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# A Pilot Study of the Effects of Post-Hurricane Katrina Floodwater Pumping on the Chemistry and Toxicity of Violet Marsh Sediments

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**PURPOSE:** The Interagency Performance Evaluation Task Force (IPET) is investigating the environmental impacts of the failure of the hurricane protection system around New Orleans, Louisiana, during Hurricane Katrina. The study is needed to determine the extent to which Katrina floodwaters in the New Orleans area may have impacted wildlife habitat and other biological resources in surrounding areas. This technical note presents preliminary data regarding the effects of pumped floodwaters on sediment chemistry and benthic invertebrate toxicity near pumping stations that pumped floodwaters into marshes near Chalmette and Violet, Louisiana.

**BACKGROUND:** Hurricane Katrina came ashore along the Alabama, Mississippi, and Louisiana coasts on August 29, 2005, resulting in significant physical damage to infrastructure. As a result of the storm, levees were breached or overtopped, resulting in flooding of New Orleans and surrounding areas, including many areas in St. Bernard Parish. Within St. Bernard Parish, floodwaters in Chalmette and Violet, Louisiana, were pumped into the adjacent Violet Marsh. There are potential undesirable environmental impacts on the marsh ecosystem resulting from levee breaches and pumping activities. The primary environmental concerns are elevated salinity and chemical and biological contaminants. To address this concern, a pilot study was conducted after the storm to compare chemistry and toxicity in sediment samples at sites in the immediate vicinity of active and inactive (flooded during Katrina) pumping stations that discharge into Violet Marsh (Figure 1). The pilot study consisted of sampling benthic invertebrates and recording salinity measurements throughout Violet Marsh, which are addressed in Ray (2006) and Lin and Kleiss (2006), respectively, and collecting sediment samples for chemical and toxicological analysis, which is the subject of the study described herein. This technical note



## Key points...

**What effect did Hurricane Katrina floodwater pumping have on sediments in Violet Marsh, Louisiana? Did floodwater pumping result in elevated chemical concentrations or toxicity to benthic organisms? A pilot study was conducted to answer these questions. Samples were collected at four pump stations 3-1/2 months after Hurricane Katrina. The pilot study compared chemistry and toxicity in sediments at active and inactive pump stations. The study indicated the potential for adverse effects of chemicals on benthic organisms in Violet Marsh. Further studies are recommended to verify this potential; the information collected in the current study will be used to guide future investigations in Violet Marsh.**

**The Interagency Performance Evaluation Task Force (IPET) website can be accessed at: <https://ipet.wes.army.mil/>.**

describes a pilot study representing an initial effort to discern patterns in chemical contamination and toxicity of sediments at select pumping stations along Violet Marsh. This information will be used to guide potential future studies in the area.

