POLLUTION IMPACT IN MISSISSIPPI COASTAL WATERS

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MISSISSIPPI-ALABAMA
SEA GRANT CONSORTIUM

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Introduction

Mississippi Sound forms the southern boundary of the states of Mississippi and Alabama. This elongated, shallow embayment is bordered on the north by a series of small bays, marshes, bayous and rivers and on the south by a chain of offshore islands. Fresh water input is primarily through the Pearl and Pascagoula drainage basins but also from St. Louis Bay and Biloxi Bay. On the western end of the Sound water enters from Lake Pontchartrain-Borgne in Louisiana, and at the eastern extremity water enters from Mobile Bay. Mississippi River water may also be introduced through the Chandeleur Sound. Water from the Gulf of Mexico enters the Sound by tidal exchange through the island passes.

Mississippi Sound is part of the "fertile fisheries crescent" of the northern Gulf of Mexico, a reference to the extensive seafood resources in this nursery region. In the past this resource has not been extensively utilized though some serious efforts are now being made to exploit the economic reserves of the seafood resource. There is some doubt, however, that the full potential of this area will ever be realized because of the concurrent interest by the states of Mississippi and Alabama to develop other resources. It is not surprising to note that these two states share some of the most desirable industrial climates of the country. At a time when already heavily industrialized areas in the United States are seeing the results of careless industrial development and are reacting with severe restraints, the Southeast is still holding to a doctrine of "industry at any cost." Neither Mississippi nor Alabama will anytime soon experience the phenomenal growth of Florida or Texas; however, some recent developments have created substantial concern among environmentalists. Several of the chemical plants in the Pascagoula River region are presently undergoing expansion; an oil refinery in the area will soon be one of the largest in the world; oil drilling continues in Mobile Bay and will escalate as our desire to become energy independent increases. Several new industries are in the process of locating in southeast Mississippi and southwest Alabama.

This region also has great potential for residential growth in the next decade as the populace migrates to the coastlines of the "sun-belt" states. All such development will put a strain on the environment because both industrial and residential expansion result in tremendous waste byproducts. Furthermore they will compete for the same aquatic habitats that are essential to support the fisheries industry. As Cairns[1] has stated succintly, "All industries discharging wastes are using the environment as an extension of their waste disposal system." Those responsible for making decisions with regard to coastal development should consider key economic factors in planning and accepting bids for future growth. Given little consideration in the past are environmental factors, particularly those relating to pollution. Among the more vital environmental issues are those relating to: the detrimental effects of pollution, the types of pollutants presently in the Sound and those likely to be introduced in the future, where the pollutants accumulate - biota, water or sediments, what regions in the Sound are most polluted, how pollutants migrate in the Sound, the dangers of polluted sediments and measures that may be taken to prevent needless destruction of the environment. Though the economic data is substantial and sufficient for proper decisions, the scientific data is not.

Several studies have been completed and some are in progress that purport at least in part to establish guidelines or criteria for the assurance of environmental protection. St. Louis Bay, at the western end of Mississippi is the area of least commercial development on the Mississippi coast and until 1978 had almost no industry. A baseline study was completed in this bay in 1978 including a vast number of chemical monitoring measurements. In 1979 another study was begun at the eastern end of Mississippi Sound, the most industrialized region, to look at pollution transport. This study will be expanded in 1981-82 to include all of the Sound to look at the processes that are effective in the migration and fate of pollutants in the coastal estuaries of Mississippi and Alabama. Results of these two studies will be discussed with emphasis on the current pollutant transport study.

Results and Discussion

St. Louis Bay. Prior to the start-up of a titanium dioxide plant on St. Louis Bay, a one-year baseline study was made in 1978 of this area and the rivers discharging into the bay. The survey included physical oceanography; benthic organism, fish and plankton studies; microbiology; marsh plant surveys and chemical surveys. Pesticides were one element of the chemical survey.[2] The authors were responsible for hydrocarbons and trace metals in sediments,[3,4] trace metals in organisms[4] and trace metals[4] and water quality parameters[5] in the water column. A map of the sampling area for these analyses is depicted in Fig. 1. The data for trace metal analyses have been compiled in Table 1. Trace metals in water (both soluble and particulate) were analyzed at two month intervals for a year. Surface sediment samples were collected twice during 1978 in May and December at eight stations for trace metal analysis. Surface sediment samples were collected twice, in December, 1977 and in October, 1978, at 13 stations for hydrocarbon analysis;

monthly during 1978 at the same 13 stations for total organic carbon analysis.

In the water column only strontium ever exceeded the ppb(μg/l) level. Only arsenic, strontium, zinc and iron occurred consistently at levels that were detectable by the techniques commonly used in trace metal analysis. Some concern has been expressed for levels of trace metals in this bay exceeding what the U.S. Environmental Protection Agency (EPA) classifies as "safe".[6] Unfortunately many of the criteria established by EPA apply only to water used for drinking purposes and are practically useless in determining the level of "safeness" of brackish bay waters. However, the detection limits for all metals surveyed are below the EPA criteria, therefore some comfort may be taken that the majority of metal concentrations fell below the EPA criteria throughout the year. Arsenic is one element whose concentration levels are rather puzzling; apparently considerable amounts of arsenic are introduced to this bay in a particulate form. Strontium, iron and zinc fluctuate from station to station in what might appear to be a random manner, however all three are sensitive to pH, temperature and salinity changes which were quite variable during 1978. None of the metals measured seriously deviated from concentration values determined earlier in this bay.[7,8]

Of particular interest in this study were values of heavy metals in the sediments of St. Louis Bay. The fact that sediments tend to preserve an integrated record of pollution is well documented in St. Louis Bay sediments. Within the bay, values of trace metals in surface sediments were very uniform, not displaying the erratic behavior of metals in the water column. Sediments may be characterized as reflecting long-term trends in trace metal input to this bay and other bays along the Mississippi coast.

The levels and distribution of hydrocarbons in St. Louis Bay also demonstrate the remarkable uniformity of chemical constituents in the bay sediments. Aliphatic and aromatic hydrocarbons occurred at low ppm levels at all sampling sites. The preservation of a long-term record of input is shown in the amazing similarity of 1977 and 1978 hydrocarbon values. The study of St. Louis Bay as well as a previous study of Biloxi Bay[9] suffer from some serious shortcomings. No effort was really made to look at the processes involved in pollutant transport and deposition. Because of the pressing need for this type of information, a four-year program was begun in 1979 to meet the following objectives:

(1) As completely as possible identify the type, source, and toxicity distribution of pollutants in the Sound,

(2) Investigate the processes operative in the dispersal and deposition of pollutants,

(3) Develop a system of guidelines to assure responsible coastal zone planning.

As a preliminary investigation surface sediment samples were gathered from sites in Biloxi Bay and the Pascagoula River in 1978. These two regions, especially the Pascagoula River, have heavy concentrations of industrial and residential activity relative to areas further west. Most evidence tends to indicate that organic pollutants are the dominant pollutant type in the Sound. National Pollutant Discharge Elimination Systems (NPDES) permits in the Pascagoula region list a wide variety of organic pollutants. Trace metals appear to be of secondary importance. Therefore, this preliminary study stressed the organic compounds in the sediments. Partial results are shown in Fig. 2. Location of the stations is not nearly so significant as the extreme variability seen in organic composition of sediments taken from these two areas. Stations not very far removed from each other and containing very similar geological structures contain quite different levels of organic pollutants. The grossly elevated levels of organics, not explainable by natural phenomena, clearly demonstrates the need for a comprehensive organic chemical monitoring program in the Sound.

