.25
423.39	272.83	0.00	71.2	0.140E+01	64.56	64.39
436.51	273.30	0.00	71.5	0.140E+01	64.70	64.53
449.63	273.75	0.00	71.8	0.139E+01	64.83	64.67
462.75	274.19	0.00	72.1	0.139E+01	64.97	64.80
475.87	274.62	0.00	72.4	0.138E+01	65.09	64.93
489.00	275.03	0.00	72.7	0.138E+01	65.22	65.05
** REGULATORY MIXING ZONE BOUNDARY is within the Near-Field Region (NFR) **						
502.12	275.42	0.00	73.0	0.137E+01	65.33	65.17
515.24	275.81	0.00	73.2	0.137E+01	65.45	65.29
528.36	276.19	0.00	73.5	0.136E+01	65.56	65.40
541.48	276.55	0.00	73.7	0.136E+01	65.67	65.51
554.60	276.91	0.00	74.0	0.135E+01	65.78	65.62
567.72	277.26	0.00	74.2	0.135E+01	65.88	65.72
580.84	277.60	0.00	74.4	0.134E+01	65.99	65.82
593.96	277.93	0.00	74.6	0.134E+01	66.09	65.92
607.09	278.26	0.00	74.9	0.134E+01	66.18	66.02
620.21	278.57	0.00	75.1	0.133E+01	66.28	66.12
633.33	278.89	0.00	75.3	0.133E+01	66.37	66.21
646.45	279.19	0.00	75.5	0.132E+01	66.47	66.30
659.57	279.49	0.00	75.7	0.132E+01	66.56	66.39
672.69	279.79	0.00	75.9	0.132E+01	66.64	66.48
685.81	280.08	0.00	76.1	0.131E+01	66.73	66.57
698.93	280.36	0.00	76.3	0.131E+01	66.82	66.65
712.05	280.64	0.00	76.5	0.131E+01	66.90	66.73
725.18	280.91	0.00	76.7	0.130E+01	66.98	66.82
738.30	281.18	0.00	76.9	0.130E+01	67.06	66.90
751.42	281.45	0.00	77.1	0.130E+01	67.14	66.98
764.54	281.71	0.00	77.2	0.129E+01	67.22	67.06
777.66	281.97	0.00	77.4	0.129E+01	67.30	67.13
790.78	282.22	0.00	77.6	0.129E+01	67.37	67.21
803.90	282.47	0.00	77.8	0.129E+01	67.45	67.28
817.02	282.72	0.00	77.9	0.128E+01	67.52	67.36
830.14	282.96	0.00	78.1	0.128E+01	67.59	67.43
843.27	283.20	0.00	78.3	0.128E+01	67.67	67.50
856.39	283.43	0.00	78.4	0.128E+01	67.74	67.57
869.51	283.67	0.00	78.6	0.127E+01	67.81	67.64
882.63	283.90	0.00	78.7	0.127E+01	67.88	67.71
895.75	284.12	0.00	78.9	0.127E+01	67.94	67.78
908.87	284.35	0.00	79.1	0.126E+01	68.01	67.85
921.99	284.57	0.00	79.2	0.126E+01	68.08	67.91
935.11	284.79	0.00	79.4	0.126E+01	68.14	67.98
948.23	285.00	0.00	79.5	0.126E+01	68.21	68.04
961.36	285.22	0.00	79.7	0.126E+01	68.27	68.11
974.48	285.43	0.00	79.8	0.125E+01	68.34	68.17
987.60	285.64	0.00	80.0	0.125E+01	68.40	68.23
1000.72	285.85	0.00	80.1	0.125E+01	68.46	68.30
1013.84	286.05	0.00	80.3	0.125E+01	68.52	68.36
1026.96	286.25	0.00	80.4	0.124E+01	68.58	68.42
1040.08	286.45	0.00	80.5	0.124E+01	68.64	68.48
1053.20	286.65	0.00	80.7	0.124E+01	68.70	68.54
1066.32	286.85	0.00	80.8	0.124E+01	68.76	68.60
1079.44	287.04	0.00	81.0	0.124E+01	68.82	68.66
1092.57	287.23	0.00	81.1	0.123E+01	68.88	68.71
1105.69	287.42	0.00	81.2	0.123E+01	68.93	68.77

1118.81	287.61	0.00	81.4	0.123E+01	68.99	68.83
1131.93	287.80	0.00	81.5	0.123E+01	69.05	68.88
1145.05	287.98	0.00	81.6	0.123E+01	69.10	68.94
1158.17	288.17	0.00	81.8	0.122E+01	69.16	68.99
1171.29	288.35	0.00	81.9	0.122E+01	69.21	69.05
1184.41	288.53	0.00	82.0	0.122E+01	69.27	69.10
1197.53	288.71	0.00	82.1	0.122E+01	69.32	69.16
1210.66	288.88	0.00	82.3	0.122E+01	69.37	69.21
1223.78	289.06	0.00	82.4	0.121E+01	69.42	69.26
1236.90	289.23	0.00	82.5	0.121E+01	69.48	69.31
1250.02	289.40	0.00	82.6	0.121E+01	69.53	69.36
1263.14	289.58	0.00	82.8	0.121E+01	69.58	69.42
1276.26	289.74	0.00	82.9	0.121E+01	69.63	69.47
1289.38	289.91	0.00	83.0	0.120E+01	69.68	69.52
1302.50	290.08	0.00	83.1	0.120E+01	69.73	69.57
1315.62	290.25	0.00	83.2	0.120E+01	69.78	69.62
1328.75	290.41	0.00	83.4	0.120E+01	69.83	69.67
1341.87	290.57	0.00	83.5	0.120E+01	69.88	69.72
1354.99	290.73	0.00	83.6	0.120E+01	69.93	69.76
1368.11	290.89	0.00	83.7	0.119E+01	69.98	69.81
1381.23	291.05	0.00	83.8	0.119E+01	70.02	69.86
1394.35	291.21	0.00	83.9	0.119E+01	70.07	69.91
1407.47	291.37	0.00	84.0	0.119E+01	70.12	69.95
1420.59	291.52	0.00	84.2	0.119E+01	70.16	70.00
1433.71	291.68	0.00	84.3	0.119E+01	70.21	70.05
1446.84	291.83	0.00	84.4	0.119E+01	70.26	70.09
1459.96	291.99	0.00	84.5	0.118E+01	70.30	70.14
1473.08	292.14	0.00	84.6	0.118E+01	70.35	70.18
1486.20	292.29	0.00	84.7	0.118E+01	70.39	70.23
1499.32	292.44	0.00	84.8	0.118E+01	70.44	70.27
1512.44	292.59	0.00	84.9	0.118E+01	70.48	70.32

 Cumulative travel time =   60757. sec

 Some concentration build-up near bank/shore due to recirculation effects.
   Find concentration and thickness values for the RECIRCULATION REGION
   at end of MOD329!

END OF MOD327: STRONGLY DEFLECTED JET (3-D) WITH LEESIDE RECIRCULATION ZONE

BEGIN MOD329: STRONGLY DEFLECTED PLUME WITH LEESIDE RECIRCULATION ZONE

 This flow region is INSIGNIFICANT in spatial extent and will be by-passed.

 The near-shore RECIRCULATION REGION extends back to the discharge location:
    Concentration C within that region: 0.589E+00
    Layer thickness BV within that region: 70.48

END OF MOD329: STRONGLY DEFLECTED PLUME WITH LEESIDE RECIRCULATION ZONE

** End of NEAR-FIELD REGION (NFR) **

CORMIX3: Buoyant Surface Discharges   End of Prediction File
3333333333333333333333333333333333333333333333333333333333333333333333333333

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CORMIX3 PREDICTION FILE:
3333333333333333333333333333333333333333333333333333333333333333333333333333333333333333
                    CORNELL MIXING ZONE EXPERT SYSTEM
Subsystem CORMIX3:                                          Subsystem version:
 Buoyant Surface Discharges
------------------------------------------------------------------------------
------------------------------------------------------------------------------
CASE DESCRIPTION
 Site name/label:         Glendale E2 Clinton PA Discharges at Hun
 Design case:
 FILE NAME:               cormix\sim\        .cx3
 Time of Fortran run:

ENVIRONMENT PARAMETERS (metric units)
 Bounded section
 BS    =     15.24  AS    =     24.84  QA    =      1.37
 HA    =      1.63  HD    =      2.10
 UA    =     0.055 F     =     0.202 USTAR =0.8733E-02
 UW    =     5.000 UWSTAR=0.5523E-02
 Uniform density environment
 STRCND=  U         RHOAM =  999.8000

DISCHARGE PARAMETERS (metric units)
 BANK  =  RIGHT     DISTB =      4.10  Configuration:
 Rectangular channel geometry:
 B0    =     5.180 H0    =     1.070 A0    =0.5543E+01  AR    =      0.207
 SIGMA =     90.00  SLOPE =     26.00
 U0    =     0.193 Q0    =     1.070       =0.1070E+01
 RHO0  =  999.8000  DRHO0 =0.0000E+00  GP0   =0.0000E+00
 C0    =0.1000E+03  CUNITS=  X
 IPOLL =  1         KS    =0.0000E+00  KD    =0.0000E+00

FLUX VARIABLES (metric units)
 Q0    =0.1070E+01  M0    =0.2066E+00  J0    =0.0000E+00
 Associated length scales (meters)
 LQ    =      2.35  LM    =  99999.00  Lm    =      8.26  Lb    =      0.00
 LQ2D  =      3.40  LM2D  =  99999.00  Lm2D  =     41.89

NON-DIMENSIONAL PARAMETERS
 FR0   =  99999.00  FRCH  =  99999.00  R     =      3.51

FLOW CLASSIFICATION
 333333333333333333333333333333333333333333
 3  Flow class (CORMIX3)      =    SA2    3
 3  Applicable layer depth HS =     2.10  3
 333333333333333333333333333333333333333333

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
 C0    =0.1000E+03  CUNITS=  X
 NTOX  =  1         CMC   =0.1000E+02  CCC   =  CSTD
 NSTD  =  1         CSTD  =0.1000E+01
 REGMZ =  1
 REGSPC=  1         XREG  =    500.00  WREG  =      0.00  AREG  =      0.00
 XINT  =   2000.00  XMAX  =   2000.00

X-Y-Z COORDINATE SYSTEM:
    ORIGIN is located at the WATER SURFACE and at center of discharge
      channel/outlet:      4.10 m  from the RIGHT bank/shore.
    X-axis points downstream
    Y-axis points to left as seen by an observer looking downstream
    Z-axis points vertically upward (in CORMIX3, all values Z = 0.00)
NSTEP =100 display intervals per module
------------------------------------------------------------------------------
------------------------------------------------------------------------------
BEGIN MOD301: DISCHARGE MODULE (FLOW ESTABLISHMENT)

Profile definitions:
   BV = Gaussian 1/e (37%) vertical thickness
   BH = Gaussian 1/e (37%) horizontal half-width, normal to trajectory
   S = hydrodynamic centerline dilution
   C = centerline concentration (includes reaction effects, if any)

       X        Y       Z        S       C       BV       BH
     0.36     1.32    0.00     1.0 0.100E+03   1.62     2.92
 Cumulative travel time =           7. sec

END OF MOD301: DISCHARGE MODULE (FLOW ESTABLISHMENT)
------------------------------------------------------------------------------
------------------------------------------------------------------------------
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BEGIN MOD317: WEAKLY DEFLECTED JET (3-D) WITH LEESIDE RECIRCULATION ZONE

Surface JET into a crossflow

Near-field limitation in bounded channel.
Profile definitions:
BV = Gaussian 1/e (37%) vertical thickness
BH = Gaussian 1/e (37%) horizontal half-width, normal to trajectory
S = hydrodynamic centerline dilution
C = centerline concentration (includes reaction effects, if any)