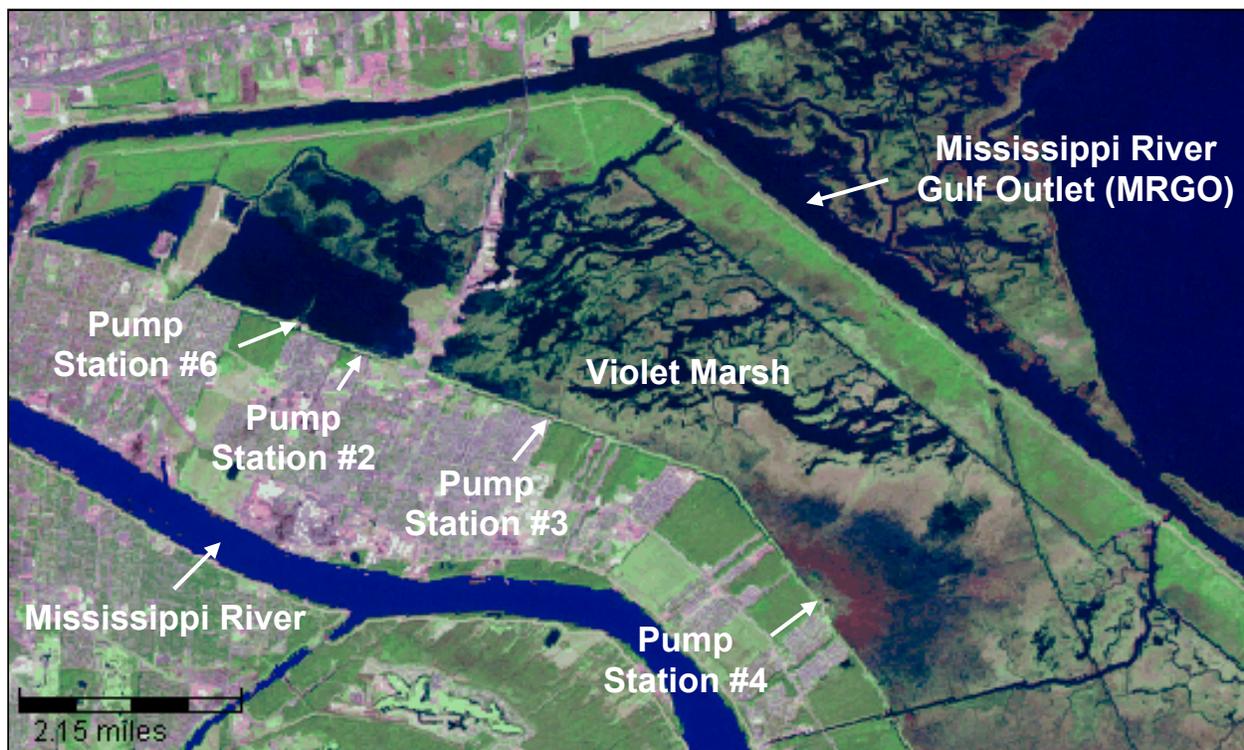


Figure 1. Aerial view of study area and pump station locations.

**STUDY AREA:** Sediment samples were collected on 13-14 December 2005, approximately 3-1/2 months after Hurricane Katrina made landfall. Four pumping stations located along the Back Protection Levee along the Forty Arpent Canal in Chalmette, Louisiana were chosen based on pumping activities after Hurricane Katrina (Figure 1). Pump Stations Meraux #4 and Jean Lafitte #6 were fully operational and pumped daily after the storm (Figures 2 and 3), whereas Pump Stations Guichard #2 and Bayou Villere #3 were selected because they were flooded during Katrina and were not operational during this time (Figures 4 and 5). Samples were collected within 50 m of the outfall from each pump station.

**METHODS:** One sediment sample was collected via aluminum boat or airboat at each pump station in water approximately 1 m deep using a pole-mounted Ekman dredge (232 cm<sup>2</sup>/sample). The top-mounted doors on the sampler were opened and the top 12-15 cm of sediment were removed with a pre-cleaned polyethylene spoon. Samples were placed in a pre-cleaned 2-liter polyethylene container and held on wet ice until transport. Samples were transported to laboratory facilities at the U.S. Army Engineer Research and Development Center (ERDC), Vicksburg, MS, where the samples were held at 4 °C until analysis.



Figure 2. Pump Station Meraux #4 sampling station (pumped).