The Pascagoula River is the site of most domestic development on the Mississippi Coast and also the most flagrant example of its improper management. Therefore, most work in 1979-80 has concentrated on this river system. NPDES permits, location and type of industry in the surrounding area and preliminary results shown in Fig. 2 suggested several types of organic pollutants as the prime candidates for investigation. Phenolics were included because of their abundance in waste discharges and because they are among the "priority pollutants" compiled by EPA.[10] Of even more significance are the hydrocarbons. These compounds hidden in such innocuous NPDES phrases as "oil and grease" include the polynuclear aromatics, many of which have known carcinogenicity.[11-16] The nearly completed superport off the Louisiana coast, a one-billion dollar expansion of an oil refinery in Pascagoula, pipelines in the Sound, oil drilling off Louisiana and Alabama, local creosote plants,[17,18] coal generated power plants, urban run-off,[19] careless disposal of motor oils[20] and even sewage,[21,22] add to the hydrocarbon budget of the Sound.

Preference in analysis for this study has been given to sediments because of their tenacity for pollutants,[19,23-36] their capacity to retain pollutants in a locale, their preservation of pollution history and their potential toxicity over long periods of time. Surface sediments have been collected from large numbers of sites in the eastern Sound to document recent pollution incidents. The most comprehensive sampling was conducted in the Escatawpa River in which are located a large paper mill, a chemical manufacturer, seafood processors and some small shipyards. Figure 3 contains results of this study. The industrial zone was located mid-way along this transect, covering the five miles above the confluence with the E. Pascagoula River. Note that exceedingly high values of organic matter and hydrocarbons are not restricted just to the industrial area. Because tidal salt wedges penetrate beyond this point it may not be surprising to see elevated pollutant levels up-river of the source. Nevertheless there is convincing evidence that the majority of discharged pollutant does not migrate very far from the origin. Figure 4 depicts the gas chromatograms of hydrocarbons from two sites less than 100 feet apart in a canal near a paper mill in the Escatawpa River industrial zone. At one end of the canal (Site I) hydrocarbons are mostly low molecular weight with large quantities of branched-isomeric aliphatics looking very much like fresh fuel oil residues. At the other site (II) the hydrocarbons are more uniformly distributed over the entire molecular weight spectrum. Lyons and Gaudette[37] also noticed this phenomenon in assaying pollutants as a function of distance from discharge. The limited mobility is some cause for guarded relief because pollutants may not be widely dispersed, however caution is required since monitoring efforts must be very selective in the choice and number of sampling sites in order to give an accurate depiction of pollution profiles of these regions.

Sediment cores have been collected to give information about pollutant levels as a function of sediment depth. In November, 1979 10-foot cores were collected at the sites designated on the map in Fig. 5 in the

Pascagoula River area to coincide with areas where polluted sediments would tend to accumulate. The extreme variability in analysis results reflects that seen in the surface sample analysis. One particularly interesting core sample was collected in Dead River, an oxbow lake just south of the newly constructed I-10 bridge over the W. Pascagoula River. The more salient points are included in the display in Fig. 6. The clay and silt composition of each core is very important in the interpretation of pollutant levels because of the affinity of organic pollutants for fine-grained materials. At most sites in the Pascagoula River a close correlation exists between levels of naturally occurring organic compounds and percent clay. However at Dead River (an excellent accumulation site for fine-grained materials), hydrocarbons near the surface exceed what would be expected if they were of natural origin. The distribution of hydrocarbons ascertained by gas chromatography and fluorescence spectrophotometry indicate degraded fuel oil in the surface sediments; the presence of these residues have been noted at other sites as well, and as in Dead River, not always at maximum concentrations in the uppermost levels. Further elucidation by mass spectrometry of the aromatics revealed a very unusual assemblage of long chained alkyl substituted benzenes. This information definitely points to an anthropogenic source of the hydrocarbons. The definition of various strata in the sedimentary column by geologic and chemical description will be presented to the Corps of Engineers to enable them to better assess the possible side-effects of dredging at various depths and to get estimates of overall pollutant levels in the dredge spoil taken from various locales.

Freshwater discharge and surface currents are primarily responsible for the sediment migration and deposition patterns seen in the Sound, though tidal currents[35] and macrobenthos also play a role.[36,38] Less obvious modes are storm scouring, dredging[39] and fish trawling.[40] The actual impact of disturbing polluted sediments is being determined for all polluted Sound sediments by various analysis. The stability of resuspensions of polluted sediments has been determined by resuspending sediments in site water, at various pH, salinity and temperature and measuring the rate of re-deposition. The rate of deposition varies considerably and sometimes in a very unpredictable manner. Examples of two quite diverse behaviors are shown in Fig. 7. Both areas have considerable industry and are in areas of high clay sediment composition. Though the Bayou Casotte sediment suspension initially is quite high, it very rapidly drops to background levels. Sediments from the Halter Marine site in the Escatawpa River, on the other hand, though initially at lower suspended solids values, maintain suspensions well above background for very long periods of time. This characteristic of sediments is quite important, for it affects the ability of associated pollutants to be leached from sediments and also will determine the efficiency with which polluted sediments can be dispersed over broad areas after a period of disturbance.

Table 3 contains a listing of a number of characteristics of sediments found within the Pascagoula River system. Included is a rating of the stability of resuspended sediments, i.e. how effectively do the sediments remain in suspension after a period of resuspension. Table 3 also includes a compilation of results of tests to determine the actual toxicity of sediments to several ecologically valuable species of indigenous organisms. In these tests _Mysidopsis almyra_ or mysid shrimp, _Cyprinodon variegatus_ or sheepshead minnow and an amphipod, _Gammarus mucronatus_ were exposed to water previously shaken with sediment then filtered, water with suspended material and sediment that was allowed to settle in a tank, to comply with EPA's three-phase bioassay conditions.[41] As a group, the sediments from the Escatawpa River appear to have the highest toxicity of any from this system. Of further concern is the fact that most of these sediments form fairly stable suspensions and are prone to being disturbed (see "disturbance potential", Table 3). Though a high rating in any one category e.g. "disturbance potential" or "suspension stability" may not be significant, consistently high ratings in all categories pertinent to considerations of the potential harm of polluted sediments is significant. Table 3 is not all-inclusive but contains much of the evidence that can be used in objectively evaluating the sediments of the Pascagoula River.

Conclusions

(1) These studies of St. Louis Bay and the Pascagoula River provided a considerable number of contrasts. St. Louis Bay prior to any major development displayed sediment profiles with almost complete lack of any elevated pollutant levels and a distribution of trace metals and hydrocarbons consistent with a relatively pristine environment. On the other hand, areas in the Pascagoula River, used for many years as prime industrial sites, have very high pollutant levels in the sediments, particularly hydrocarbon pollutants which serve as painful reminders of past disposal practices.