X	Y	Z	S	C	BV	BH
0.36	1.32	0.00	1.0	0.100E+03	1.61	2.92
0.52	1.40	0.00	1.0	0.996E+02	1.62	2.92
0.68	1.47	0.00	1.0	0.992E+02	1.62	2.93
0.84	1.55	0.00	1.0	0.988E+02	1.63	2.94
0.99	1.62	0.00	1.0	0.984E+02	1.64	2.95
1.15	1.70	0.00	1.0	0.980E+02	1.65	2.96
1.31	1.77	0.00	1.0	0.976E+02	1.66	2.97
1.47	1.85	0.00	1.0	0.973E+02	1.67	2.98
1.63	1.93	0.00	1.0	0.969E+02	1.68	2.98
1.80	2.00	0.00	1.0	0.965E+02	1.69	2.99
1.96	2.08	0.00	1.0	0.961E+02	1.70	3.00
2.12	2.15	0.00	1.0	0.958E+02	1.71	3.01
2.28	2.23	0.00	1.0	0.954E+02	1.72	3.02
2.45	2.31	0.00	1.1	0.950E+02	1.72	3.03
2.61	2.38	0.00	1.1	0.947E+02	1.73	3.04
2.77	2.46	0.00	1.1	0.943E+02	1.74	3.05
2.94	2.53	0.00	1.1	0.940E+02	1.75	3.05
3.11	2.61	0.00	1.1	0.936E+02	1.76	3.06
3.27	2.69	0.00	1.1	0.933E+02	1.77	3.07
3.44	2.76	0.00	1.1	0.929E+02	1.78	3.08
3.61	2.84	0.00	1.1	0.926E+02	1.79	3.09
3.77	2.91	0.00	1.1	0.922E+02	1.80	3.10
3.94	2.99	0.00	1.1	0.919E+02	1.80	3.11
4.11	3.07	0.00	1.1	0.915E+02	1.81	3.11
4.28	3.14	0.00	1.1	0.912E+02	1.82	3.12
4.45	3.22	0.00	1.1	0.909E+02	1.83	3.13
4.62	3.29	0.00	1.1	0.905E+02	1.84	3.14
4.79	3.37	0.00	1.1	0.902E+02	1.85	3.15
4.96	3.45	0.00	1.1	0.899E+02	1.86	3.16
5.14	3.52	0.00	1.1	0.896E+02	1.87	3.17
5.31	3.60	0.00	1.1	0.893E+02	1.88	3.17
5.48	3.67	0.00	1.1	0.889E+02	1.89	3.18
5.66	3.75	0.00	1.1	0.886E+02	1.89	3.19
5.83	3.82	0.00	1.1	0.883E+02	1.90	3.20
6.01	3.90	0.00	1.1	0.880E+02	1.91	3.21
6.18	3.98	0.00	1.1	0.877E+02	1.92	3.22
6.36	4.05	0.00	1.1	0.874E+02	1.93	3.23
6.53	4.13	0.00	1.1	0.871E+02	1.94	3.24
6.71	4.20	0.00	1.2	0.868E+02	1.95	3.24
6.89	4.28	0.00	1.2	0.865E+02	1.96	3.25
7.07	4.36	0.00	1.2	0.862E+02	1.97	3.26
7.24	4.43	0.00	1.2	0.859E+02	1.97	3.27
7.42	4.51	0.00	1.2	0.856E+02	1.98	3.28
7.60	4.58	0.00	1.2	0.853E+02	1.99	3.29
7.78	4.66	0.00	1.2	0.850E+02	2.00	3.30
7.97	4.74	0.00	1.2	0.847E+02	2.01	3.30
8.15	4.81	0.00	1.2	0.844E+02	2.02	3.31
8.33	4.89	0.00	1.2	0.841E+02	2.03	3.32
8.51	4.96	0.00	1.2	0.838E+02	2.04	3.33
8.69	5.04	0.00	1.2	0.836E+02	2.05	3.34
8.88	5.12	0.00	1.2	0.833E+02	2.05	3.35
9.06	5.19	0.00	1.2	0.830E+02	2.06	3.36
9.25	5.27	0.00	1.2	0.827E+02	2.07	3.37
9.43	5.34	0.00	1.2	0.825E+02	2.08	3.37
9.62	5.42	0.00	1.2	0.822E+02	2.09	3.38
9.80	5.50	0.00	1.2	0.819E+02	2.10	3.39
9.99	5.57	0.00	1.2	0.816E+02	2.11	3.40
10.18	5.65	0.00	1.2	0.814E+02	2.12	3.41
10.37	5.72	0.00	1.2	0.811E+02	2.13	3.42
10.56	5.80	0.00	1.2	0.809E+02	2.13	3.43
10.74	5.87	0.00	1.2	0.806E+02	2.14	3.43
10.93	5.95	0.00	1.2	0.803E+02	2.15	3.44
11.12	6.03	0.00	1.2	0.801E+02	2.16	3.45
11.32	6.10	0.00	1.3	0.798E+02	2.17	3.46
11.51	6.18	0.00	1.3	0.796E+02	2.18	3.47
11.70	6.25	0.00	1.3	0.793E+02	2.19	3.48
11.89	6.33	0.00	1.3	0.791E+02	2.20	3.49

12.08	6.41	0.00	1.3	0.788E+02	2.21	3.50
12.28	6.48	0.00	1.3	0.786E+02	2.21	3.50
12.47	6.56	0.00	1.3	0.783E+02	2.22	3.51
12.67	6.63	0.00	1.3	0.781E+02	2.23	3.52
12.86	6.71	0.00	1.3	0.778E+02	2.24	3.53
13.06	6.79	0.00	1.3	0.776E+02	2.25	3.54
13.25	6.86	0.00	1.3	0.773E+02	2.26	3.55
13.45	6.94	0.00	1.3	0.771E+02	2.27	3.56
13.65	7.01	0.00	1.3	0.769E+02	2.28	3.56
13.84	7.09	0.00	1.3	0.766E+02	2.29	3.57
14.04	7.17	0.00	1.3	0.764E+02	2.29	3.58
14.24	7.24	0.00	1.3	0.762E+02	2.30	3.59
14.44	7.32	0.00	1.3	0.759E+02	2.31	3.60
14.64	7.39	0.00	1.3	0.757E+02	2.32	3.61
14.84	7.47	0.00	1.3	0.755E+02	2.33	3.62
15.04	7.55	0.00	1.3	0.752E+02	2.34	3.63
15.24	7.62	0.00	1.3	0.750E+02	2.35	3.63
15.45	7.70	0.00	1.3	0.748E+02	2.36	3.64
15.65	7.77	0.00	1.3	0.746E+02	2.37	3.65
15.85	7.85	0.00	1.3	0.743E+02	2.37	3.66
16.06	7.92	0.00	1.3	0.741E+02	2.38	3.67
16.26	8.00	0.00	1.4	0.739E+02	2.39	3.68
16.47	8.08	0.00	1.4	0.737E+02	2.40	3.69
16.67	8.15	0.00	1.4	0.735E+02	2.41	3.69
16.88	8.23	0.00	1.4	0.732E+02	2.42	3.70
17.08	8.30	0.00	1.4	0.730E+02	2.43	3.71
17.29	8.38	0.00	1.4	0.728E+02	2.44	3.72
17.50	8.46	0.00	1.4	0.726E+02	2.44	3.73
17.71	8.53	0.00	1.4	0.724E+02	2.45	3.74
17.92	8.61	0.00	1.4	0.722E+02	2.46	3.75
18.12	8.68	0.00	1.4	0.720E+02	2.47	3.76
18.33	8.76	0.00	1.4	0.718E+02	2.48	3.76
18.55	8.84	0.00	1.4	0.716E+02	2.49	3.77
18.76	8.91	0.00	1.4	0.714E+02	2.50	3.78

Cumulative travel time = 46. sec
JET INTERACTS WITH THE BOTTOM within this region.

Some concentration build-up near bank/shore due to recirculation effects.
Find concentration and thickness values for the RECIRCULATION REGION
at end of MOD329!

END OF MOD317: WEAKLY DEFLECTED JET (3-D) WITH LEESIDE RECIRCULATION ZONE

Because of the strong horizontal momentum flux of this discharge, severe
PLUME INTERACTION WITH BOTH BANKS occurs.
Consider a different discharge design with a reduced offshore momentum flux.

In the next prediction module, the plume centerline will be set
to follow the bank/shore.

A subsequent module (MOD381) will predict the properties of the
LATERALLY mixed plume with the given near-field dilution and will
compute a POSSIBLE UPSTREAM WEDGE INTRUSION.

BEGIN MOD381: MIXED PLUME/BOUNDED CHANNEL/POSSIBLE UPSTREAM WEDGE INTRUSION

```
CORMIX3 PREDICTION FILE:
3333333333333333333333333333333333333333333333333333333333333333333333333333333333333333
                    CORNELL MIXING ZONE EXPERT SYSTEM
Subsystem CORMIX3:                                          Subsystem version:
 Buoyant Surface Discharges
------------------------------------------------------------------------------
------------------------------------------------------------------------------
CASE DESCRIPTION
 Site name/label:         Glendale E2 Clinton PA Discharges at Hun
 Design case:
 FILE NAME:               cormix\sim\        .cx3
 Time of Fortran run:

ENVIRONMENT PARAMETERS (metric units)
 Bounded section
 BS    =     15.24  AS    =     24.84  QA    =      1.37
 HA    =      1.63  HD    =      2.10
 UA    =     0.055 F     =     0.202 USTAR =0.8733E-02
 UW    =     5.000 UWSTAR=0.5523E-02
 Uniform density environment
 STRCND=  U         RHOAM =  999.8000

DISCHARGE PARAMETERS (metric units)
 BANK  =  RIGHT     DISTB =      4.10  Configuration:
 Rectangular channel geometry:
 B0    =     5.180 H0    =     1.070 A0    =0.5543E+01  AR    =      0.207
 SIGMA =     90.00  SLOPE =     26.00
 U0    =     0.193 Q0    =     1.070       =0.1070E+01
 RHO0  =  999.8000  DRHO0 =0.0000E+00  GP0   =0.0000E+00
 C0    =0.1000E+03  CUNITS=  X
 IPOLL =  1         KS    =0.0000E+00  KD    =0.0000E+00

FLUX VARIABLES (metric units)
 Q0    =0.1070E+01  M0    =0.2066E+00  J0    =0.0000E+00
 Associated length scales (meters)
 LQ    =      2.35  LM    =  99999.00  Lm    =      8.26  Lb    =      0.00
 LQ2D  =      3.40  LM2D  =  99999.00  Lm2D  =     41.89

NON-DIMENSIONAL PARAMETERS
 FR0   =  99999.00  FRCH  =  99999.00  R     =      3.51

FLOW CLASSIFICATION
 33333333333333333333333333333333333333333
 3  Flow class (CORMIX3)      =    SA2    3
 3  Applicable layer depth HS =     2.10  3
 33333333333333333333333333333333333333333

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
 C0    =0.1000E+03  CUNITS=  X
 NTOX  =  1         CMC   =0.1000E+02  CCC   =  CSTD
 NSTD  =  1         CSTD  =0.1000E+01
 REGMZ =  1
 REGSPC=  1         XREG  =    500.00  WREG  =      0.00  AREG  =      0.00
 XINT  =   2000.00  XMAX  =   2000.00

X-Y-Z COORDINATE SYSTEM:
    ORIGIN is located at the WATER SURFACE and at center of discharge
      channel/outlet:      4.10 m  from the RIGHT bank/shore.
    X-axis points downstream
    Y-axis points to left as seen by an observer looking downstream
    Z-axis points vertically upward (in CORMIX3, all values Z = 0.00)
NSTEP =100 display intervals per module
------------------------------------------------------------------------------
------------------------------------------------------------------------------
BEGIN MOD301: DISCHARGE MODULE (FLOW ESTABLISHMENT)

Profile definitions:
   BV = Gaussian 1/e (37%) vertical thickness
   BH = Gaussian 1/e (37%) horizontal half-width, normal to trajectory
   S = hydrodynamic centerline dilution
   C = centerline concentration (includes reaction effects, if any)

       X        Y       Z        S       C       BV       BH
     0.36     1.32    0.00     1.0 0.100E+03   1.62     2.92
 Cumulative travel time =           7. sec

END OF MOD301: DISCHARGE MODULE (FLOW ESTABLISHMENT)
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------------------------------------------------------------------------------
```

BEGIN MOD317: WEAKLY DEFLECTED JET (3-D) WITH LEESIDE RECIRCULATION ZONE

Surface JET into a crossflow

Near-field limitation in bounded channel.
Profile definitions:
BV = Gaussian 1/e (37%) vertical thickness
BH = Gaussian 1/e (37%) horizontal half-width, normal to trajectory
S = hydrodynamic centerline dilution
C = centerline concentration (includes reaction effects, if any)