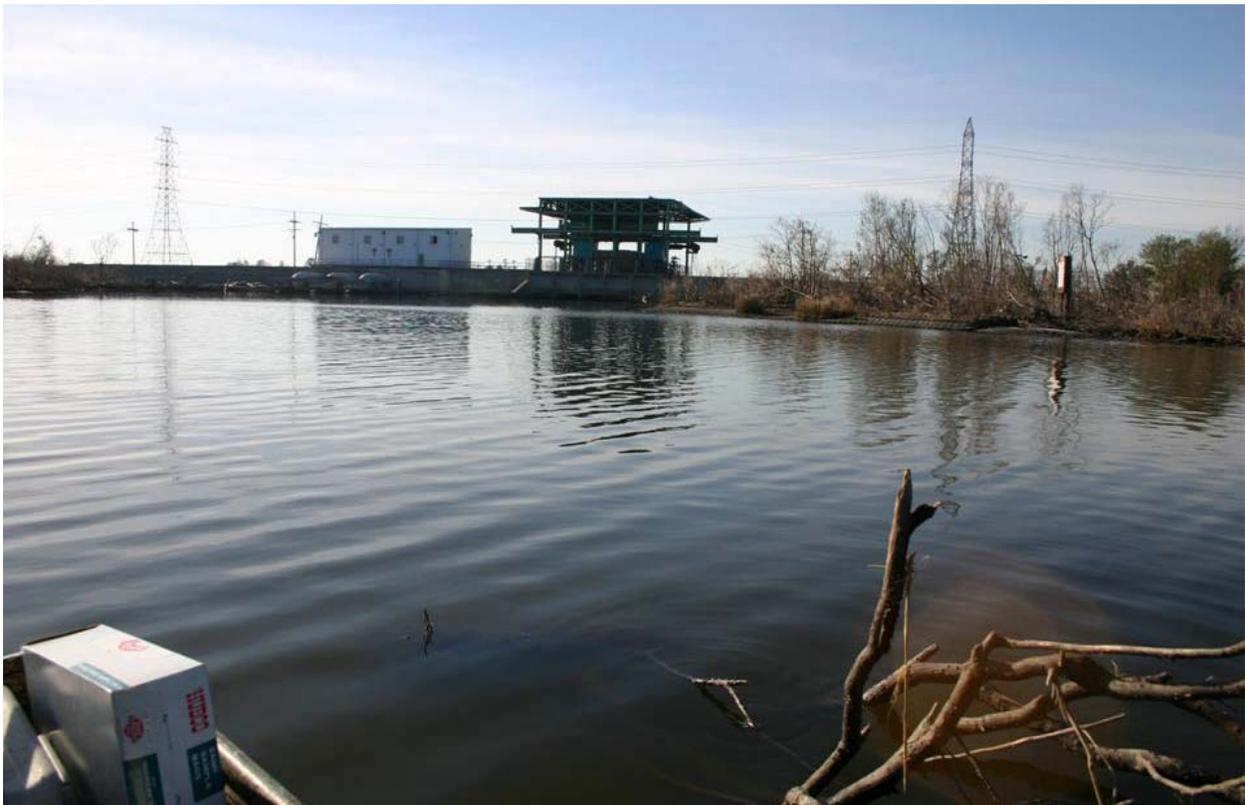


Figure 3. Pump Station Jean Lafitte #6 sampling station (pumped).



Figure 4. Pump Station Guichard #2 sampling station (did not pump).



Figure 5. Pump Station Bayou Villere #3 sampling station (did not pump).

**Chemistry.** Samples were prepared and analyzed for volatile organics, total petroleum hydrocarbons, polycyclic aromatic hydrocarbons, and metals using U.S. Environmental Protection Agency (USEPA) methods found in SW-846, *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods* (USEPA 1994) and updates. Each pump station sample was prepared and analyzed for the following parameters using the referenced methods or a slight modification. Samples were analyzed for volatile organic compounds (benzene, toluene, ethylbenzene, total xylenes and gasoline range organics (GRO)) using methods 5035 (Purge-and-Trap) and 8260B (Gas Chromatography/Mass Spectrometry (GC/MS)). These methods were modified to include the GRO GC/MS fingerprint by analyzing an unleaded gasoline standard. Samples analyzed for semi-volatile organic compounds (including diesel range organics (DRO) and oil range organics (ORO)) were prepared following method 3540C (Soxhlet Extraction) and analyzed using method 8270C (Gas Chromatography/Mass Spectrometry (GC/MS)). These methods were modified to include the DRO and ORO GC/MS fingerprints by analyzing diesel fuel and motor oil standards. Samples analyzed for metals were prepared using method 3050B (Acid Digestion) and quantified using method 6010B (Inductively Coupled Plasma-Atomic Emission Spectrometry). Samples for total organic carbon (TOC) analysis were prepared and quantified following a modification of method 9060A for sediment samples.

**Toxicity.** Whole sediment acute toxicity tests using the estuarine amphipod *Leptocheirus plumulosus* were conducted according to standard guidance (USEPA 1994). Experimental conditions are outlined in Table 1. Test sediments were stored in the dark at  $4 \pm 1$  °C and used in testing within eight days of collection. Sediments were thoroughly homogenized with a laboratory impeller mixer for five minutes prior to use and approximately 175 mL (2 cm depth) of each test sediment was added to each of five replicate test chambers (1-L beakers). Overlying water, 20 ‰ synthetic seawater (Crystal Sea<sup>®</sup> Marine Mix; Marine Enterprises International, Inc., Baltimore, MD, U.S.A.), was added and test chambers were allowed to equilibrate overnight. Test chambers were held under ambient light (16 hr light: 8 hr dark) and supplied trickle-flow aeration in a temperature ( $25.0 \pm 1.0$  °C) regulated water bath. At test initiation, *L. plumulosus* (500 – 750 µm) were obtained from ERDC in-house cultures and 20 amphipods were gently transferred randomly into each test chamber. Water quality measurements (temperature, dissolved oxygen, pH and salinity) were determined at test initiation and termination. Environmental chamber temperature (min/max) was monitored and recorded daily. Pore water ammonia was also measured in the bulk sediment using an ISE meter (Thermo Orion Electron Corp., Beverly, MA), equipped with a model 95-12 ammonia sensitive electrode (Thermo Orion Electron Corp., Beverly, MA). Animals were not fed during the test.