(2) Metal and hydrocarbon values were very uniformly distributed in the sediments of St. Louis Bay which is quite typical of areas subject only to natural inputs. Sediments of the Pascagoula River are extremely heterogeneous indicating not only anthropogenic sources of input but

that the Pascagoula River has little ability to disperse or "dilute" polluted sediments which are deposited and concentrated near the point of origin.

(3) The Corps of Engineers typically makes dredge permit decisions based in part upon gross analysis of composite sediment samples from dredge areas. The extreme variability of pollutant levels and type with depth in the sediment column of the Pascagoula River indicates a need for a change in this policy. By carefully constructing profiles of the sediment columns by textural, foraminiferal and chemical analysis of different areas, a better estimation may be made of the actual amounts of pollutants involved in dredging operations.

(4) As important as the level of toxic substances in the sediments of an area, are other characteristics that are essential to an understanding of the threat posed by polluted sediments. Toxicity measurements, sediment settling characteristics, and knowledge of activities likely to cause disturbance all suggest that there are some real trouble spots in the Escatawpa River region of the Pascagoula River area of the Mississippi Sound. This information is being gathered into a format to aid decision-makers in developing a more realistic consciousness of the impact of haphazard development and to promote more responsible coastal zone management in Mississippi.

Acknowledgements

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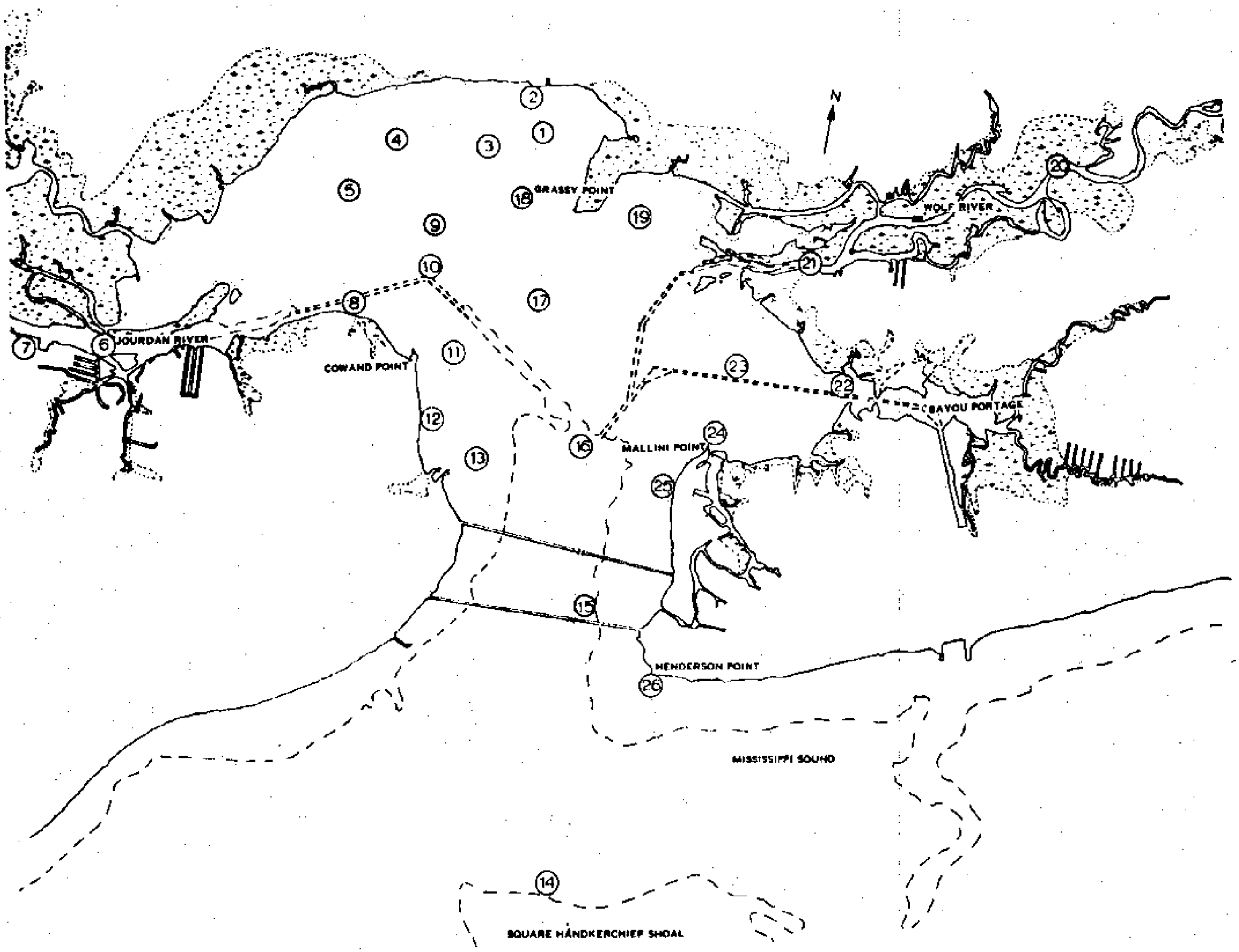


Figure 1. St. Louis Bay Sampling sites.