X	Y	Z	S	C	BV	BH
0.36	1.32	0.00	1.0	0.100E+03	1.61	2.92
0.52	1.40	0.00	1.0	0.996E+02	1.62	2.92
0.68	1.47	0.00	1.0	0.992E+02	1.62	2.93
0.84	1.55	0.00	1.0	0.988E+02	1.63	2.94
0.99	1.62	0.00	1.0	0.984E+02	1.64	2.95
1.15	1.70	0.00	1.0	0.980E+02	1.65	2.96
1.31	1.77	0.00	1.0	0.976E+02	1.66	2.97
1.47	1.85	0.00	1.0	0.973E+02	1.67	2.98
1.63	1.93	0.00	1.0	0.969E+02	1.68	2.98
1.80	2.00	0.00	1.0	0.965E+02	1.69	2.99
1.96	2.08	0.00	1.0	0.961E+02	1.70	3.00
2.12	2.15	0.00	1.0	0.958E+02	1.71	3.01
2.28	2.23	0.00	1.0	0.954E+02	1.72	3.02
2.45	2.31	0.00	1.1	0.950E+02	1.72	3.03
2.61	2.38	0.00	1.1	0.947E+02	1.73	3.04
2.77	2.46	0.00	1.1	0.943E+02	1.74	3.05
2.94	2.53	0.00	1.1	0.940E+02	1.75	3.05
3.11	2.61	0.00	1.1	0.936E+02	1.76	3.06
3.27	2.69	0.00	1.1	0.933E+02	1.77	3.07
3.44	2.76	0.00	1.1	0.929E+02	1.78	3.08
3.61	2.84	0.00	1.1	0.926E+02	1.79	3.09
3.77	2.91	0.00	1.1	0.922E+02	1.80	3.10
3.94	2.99	0.00	1.1	0.919E+02	1.80	3.11
4.11	3.07	0.00	1.1	0.915E+02	1.81	3.11
4.28	3.14	0.00	1.1	0.912E+02	1.82	3.12
4.45	3.22	0.00	1.1	0.909E+02	1.83	3.13
4.62	3.29	0.00	1.1	0.905E+02	1.84	3.14
4.79	3.37	0.00	1.1	0.902E+02	1.85	3.15
4.96	3.45	0.00	1.1	0.899E+02	1.86	3.16
5.14	3.52	0.00	1.1	0.896E+02	1.87	3.17
5.31	3.60	0.00	1.1	0.893E+02	1.88	3.17
5.48	3.67	0.00	1.1	0.889E+02	1.89	3.18
5.66	3.75	0.00	1.1	0.886E+02	1.89	3.19
5.83	3.82	0.00	1.1	0.883E+02	1.90	3.20
6.01	3.90	0.00	1.1	0.880E+02	1.91	3.21
6.18	3.98	0.00	1.1	0.877E+02	1.92	3.22
6.36	4.05	0.00	1.1	0.874E+02	1.93	3.23
6.53	4.13	0.00	1.1	0.871E+02	1.94	3.24
6.71	4.20	0.00	1.2	0.868E+02	1.95	3.24
6.89	4.28	0.00	1.2	0.865E+02	1.96	3.25
7.07	4.36	0.00	1.2	0.862E+02	1.97	3.26
7.24	4.43	0.00	1.2	0.859E+02	1.97	3.27
7.42	4.51	0.00	1.2	0.856E+02	1.98	3.28
7.60	4.58	0.00	1.2	0.853E+02	1.99	3.29
7.78	4.66	0.00	1.2	0.850E+02	2.00	3.30
7.97	4.74	0.00	1.2	0.847E+02	2.01	3.30
8.15	4.81	0.00	1.2	0.844E+02	2.02	3.31
8.33	4.89	0.00	1.2	0.841E+02	2.03	3.32
8.51	4.96	0.00	1.2	0.838E+02	2.04	3.33
8.69	5.04	0.00	1.2	0.836E+02	2.05	3.34
8.88	5.12	0.00	1.2	0.833E+02	2.05	3.35
9.06	5.19	0.00	1.2	0.830E+02	2.06	3.36
9.25	5.27	0.00	1.2	0.827E+02	2.07	3.37
9.43	5.34	0.00	1.2	0.825E+02	2.08	3.37
9.62	5.42	0.00	1.2	0.822E+02	2.09	3.38
9.80	5.50	0.00	1.2	0.819E+02	2.10	3.39
9.99	5.57	0.00	1.2	0.816E+02	2.11	3.40
10.18	5.65	0.00	1.2	0.814E+02	2.12	3.41
10.37	5.72	0.00	1.2	0.811E+02	2.13	3.42
10.56	5.80	0.00	1.2	0.809E+02	2.13	3.43
10.74	5.87	0.00	1.2	0.806E+02	2.14	3.43
10.93	5.95	0.00	1.2	0.803E+02	2.15	3.44
11.12	6.03	0.00	1.2	0.801E+02	2.16	3.45
11.32	6.10	0.00	1.3	0.798E+02	2.17	3.46
11.51	6.18	0.00	1.3	0.796E+02	2.18	3.47
11.70	6.25	0.00	1.3	0.793E+02	2.19	3.48
11.89	6.33	0.00	1.3	0.791E+02	2.20	3.49

12.08	6.41	0.00	1.3	0.788E+02	2.21	3.50
12.28	6.48	0.00	1.3	0.786E+02	2.21	3.50
12.47	6.56	0.00	1.3	0.783E+02	2.22	3.51
12.67	6.63	0.00	1.3	0.781E+02	2.23	3.52
12.86	6.71	0.00	1.3	0.778E+02	2.24	3.53
13.06	6.79	0.00	1.3	0.776E+02	2.25	3.54
13.25	6.86	0.00	1.3	0.773E+02	2.26	3.55
13.45	6.94	0.00	1.3	0.771E+02	2.27	3.56
13.65	7.01	0.00	1.3	0.769E+02	2.28	3.56
13.84	7.09	0.00	1.3	0.766E+02	2.29	3.57
14.04	7.17	0.00	1.3	0.764E+02	2.29	3.58
14.24	7.24	0.00	1.3	0.762E+02	2.30	3.59
14.44	7.32	0.00	1.3	0.759E+02	2.31	3.60
14.64	7.39	0.00	1.3	0.757E+02	2.32	3.61
14.84	7.47	0.00	1.3	0.755E+02	2.33	3.62
15.04	7.55	0.00	1.3	0.752E+02	2.34	3.63
15.24	7.62	0.00	1.3	0.750E+02	2.35	3.63
15.45	7.70	0.00	1.3	0.748E+02	2.36	3.64
15.65	7.77	0.00	1.3	0.746E+02	2.37	3.65
15.85	7.85	0.00	1.3	0.743E+02	2.37	3.66
16.06	7.92	0.00	1.3	0.741E+02	2.38	3.67
16.26	8.00	0.00	1.4	0.739E+02	2.39	3.68
16.47	8.08	0.00	1.4	0.737E+02	2.40	3.69
16.67	8.15	0.00	1.4	0.735E+02	2.41	3.69
16.88	8.23	0.00	1.4	0.732E+02	2.42	3.70
17.08	8.30	0.00	1.4	0.730E+02	2.43	3.71
17.29	8.38	0.00	1.4	0.728E+02	2.44	3.72
17.50	8.46	0.00	1.4	0.726E+02	2.44	3.73
17.71	8.53	0.00	1.4	0.724E+02	2.45	3.74
17.92	8.61	0.00	1.4	0.722E+02	2.46	3.75
18.12	8.68	0.00	1.4	0.720E+02	2.47	3.76
18.33	8.76	0.00	1.4	0.718E+02	2.48	3.76
18.55	8.84	0.00	1.4	0.716E+02	2.49	3.77
18.76	8.91	0.00	1.4	0.714E+02	2.50	3.78

 Cumulative travel time = 46. sec
 JET INTERACTS WITH THE BOTTOM within this region.

 Some concentration build-up near bank/shore due to recirculation effects.
   Find concentration and thickness values for the RECIRCULATION REGION
   at end of MOD329!

END OF MOD317: WEAKLY DEFLECTED JET (3-D) WITH LEESIDE RECIRCULATION ZONE

 Because of the strong horizontal momentum flux of this discharge, severe
   PLUME INTERACTION WITH BOTH BANKS occurs.
 Consider a different discharge design with a reduced offshore momentum flux.

 In the next prediction module, the plume centerline will be set
   to follow the bank/shore.

 A subsequent module (MOD381) will predict the properties of the
   LATERALLY mixed plume with the given near-field dilution and will
   compute a POSSIBLE UPSTREAM WEDGE INTRUSION.

