DREDGED MATERIAL RESEARCH PROGRAM

TECHNICAL REPORT D-78-45

EVALUATION OF THE ELUTRIATE TEST AS A METHOD OF PREDICTING CONTAMINANT RELEASE DURING OPEN-WATER DISPOSAL OF DREDGED SEDIMENTS AND ENVIRONMENTAL IMPACT OF OPEN-WATER DREDGED MATERIAL DISPOSAL

VOL. II DATA REPORT (continued)

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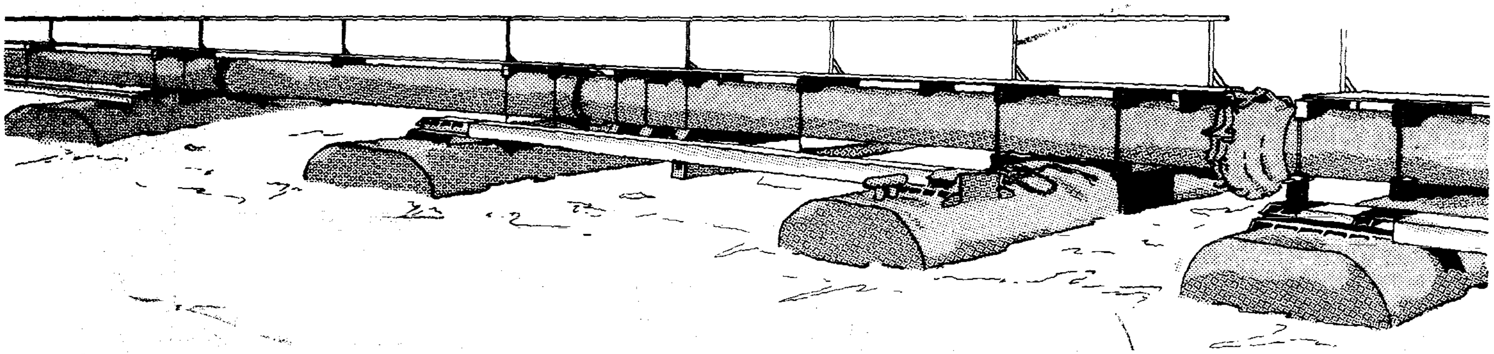

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GBEC Disposal Operations

Lee *et al.*[31] monitored the results of seven disposal operations involving sediment dredged from the GBEC. This section summarizes the results from the four operations for which there are sufficient data for comparison with elutriate test result data. A complete description of the experimental procedures, dump nomenclature,and results are presented in Lee *et al.*[31]

In each operation, the sampling ship was positioned approximately 30 to 300 meters downcurrent from the dumping site. The physical and chemical characteristics of the water column before, during, and after passage of the surface turbid plume arising from the dump were monitored. The sampling vessel was positioned in such a way that the center of the surface turbid plume would pass directly beneath the sampling boat. The presence of the turbid plume was indicated by a decreased percent transmission of the water. The proximity of the sampling vessel to the point of discharge enabled a comparison of the turbidity and the release of any contaminants for each dump monitored.

The total depth of the water column in the region of the monitoring site was 16 to 19 meters. In general, samples were obtained by continuous pumping of the surface (1 m), mid-depth, and bottom (approximately 1 meter from the sediment-water interface) waters. For parameters such as percent transmission, D.O., pH, and salinity measurements were made with submersible transducers. Generally the transducers were maintained at a fixed depth throughout the disposal operation. All disposal operations took place near Buoy D in the GBEC Disposal Site. This buoy was used as a marker for the location of the dump site.

Galveston Dump No. 3

The third monitored GBEC disposal operation occurred at 14:30 on August 28, 1975. The surface turbid plume arrived at the sampling ship at 14:34 and passed at 14:36. Approximately 1300 cubic yards of material dredged between Buoys 6 and 8 were disposed of during the dump. The sampling boat was located about 200 meters from the dump site. The surface current was 77 cm/sec. Near the bottom it was on the order of 21 cm/sec.