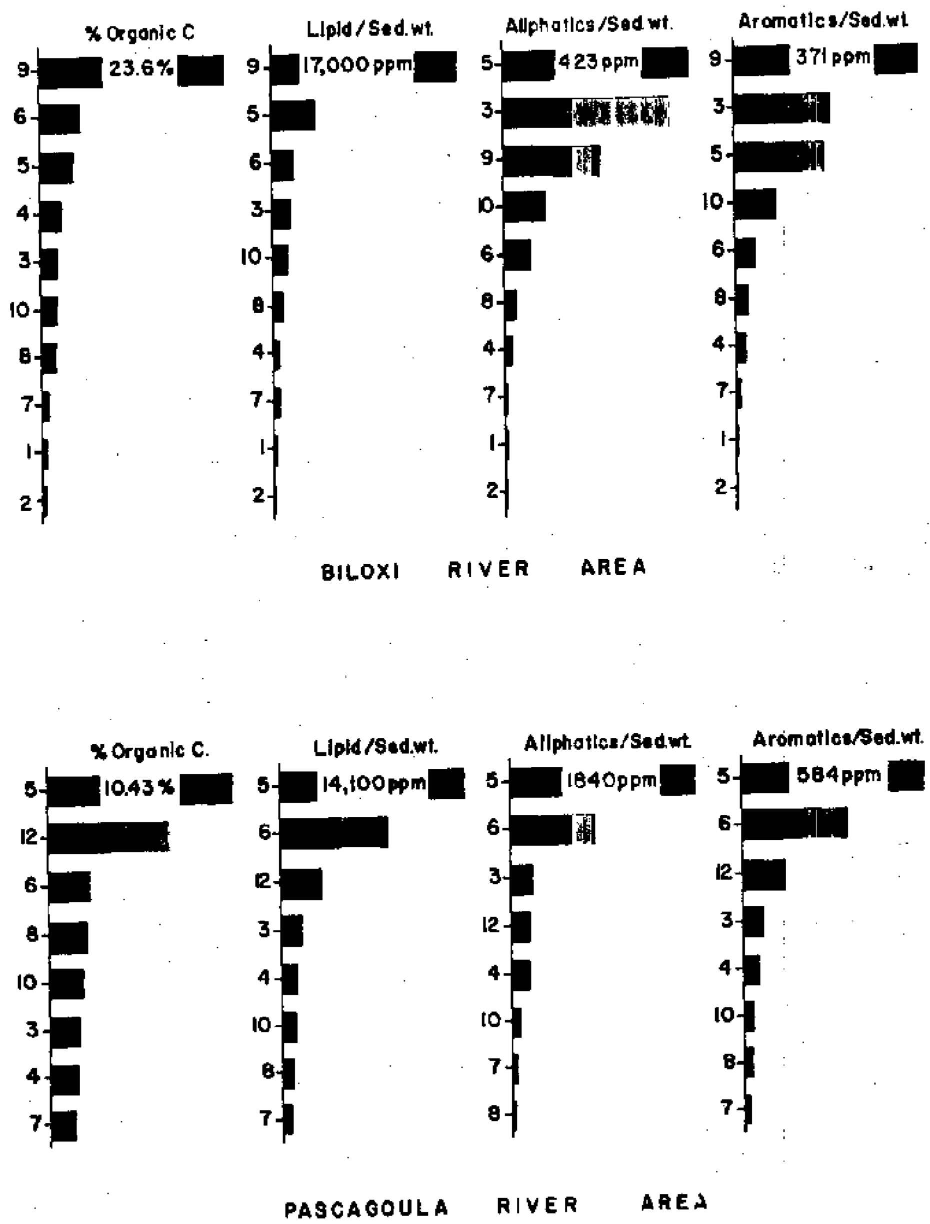


Figure 2. 1978 Sediment Survey of Biloxi Bay and Pascagoula River.

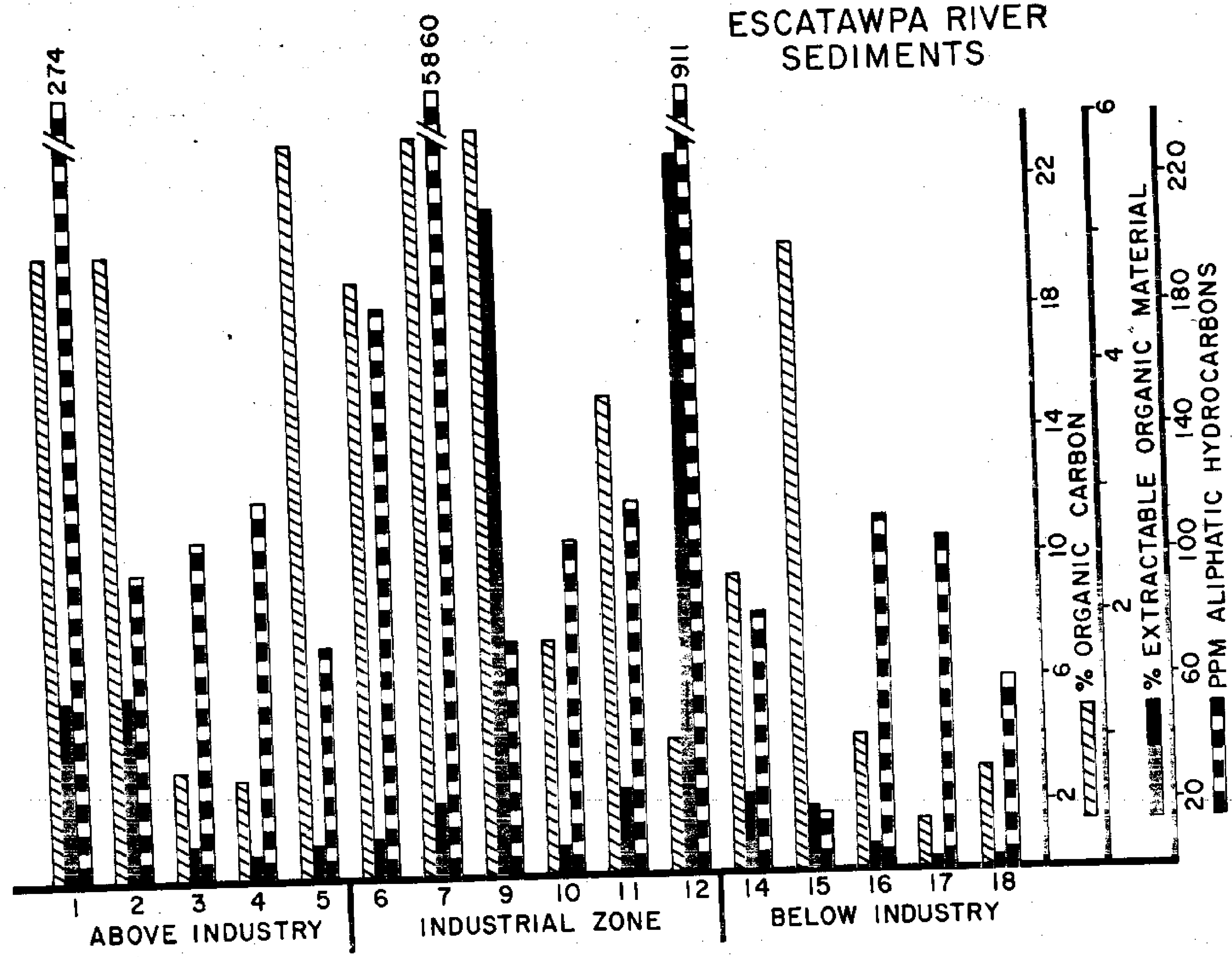


Figure 3. Organics in Escatawpa River. Stations 1-18 are located in sequence in the river with #1-5 being upriver of the principle pollution sources and #14-18 downriver of these sources.