BEGIN MOD381: MIXED PLUME/BOUNDED CHANNEL/POSSIBLE UPSTREAM WEDGE INTRUSION

```
CORMIX3 PREDICTION FILE:
3333333333333333333333333333333333333333333333333333333333333333333333333333333333
                    CORNELL MIXING ZONE EXPERT SYSTEM
Subsystem CORMIX3:                                          Subsystem version:
 Buoyant Surface Discharges
------------------------------------------------------------------------------
------------------------------------------------------------------------------
CASE DESCRIPTION
 Site name/label:         Filterbed PA Discharge at Buffalo Bayou
 Design case:
 FILE NAME:               cormix\sim\        .cx3
 Time of Fortran run:

ENVIRONMENT PARAMETERS (metric units)
 Bounded section
 BS    =     93.00  AS    =    419.43  QA    =     57.04
 HA    =      4.51  HD    =      3.50
 UA    =     0.136  F     =     0.015 USTAR =0.5866E-02
 UW    =     5.000 UWSTAR=0.5525E-02
 Density stratified environment
 STRCND=  A         RHOAM = 1002.1000
 RHOAS =  999.2000  RHOAB = 1005.0000  RHOAEF= 1002.1000  E     =0.0000E+00

DISCHARGE PARAMETERS (metric units)
 BANK  =  RIGHT     DISTB =      2.20  Configuration:
 Circular discharge pipe:
 D0    =     1.830 A0    =     0.145
 Dimensions of equivalent rectangular discharge:
 B0    =     0.381 H0    =     0.380 A0    =0.1446E+00  AR    =      0.998
 SIGMA =     90.00  SLOPE =     40.00
 U0    =     7.398 Q0    =     1.070       =0.1070E+01
 RHO0  = 1002.1000  DRHO0 =0.0000E+00  GP0   =0.0000E+00
 C0    =0.1000E+03  CUNITS=  X
 IPOLL =  1         KS    =0.0000E+00  KD    =0.0000E+00

FLUX VARIABLES (metric units)
 Q0    =0.1070E+01  M0    =0.7916E+01  J0    =0.0000E+00
 Associated length scales (meters)
 LQ    =     0.38  LM    =  99999.00  Lm    =     20.69  Lb    =      0.00

NON-DIMENSIONAL PARAMETERS
 FR0   =  99999.00  FRCH  =  99999.00  R     =     54.40

FLOW CLASSIFICATION
 33333333333333333333333333333333333333
 3  Flow class (CORMIX3)      =    SA1    3
 3  Applicable layer depth HS =     3.50  3
 33333333333333333333333333333333333333

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
 C0    =0.1000E+03  CUNITS=  X
 NTOX  =  1         CMC   =0.1000E+02  CCC   =  CSTD
 NSTD  =  1         CSTD  =0.1000E+01
 REGMZ =  1
 REGSPC=  1         XREG  =    500.00  WREG  =      0.00  AREG  =      0.00
 XINT  =   2000.00  XMAX  =   2000.00

X-Y-Z COORDINATE SYSTEM:
    ORIGIN is located at the WATER SURFACE and at center of discharge
      channel/outlet:      2.20 m  from the RIGHT bank/shore.
    X-axis points downstream
    Y-axis points to left as seen by an observer looking downstream
    Z-axis points vertically upward (in CORMIX3, all values Z = 0.00)
NSTEP =100 display intervals per module
------------------------------------------------------------------------------
------------------------------------------------------------------------------
BEGIN MOD301: DISCHARGE MODULE (FLOW ESTABLISHMENT)

Profile definitions:
   BV = Gaussian 1/e (37%) vertical thickness
   BH = Gaussian 1/e (37%) horizontal half-width, normal to trajectory
   S = hydrodynamic centerline dilution
   C = centerline concentration (includes reaction effects, if any)

       X        Y       Z        S       C       BV       BH
      0.02     1.44    0.00     1.0 0.100E+03   0.44     0.28
 Cumulative travel time =           0. sec

END OF MOD301: DISCHARGE MODULE (FLOW ESTABLISHMENT)
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BEGIN MOD317: WEAKLY DEFLECTED JET (3-D) WITH LEESIDE RECIRCULATION ZONE

Surface JET into a crossflow

Profile definitions:
BV = Gaussian 1/e (37%) vertical thickness
BH = Gaussian 1/e (37%) horizontal half-width, normal to trajectory
S = hydrodynamic centerline dilution
C = centerline concentration (includes reaction effects, if any)

X	Y	Z	S	C	BV	BH
0.02	1.44	0.00	1.0	0.100E+03	0.44	0.28
0.08	1.82	0.00	1.1	0.892E+02	0.48	0.32
0.14	2.20	0.00	1.2	0.806E+02	0.52	0.36
0.21	2.58	0.00	1.4	0.734E+02	0.56	0.41
0.28	2.97	0.00	1.5	0.675E+02	0.61	0.45
0.36	3.35	0.00	1.6	0.624E+02	0.65	0.49
0.44	3.73	0.00	1.7	0.580E+02	0.69	0.53
0.53	4.11	0.00	1.8	0.542E+02	0.73	0.57
0.62	4.49	0.00	2.0	0.509E+02	0.78	0.62
0.72	4.88	0.00	2.1	0.480E+02	0.82	0.66
0.82	5.26	0.00	2.2	0.453E+02	0.86	0.70
0.93	5.64	0.00	2.3	0.430E+02	0.90	0.74
1.05	6.02	0.00	2.4	0.409E+02	0.95	0.79
1.17	6.40	0.00	2.6	0.390E+02	0.99	0.83
1.30	6.79	0.00	2.7	0.372E+02	1.03	0.87
1.43	7.17	0.00	2.8	0.356E+02	1.07	0.91
1.57	7.55	0.00	2.9	0.341E+02	1.11	0.95
1.71	7.93	0.00	3.0	0.328E+02	1.16	1.00
1.86	8.31	0.00	3.2	0.315E+02	1.20	1.04
2.01	8.70	0.00	3.3	0.304E+02	1.24	1.08
2.17	9.08	0.00	3.4	0.293E+02	1.28	1.12
2.34	9.46	0.00	3.5	0.283E+02	1.32	1.16
2.51	9.84	0.00	3.7	0.274E+02	1.37	1.21
2.69	10.22	0.00	3.8	0.265E+02	1.41	1.25
2.87	10.61	0.00	3.9	0.257E+02	1.45	1.29
3.06	10.99	0.00	4.0	0.249E+02	1.49	1.33
3.25	11.37	0.00	4.1	0.242E+02	1.54	1.37
3.45	11.75	0.00	4.3	0.235E+02	1.58	1.42
3.65	12.13	0.00	4.4	0.229E+02	1.62	1.46
3.86	12.52	0.00	4.5	0.222E+02	1.66	1.50
4.07	12.90	0.00	4.6	0.217E+02	1.70	1.54
4.30	13.28	0.00	4.7	0.211E+02	1.75	1.58
4.52	13.66	0.00	4.9	0.206E+02	1.79	1.63
4.75	14.04	0.00	5.0	0.201E+02	1.83	1.67
4.99	14.42	0.00	5.1	0.196E+02	1.87	1.71
5.23	14.81	0.00	5.2	0.192E+02	1.91	1.75
5.48	15.19	0.00	5.3	0.187E+02	1.96	1.79
5.73	15.57	0.00	5.5	0.183E+02	2.00	1.84
5.99	15.95	0.00	5.6	0.179E+02	2.04	1.88
6.26	16.33	0.00	5.7	0.175E+02	2.08	1.92
6.53	16.72	0.00	5.8	0.172E+02	2.12	1.96
6.80	17.10	0.00	5.9	0.168E+02	2.17	2.00
7.08	17.48	0.00	6.1	0.165E+02	2.21	2.05
7.37	17.86	0.00	6.2	0.162E+02	2.25	2.09
7.66	18.24	0.00	6.3	0.159E+02	2.29	2.13
7.96	18.63	0.00	6.4	0.156E+02	2.33	2.17
8.26	19.01	0.00	6.5	0.153E+02	2.38	2.21
8.57	19.39	0.00	6.7	0.150E+02	2.42	2.26
8.89	19.77	0.00	6.8	0.147E+02	2.46	2.30
9.20	20.15	0.00	6.9	0.145E+02	2.50	2.34
9.53	20.54	0.00	7.0	0.142E+02	2.55	2.38
9.86	20.92	0.00	7.1	0.140E+02	2.59	2.42
10.20	21.30	0.00	7.3	0.138E+02	2.63	2.47
10.54	21.68	0.00	7.4	0.135E+02	2.67	2.51
10.89	22.06	0.00	7.5	0.133E+02	2.71	2.55
11.24	22.45	0.00	7.6	0.131E+02	2.76	2.59
11.60	22.83	0.00	7.8	0.129E+02	2.80	2.63
11.96	23.21	0.00	7.9	0.127E+02	2.84	2.68
12.33	23.59	0.00	8.0	0.125E+02	2.88	2.72
12.70	23.97	0.00	8.1	0.123E+02	2.92	2.76
13.08	24.36	0.00	8.2	0.121E+02	2.97	2.80
13.47	24.74	0.00	8.4	0.120E+02	3.01	2.84
13.86	25.12	0.00	8.5	0.118E+02	3.05	2.89
14.26	25.50	0.00	8.6	0.116E+02	3.09	2.93
14.66	25.88	0.00	8.7	0.115E+02	3.13	2.97
15.07	26.27	0.00	8.8	0.113E+02	3.18	3.01

15.48	26.65	0.00	9.0	0.112E+02	3.22	3.05
15.90	27.03	0.00	9.1	0.110E+02	3.26	3.10
16.32	27.41	0.00	9.2	0.109E+02	3.30	3.14
16.75	27.79	0.00	9.3	0.107E+02	3.34	3.18
17.19	28.18	0.00	9.4	0.106E+02	3.39	3.22
17.63	28.56	0.00	9.6	0.105E+02	3.43	3.26
18.08	28.94	0.00	9.7	0.103E+02	3.47	3.31
18.53	29.32	0.00	9.8	0.102E+02	3.51	3.35
18.99	29.70	0.00	9.9	0.101E+02	3.55	3.39

** CMC HAS BEEN FOUND **
The pollutant concentration in the plume falls below CMC value of 0.100E+02
in the current prediction interval.
This is the extent of the TOXIC DILUTION ZONE.

19.45	30.09	0.00	10.0	0.996E+01	3.60	3.43
19.92	30.47	0.00	10.2	0.984E+01	3.64	3.47
20.39	30.85	0.00	10.3	0.973E+01	3.68	3.52
20.87	31.23	0.00	10.4	0.961E+01	3.72	3.56
21.36	31.61	0.00	10.5	0.950E+01	3.76	3.60
21.85	32.00	0.00	10.6	0.940E+01	3.81	3.64
22.34	32.38	0.00	10.8	0.929E+01	3.85	3.68
22.84	32.76	0.00	10.9	0.919E+01	3.89	3.73
23.35	33.14	0.00	11.0	0.909E+01	3.93	3.77
23.86	33.52	0.00	11.1	0.899E+01	3.97	3.81
24.38	33.91	0.00	11.2	0.889E+01	4.02	3.85
24.90	34.29	0.00	11.4	0.880E+01	4.06	3.90
25.43	34.67	0.00	11.5	0.870E+01	4.10	3.94
25.97	35.05	0.00	11.6	0.861E+01	4.14	3.98
26.51	35.43	0.00	11.7	0.853E+01	4.18	4.02
27.05	35.82	0.00	11.8	0.844E+01	4.23	4.06
27.60	36.20	0.00	12.0	0.835E+01	4.27	4.11
28.16	36.58	0.00	12.1	0.827E+01	4.31	4.15
28.72	36.96	0.00	12.2	0.819E+01	4.35	4.19
29.29	37.34	0.00	12.3	0.811E+01	4.39	4.23
29.86	37.73	0.00	12.5	0.803E+01	4.44	4.27
30.44	38.11	0.00	12.6	0.795E+01	4.48	4.32
31.03	38.49	0.00	12.7	0.788E+01	4.52	4.36
31.62	38.87	0.00	12.8	0.780E+01	4.56	4.40
32.21	39.25	0.00	12.9	0.773E+01	4.60	4.44
32.81	39.64	0.00	13.1	0.766E+01	4.65	4.48

Cumulative travel time = 29. sec

Some concentration build-up near bank/shore due to recirculation effects.
Find concentration and thickness values for the RECIRCULATION REGION
at end of MOD329!

END OF MOD317: WEAKLY DEFLECTED JET (3-D) WITH LEESIDE RECIRCULATION ZONE

BEGIN MOD327: STRONGLY DEFLECTED JET (3-D) WITH LEESIDE RECIRCULATION ZONE

Profile definitions:
BV = Gaussian 1/e (37%) vertical thickness
BH = Gaussian 1/e (37%) horizontal half-width, normal to trajectory
S = hydrodynamic centerline dilution
C = centerline concentration (includes reaction effects, if any)

X	Y	Z	S	C	BV	BH
32.81	39.64	0.00	13.1	0.766E+01	11.30	10.91
34.41	40.22	0.00	13.5	0.742E+01	11.48	11.08
36.01	40.54	0.00	13.7	0.730E+01	11.57	11.18
37.60	40.78	0.00	13.9	0.721E+01	11.64	11.25
39.20	40.97	0.00	14.0	0.714E+01	11.70	11.31
40.80	41.14	0.00	14.1	0.708E+01	11.75	11.36
42.39	41.28	0.00	14.2	0.702E+01	11.80	11.40
43.99	41.41	0.00	14.3	0.697E+01	11.83	11.44
45.59	41.53	0.00	14.4	0.693E+01	11.87	11.47
47.18	41.64	0.00	14.5	0.689E+01	11.90	11.51
48.78	41.74	0.00	14.6	0.686E+01	11.93	11.54
50.38	41.84	0.00	14.7	0.682E+01	11.96	11.57
51.97	41.93	0.00	14.7	0.679E+01	11.99	11.59
53.57	42.02	0.00	14.8	0.676E+01	12.02	11.62
55.17	42.10	0.00	14.8	0.673E+01	12.04	11.64
56.76	42.18	0.00	14.9	0.671E+01	12.06	11.67
58.36	42.25	0.00	15.0	0.668E+01	12.09	11.69
59.96	42.32	0.00	15.0	0.666E+01	12.11	11.71
61.55	42.39	0.00	15.1	0.664E+01	12.13	11.73
63.15	42.46	0.00	15.1	0.661E+01	12.15	11.75
64.75	42.52	0.00	15.2	0.659E+01	12.17	11.77
66.35	42.58	0.00	15.2	0.657E+01	12.19	11.79

67.94	42.64	0.00	15.3	0.655E+01	12.20	11.81
69.54	42.70	0.00	15.3	0.653E+01	12.22	11.82
71.14	42.76	0.00	15.4	0.651E+01	12.24	11.84
72.73	42.81	0.00	15.4	0.650E+01	12.26	11.86
74.33	42.87	0.00	15.4	0.648E+01	12.27	11.87
75.93	42.92	0.00	15.5	0.646E+01	12.29	11.89
77.52	42.97	0.00	15.5	0.645E+01	12.30	11.91
79.12	43.02	0.00	15.6	0.643E+01	12.32	11.92
80.72	43.07	0.00	15.6	0.641E+01	12.33	11.94
82.31	43.12	0.00	15.6	0.640E+01	12.35	11.95
83.91	43.16	0.00	15.7	0.638E+01	12.36	11.96
85.51	43.21	0.00	15.7	0.637E+01	12.37	11.98
87.10	43.26	0.00	15.7	0.636E+01	12.39	11.99
88.70	43.30	0.00	15.8	0.634E+01	12.40	12.00
90.30	43.34	0.00	15.8	0.633E+01	12.41	12.02
91.89	43.39	0.00	15.8	0.632E+01	12.43	12.03
93.49	43.43	0.00	15.9	0.630E+01	12.44	12.04
95.09	43.47	0.00	15.9	0.629E+01	12.45	12.05
96.68	43.51	0.00	15.9	0.628E+01	12.46	12.07
98.28	43.55	0.00	16.0	0.627E+01	12.48	12.08
99.88	43.59	0.00	16.0	0.625E+01	12.49	12.09
101.48	43.63	0.00	16.0	0.624E+01	12.50	12.10
103.07	43.66	0.00	16.1	0.623E+01	12.51	12.11
104.67	43.70	0.00	16.1	0.622E+01	12.52	12.12
106.27	43.74	0.00	16.1	0.621E+01	12.53	12.14
107.86	43.77	0.00	16.1	0.620E+01	12.54	12.15
109.46	43.81	0.00	16.2	0.619E+01	12.55	12.16
111.06	43.84	0.00	16.2	0.618E+01	12.56	12.17
112.65	43.88	0.00	16.2	0.617E+01	12.57	12.18
114.25	43.91	0.00	16.2	0.616E+01	12.58	12.19
115.85	43.95	0.00	16.3	0.615E+01	12.59	12.20
117.44	43.98	0.00	16.3	0.614E+01	12.60	12.21
119.04	44.01	0.00	16.3	0.613E+01	12.61	12.22
120.64	44.05	0.00	16.4	0.612E+01	12.62	12.23
122.23	44.08	0.00	16.4	0.611E+01	12.63	12.24
123.83	44.11	0.00	16.4	0.610E+01	12.64	12.25
125.43	44.14	0.00	16.4	0.609E+01	12.65	12.26
127.02	44.17	0.00	16.5	0.608E+01	12.66	12.27
128.62	44.20	0.00	16.5	0.607E+01	12.67	12.28
130.22	44.23	0.00	16.5	0.606E+01	12.68	12.28
131.82	44.26	0.00	16.5	0.605E+01	12.69	12.29
133.41	44.29	0.00	16.5	0.604E+01	12.70	12.30
135.01	44.32	0.00	16.6	0.603E+01	12.71	12.31
136.61	44.35	0.00	16.6	0.603E+01	12.72	12.32
138.20	44.38	0.00	16.6	0.602E+01	12.72	12.33
139.80	44.41	0.00	16.6	0.601E+01	12.73	12.34
141.40	44.44	0.00	16.7	0.600E+01	12.74	12.35
142.99	44.47	0.00	16.7	0.599E+01	12.75	12.35
144.59	44.49	0.00	16.7	0.599E+01	12.76	12.36
146.19	44.52	0.00	16.7	0.598E+01	12.77	12.37
147.78	44.55	0.00	16.7	0.597E+01	12.77	12.38
149.38	44.57	0.00	16.8	0.596E+01	12.78	12.39
150.98	44.60	0.00	16.8	0.596E+01	12.79	12.39
152.57	44.63	0.00	16.8	0.595E+01	12.80	12.40
154.17	44.65	0.00	16.8	0.594E+01	12.81	12.41
155.77	44.68	0.00	16.9	0.593E+01	12.81	12.42
157.36	44.71	0.00	16.9	0.593E+01	12.82	12.43
158.96	44.73	0.00	16.9	0.592E+01	12.83	12.43
160.56	44.76	0.00	16.9	0.591E+01	12.84	12.44
162.15	44.78	0.00	16.9	0.590E+01	12.85	12.45
163.75	44.81	0.00	17.0	0.590E+01	12.85	12.46
165.35	44.83	0.00	17.0	0.589E+01	12.86	12.46
166.95	44.86	0.00	17.0	0.588E+01	12.87	12.47
168.54	44.88	0.00	17.0	0.588E+01	12.87	12.48
170.14	44.90	0.00	17.0	0.587E+01	12.88	12.49
171.74	44.93	0.00	17.1	0.586E+01	12.89	12.49
173.33	44.95	0.00	17.1	0.586E+01	12.90	12.50
174.93	44.98	0.00	17.1	0.585E+01	12.90	12.51
176.53	45.00	0.00	17.1	0.584E+01	12.91	12.51
178.12	45.02	0.00	17.1	0.584E+01	12.92	12.52
179.72	45.05	0.00	17.1	0.583E+01	12.92	12.53
181.32	45.07	0.00	17.2	0.582E+01	12.93	12.53
182.91	45.09	0.00	17.2	0.582E+01	12.94	12.54
184.51	45.11	0.00	17.2	0.581E+01	12.94	12.55
186.11	45.14	0.00	17.2	0.581E+01	12.95	12.56
187.70	45.16	0.00	17.2	0.580E+01	12.96	12.56
189.30	45.18	0.00	17.3	0.579E+01	12.96	12.57
190.90	45.20	0.00	17.3	0.579E+01	12.97	12.57
192.49	45.22	0.00	17.3	0.578E+01	12.98	12.58