Optical properties. Figure 86 shows the percent transmission at 2, 9, and 16 meters following Galveston Dump No. 3. The presence of suspended material at these depths was first observed 4.5, 6.5, and 4.0 minutes, respectively, following the disposal. As shown in Figure 86, the greatest turbidity was found at the bottom depth, where turbid conditons persisted for 16 minutes.

Dissolved oxygen. Dissolved oxygen data for Galveston Dump No. 3 (Figure 87) show that at 15 meters there was an increase in D.O., approximately 0.5 mg/l, just after the dump occurred. After the surface plume arrived, a D.O. decrease of 1 mg/l from the baseline was observed. Ten minutes after disposal, the concentration of D.O. returned to the pre-disposal levels.

Heavy metals. Table 268 presents the water column concentrations of heavy metals monitored for Galveston Dump No. 3. Soluble manganese and lead concentrations at 1, 9, and 18 meters increased with time after the dump occurred and remained elevated after the plume passed. Zinc, iron, and nickel concentrations increased during plume passage but decreased afterwards to pre-disposal levels. There were no changes in chromium, cadmium, copper, mercury, or arsenic as a result of this disposal operation.

Nitrogen compounds. Although the ammonium concentration remained essentially the same for all surface and mid-depth samples in Galveston Dump No. 3 (Table 269), it increased four to five-fold near the bottom when the plume

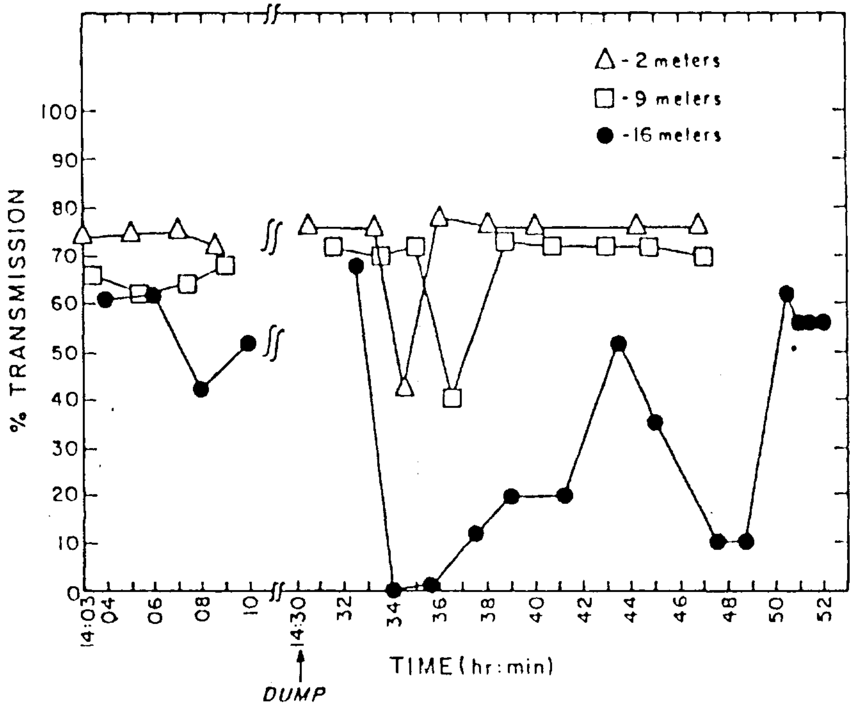

Figure 86

Percent Transmission: Galveston Dump No. 3
near Buoy D, Dredged Material from
Galveston Bay Entrance Channel
Buoys 6-8, August 28, 1975