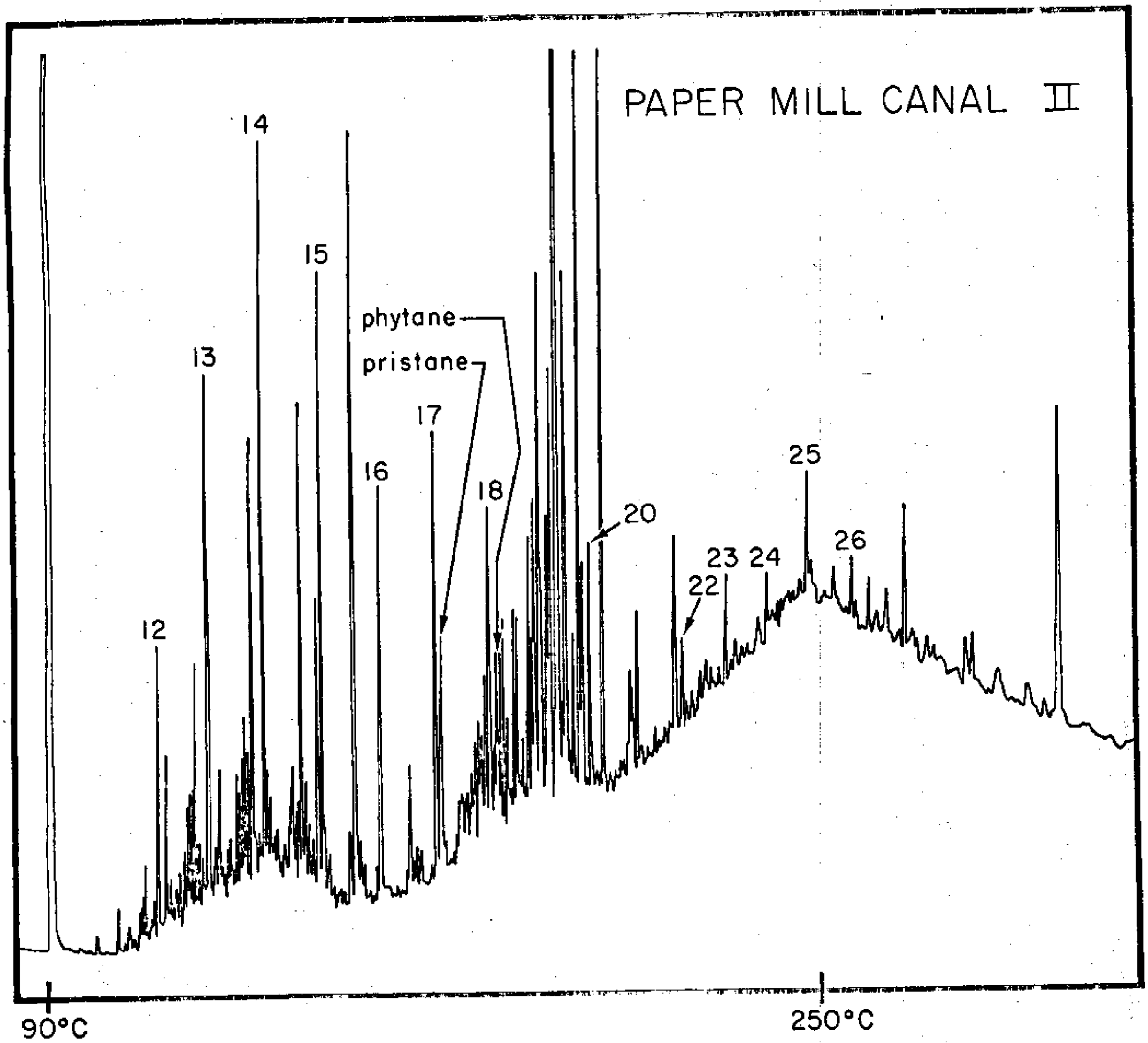


Figure 4. Gas Chromatograms of Hydrocarbons in a Paper Mill Canal. Site I is located at the deadend of a canal adjacent to a paper mill, site II is ca. 100 feet away at the mouth of the canal. Integers denote carbon numbers of identified alkanes. G.C. conditions are: 25 m glass capillary OV-101, temperature programmed from 90° to 250°C @ 40/mm, He flow of 3 ml/mm using injection splitter.

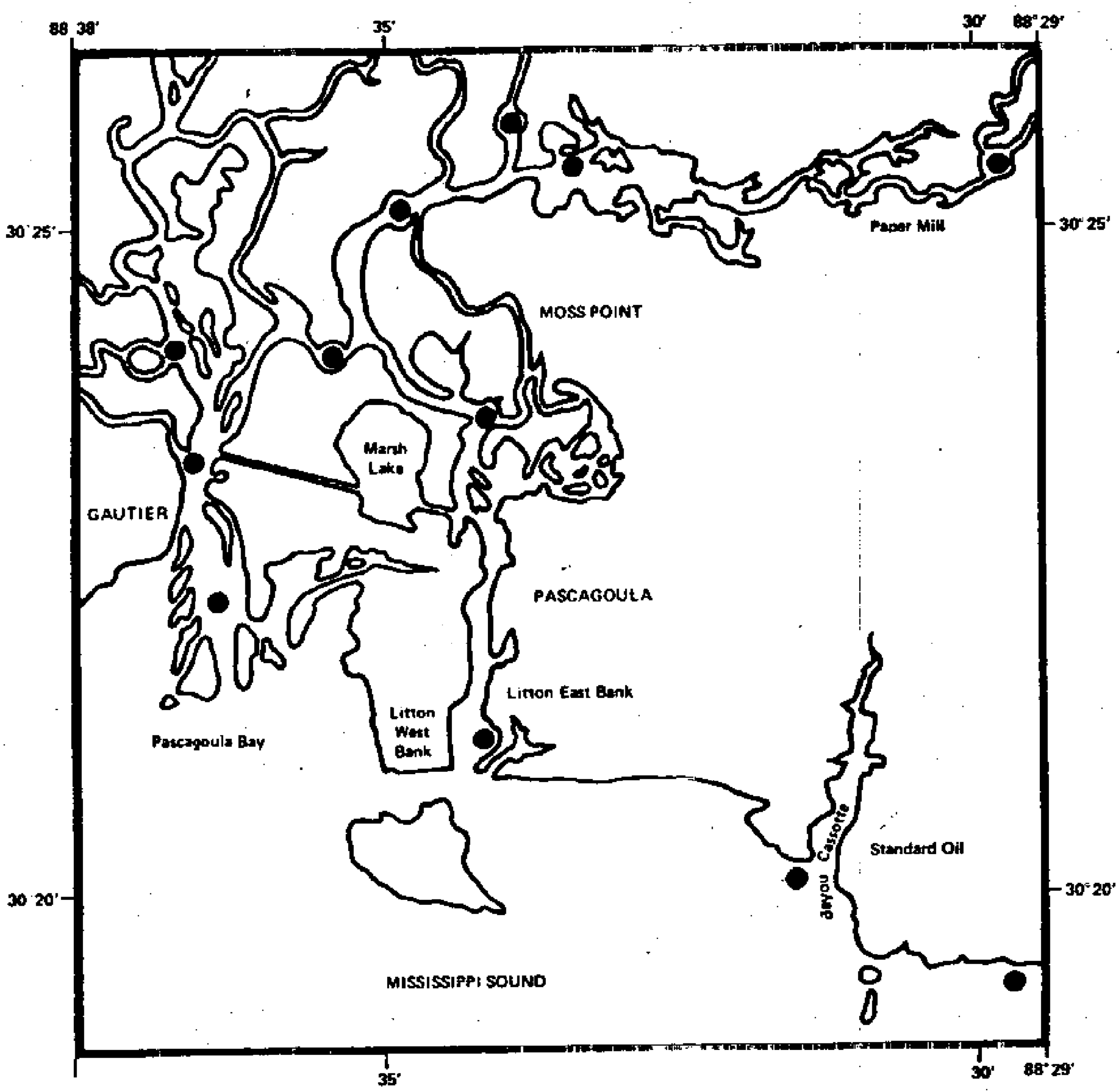


Figure 5. Pascagoula River Coring Sites. Dots designate the sampling stations for 10-foot sediment cores.