```
 Cumulative travel time =        1203. sec

 Some concentration build-up near bank/shore due to recirculation effects.
   Find concentration and thickness values for the RECIRCULATION REGION
   at end of MOD329!

END OF MOD327: STRONGLY DEFLECTED JET (3-D) WITH LEESIDE RECIRCULATION ZONE
------------------------------------------------------------------------------
------------------------------------------------------------------------------
BEGIN MOD329: STRONGLY DEFLECTED PLUME WITH LEESIDE RECIRCULATION ZONE

 This flow region is INSIGNIFICANT in spatial extent and will be by-passed.

 The near-shore RECIRCULATION REGION extends back to the discharge location:
    Concentration C within that region:        0.289E+01
    Layer thickness BV within that region:    12.98

END OF MOD329: STRONGLY DEFLECTED PLUME WITH LEESIDE RECIRCULATION ZONE
------------------------------------------------------------------------------
------------------------------------------------------------------------------
** End of NEAR-FIELD REGION (NFR) **
------------------------------------------------------------------------------

The initial plume WIDTH values in the next far-field module will be
  CORRECTED by a factor  0.65 to conserve the mass flux in the far-field!
------------------------------------------------------------------------------
BEGIN MOD341: BUOYANT AMBIENT SPREADING

 Plume is ATTACHED to RIGHT bank/shore.
   Plume width is now determined from RIGHT bank/shore.
```

```
CORMIX3 PREDICTION FILE:
3333333333333333333333333333333333333333333333333333333333333333333333333333333333333333
                    CORNELL MIXING ZONE EXPERT SYSTEM
Subsystem CORMIX3:                                          Subsystem version:
 Buoyant Surface Discharges
------------------------------------------------------------------------------
------------------------------------------------------------------------------
CASE DESCRIPTION
 Site name/label:         Filterbed PA Discharge at Buffalo Bayou
 Design case:
 FILE NAME:               cormix\sim\        .cx3
 Time of Fortran run:

ENVIRONMENT PARAMETERS (metric units)
 Bounded section
 BS    =     93.00  AS    =    419.43  QA    =     57.04
 HA    =      4.51  HD    =      4.40
 UA    =     0.136  F     =     0.015 USTAR =0.5866E-02
 UW    =     5.000 UWSTAR=0.5525E-02
 Density stratified environment
 STRCND=  A         RHOAM = 1002.1000
 RHOAS =  999.2000  RHOAB = 1005.0000  RHOAEF= 1002.1000  E     =0.0000E+00

DISCHARGE PARAMETERS (metric units)
 BANK  =  RIGHT     DISTB =     15.24  Configuration:
 Rectangular channel geometry:
 B0    =     1.830 H0    =     0.380 A0    =0.6954E+00  AR    =     0.208
 SIGMA =     90.00  SLOPE =     40.00
 U0    =     1.539 Q0    =     1.070       =0.1070E+01
 RHO0  = 1002.1000  DRHO0 =0.0000E+00  GP0   =0.0000E+00
 C0    =0.1000E+03  CUNITS=  X
 IPOLL =  1         KS    =0.0000E+00  KD    =0.0000E+00

FLUX VARIABLES (metric units)
 Q0    =0.1070E+01  M0    =0.1646E+01  J0    =0.0000E+00
 Associated length scales (meters)
 LQ    =     0.83  LM    =  99999.00  Lm    =     9.43  Lb    =     0.00

NON-DIMENSIONAL PARAMETERS
 FR0   =  99999.00  FRCH  =  99999.00  R     =    11.31

FLOW CLASSIFICATION
 3333333333333333333333333333333333333333333
 3  Flow class (CORMIX3)      =    SA1    3
 3  Applicable layer depth HS =     4.40  3
 3333333333333333333333333333333333333333333

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
 C0    =0.1000E+03  CUNITS=  X
 NTOX  =  1         CMC   =0.1000E+02  CCC   =  CSTD
 NSTD  =  1         CSTD  =0.1000E+01
 REGMZ =  1
 REGSPC=  1         XREG  =    500.00  WREG  =     0.00  AREG  =     0.00
 XINT  =   2000.00  XMAX  =   2000.00

X-Y-Z COORDINATE SYSTEM:
    ORIGIN is located at the WATER SURFACE and at center of discharge
      channel/outlet:     15.24 m  from the RIGHT bank/shore.
    X-axis points downstream
    Y-axis points to left as seen by an observer looking downstream
    Z-axis points vertically upward (in CORMIX3, all values Z = 0.00)
NSTEP =100 display intervals per module
------------------------------------------------------------------------------
------------------------------------------------------------------------------
BEGIN MOD301: DISCHARGE MODULE (FLOW ESTABLISHMENT)

Profile definitions:
   BV = Gaussian 1/e (37%) vertical thickness
   BH = Gaussian 1/e (37%) horizontal half-width, normal to trajectory
   S = hydrodynamic centerline dilution
   C = centerline concentration (includes reaction effects, if any)

       X        Y       Z        S       C       BV       BH
     0.20     2.44    0.00     1.0 0.100E+03   0.57     1.03
 Cumulative travel time =           2. sec