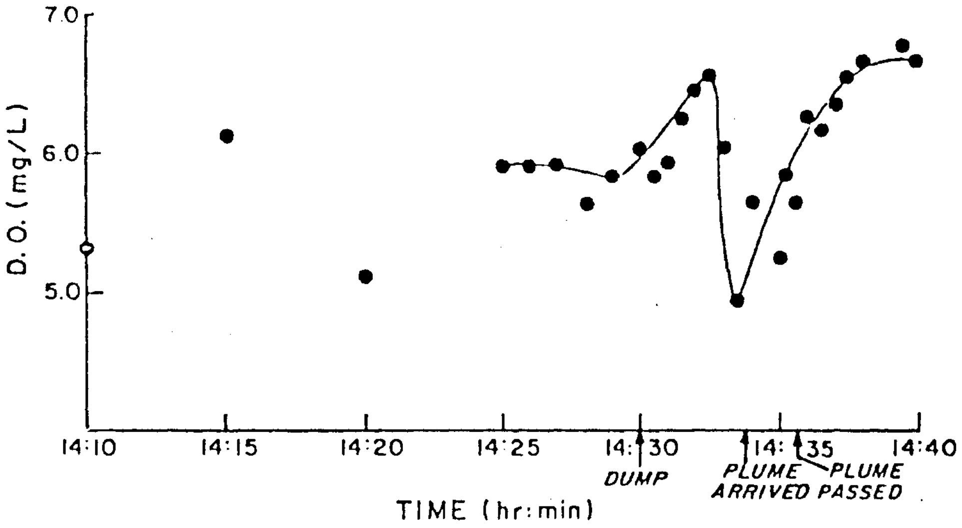

Figure 87

Dissolved Oxygen Concentrations: Galveston Dump No. 3, Depth 15 m, Dredged Material from Galveston Bay Entrance Channel Buoys 6-8
August 28, 1975

Table 268

Heavy Metal Concentrations: Galveston Dump No. 3 Near Buoy D, Dredged Materials from Galveston Bay Entrance Channel Buoys 6 through 8

(August 28, 1975)

Time of Collection (hr:min:sec)	Depth (m)	Mn		Cd		Cr		Zn		Ni		Pb		Cu		Fe		Hg		As	
		SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT
14:02:00	1	186	-	1.5	-	<2	<2	6.9	14.6	10.0	-	8.0	-	6.1	10.3	26	65	0.003	0.003	<2	<2
14:04:00	9	158	150	1.7	-	<2	<2	6.1	-	11.3	-	12.7	-	7.8	-	17	-	0.003	0.003	<2	<2
14:05:00	18	129	144	1.3	-	<2	<2	3.6	6.4	7.5	-	9.3	-	5.0	-	21	45	<0.001	0.003	<2	<2
14:30 - Dump occurred.																					
14:32:30	1	186	-	1.3	-	<2	<2	1.0	29.8	10.0	-	11.3	-	3.9	-	11	-	<0.001	0.003	<2	<2
14:33:00	9	201	-	1.5	-	<2	<2	8.5	24.0	10.0	-	12.0	-	5.6	-	16	-	0.003	0.003	<2	<2
14:34 - Surface turbid plume arrived at sampling location.																					
14:34:30	18	158	-	1.5	-	<2	<2	11.4	-	10.0	-	8.0	-	5.0	-	131	-	<0.001	0.013	<2	<2
14:35:00	1	243	-	1.7	-	<2	<2	11.0	-	12.5	-	16.0	-	5.6	-	43	-	<0.001	0.006	<2	<2
14:35:30	9	201	-	2.0	-	<2	<2	15.7	-	12.5	-	14.0	-	10.5	-	69	281	0.003	0.003	<2	<2
14:36:00	18	143	-	1.3	-	<2	<2	9.0	-	11.3	-	9.3	-	5.0	-	92	-	0.003	0.016	<2	<2
14:36 - Surface turbid plume passed sampling location.																					
14:37:00	1	186	-	1.3	-	<2	<2	3.8	9.0	10.0	-	10.7	-	4.4	4.7	24	-	0.003	0.003	<2	<2
14:38:00	9	201	-	1.3	-	<2	<2	8.6	13.5	10.0	-	14.0	-	6.1	-	28	-	0.003	0.003	<2	<2
14:39:00	18	172	-	1.9	-	<2	<2	11.8	-	10.0	-	39.3	-	8.9	-	47	-	<0.001	0.006	<2	<2

SOL and TOT represent soluble fraction and total particulate concentration, respectively.
Dash (-) indicates no data available.