The test assessment endpoint was survival. Test sediments were assessed along with a performance control sediment (Sequim, WA, USA Lat. 48.0587 Long. -123.0235 and a reference sediment (Lake Pontchartrain, Louisiana, USA; Lat. -89.826389, Long. 30.220556; collected prior to Hurricane Katrina). Both performance control and reference sediments were collected from relatively pristine uncontaminated areas and have undergone rigorous biological and chemical analysis. For tests to be considered valid, at least 90 percent survival had to be observed in the performance control and overlying water quality (pH, temperature, dissolved oxygen) within the ranges specified by guidance (USEPA 1994). In order for a test sediment to be considered “toxic,” two criteria must be met; the survival in the test sediment must be statistically reduced compared to the reference sediment and the reduction must be greater than 20 percent of the reference survival value (USEPA/USACE 1998). Data normality (Kolmogorov-Smirnov test),

homogeneity (Levene's Test), and treatment differences ( $\alpha = 0.05$ ) compared to the reference sediment were determined using SigmaStat statistical software (SPSS, Chicago, IL). Survival data were arcsine-square root transformed and a simple t-test was used to determine if statistical differences existed between individual test sediments and the reference sediment.

<b>Table 1</b> <b><i>Leptocheirus plumulosus</i> test conditions</b>	
Test duration	10 d
Test type	Static non-renewal
Temperature	20-25°C
Salinity	20‰ (range 2-32)
Light quality (quantity)	Ambient laboratory (16 h light : 8 h dark)
Test chamber	1 L glass beaker
Sediment depth	2 cm
Age of test organisms	Mature 3-5 mm
Organisms per chamber	20
Replicates per treatment	5
Feeding regime	None
Test aeration	Trickle flow (< 100 bubbles / min)
Test acceptability criterion	≥ 90% survival in controls

## RESULTS

**Chemical Analysis.** Visual analysis of samples upon collection indicated that all four sediments were composed of primarily fine, unconsolidated material with substantial amounts of decaying vegetative matter. Grain size analysis of sediments confirmed the visual analysis (Table 2). Water quality measurements were taken at the water surface using a YSI Model 85 meter. Salinity at the sampling sites ranged between 11 and 12 ‰ and temperatures ranged from 12 °C to 15 °C. Dissolved oxygen concentrations at the surface were all at or above 100 percent saturation. A distinct petroleum odor was detected in sediment and an oily sheen was observed at the water surface during sediment sampling at Pump Station #4.

<b>Table 2</b> <b>Test sediment grain size analysis</b>			
<b>Treatment</b>	<b>Gravel (%)</b>	<b>Sand (%)</b>	<b>Fines (%)</b>
SC (control)	0	6.2	93.8
LP (reference)	NT	NT	NT
PS-2	0	9.3	90.7
PS-3	0	6.5	93.5
PS-4	0	17.9	82.1
PS-6	0	2.3	97.7
NT = Not tested.			

Volatile organic compounds and GRO were below detection limits for these compounds, 15 to 40 ug/kg and 250 to 730 ug/kg, respectively (Table 3). Results from semi-volatile organics analyses show detectable levels of ORO in all samples. Trace levels of DRO were detected in

Pump Station #4. Concentrations in the µg/kg range of four to six PAHs were detected in Pump Station #2 and #4 sediments. Bis(2-ethylhexyl)phthalate was detected in all four samples, as well as the method blank. Results from metals analyses show detectable levels, except for antimony and thallium, in all pump station samples. Slightly higher levels of lead were detected at Pump Stations #2 and #6 than at Pump Stations #3 and #4. Results from TOC analyses showed the highest levels in Pump Stations #2 and #6 with lesser values in Pump Stations #3 and #4.