END OF MOD301: DISCHARGE MODULE (FLOW ESTABLISHMENT)
------------------------------------------------------------------------------
------------------------------------------------------------------------------
```

BEGIN MOD317: WEAKLY DEFLECTED JET (3-D) WITH LEESIDE RECIRCULATION ZONE

Surface JET into a crossflow

Profile definitions:
BV = Gaussian 1/e (37%) vertical thickness
BH = Gaussian 1/e (37%) horizontal half-width, normal to trajectory
S = hydrodynamic centerline dilution
C = centerline concentration (includes reaction effects, if any)

X	Y	Z	S	C	BV	BH
0.20	2.44	0.00	1.0	0.100E+03	0.57	1.03
0.28	2.56	0.00	1.0	0.983E+02	0.58	1.04
0.36	2.68	0.00	1.0	0.967E+02	0.60	1.06
0.44	2.80	0.00	1.1	0.951E+02	0.61	1.07
0.53	2.92	0.00	1.1	0.936E+02	0.62	1.08
0.61	3.04	0.00	1.1	0.921E+02	0.64	1.10
0.69	3.16	0.00	1.1	0.907E+02	0.65	1.11
0.78	3.27	0.00	1.1	0.893E+02	0.67	1.12
0.87	3.39	0.00	1.1	0.879E+02	0.68	1.14
0.95	3.51	0.00	1.2	0.866E+02	0.69	1.15
1.04	3.63	0.00	1.2	0.854E+02	0.71	1.16
1.13	3.75	0.00	1.2	0.841E+02	0.72	1.17
1.22	3.87	0.00	1.2	0.829E+02	0.73	1.19
1.32	3.99	0.00	1.2	0.818E+02	0.75	1.20
1.41	4.11	0.00	1.2	0.806E+02	0.76	1.21
1.51	4.22	0.00	1.3	0.795E+02	0.77	1.23
1.60	4.34	0.00	1.3	0.785E+02	0.79	1.24
1.70	4.46	0.00	1.3	0.774E+02	0.80	1.25
1.80	4.58	0.00	1.3	0.764E+02	0.81	1.27
1.90	4.70	0.00	1.3	0.754E+02	0.83	1.28
2.00	4.82	0.00	1.3	0.745E+02	0.84	1.29
2.10	4.94	0.00	1.4	0.735E+02	0.85	1.31
2.20	5.06	0.00	1.4	0.726E+02	0.87	1.32
2.31	5.17	0.00	1.4	0.717E+02	0.88	1.33
2.41	5.29	0.00	1.4	0.708E+02	0.89	1.35
2.52	5.41	0.00	1.4	0.700E+02	0.91	1.36
2.63	5.53	0.00	1.4	0.692E+02	0.92	1.37
2.74	5.65	0.00	1.5	0.683E+02	0.93	1.38
2.85	5.77	0.00	1.5	0.676E+02	0.95	1.40
2.96	5.89	0.00	1.5	0.668E+02	0.96	1.41
3.07	6.01	0.00	1.5	0.660E+02	0.97	1.42
3.18	6.13	0.00	1.5	0.653E+02	0.99	1.44
3.30	6.24	0.00	1.5	0.646E+02	1.00	1.45
3.42	6.36	0.00	1.6	0.639E+02	1.01	1.46
3.53	6.48	0.00	1.6	0.632E+02	1.03	1.48
3.65	6.60	0.00	1.6	0.625E+02	1.04	1.49
3.77	6.72	0.00	1.6	0.618E+02	1.05	1.50
3.89	6.84	0.00	1.6	0.612E+02	1.07	1.52
4.01	6.96	0.00	1.7	0.605E+02	1.08	1.53
4.14	7.08	0.00	1.7	0.599E+02	1.09	1.54
4.26	7.19	0.00	1.7	0.593E+02	1.11	1.55
4.39	7.31	0.00	1.7	0.587E+02	1.12	1.57
4.51	7.43	0.00	1.7	0.581E+02	1.13	1.58
4.64	7.55	0.00	1.7	0.576E+02	1.15	1.59
4.77	7.67	0.00	1.8	0.570E+02	1.16	1.61
4.90	7.79	0.00	1.8	0.564E+02	1.17	1.62
5.03	7.91	0.00	1.8	0.559E+02	1.19	1.63
5.16	8.03	0.00	1.8	0.554E+02	1.20	1.65
5.30	8.14	0.00	1.8	0.548E+02	1.21	1.66
5.43	8.26	0.00	1.8	0.543E+02	1.23	1.67
5.57	8.38	0.00	1.9	0.538E+02	1.24	1.69
5.70	8.50	0.00	1.9	0.533E+02	1.25	1.70
5.84	8.62	0.00	1.9	0.529E+02	1.27	1.71
5.98	8.74	0.00	1.9	0.524E+02	1.28	1.73
6.12	8.86	0.00	1.9	0.519E+02	1.29	1.74
6.26	8.98	0.00	1.9	0.515E+02	1.31	1.75
6.41	9.09	0.00	2.0	0.510E+02	1.32	1.76
6.55	9.21	0.00	2.0	0.506E+02	1.33	1.78
6.70	9.33	0.00	2.0	0.501E+02	1.34	1.79
6.84	9.45	0.00	2.0	0.497E+02	1.36	1.80
6.99	9.57	0.00	2.0	0.493E+02	1.37	1.82
7.14	9.69	0.00	2.0	0.489E+02	1.38	1.83
7.29	9.81	0.00	2.1	0.485E+02	1.40	1.84
7.44	9.93	0.00	2.1	0.481E+02	1.41	1.86
7.59	10.05	0.00	2.1	0.477E+02	1.42	1.87
7.74	10.16	0.00	2.1	0.473E+02	1.44	1.88
7.90	10.28	0.00	2.1	0.469E+02	1.45	1.90
8.05	10.40	0.00	2.1	0.465E+02	1.46	1.91

8.21	10.52	0.00	2.2	0.462E+02	1.48	1.92
8.37	10.64	0.00	2.2	0.458E+02	1.49	1.94
8.53	10.76	0.00	2.2	0.454E+02	1.50	1.95
8.69	10.88	0.00	2.2	0.451E+02	1.52	1.96
8.85	11.00	0.00	2.2	0.447E+02	1.53	1.97
9.01	11.11	0.00	2.3	0.444E+02	1.54	1.99
9.18	11.23	0.00	2.3	0.441E+02	1.56	2.00
9.34	11.35	0.00	2.3	0.437E+02	1.57	2.01
9.51	11.47	0.00	2.3	0.434E+02	1.58	2.03
9.68	11.59	0.00	2.3	0.431E+02	1.60	2.04
9.85	11.71	0.00	2.3	0.428E+02	1.61	2.05
10.01	11.83	0.00	2.4	0.425E+02	1.62	2.07
10.19	11.95	0.00	2.4	0.422E+02	1.64	2.08
10.36	12.06	0.00	2.4	0.419E+02	1.65	2.09
10.53	12.18	0.00	2.4	0.416E+02	1.66	2.11
10.71	12.30	0.00	2.4	0.413E+02	1.67	2.12
10.88	12.42	0.00	2.4	0.410E+02	1.69	2.13
11.06	12.54	0.00	2.5	0.407E+02	1.70	2.14
11.24	12.66	0.00	2.5	0.404E+02	1.71	2.16
11.42	12.78	0.00	2.5	0.401E+02	1.73	2.17
11.60	12.90	0.00	2.5	0.398E+02	1.74	2.18
11.78	13.01	0.00	2.5	0.396E+02	1.75	2.20
11.96	13.13	0.00	2.5	0.393E+02	1.77	2.21
12.14	13.25	0.00	2.6	0.390E+02	1.78	2.22
12.33	13.37	0.00	2.6	0.388E+02	1.79	2.24
12.51	13.49	0.00	2.6	0.385E+02	1.81	2.25
12.70	13.61	0.00	2.6	0.383E+02	1.82	2.26
12.89	13.73	0.00	2.6	0.380E+02	1.83	2.28
13.08	13.85	0.00	2.6	0.378E+02	1.85	2.29
13.27	13.97	0.00	2.7	0.375E+02	1.86	2.30
13.46	14.08	0.00	2.7	0.373E+02	1.87	2.32
13.66	14.20	0.00	2.7	0.371E+02	1.89	2.33
13.85	14.32	0.00	2.7	0.368E+02	1.90	2.34

Cumulative travel time = 13. sec

Some concentration build-up near bank/shore due to recirculation effects.
Find concentration and thickness values for the RECIRCULATION REGION
at end of MOD329!

END OF MOD317: WEAKLY DEFLECTED JET (3-D) WITH LEESIDE RECIRCULATION ZONE

BEGIN MOD327: STRONGLY DEFLECTED JET (3-D) WITH LEESIDE RECIRCULATION ZONE

Profile definitions:
BV = Gaussian 1/e (37%) vertical thickness
BH = Gaussian 1/e (37%) horizontal half-width, normal to trajectory
S = hydrodynamic centerline dilution
C = centerline concentration (includes reaction effects, if any)

X	Y	Z	S	C	BV	BH
13.85	14.32	0.00	2.7	0.368E+02	4.56	5.62
15.57	14.77	0.00	2.9	0.349E+02	4.69	5.76
17.29	14.98	0.00	2.9	0.341E+02	4.76	5.82
19.02	15.13	0.00	3.0	0.335E+02	4.80	5.86
20.74	15.25	0.00	3.0	0.331E+02	4.84	5.90
22.46	15.35	0.00	3.1	0.327E+02	4.87	5.93
24.18	15.44	0.00	3.1	0.324E+02	4.90	5.95
25.91	15.52	0.00	3.1	0.321E+02	4.92	5.98
27.63	15.60	0.00	3.1	0.318E+02	4.94	6.00
29.35	15.66	0.00	3.2	0.316E+02	4.96	6.02
31.07	15.73	0.00	3.2	0.314E+02	4.98	6.04
32.80	15.79	0.00	3.2	0.312E+02	5.00	6.06
34.52	15.84	0.00	3.2	0.310E+02	5.02	6.07
36.24	15.89	0.00	3.2	0.308E+02	5.03	6.09
37.96	15.94	0.00	3.3	0.307E+02	5.05	6.10
39.69	15.99	0.00	3.3	0.305E+02	5.06	6.12
41.41	16.04	0.00	3.3	0.303E+02	5.08	6.13
43.13	16.08	0.00	3.3	0.302E+02	5.09	6.14
44.85	16.12	0.00	3.3	0.301E+02	5.10	6.15
46.58	16.16	0.00	3.3	0.299E+02	5.11	6.17
48.30	16.20	0.00	3.4	0.298E+02	5.13	6.18
50.02	16.24	0.00	3.4	0.297E+02	5.14	6.19
51.74	16.28	0.00	3.4	0.296E+02	5.15	6.20
53.47	16.31	0.00	3.4	0.295E+02	5.16	6.21
55.19	16.35	0.00	3.4	0.294E+02	5.17	6.22
56.91	16.38	0.00	3.4	0.293E+02	5.18	6.23
58.63	16.41	0.00	3.4	0.292E+02	5.19	6.24
60.36	16.45	0.00	3.4	0.291E+02	5.20	6.25

62.08	16.48	0.00	3.5	0.290E+02	5.21	6.26
63.80	16.51	0.00	3.5	0.289E+02	5.22	6.27
65.52	16.54	0.00	3.5	0.288E+02	5.23	6.28
67.25	16.57	0.00	3.5	0.287E+02	5.24	6.29
68.97	16.60	0.00	3.5	0.286E+02	5.24	6.29
70.69	16.62	0.00	3.5	0.285E+02	5.25	6.30
72.41	16.65	0.00	3.5	0.284E+02	5.26	6.31
74.14	16.68	0.00	3.5	0.284E+02	5.27	6.32
75.86	16.70	0.00	3.5	0.283E+02	5.28	6.33
77.58	16.73	0.00	3.5	0.282E+02	5.28	6.33
79.30	16.75	0.00	3.6	0.281E+02	5.29	6.34
81.03	16.78	0.00	3.6	0.281E+02	5.30	6.35
82.75	16.80	0.00	3.6	0.280E+02	5.31	6.36
84.47	16.83	0.00	3.6	0.279E+02	5.31	6.36
86.19	16.85	0.00	3.6	0.278E+02	5.32	6.37
87.92	16.88	0.00	3.6	0.278E+02	5.33	6.38
89.64	16.90	0.00	3.6	0.277E+02	5.34	6.38
91.36	16.92	0.00	3.6	0.277E+02	5.34	6.39
93.08	16.94	0.00	3.6	0.276E+02	5.35	6.40
94.81	16.97	0.00	3.6	0.275E+02	5.36	6.40
96.53	16.99	0.00	3.6	0.275E+02	5.36	6.41
98.25	17.01	0.00	3.6	0.274E+02	5.37	6.42
99.97	17.03	0.00	3.7	0.273E+02	5.38	6.42
101.70	17.05	0.00	3.7	0.273E+02	5.38	6.43
103.42	17.07	0.00	3.7	0.272E+02	5.39	6.44
105.14	17.09	0.00	3.7	0.272E+02	5.39	6.44
106.86	17.11	0.00	3.7	0.271E+02	5.40	6.45
108.59	17.13	0.00	3.7	0.271E+02	5.41	6.45
110.31	17.15	0.00	3.7	0.270E+02	5.41	6.46
112.03	17.17	0.00	3.7	0.270E+02	5.42	6.46
113.75	17.19	0.00	3.7	0.269E+02	5.42	6.47
115.48	17.21	0.00	3.7	0.269E+02	5.43	6.48
117.20	17.23	0.00	3.7	0.268E+02	5.43	6.48
118.92	17.25	0.00	3.7	0.268E+02	5.44	6.49
120.64	17.26	0.00	3.7	0.267E+02	5.45	6.49
122.37	17.28	0.00	3.8	0.267E+02	5.45	6.50
124.09	17.30	0.00	3.8	0.266E+02	5.46	6.50
125.81	17.32	0.00	3.8	0.266E+02	5.46	6.51
127.53	17.33	0.00	3.8	0.265E+02	5.47	6.51
129.26	17.35	0.00	3.8	0.265E+02	5.47	6.52
130.98	17.37	0.00	3.8	0.264E+02	5.48	6.52
132.70	17.39	0.00	3.8	0.264E+02	5.48	6.53
134.42	17.40	0.00	3.8	0.263E+02	5.49	6.53
136.15	17.42	0.00	3.8	0.263E+02	5.49	6.54
137.87	17.44	0.00	3.8	0.262E+02	5.50	6.54
139.59	17.45	0.00	3.8	0.262E+02	5.50	6.55
141.31	17.47	0.00	3.8	0.262E+02	5.51	6.55
143.04	17.49	0.00	3.8	0.261E+02	5.51	6.56
144.76	17.50	0.00	3.8	0.261E+02	5.52	6.56
146.48	17.52	0.00	3.8	0.260E+02	5.52	6.57
148.20	17.53	0.00	3.8	0.260E+02	5.53	6.57
149.93	17.55	0.00	3.9	0.260E+02	5.53	6.58
151.65	17.56	0.00	3.9	0.259E+02	5.54	6.58
153.37	17.58	0.00	3.9	0.259E+02	5.54	6.59
155.09	17.59	0.00	3.9	0.258E+02	5.54	6.59
156.82	17.61	0.00	3.9	0.258E+02	5.55	6.59
158.54	17.62	0.00	3.9	0.258E+02	5.55	6.60
160.26	17.64	0.00	3.9	0.257E+02	5.56	6.60
161.98	17.65	0.00	3.9	0.257E+02	5.56	6.61
163.71	17.67	0.00	3.9	0.256E+02	5.57	6.61
165.43	17.68	0.00	3.9	0.256E+02	5.57	6.62
167.15	17.70	0.00	3.9	0.256E+02	5.58	6.62
168.87	17.71	0.00	3.9	0.255E+02	5.58	6.62
170.60	17.73	0.00	3.9	0.255E+02	5.58	6.63
172.32	17.74	0.00	3.9	0.255E+02	5.59	6.63
174.04	17.75	0.00	3.9	0.254E+02	5.59	6.64
175.76	17.77	0.00	3.9	0.254E+02	5.60	6.64
177.49	17.78	0.00	3.9	0.254E+02	5.60	6.65
179.21	17.79	0.00	3.9	0.253E+02	5.61	6.65
180.93	17.81	0.00	4.0	0.253E+02	5.61	6.65
182.65	17.82	0.00	4.0	0.253E+02	5.61	6.66
184.38	17.83	0.00	4.0	0.252E+02	5.62	6.66
186.10	17.85	0.00	4.0	0.252E+02	5.62	6.67

Cumulative travel time = 1280. sec

Some concentration build-up near bank/shore due to recirculation effects.
Find concentration and thickness values for the RECIRCULATION REGION
at end of MOD329!