Table 269

Nitrogen Compound Data: Galveston Dump No. 3 near Buoy D Dredged Materials from Galveston Bay Entrance Channel Buoys 6 through 8

(August 28, 1975)

Time of Collection (hr:min:sec)	Depth (m)	Organic N (mg N/l)	Ammonium (mg N/l)	Nitrate (mg N/l)
14:02:00	1	0.35	0.01	0.06
14:04:00	9	0.30	0.02	1.50*
14:05:00	18	0.31	<0.01	0.06
14:30:00 - Disposal occurred.				
14:32:30	1	0.35	0.01	0.05
14:33:00	9	0.39	0.01	0.04
14:34:00 - Surface turbid plume arrived at sampling location.				
14:34:30	18	0.36	0.04	*
14:35:00	1	0.35	0.01	0.05
14:35:30	9	0.19	0.01	0.06
14:36:00 - Surface turbid plume passed sampling location.				
14:36:00	18	1.99	0.05	0.05
14:37:00	1	0.35	0.01	0.06
14:38:00	9	0.38	0.02	0.06
14:39:00	18	1.19	0.01	0.05

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*These samples appear to have been contaminated.

reached the sampling ship. Just three minutes later, when the plume had apparently passed, the concentration at the bottom essentially returned to the detection limit of the analytical procedure used. Organic N concentrations in the surface and mid-depth waters did not appear to be affected by the disposal, although bottom water concentrations increased from 0.31 mg N/l before disposal to as high as 1.99 mg N/l after the surface turbid plume passed the sampling site. As expected, disposal apparently had no effect on nitrate concentrations.

Phosphorus compounds. Table 270 presents the soluble orthophosphate data for Galveston Dump No. 3. The greatest increase (53-fold) in the soluble ortho P concentrations occurred at the 9 m depth. In less than three minutes, soluble ortho P returned to the concentrations present 30 minutes before disposal. There appears to be an inverse relationship between soluble orthophosphate concentrations and light transmission. The data seem to indicate that soluble ortho P was released as the turbid plume of dredged material passed, although surface concentrations of soluble orthophosphate did not appear to change during this disposal operation. However, no surface water sample was taken just prior to 14:35, which is when the turbidity pattern would have indicated an increase in soluble ortho P concentrations, were such an increase to occur.

The concentration pattern of soluble orthophosphate near the bottom during Galveston Dump No. 3 is not clear because of the limited number of samples collected. Concentrations appeared to rise during the monitoring period. However, since bottom sampling ceased nine minutes after the dump, it is not possible to determine the extent or duration of this increase.

Organic compounds. Concentrations of soluble TOC in composite samples collected before, during, and after

Table 270

Soluble Orthophosphate Concentrations: Galveston Dump No. 3 near Buoy D Dredged Materials from Galveston Bay Entrance Channel Buoys 6 through 8

(August 28, 1975)

Time of Collection (hr:min:sec)	Depth (m)	Soluble Orthophosphate (mg P/l)	
		$\bar{X}$	SD
14:02:00	1	<0.01	∿0.001
14:04:00	9	<0.01	∿0.001
14:05:00	18	0.016	0.002
	14:30 - Dump occurred.		
14:32:30	1	<0.01	∿ 0
14:33:00	9	0.154	0.001
	14:34 - Surface turbid plume arrived at sampling location.		
14:34:30	18	0.024	0.001
14:35:00	1	<0.01	∿ 0
14:35:30	9	0.531	0.008
	14:36 - Surface turbid plume passed sampling location.		
14:36:00	18	0.076	0.001
14:37:00	1	<0.01	∿0.002
14:38:00	9	<0.01	∿ 0
14:39:00	18	0.171	0.002

Standard deviation calculated from triplicate analyses of one sample. The approximate standard deviations indicate that one or more of the replicates showed a concentration below the detection limit.