<b>Table 3 Summary of hits at each pump station</b>				
<b>Analyte</b>	<b>Pumping Station #2</b>	<b>Pumping Station #3</b>	<b>Pumping Station #4</b>	<b>Pumping Station #6</b>
<b>Oil Range Organics</b>	<b>Result (mg/kg)</b>	<b>Result (mg/kg)</b>	<b>Result (mg/kg)</b>	<b>Result (mg/kg)</b>
ORO (dry)	1300	1200	830	340 J
ORO (wet)	160	230	290	46 J
<b>Diesel Range Organics</b>	<b>Result (mg/kg)</b>	<b>Result (mg/kg)</b>	<b>Result (mg/kg)</b>	<b>Result (mg/kg)</b>
DRO (dry)	<790	<530	220 J	<720
DRO (wet)	<100	<98	78 J	<99
<b>Semivolatile Organics (BNA)</b>	<b>Result (ug/kg)</b>	<b>Result (ug/kg)</b>	<b>Result (ug/kg)</b>	<b>Result (ug/kg)</b>
Fluoranthene	1600 J	<5300	500 J	<7200
Pyrene	1300 J	<5300	500 J	<7200
Benzo(a)anthracene	<7900	<5300	300 J	<7200
Chrysene	<7900	<5300	400 J	<7200
Bis(2-ethylhexyl) phthalate	1400 J,B	1700 J,B	1500 J,B	1700 J,B
Benzo(b)fluoranthene	1000 J,I	<5300	600 J,I	<7200
Benzo(k)fluoranthene	I	<5300	I	<7200
Benzo(a)pyrene	<7900	<5300	300 J	<7200
<b>Metals</b>	<b>Result (mg/kg)</b>	<b>Result (mg/kg)</b>	<b>Result (mg/kg)</b>	<b>Result (mg/kg)</b>
Aluminum	20900	20800	15100	23400
Arsenic	12 B	9.6 B	9.1 B	12 B
Barium	119	120	180	118
Beryllium	0.99	1	1.2	1.1
Cadmium	2.1	1.7	1.7	2.1
Calcium	5080	4400	6150	5410
Chromium	34.2 B	53.2 B	21.4 B	32.1 B
Cobalt	9.2	11	14	10
Copper	59.2	58.7	31	42.9
Iron	26100	26200	20900	25800
Lead	89.7	181	27.2	52
Magnesium	9130	7700	6090	9540
Manganese	409	460	463	741
Nickel	32.2	46.1	32.9	30.5
Potassium	4960	4470	3160	5330
Selenium	2 J	1 J	1 J	2 J
Silver	0.6 J	<1	<1	0.2 J
Sodium	21700	12700	6410	21000
Vanadium	49.8	43.7	36	51.3
Zinc	287	165	139	325
<b>Total Organic Carbon</b>	<b>Result (mg/kg)</b>	<b>Result (mg/kg)</b>	<b>Result (mg/kg)</b>	<b>Result (mg/kg)</b>
TOC	100000	58000	35000	94000

J: Estimated concentration above method detection limit but below LRL.  
B: Compound also present in the method blank.  
I: Analytes reported as an isomeric pair due to insufficient baseline resolution.

**Toxicity Analysis.** *Leptocheirus plumulosus* in test vessels were sieved from sediment at the termination of the 10-day exposure period (Table 4). Test sediment was evaluated for total and un-ionized ammonia and determined to be suitable for testing without manipulations. Survival of amphipods in the control sediment from Sequim Bay, WA was above the 90-percent level required for test acceptability (Table 5). Sediments from Pump Station #4 resulted in significant reductions in amphipod survival as compared to the reference Lake Pontchartrain sediment. Sediment from Pump Stations #2, #3, and #6 did not result in significant toxicity to *L. plumulosus*.