```
END OF MOD327: STRONGLY DEFLECTED JET (3-D) WITH LEESIDE RECIRCULATION ZONE
------------------------------------------------------------------------------
------------------------------------------------------------------------------
BEGIN MOD329: STRONGLY DEFLECTED PLUME WITH LEESIDE RECIRCULATION ZONE

 This flow region is INSIGNIFICANT in spatial extent and will be by-passed.

 The near-shore RECIRCULATION REGION extends back to the discharge location:
    Concentration C within that region:        0.126E+02
    Layer thickness BV within that region:     5.62

END OF MOD329: STRONGLY DEFLECTED PLUME WITH LEESIDE RECIRCULATION ZONE
------------------------------------------------------------------------------
------------------------------------------------------------------------------
** End of NEAR-FIELD REGION (NFR) **
------------------------------------------------------------------------------

The initial plume WIDTH values in the next far-field module will be
  CORRECTED by a factor  0.65 to conserve the mass flux in the far-field!
------------------------------------------------------------------------------
BEGIN MOD341: BUOYANT AMBIENT SPREADING

 Plume is ATTACHED to RIGHT bank/shore.
   Plume width is now determined from RIGHT bank/shore.
```

Appendix 9: USEPA R6 Validation Worksheets

EPA Region 6
Data Review and Validation Requirements
Dredged Material Disposal Evaluation

Project: Houston Ship Channel Expansion Channel Improvement - North of Morgan's Point

Project Initiation Date: 2 October 2018

Project Sampling Dates:

Begin: 2 October 2018

End: 6 October 2018

Final Report Date: 22 May 2019

Final Review Date: 22 May 2019

I certify the review in this document conforms to all applicable regulatory and project-specific requirements.

QA Officer Jennifer Anderson

Project Review

The following sections must be completed prior to field sampling or laboratory analysis:

The SAP/QAPP was prepared and submitted for approval by the Corps of Engineers District Office and EPA Region 6.

Submitted by:
Date submitted:

The SAP/QAPP was approved by the Corps of Engineers District Office and EPA Region 6.

Approved by:

Any deviations from District-approved protocols for sampling or analysis were clearly stated to the District and approved by the District office and EPA Region 6.

Laboratory Information

Use one sheet for each laboratory that will perform analytical work for this project.

Laboratory Name/Identification: CEERD-EL-EPC (ERDC)

Is lab NELAC certified? Yes/No If Yes, please supply certification number N

Can lab meet the QC requirements below as specified in the SAP/QAPP?

Yes/No	
Y	Analytical requirement
Y	Instrumentation
Y	MDL's
Y	Precision and accuracy
Y	Required turnaround time

Note below any requirements the laboratory is unable to meet:

Our subcontracted labs are NELAP certified. We consulted with each lab in advance to ensure that the objectives and limits found in the SAP could be met.

Laboratory Information

Use one sheet for each laboratory that will perform analytical work for this project.

Laboratory Name/Identification: Air Water & Soil Laboratories, Inc.

Is lab NELAC certified? (Yes)/No If Yes, please supply certification number 460021

Can lab meet the QC requirements below as specified in the SAP/QAPP?

Yes/No	
Y	Analytical requirement
Y	Instrumentation
Y	MDL's
Y	Precision and accuracy
Y	Required turnaround time

Note below any requirements the laboratory is unable to meet.

Laboratory Information

Use one sheet for each laboratory that will perform analytical work for this project.

Laboratory Name/Identification: Alpha Analytical

Is lab NELAC certified? Yes/No If Yes, please supply certification number DOD (L2474) TX (T104704419)

Can lab meet the QC requirements below as specified in the SAP/QAPP?

Yes/No	
Y	Analytical requirement
Y	Instrumentation
Y	MDL's
Y	Precision and accuracy
Y	Required turnaround time

Note below any requirements the laboratory is unable to meet.

Sample Custody

Was all required information on the chain-of-custody form:

(Yes/No)	
Y	Did chain of custody forms accompany samples to subcontract lab?
Y	Is the project identification on the chain of custody?
N	Are the analyses requested printed on the sample containers?
Y	Were all samples correctly identified?
↓	Were the analyses correctly identified on the chain of custody or an attached document listed on the chain of custody?
↓	Were sample dates and times listed on the chain of custody?
↓	Were the chains of custody signed by both the relinquisher and receiver of the samples?
N	Was the carrier identified on the chain of custody?
↓	If more than one chain of custody was needed for samples, are the chains of custody clearly numbered?
↓	Were samples packed on wet ice, with an expected receipt temperature of 4 ± 2°C?
N	Were any sample conditions or irregularities (broken bottles, improper temperature) noted on the chain of custody or accompanying paperwork?
Y	Was the chain of custody submitted as part of the report to the primary contractor?
↓	Were all requested analyses performed?
↓	Was adequate sample volume provided to the contractor lab?
↓	If any anomalous behavior of the samples was found, was it noted in the lab case narrative?

Additional sample custody issues or deficiencies:

Analytical Review Summary

Were all raw data included in the final report?

(Yes/No)

~	Prep logs
	Analytical logs
	Data reduction logs
↓	Calculations
Y	Data report
Y	QC Package

Verify that samples were prepared according to the method specified.

	10% check
Y	100% check

Verify that samples were analyzed according to the method specified.

	10% check
	100% check

Verify that data were properly transferred from run to data report.

	10% check
Y	100% check

Verify that QC was calculated and within limits and complete the QC forms provided in this package.

	10% check
Y	100% check

Additional data quality issues:

List of Acronyms

CCV	continuing calibration verification
IC	initial calibration
ICB	initial calibration blank
ICV	initial calibration verification
IS	internal standard
LCS/DLCS	laboratory control sample/duplicate laboratory control sample
LDR	linear dynamic range
LFB	laboratory fortified blank
MB	method blank
MDL	method detection limit
MN	*Macoma nasuta*
MS/MSD	matrix spike/matrix spike duplicate
NV	*Neanthes virens*
RL	reporting limit
SAP/QAPP	Sampling and Analysis Plan/Quality Assurance Project Plan
RIA	EPA Region 6 - Regional Implementation Manual
SRM	standard reference material

Work Order: 18J0402

Project Identification: ~~HSC-SMP~~ HSC-NMP
Reviewed by: Jenifer Nefelaev
Review Date: 5/21/19

Batches:
B18K112 (6020)
B18K187 (6020)
B18J213 (6010)
B18J233 (7474)
B18K112 (7199M)

Parameter: Metals (e.g. Silver, Arsenic)
List Metals Analyzed: CrVI, CrIII, Se, Sb, Ag, Ba, Be, Cd, Cr(Total), Cu, Pb, Ni, Ag, Th, Zn, Hg, Sb

Matrix: ☑ Sediment ☐ Water/Elutriate ☐ Tissue

Analytical Method Used: USEPA 6020, 6010, 7474, 7199M

QC Measurement	Frequency	Acceptance Criteria	Criteria Met (Y/N)	Review Comments
MB	1 per 20 samples or 1 per batch up to 20 samples	No analyte should be detected > RL	N Y	B18K112-BLK1 Ag 0.192 mg/kg RL=0.1 mg/kg B18K087-BLK1 Ba 2.4 mg/kg RL=0.1 mg/kg For the rest of the batches.
MS/MSD	1 set per 20 samples or per batch 30% RSD for precision	70 - 130% for spike limits	N Y	B18K112-MSD1 Sb 54.4%. B18L042-MSD1 Cr(VI) 0.48%. RPD 97.5% B18K112-MS1 Sb 55.3%. B18L042-MSD2 Cr(VI) 23.6%. RPD B18L042-MS1 Cr(VI) 1.21%. B18L042-MS2 Cr(VI) 23.8%. For the rest of the batches
Duplicate	1 per 20 samples or 1 per batch up to 20 samples	30% RSD for precision	N Y	B18K087-DUP1 Se-46.1%. B18K112-DUP1 Ag RPD 33.7%. For the rest of the batches
SRM	1 per 20 samples or 1 per batch up to 20 samples	70 - 130% Recovery	N Y	B18K B18J233-SRM1 Hg ~~170~~ 173%. For the rest of the batches
LCS/LFB	1 per 20 samples or 1 per batch up to 20 samples	70 - 130% Recovery	Y	For all batches

Project Identification: HSC-NMP
Reviewed by: Jennifer Nakhaev
Review Date: 5/21/19

Parameter: Metals (e.g. Silver, Arsenic)

List Metals Analyzed:

Matrix: ☑ Sediment ☐ Water/Elutriate ☐ Tissue

Analytical Method Used:

ICV	Immediately following calibration curve	90 - 110% Recovery	Y	For all batches
CCV	Minimum - check calibration at middle and end of each batch or 1 per 10 analyses, whichever is greater	90 - 110% Recovery	N Y	B18K087-~~CCV1~~ CCV4 Se ~~RPD 46.1%~~ 89.1%. B18K112-CCV2 Ag 88.3%. " -CCV3 Ag 86.6%. For the rest of the batches
LDR	Verify LDR once per quarter for ICP analyses and one time for mercury analysis		Y	For ~~the rest~~ all of the batches
IC	Verify initial calibration for AA and mercury analysis performed daily	cc > 0.9950 for all calibrations	Y	For all of the batches

Project Identification: HSC-NMP
Reviewed by: Jennifer McLaren
Review Date: 5/21/19

Parameter: Metals (e.g. Silver, Arsenic)

List Metals Analyzed:

Matrix: ☑ Sediment ☐ Water/Elutriate ☐ Tissue

Analytical Method Used:

MDL	Verify MDL study once per year for each analyte of interest	Updated annually	Y	For all of the batches
ICB	Immediately after initial calibration	No analyte should be detected > RL	Y	For all of the batches

Work Order: 18J0401 Site Wat~~er~~

Site Waters Batches:
B18K085 (6020)
B18J140 (7474)
B18K086 (6020)
B18K100 (7010)
B18L036 (7199M)

Elutriate Batches:
B18K085 (6020)
B18K016 (7474)
B18K101 (7010)
B18L043 (7199M)

Project Identification: HSC-NMP
Reviewed by: Jennifer Nekhaev
Review Date: 5/21/19

Parameter: Metals (e.g. Silver, Arsenic)

List Metals Analyzed: Sb, As, Ba, Be, Cd, Cr(total), Cu, Pb, Ni, Ag, Th, Zn, Cr(VI), Cr III, Hg, Se

Matrix: ☐ Sediment ☑ Water/Elutriate ☐ Tissue

Analytical Method Used: USEPA 6020, 6010, 7474, 7199M

QC Measurement	Frequency	Acceptance Criteria	Criteria Met (Y/N)	Review Comments
MB	1 per 20 samples or 1 per batch up to 20 samples	No analyte should be detected > RL	Y	For all batches
MS/MSD/MST	1 set per 20 samples or per batch	70 - 130% for spike limits	N	B18K085-M502 Zn 57.9%
		30% RSD for precision	Y	For all other batches
Duplicate	1 per 20 samples or 1 per batch up to 20 samples	30% RSD for precision	N	~~B18K085-DUP1~~ B18K086-DUP1 Sb 72.3>RPD
			Y	For all ~~other~~ batches
SRM	1 per 20 samples or 1 per batch up to 20 samples	70 - 130% Recovery	Y	For all batches
LCS/LFB	1 per 20 samples or 1 per batch up to 20 samples	70 - 130% Recovery	Y	For all batches

Project Identification: HSC - MMP
Reviewed by: Jenifer Netcher
Review Date: 5/21/19

Parameter: Metals (e.g. Silver, Arsenic)

List Metals Analyzed:

Matrix: ☐ Sediment ☑ Water/Elutriate ☐ Tissue

Analytical Method Used: USEPA 6020, 6010, 7474

ICV	Immediately following calibration curve	90 - 110% Recovery	Y	For all batches