Galveston Dump No. 3 were 4.8, 5.1, and 5.0 mg/l, respectively. Data on soluble TOC in the third dump showed no significant change at the 95 percent confidence level before, during, or after passage of the surface turbid plume. The soluble oil and grease content of the composite samples was below the detection limit (0.5 mg/l).

Galveston Dump No. 4

The fourth dump that was monitored occurred at 12:58 on August 29, 1975. The surface turbid plume arrived at 13:00 and passed the sampling boat at 13:02. The distance between the sampling vessel and the dump site was approximately 30 meters. The surface currents were found to be approximately 1 knot (51 cm/sec). Approximately 1100 cubic yards of material dredged between GBEC Buoys 1 and 3 were disposed of during the dump.

Optical properties. Figure 88 shows the distribution pattern of material for Galveston Dump No. 4. The data show that the suspended material was present at each depth monitored (2, 8, and 14 meters). The suspended material took 2.75, 3.25, and 2.25 minutes to reach the monitoring location at surface, mid-depth, and bottom, respectively. As in Dump No. 3, turbidity was greatest near the bottom, where turbid conditions persisted for ten minutes. The Secchi depth was 2.5 meters both prior to disposal and 37 minutes after Galveston Dump No. 4.

Temperature, dissolved oxygen, salinity and pH. Table 271 presents D.O., salinity (specific conductance), and pH data for Galveston Dump No. 4. Figure 89 shows that just after the turbid plume arrived, there was a drop of 1.7 mg/l in the D.O. concentration. The D.O. returned to pre-disposal levels ten minutes after the dump occurred. Table 271 shows that there was no significant change either in pH values or salinity during the disposal operations.