<b>Table 4 Test sediment parameters</b>					
Sample Treatment	Sediment Moisture Content (%)	Pore Water			
		pH (SU)	Salinity (‰)	Total Ammonia (mg/L)	Un-ionized Ammonia (mg/L at 25°C)
SC (control)	54.3	7.18	6	17.5	0.15
LP (reference)	21.2	6.97	34	38.6	0.20
PS-2	76.1	7.00	15	19.2	0.11
PS-3	64.9	7.12	12	15.1	0.11
PS-4	35.9	7.28	12	15.1	0.16
PS-6	74.4	7.20	14	9.62	0.09

<b>Table 5 Results from 10-day whole sediment toxicity test using <i>Leptocheirus plumulosus</i>. Statistically significant reductions (asterisks) compared to the reference sediment (Lake Pontchartrain, LA) are indicated for each treatment</b>		
Treatment	Mean Percent Survival	Coefficient of Variation (%)
Negative Control (Sequim Bay, WA)	90 ± 4	3.9
Reference (Lake Pontchartrain, LA)	95 ± 7	7.4
PS-2	89 ± 4	4.7
PS-3	91 ± 7	7.2
PS-4	76 ± 8*	10.8
PS-6	97 ± 4	4.6

\*Sediment PS-4 was statistically significantly reduced compared to both the control and reference sediments using Dunnett's Method (one-way ANOVA) and a t-test. Guidance recommends using a t-test, comparing each test sediment individually to the reference.

## DISCUSSION

**Chemical Analysis.** Although the results from volatile organics analysis suggested the absence of most volatile compounds and GRO, GC/MS results from Pump Station #4 showed a rise in the chromatogram after the GRO fingerprint (hydrocarbons with carbon number greater than approximately C9) indicating higher molecular weight compounds were present in this sample. This observation is essentially *qualitative*, since GRO compounds are not calibrated past C9, but when used in conjunction with the semi-volatile chemical data, confirmed field observations that petroleum contaminants were present.

A low level of DRO (estimated concentration between the laboratory reporting limit and the method detection limit) was detected in sediments from Pump Station #4 but not detected in the other samples. Results show detectable levels of ORO in each sample with Pump Stations #2 and #3 containing the greatest amount. Since three of the four samples had comparable moisture content (Table 1), whereas the moisture content of Pump Station #4 was substantially lower, results for ORO were also calculated on a “wet-weight” basis. Results calculated on the “wet-weight” bases show Pump Station #4 having the highest concentration of ORO. The detectable levels of the PAHs found in sediments from Pump Stations #2 and #4 also indicated petroleum contamination. Low levels of bis(2-ethylhexyl) phthalate, a plasticizer, were found in field-collected sediments and quality control samples. It is likely that these are artifacts of the sampling, preparation, and analysis due to the ubiquitous use of plastics for containers. Results from metals analyses show similar concentrations of metals between the four samples. The results for TOC show the highest levels in Pump Stations #2 and #6 (10.0 and 9.4 percent, respectively) with lower concentrations in sediments from Pump Stations #3 and #4 (5.8 and 3.5 percent, respectively).

**Toxicity Analysis.** Toxicity and analytical chemistry results can be used to determine the potential impact of chemical contaminants in the floodwaters on benthic organisms in Violet Marsh. While the effects assessed using benthic toxicity tests and sediment chemistry are not predictive of all ecological impacts on a wetland, they can be used as sentinel indicators of adverse effects. Analytical chemistry results indicated elevated levels of petroleum-based organics (e.g., motor oil, diesel fuel, and polycyclic aromatic hydrocarbons) and some metals (e.g., lead). Coupled with toxicity results, these data indicate the potential for adverse effects through direct toxicity to benthic organisms and potential adverse impacts from bioaccumulation of organics and metals into the food-chain, especially in sediments in the vicinity of Pump Station #4.

**CONCLUSIONS:** The results of the current pilot study indicate a potential for adverse effects of chemicals present in Violet Marsh on benthic organisms. Further studies will be required to describe the potential for these effects with more certitude. As part of these studies, an assessment of marsh sediments receiving discharge from dewatering activities and assessment of bioaccumulation potential of chemical contaminants in these sediments should be completed.

**POINT OF CONTACT:** For additional information contact Dr. Burton C. Suedel (601-634-4578, [Burton.Suedel@erdc.usace.army.mil](mailto:Burton.Suedel@erdc.usace.army.mil)). This technical note should be cited as follows:

Suedel, B. C., J. A. Steevens, and D. E. Splichal. 2006. *A pilot study of the effects of post-Hurricane Katrina floodwater pumping on the chemistry and toxicity of violet marsh sediments*. Environmental Laboratory Technical Notes (ERDC/TN EL-06-3). Vicksburg, MS: U.S. Army Engineer Research and Development Center. <http://el.erdc.usace.army.mil/>.