CCV	Minimum - check calibration at middle and end of each batch or 1 per 10 analyses, whichever is greater	90 - 110% Recovery	Y	For all batches
LDR	Verify LDR once per quarter for ICP analyses and one time for mercury analysis		Y	For all batches
IC	Verify initial calibration for AA and mercury analysis performed daily	cc > 0.9950 for all calibrations	Y	For all batches

Project Identification: HSC-NMP

Reviewed by: Jennifer Nietchaev

Review Date: 5/21/19

Parameter: Metals (e.g. Silver, Arsenic)

List Metals Analyzed: ~~USEPA~~

Matrix: ☐ Sediment ☑ Water/Elutriate ☐ Tissue

Analytical Method Used: USEPA 6020, 6010, 7474

MDL	Verify MDL study once per year for each analyte of interest	Updated annually	Y	for all batches
ICB	Immediately after initial calibration	No analyte should be detected > RL		for all batches

HN pest sed

Project Identification: Houston North

Reviewed by: Allyson Wooley

Review Date: 5/18/19

Parameter: ☑ PAHs & PCP ☒ Pesticides ☐ PCBs

Matrix: ☒ Sediment ☐ Water/Elutriate ☐ Tissue

Analytical Method Used: 8081 18J0402 ~~B18K~~ B18J145 18K0025

QC Measurement	Frequency	Acceptance Criteria	Criteria Met (Y/N)	Review Comments
MB	1 per 20 samples or 1 per batch up to 20 samples	No analyte should be detected > RL	Y	
MS/MSD/MST BS, BSD	1 set per 20 samples or per batch	50 - 150% for spike limits 30% for precision	N	endrin aldehyde: BS1 25.4%, BSD1 42.3%, rpd = 50 endosulfan II: MS1 22.6%, MSD1 22.7% b BHC: unable to quantify due to interference peaks
Duplicate	1 per 20 samples or 1 per batch up to 20 samples	30% RSD for precision	~~Y~~ N	44DDE: rpd 47.1
SRM	1 per 20 samples or 1 per batch up to 20 samples	Within limits specified by provider	Y	
ICV	Immediately following calibration curve	80 - 120% Recovery	N	Toxaphene ICV pattern does not match pattern of cal stds, no usable data
CCV	At the beginning of every 12 hours of analysis	<15% Difference	N	See next page

Project Identification: Houston North

Reviewed by: Allyson Wooley

Review Date: 5/18/19

Parameter: ☑ PAHs & PCP ☒ Pesticides ☐ PCBs

Matrix: ☒ Sediment ☐ Water/Elutriate ☐ Tissue

Analytical Method Used: 8081

Surrogates	Every sample	30 - 150%	N	pcb 198: 159% 18J0402-02
Internal Standard	Every sample	30 - 150%	NA	
IC	Verify after each initial calibration	<20% RSD for each analyte	Y	
MDL	Verify MDL study once per year for each analyte of interest	Updated annually	Y	
ICB	Immediately after initial calibration	No analyte should be detected > RL	Y	

CCV 3: 44DDT 117%
aBHC 120%
dBHC 121%
dieldrin 117%
endosulfan I 117%
endosulf sulfate 116%
endrin 121%
gBHC 121%
g chlordane 116%
heptachlor 119%

CCV6: endosulfan I 117%

CCV8: aBHC 120%
achlordane 118%
dBHC 118%
dieldrin 116%
endosulfan I 126%
gBHC 123%
t nonachlor 118%

Project Identification: Houston North

Reviewed by: Allyson Wooley

Review Date: 5/18/19

Parameter: ☑ PAHs & PCP ☒ Pesticides ☐ PCBs

Matrix: ☑ Sediment ☒ Water/Elutriate ☐ Tissue

Analytical Method Used: 8081 18J0401 18J0403 B18J159, B18J226 18K0002

QC Measurement	Frequency	Acceptance Criteria	Criteria Met (Y/N)	Review Comments
MB	1 per 20 samples or 1 per batch up to 20 samples	No analyte should be detected > RL	Y	
MS/MSD/MST	1 set per 20 samples or per batch	50 - 150% for spike limits 30% for precision	Y	
Duplicate	1 per 20 samples or 1 per batch up to 20 samples	30% RSD for precision	Y	
SRM	1 per 20 samples or 1 per batch up to 20 samples	Within limits specified by provider	N	
ICV	Immediately following calibration curve	80 - 120% Recovery	N	dBHC 127%. No toxaphene ICV, pattern of 2nd source standard did not match pattern of calibration stds.
CCV	At the beginning of every 12 hours of analysis	<15% Difference	N	CCV7: 44DDT 83.3%, oxychlordane 82.9%.

Project Identification: Houston North

Reviewed by: Allyson Wooley

Review Date: 5/18/19

Parameter: ☑ PAHs & PCP ☒ Pesticides ☐ PCBs

Matrix: ☑ Sediment ☒ Water/Elutriate ☐ Tissue

Analytical Method Used:

Surrogates	Every sample	30 - 150%	Y	
Internal Standard	Every sample	30 - 150%	NA	
IC	Verify after each initial calibration	<20% RSD for each analyte	Y	
MDL	Verify MDL study once per year for each analyte of interest	Updated annually	Y	
ICB	Immediately after initial calibration	No analyte should be detected > RL	Y	

HW conf scd

Project Identification: Houston North

Reviewed by: Allyson Wooley

Review Date: 5/18/19

Parameter: ☑ PAHs & PCP ☐ Pesticides ☒ PCBs

Matrix: ☒ Sediment ☐ Water/Elutriate ☐ Tissue

Analytical Method Used: 8082 18J0402

QC Measurement	Frequency	Acceptance Criteria	Criteria Met (Y/N)	Review Comments
MB	1 per 20 samples or 1 per batch up to 20 samples	No analyte should be detected > RL	Y	
MS/MSD/~~MST~~ BS, BSD	1 set per 20 samples or per batch	50 - 150% for spike limits 30% for precision	N	pcb 18, 44, 52 not determined, sample concentration greater than spike concentration for ms/msd ms3: pcb 28 @ 47.7%.
Duplicate	1 per 20 samples or 1 per batch up to 20 samples	30% RSD for precision	N	dup1 - pcb 28 rpd 52.2
SRM	1 per 20 samples or 1 per batch up to 20 samples	Within limits specified by provider	Y	
ICV	Immediately following calibration curve	80 - 120% Recovery	Y	
CCV	At the beginning of every 12 hours of analysis	<15% Difference	N	2456TMX: ccv8 122%, ccvJ 142%, ccvI 119% pcb8: ccvJ 114%.

Project Identification: Houston North

Reviewed by: Allyson Wooley

Review Date: 5/18/19

Parameter: ☑ PAHs & PCP ☐ Pesticides ☒ PCBs

Matrix: ☒ Sediment ☐ Water/Elutriate ☐ Tissue

Analytical Method Used: 8082 18J0402 B18J145 18K0025

Surrogates	Every sample	30 - 150%	N	2456TMX: BS3 14%, BSD3 10%.
Internal Standard	Every sample	30 - 150%	NA	
IC	Verify after each initial calibration	<20% RSD for each analyte	Y	
MDL	Verify MDL study once per year for each analyte of interest	Updated annually	Y	
ICB	Immediately after initial calibration	No analyte should be detected > RL	Y	

HN conc
H2O

Project Identification: Houston North
Reviewed by: Allyson Wooley
Review Date: 5/18/19

Parameter: ☑ PAHs & PCP ☐ Pesticides ☒ PCBs
Matrix: ☑ Sediment ☒ Water/Elutriate ☐ Tissue

Analytical Method Used: 8082 18J0403 18J0401

QC Measurement	Frequency	Acceptance Criteria	Criteria Met (Y/N)	Review Comments
MB	1 per 20 samples or 1 per batch up to 20 samples	No analyte should be detected > RL	Y	
MS/MSD~~/MST~~ BS, BSD	1 set per 20 samples or per batch	50 - 150% for spike limits 30% for precision	Y	
Duplicate	1 per 20 samples or 1 per batch up to 20 samples	30% RSD for precision	Y	
SRM	1 per 20 samples or 1 per batch up to 20 samples	Within limits specified by provider	N/A	not available
ICV	Immediately following calibration curve	80 - 120% Recovery	Y	
CCV	At the beginning of every 12 hours of analysis	<15% Difference	Y	

Project Identification: Houston North

Reviewed by: Allyson Wooley

Review Date: 5/18/19

Parameter: ☑ PAHs & PCP ☐ Pesticides ☒ PCBs

Matrix: ☑ Sediment ☒ Water/Elutriate ☐ Tissue

Analytical Method Used:

Surrogates	Every sample	30 - 150%	N	pcb 198: BS3 28.9%
Internal Standard	Every sample	30 - 150%	NA	
IC	Verify after each initial calibration	<20% RSD for each analyte	Y	
MDL	Verify MDL study once per year for each analyte of interest	Updated annually	Y	
ICB	Immediately after initial calibration	No analyte should be detected > RL	Y	

Work order: 18J0402

Batches:
WG1167101 (8270 SIM)
WG1167103 (8270-PCP)

Project Identification: HSC-NMP
Reviewed by: Jenifer Nakahara
Review Date: 5/21/19

Parameter: ☑ PAHs & PCP ☐ Pesticides ☐ PCBs
Matrix: ☑ Sediment ☐ Water/Elutriate ☐ Tissue

Analytical Method Used:

QC Measurement	Frequency	Acceptance Criteria	Criteria Met (Y/N)	Review Comments
MB	1 per 20 samples or 1 per batch up to 20 samples	No analyte should be detected > RL	Y	
MS/MSD/MST	1 set per 20 samples or per batch	50 - 150% for spike limits 30% for precision	N Y	WG1167101-4 MS naphthalene 46%. For the another batch
Duplicate	1 per 20 samples or 1 per batch up to 20 samples	30% RSD for precision	N	Duplicate was performed on the matrix spike
SRM	1 per 20 samples or 1 per batch up to 20 samples	Within limits specified by provider	N	replaced with LCS
ICV	Immediately following calibration curve	80 - 120% Recovery	Y	
CCV	At the beginning of every 12 hours of analysis	<15% Difference	Y	

Project Identification: HSC-NMP
Reviewed by: Jennifer Nothaer
Review Date: 5/21/19

Parameter: ☑ PAHs & PCP ☐ Pesticides ☐ PCBs
Matrix: ☑ Sediment ☐ Water/Elutriate ☐ Tissue

Analytical Method Used:

Surrogates	Every sample	30 - 150%	Y	
Internal Standard	Every sample	30 - 150%	Y	
IC	Verify after each initial calibration	<20% RSD for each analyte	Y	
MDL	Verify MDL study once per year for each analyte of interest	Updated annually	Y	
ICB	Immediately after initial calibration	No analyte should be detected > RL	Y	

Work Orders: 18J0401 Site Water
18J0403 Elutriate

Project Identification: HSC-NMP
Reviewed by: Jenifer Nettheim
Review Date: 5/21/19

Site Water Batches:
WG1167814 (8270-PCP)
WG1173490 (8270-PCP)
WG1167722 (PAH SIM)
WG1173002 (PAH SIM)

Elutriate Batches:
WG1175682 (8270-PCP)
WG1175786 (PAH SIM)

Parameter: ☑ PAHs & PCP ☐ Pesticides ☐ PCBs
Matrix: ☐ Sediment ☑ Water/Elutriate ☐ Tissue

Analytical Method Used:

QC Measurement	Frequency	Acceptance Criteria	Criteria Met (Y/N)	Review Comments
MB	1 per 20 samples or 1 per batch up to 20 samples	No analyte should be detected > RL	Y	
MS/MSD/MST	1 set per 20 samples or per batch	50 - 150% for spike limits 30% for precision	Y N	~~WG1175786-4 Acenaphthene 36%.~~ For all other batches WG1175786-4 Acenaphthene 36%. MS/MSD was not performed for PCP
Duplicate	1 per 20 samples or 1 per batch up to 20 samples	30% RPD for precision	N	
SRM	1 per 20 samples or 1 per batch up to 20 samples	Within limits specified by provider	N	replaced with LCS
ICV	Immediately following calibration curve	80 - 120% Recovery	Y	
CCV	At the beginning of every 12 hours of analysis	<15% Difference	Y	

Project Identification:

Reviewed by:

Review Date:

Parameter: ☑ PAHs & PCP ☐ Pesticides ☐ PCBs
Matrix: ☐ Sediment ☑ Water/Elutriate ☐ Tissue

Analytical Method Used:

Surrogates	Every sample	30 - 150%	N	WG11734490-1 PCP surrogate (phenol-d5) 23%. WG11734490-3 PCP surr (phenol-d5) 25%. WG11678143 PCP surrogate (phenol-d5) 28%. 1870401-01,-03,-04,-05,-06,-07,-08,-09,-10,-11,-13,-14 22%, 18%, 12%, 18%, 18%, 15%, 12%, 18%, 19%. WG11734490-2 PCP surrogate (phenol-d5) 24%. Phenol-d5 23%, 20%, 20%. 1870401-15 Phenol-d5 16%.
Internal Standard	Every sample	30 - 150%	Y	
IC	Verify after each initial calibration	<20% RSD for each analyte	Y	
MDL	Verify MDL study once per year for each analyte of interest	Updated annually	Y	
ICB	Immediately after initial calibration	No analyte should be detected > RL	Y	

WG1873403-02 Phenol-d5 28%. 1870403-08 Phenol-d5 25%. 1870403-12 Phenol-d5 26%.
" -03 " 22%. " -09 " 24%.
" -06 " 29%. " -10 " 26%.
" -07 " 26%. " -11 " 23%.