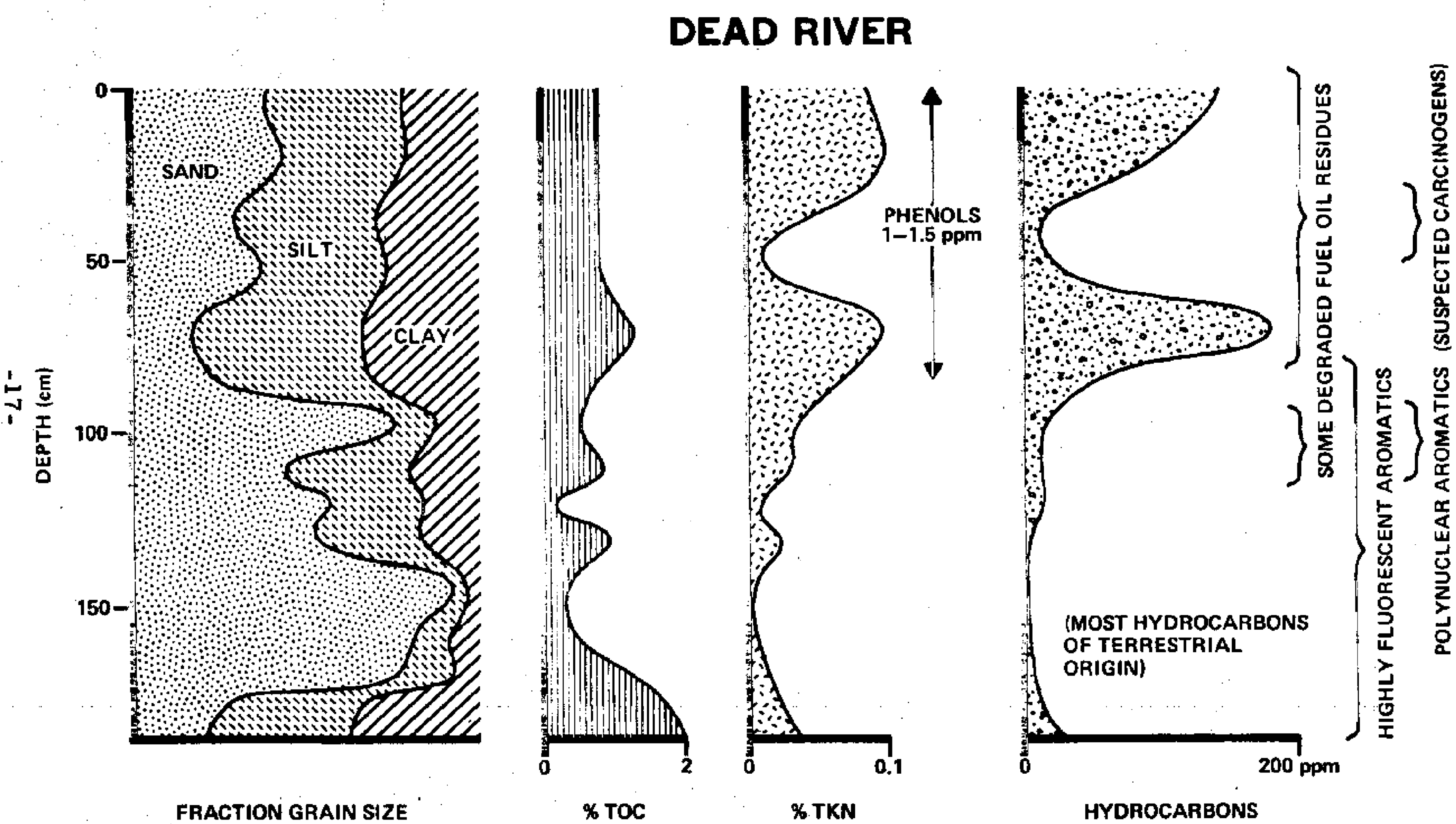
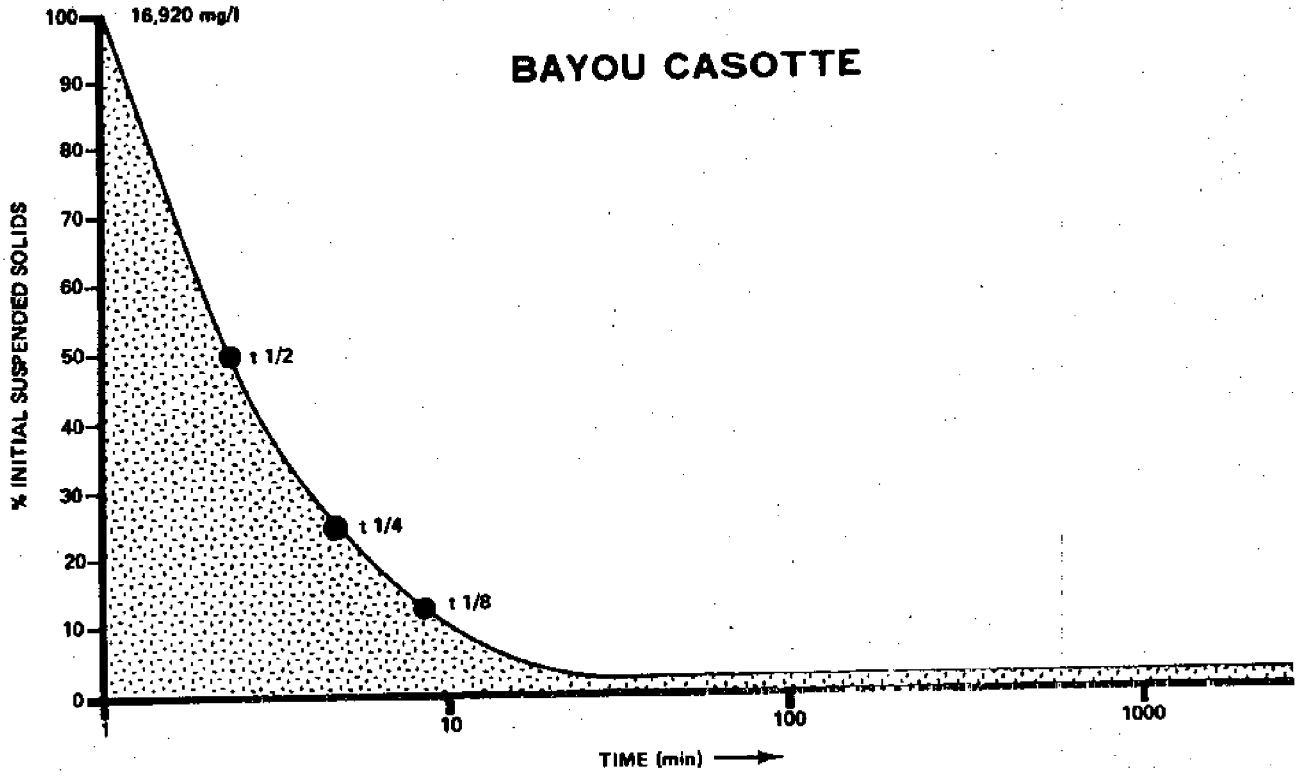


Figure 6. Geologic-Chemical Profiles of W. Pascagoula River sediments. Dead River is the site of an oxbow lake located on the W. Pascagoula River just south of the I-10 bridge.