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Appendix A

<b>Table A1 Summary of non-detected analytes in Violet Marsh sediments</b>				
<b>Analyte</b>	<b>Pump Station #2</b>	<b>Pump Station #3</b>	<b>Pump Station #4</b>	<b>Pump Station #6</b>
<b>Volatile Organics</b>	<b>Result (ug/kg)</b>	<b>Result (ug/kg)</b>	<b>Result (ug/kg)</b>	<b>Result (ug/kg)</b>
Benzene	<40	<25	<15	<30
Toluene	<40	<25	<15	<30
Ethylbenzene	<40	<25	<15	<30
Xylenes	<40	<25	<15	<30
<b>Gasoline Range Organics</b>	<b>Result (ug/kg)</b>	<b>Result (ug/kg)</b>	<b>Result (ug/kg)</b>	<b>Result (ug/kg)</b>
GRO	<730	<470	<250	<620
<b>Oil Range Organics</b>	<b>Result (mg/kg)</b>	<b>Result (mg/kg)</b>	<b>Result (mg/kg)</b>	<b>Result (mg/kg)</b>
ORO	(dry)	1300	1200	830
	(wet)	160	230	290
<b>Diesel Range Organics</b>	<b>Result (mg/kg)</b>	<b>Result (mg/kg)</b>	<b>Result (mg/kg)</b>	<b>Result (mg/kg)</b>
DRO	(dry)	<790	<530	220 J
	(wet)	<100	<98	78 J
<b>Semivolatile Organics (BNA)</b>	<b>Result (ug/kg)</b>	<b>Result (ug/kg)</b>	<b>Result (ug/kg)</b>	<b>Result (ug/kg)</b>
Phenol	<7900	<5300	<2800	<7200
Bis(2-chloroethyl) ether	<7900	<5300	<2800	<7200
2-Chlorophenol	<7900	<5300	<2800	<7200
1,3-Dichlorobenzene	<7900	<5300	<2800	<7200
1,4-Dichlorobenzene	<7900	<5300	<2800	<7200
1,2-Dichlorobenzene	<7900	<5300	<2800	<7200
Benzyl alcohol	<79000	<53000	28000	<72000
2-Methylphenol	<7900	<5300	<2800	<7200
2,2'-Oxybis(1-chloropropane)	<7900	<5300	<2800	<7200
N-Nitrosodi-n-propylamine	<7900	<5300	<2800	<7200
Hexachloroethane	<7900	<5300	<2800	<7200
4-Methylphenol	<7900	<5300	<2800	<7200
Nitrobenzene	<7900	<5300	<2800	<7200
Isophorone	<7900	<5300	<2800	<7200
2-Nitrophenol	<16000	<11000	<5600	<14000
2,4-Dimethylphenol	<16000	<11000	<5600	<14000
Bis(2-chloroethoxy)methane	<7900	<5300	<2800	<7200
2,4-Dichlorophenol	<7900	<5300	<2800	<7200
<b>Semivolatile Organics (BNA)</b>	<b>Result (ug/kg)</b>	<b>Result (ug/kg)</b>	<b>Result (ug/kg)</b>	<b>Result (ug/kg)</b>
Benzoic acid	<79000	<53000	<28000	<72000
1,2,4-Trichlorobenzene	<7900	<5300	<2800	<7200
Naphthalene	<7900	<5300	<2800	<7200
4-Chloroaniline	<16000	<11000	<5600	<14000
Hexachlorobutadiene	<7900	<5300	<2800	<7200
4-Chloro-3-methylphenol	<16000	<11000	5600	<14000
2-Methylnaphthalene	<7900	<5300	<2800	<7200
Hexachlorocyclopentadiene	<32000	<21000	<11000	<29000
2,4,6-Trichlorophenol	<7900	<5300	<2800	<7200
2,4,5-Trichlorophenol	<7900	<5300	<2800	<7200
2-Chloronaphthalene	<7900	<5300	<2800	<7200