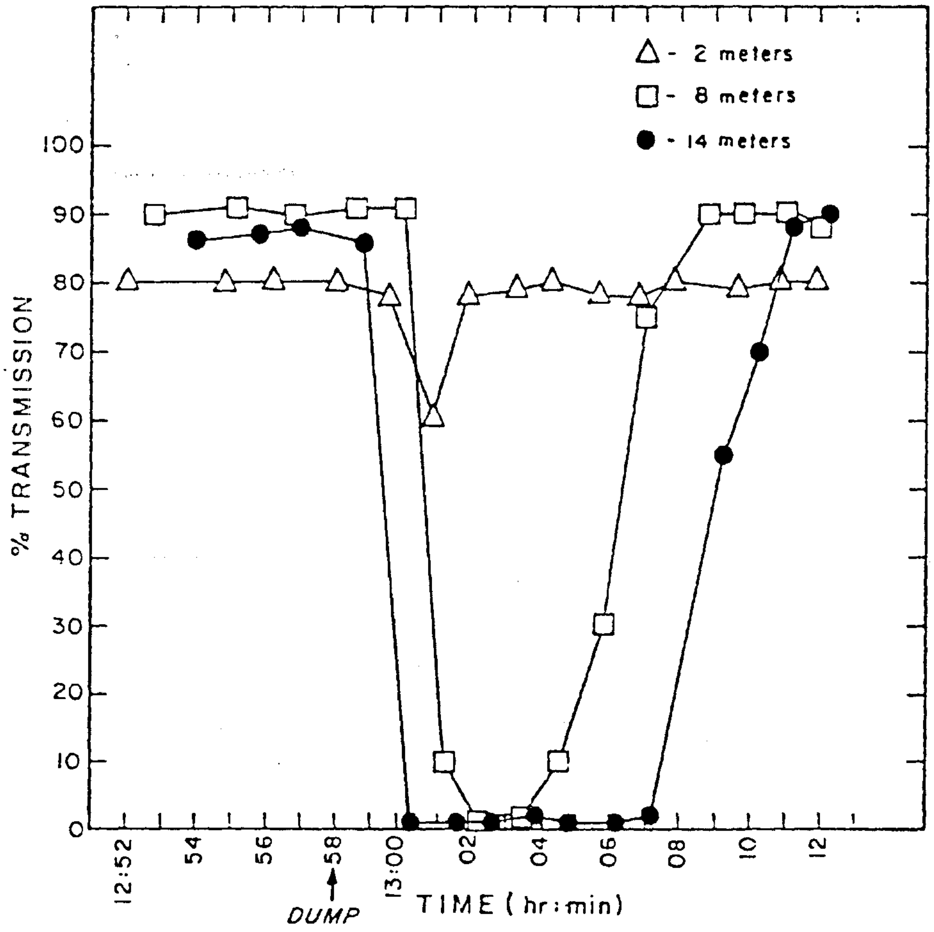

Figure 88
Percent Transmission: Galveston Dump No. 4
Dredged Material from Galveston Bay Entrance
Channel, Buoys 1-3, August 29, 1975

Table 271

Hydrolab Data: Galveston Dump No. 4*, Dredged Materials from Galveston Bay Entrance Channel Buoys 1 through 3

(August 29, 1975)

Time of Collection (hr:min:sec)	pH	Dissolved Oxygen (mg/1@29°C)	Specific Conductance (μmhos/cm)	Salinity (°/oo)
12:47:30	8.3	6.5	43,000	28
12:54:30	8.2	6.6	48,000	31
12:55:00	8.2	6.5	48,000	31
12:57:00	8.2	6.5	48,000	31
12:58 - Dump occurred.				
12:58:00	8.2	6.5	48,000	31
12:58:15	8.2	6.6	48,000	31
12:58:45	8.2	6.5	48,000	31
12:59:15	8.2	6.5	48,000	31
13:00 - Surface turbid plume arrived at sampling location.				
13:000:00	8.2	6.5	48,000	31
13:00:30	8.1	4.8	47,000	30
13:01:00	8.1	5.5	47,000	30
13:01:30	8.2	6.0	47,000	30
13:03:00	8.2	6.4	48,000	31
13:02 - Surface turbid plume passed sampling location.				
13:03:00	8.2	6.3	48,000	31
13:04:00	-	6.5	47,000	30
13:04:30	-	6.4	-	-
13:05:00	8.2	6.4	47,000	30
13:05:30	-	-	-	-
13:06:30	8.2	6.3	47,000	30
13:07:30	8.2	6.3	47,000	30
13:08:30	8.2	6.4	47,000	30
13:09:30	8.2	6.5	47,000	30
13:10:30	8.2	6.6	47,000	30

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*Depth - 14 m.

Dash (-) indicates no reading taken.