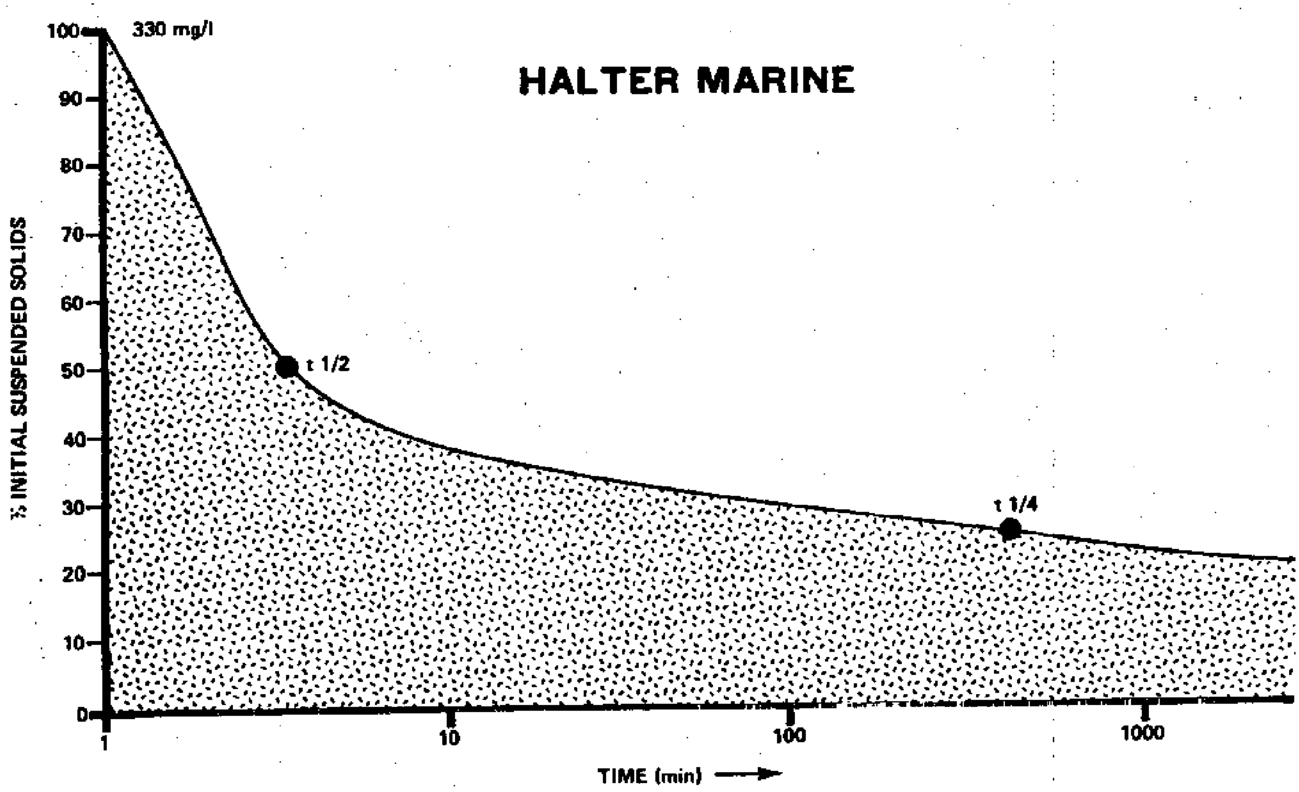


Figure 7. Sediment Settling Rates. Total suspended solids are plotted as a function of % of initial suspended solids following dispersal of sediment in site water (1:4, w:v). Times are marked when these values have fallen to 1/2, 1/4 and 1/8 of the initial value. Halter Marine sediments were obtained from a region in the Escatawpa River.

Table 1

Trace Metals in Water & Sediments of St. Louis Bay*

Station Number	As	Sb	Be	Cd	Cr	Co	Cu	Pb	Hg	Mo	Ni	Se	Sr	Ti	V	Zn	Fe
1	<2†	<2	<0.2	<3	<100	<20	<10	<20	<0.2	<80	<30	<2	28.8-3400	<300	<200	14.7-272	<10-110
	<0.02-0.199§	<0.02	<0.02	<0.19	<2.1	<1.4	<1	<2.1	**	<16	<3.9	<0.01	<2.5	<73	<15	6.87-17.3	120-873
	5.55††	<0.025	0.632	<0.087	8.645	3.13	6.765	11.35	0.0534	<4.7	6.66	<0.13	<1.2	362.5	<6.4	65.6	17,900
3	<2	<2	<0.2	<3	<100	<20	<10	<20	<0.2	<80	<30	<2	<10-3540	<300	<200	<5-272	<10-110
	<0.02-0.302	<0.02	<0.02	<0.19	<2.1	<1.4	<1	<2.1	**	<16	<3.9	<0.01	<2.5	<73	<15	3.90-177	120-728
	6.72	<0.025	0.689	<0.087	9.73	7.54	10.335	13.8	0.1068	<4.7	8.26	<0.13	<1.2	277.5	<6.4	72.95	20,000
7	<2	<2	<0.2	<3	<100	<20	<10	<20	<0.2	<80	<30	<2	<10-1810	<300	<200	15.8-190	<10-102
	<0.02-0.168	<0.02	<0.02	<0.19	<2.1	<1.4	<1	<2.1	**	<16	<3.9	<0.01	<2.5	<73	<15	4.15-177	49.4-826
	0.766	<0.025	<0.193	<0.087	2.225	2.275	2.310	6.010	0.1678	<4.7	1.615	<0.13	<1.2	122.0	<6.4	17.10	3,590
16	<2	<2	<0.2	<3	<100	<20	<10	<20-70	<0.2	<80	<30	<2	117-3660	<300	<200	7.88-233	<10-87.1
	<0.02-.200	<0.02	<0.02	<0.19	<2.1	<1.4	<1	<2.1	**	<16	<3.9	<0.01	<2.5	<73	<15	5.88-85.4	83.8-391
	7.38	<0.025	0.888	<0.087	11.60	7.905	9.735	16.90	0.0988	<4.7	10.43	<0.13	<1.2	358.5	<6.4	65.70	21,800
18	<2	<2	<0.2	<3	<100	<20	<10	<20	<0.2	<80	<30	<2	39.2-2160	<300	<200	<5-179	<10-56.7
	<0.02-0.184	<0.02	<0.02	<0.19	<2.1	<1.4	<1	<2.1	**	<16	<3.9	<0.01	<2.5	<73	<15	3.90-14.3	134-606
	8.47	<0.025	<0.663	<0.087	9.48	6.96	7.06	15.9	0.908	<4.7	7.215	<0.13	<1.2	274	<6.4	50.45	18,150
19	<2	<2	<0.2	<3	<100	<20	<10-30	<20	<0.2	<80	<30	<2	<10-2640	<300	<200	<5-160	<10-209
	<0.02-0.172	<0.02	<0.02	<0.19	<2.1	<1.4	<1	<2.1	**	<16	<3.9	<0.01	<2.5	<73	<15	6.13-24.5	75.2-576
	8.325	<0.025	0.458	<0.087	12.18	7.64	8.545	17.8	0.1034	<4.7	8.365	<0.13	<1.2	306.5	<6.4	59.3	22,350
20	<2	<2	<0.2	<3	<100	<20	<10	<20	<0.2	<80	<30	<2	<10-123	<300	<200	5.96-157	<10-148
	<0.02-0.292	<0.02	<0.02	<0.19	<2.1	<1.4	<1	<2.1	**	<16	<3.9	<0.01	<2.5	<73	<15	3.90-38.1	376-949
	0.7685	<0.025	0.267	<0.087	5.365	2.623	3.165	9.77	0.0568	<4.7	3.38	<0.13	<1.2	224.75	<6.4	19.85	5,760
22	<2	<2	<0.2	<3	<100	<20	<10	<20	<0.2	<80	<30	<2	56.1-3500	<300	<200	5.93-265	<10-120
	<0.02-0.107	<0.02	<0.02	<0.19	<2.1	<1.4	<1	<2.1	**	<16	<3.9	<0.01	<2.5	<73	<15	8.36-29.7	138-855
	2.105	<0.025	0.1205	<0.087	4.64	0.658	3.165	6.375	0.0469	<4.7	2.34	<0.13	<1.2	158	<6.4	24.2	5,730

*Summary of data collected in a study in 1980 funded by E. I. du Pont de Nemours & Co.