<b>Table A1 Summary of non-detected analytes in Violet Marsh sediments</b>				
<b>Analyte</b>	<b>Pump Station #2</b>	<b>Pump Station #3</b>	<b>Pump Station #4</b>	<b>Pump Station #6</b>
2-Nitroaniline	<79000	<53000	<28000	<72000
Acenaphthylene	<7900	<5300	<2800	<7200
Dimethyl phthalate	<7900	<5300	<2800	<7200
2,6-Dinitrotoluene	<7900	<5300	<2800	<7200
3-Nitroaniline	<79000	<53000	<28000	<72000
Acenaphthene	<7900	<5300	<2800	<7200
2,4-Dinitrophenol	<79000	<53000	<28000	<72000
Dibenzofuran	<7900	<5300	<2800	<7200
4-Nitrophenol	<79000	<53000	<28000	<72000
2,4-Dinitrotoluene	<7900	<5300	<2800	<7200
Fluorene	<7900	<5300	<2800	<7200
Diethyl phthalate	<7900	<5300	<2800	<7200
4-Chorophenyl phenyl ether	<7900	<5300	<2800	<7200
4-Nitroaniline	<79000	<53000	<28000	<72000
4,6-Dinitro-2-methylphenol	<79000	<53000	<28000	<72000
N-Nitrosodiphenylamine	<7900	<5300	<2800	<7200
Hexachlorobenzene	<7900	<5300	<2800	<7200
4-Bromophenyl phenyl ether	<7900	<5300	<2800	<7200
Pentachlorophenol	<79000	<53000	<28000	<72000
Phenanthrene	<7900	<5300	<2800	<7200
Anthracene	<7900	<5300	<2800	<7200
Di-n-butyl phthalate	<7900	<5300	<2800	<7200
Fluoranthene	1600 J	<5300	500 J	<7200
Pyrene	1300 J	<5300	500 J	<7200
Butyl benzyl phthalate	<7900	<5300	<2800	<7200
Benzo(a)anthracene	<7900	<5300	300 J	<7200
3,3'-Dichlorobenzidine	<32000	<21000	<11000	<29000
Chrysene	<7900	<5300	400 J	<7200
Bis(2-ethylhexyl) phthalate	1400 J,B	1700 J,B	1500 J,B	1700 J,B
Di-n-octyl phthalate	<7900	<5300	<2800	<7200
Benzo(b)fluoranthene	1000 J,I	<5300	600 J,I	<7200
Benzo(k)fluoranthene	I	<5300	I	<7200
Benzo(a)pyrene	<7900	<5300	300 J	<7200
Indeno(1,2,3-cd)pyrene	<7900	<5300	<2800	<7200
Dibenzo(a,h)anthracene	<7900	<5300	<2800	<7200
Benzo(g,h,i)perylene	<7900	<5300	<2800	<7200
<b>Metals</b>	<b>Result (mg/kg)</b>	<b>Result (mg/kg)</b>	<b>Result (mg/kg)</b>	<b>Result (mg/kg)</b>
Aluminum	20900	20800	15100	23400
Antimony	<4	<4	<4	<4
Arsenic	12 B	9.6 B	9.1 B	12 B
Barium	119	120	180	118
Beryllium	0.99	1	1.2	1.1
Cadmium	2.1	1.7	1.7	2.1
Calcium	5080	4400	6150	5410
Chromium	34.2 B	53.2 B	21.4 B	32.1 B
Cobalt	9.2	11	14	10

**Table A1  
Summary of non-detected analytes in Violet Marsh sediments**

Analyte	Pump Station #2	Pump Station #3	Pump Station #4	Pump Station #6
Copper	59.2	58.7	31	42.9
Iron	26100	26200	20900	25800
Lead	89.7	181	27.2	52
Magnesium	9130	7700	6090	9540
Manganese	409	460	463	741
Nickel	32.2	46.1	32.9	30.5
Potassium	4960	4470	3160	5330
Selenium	2 J	1 J	1 J	2 J
Silver	0.6 J	<1	<1	0.2 J
Sodium	21700	12700	6410	21000
Thallium	<6	<6	<6	<6
Vanadium	49.8	43.7	36	51.3
Zinc	287	165	139	325
<b>Total Organic Carbon</b>	<b>Result (mg/kg)</b>	<b>Result (mg/kg)</b>	<b>Result (mg/kg)</b>	<b>Result (mg/kg)</b>
TOC	100000	58000	35000	94000

J: Estimated concentration above method detection limit but below LRL.  
 B: Compound also present in the method blank.  
 I: Analytes reported as an isomeric pair due to insufficient baseline resolution.