†Range of soluble trace metal concentrations in μg/l.

§Range of particulate trace metal concentrations in μg/l.

**Inconclusive results.

††Mean of surface sediment trace metal concentrations in μg/g.

Table 2

St. Louis Bay - High Molecular Weight Hydrocarbons
1977 Mean Value/1978 Mean Value

Station Number	% Organic Carbon	Aliphatic/ Dry Wt. (ppm)	Aromatic/ Dry Wt. (ppm)	n-alkanes/ Dry Wt. (ppm)	n-alkanes/ Aliphatics (%)
1	1.46/1.29	7.83/3.79	4.58/2.25	4.45/2.28	54.2/59.6
3	1.67/1.59	7.44/5.59	3.53/1.21	4.06/3.46	54.2/61.8
5	1.40/1.61	7.39/5.97	2.84/1.71	3.67/3.64	49.7/60.8
6	3.20/2.87	10.3/5.38	7.34/1.29	5.66/2.72	55.6/50.7
9	1.48/2.10	7.06/6.36	4.16/1.74	3.68/4.04	51.8/63.2
11	1.47/1.27	3.60/3.85	1.53/0.970	1.79/2.46	50.0/64.2
15	2.29/1.99	4.85/6.69	1.66/1.88	2.24/4.14	46.4/61.9
17	1.32/1.06	3.19/3.20	1.87/1.25	1.58/1.84	50.3/58.2
18	1.48/1.18	8.99/2.25	3.21/0.660	5.67/1.15	61.1/46.0
19	1.51/1.49	4.93/3.26	2.74/0.995	2.23/1.71	45.6/51.4
21	1.32/1.51	2.67/4.28	1.75/1.52	1.71/2.81	56.6/64.5
22	2.03/0.746	7.06/3.35	1.72/3.37	3.12/1.22	44.8/55.8
24	0.582/0.654	1.15/0.710	1.61/0.349	0.466/0.347	42.6/47.7

TABLE 3

SEDIMENT TOXICITY RATINGS[1]

Area Tested (Selection Criteria)	Exposure Mortalities, 3-Phase[2] Mysid Shrimp LP	Mysid Shrimp PP	Mysid Shrimp SP	Sheepshead LP	Sheepshead PP	Amphipods SP	Likely Agent	Suspension Stability[3]	Disturbance Potential[4]
Lake Yazoo (Mouth E. Pascagoula River; industrial discharge)	5 (100%) 5 (50%) 3 (10%)	5 (100%) 5 (50%)	5	5 (100%)	5 (100%)	5	Caustic	3	4
Mary Walker Bayou (W. Pascagoula River; numerous marinas)			5			3	Aromatic Hydrocarbons	2	5
Elevator Bayou (E. Pascagoula River; down river of all industry)						1		2	1
Paper Mill (Escatawpa River canal; proximity of paper mill)	3 (100%) 1 (50%) 1 (10%)	5 (100%) 4 (50%) 4 (50%)	5			5		3	2
Halter Marine (Escatawpa River; manufacturing)	4 (100%) 2 (50%) 1 (10%)	1 (100%)						1	4
Pogey Plant (Chemical industry; fish meal processors)	5 (100%) 5 (50%) 1 (10%) 1 (1%)	5 (100%) 5 (50%) 5 (10%)	5			5		5	5
Twin Island (Mouth W. Pascagoula River)					1 (100%) 1 (50%)			2	2
Bayou Cassote (industrial area)		2 (100%) 1 (50%) 1 (10%)	1			1		2	5
Griffin Point (Sewage outfall)		1 (100%) 1 (50%) 1 (10%)	3			2		5	4
McInnis Lake (Sewage outfall, bridge construction)						1		4	1

[1] The higher the number rating in each category, the greater the potential risk posed by polluted sediments in the respective areas. A ranking for biota susceptibility and pollutant level will be included at a later date.

[2] EPA 3-phase bioassays with exposure to soluble components of sediment (LP), suspended and solubles (PP), and settled sediment (SP). Organisms used are mysid shrimp (*Mysidopsis almyra*), sheepshead minnows (*Cyprinodon variegatus*), and an amphipod (*Gammarous mucronatus*). Mortalities are listed as 5 (81–100% mortality at end of exposure; 4 (60–80% mortality); 3 (41–60% mortality); 2 (21–40% mortality); and 1 (5–20% mortality). Parentheses following rating indicate: (amount of soluble or particulate phase)/(amount of soluble or particulate phase + diluent water) x 100%.

[3] Rating depends on how high in the following rating system each sediment ranks: if time for a suspension in water to drop to ½ initial value ($t_{1/2}$) $\geq$ 15 mm and if ¼ initial value ($t_{1/4}$) is reached in $\geq$ 30 min. and if the initial suspended solids (ISS) (after dispersal) $\geq$ 5,000 mg/ℓ, sediment is ranked a 5; if $t_{1/2} \geq 10$ min., $t_{1/4} \geq 20$ min., ISS $\geq$ 2,500 mg/ℓ = rank of 4; if $t_{1/2} \geq 5$ min., $t_{1/4} \geq 10$ min., ISS $\geq$ 1,000 mg/ℓ = rank of 3; if $t_{1/2} \geq 2$ mm, $t_{1/4} \geq 4$ min., ISS $\geq$ 500 mg/ℓ = rank of 2; all others, rank of 1. This ranking is still tentative because some sediments have very unusual characteristics in the simulated resuspension studies that are not reflected in this ranking scheme.

[4] Probability that sediments from this location could be disturbed, thereby exposing the water column and biota to toxic agents. The highest rating of 5 is applied to areas with considerable boat traffic, dredging activity, or to areas which are in the main river flow and subject to runoff disturbance or are subjected to high tidal and/or benthic activity. A rating of 4 designates areas where boat traffic is restricted and are somewhat protected from those elements characteristic of areas of rating 5. A 3 signifies an area that is moderately affected by tides, is isolated from most man-made disturbances, and is subjected to disturbances infrequently. A 2 is given to those regions with little potential to disturbances under usual conditions either because of isolation from main stream flow or because of characteristics undesirable to sports or recreational boating. A rating of 1 is reserved for those areas that are subjected to disturbances only under extraordinary circumstances.

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