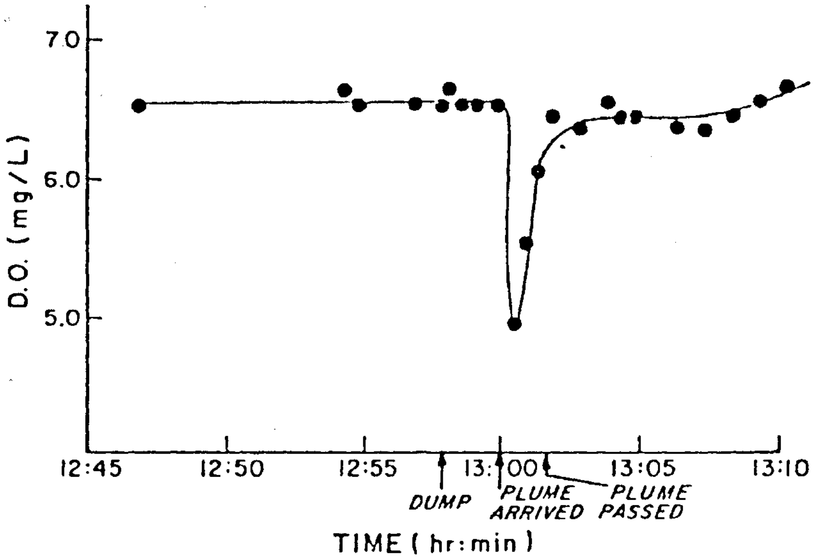

Figure 89

Dissolved Oxygen Concentrations: Galveston Dump No. 4
Dredged Material from Galveston Bay Entrance Channel
Buoys 1-3, August 29, 1975

Heavy metals. Table 272 presents the heavy metal results from Dump No. 4. No manganese release was observed in Galveston Dump No. 4; in fact, manganese concentrations appeared to decrease toward the end of the turbid plume passage, possibly because of dilution and/or precipitation. Sorption of lead and zinc apparently also occurred, as soluble concentrations of both metals decreased during plume passage.

Four samples, two from 8 meters and two from 14 meters, showed increased mercury concentrations. These values ranged from 0.010 to 0.048 µg/l (0.003 µg/l was observed prior to disposal). These higher concentrations occurred about two minutes after the surface turbid plume had passed the sampling location. Transmissometer data (Figure 88) shows that the plume was still present at the 8 and 14 meter depths during this time. Samples taken about one minute later showed that mercury levels had returned to pre-disposal concentrations. There appeared to be a slight elevation in mercury concentrations in the surface waters, but this was declining at the end of the monitoring period.

Nitrogen compounds. The results of nitrogen compound analysis for Dump No. 4 are presented in Table 273. A sudden increase in ammonium concentrations in the surface and mid-depth water samples was observed at 13:02:30. A very sharp increase in organic N concentration (to 7.24 mg N/1) was observed in the surface water at 13:02:30. However, by 5 minutes after the surface turbid plume passed the sampling ship, concentrations decreased and seemed to stabilize. Organic N concentrations in the mid-depth water almost doubled. However, by 10 minutes after the surface plume passed, concentrations apparently returned to ambient levels. Table 273 shows a time lag between the increase of organic N concentrations in the surface and mid-depth water. This lag was related to the fact that the surface current velocity was considerably higher than mid-depth or bottom current velocity.

Table 272

Heavy Metal* Concentrations: Galveston Dump No. 4 Near Buoy D

Dredged Materials from Galveston Bay Entrance

Channel Buoys 1 through 3

(August 29, 1975)

(μg/l)

Time of Collection (hr:min:sec)	Depth (m)	Mn		Cd		Cr		Zn		Ni		Pb		Cu		Fe		Hg		As	
		SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT
12:54:00	14	186	-	1.7	-	<2	<2	17.8	-	11.3	-	9.3	-	7.2	-	58	431	0.003	0.003	< 2	<2
12:58 - Dump occurred.																					
12:59:30	14	201	-	1.5	-	<2	<2	13.8	-	12.5	-	14.7	-	5.6	-	35	344	<0.001	0.003	< 2	<2
13:00 - Surface turbid plume arrived at sampling location.																					
13:00:30	1	172	-	1.5	-	<2	<2	12.8	-	10.0	-	12.7	-	8.3	-	18	46	<0.001	<0.001	< 2	<2
13:01:30	8	186	-	1.7	-	<2	<2	7.2	-	10.0	-	10.0	-	4.4	-	13	103	0.003	0.003	< 2	<2
13:02 - Surface turbid plume passed sampling location.																					
13:02:30	1	123	160	2.1	-	<2	<2	13.2	92.1	-	-	3.6	59.8	6.1	28.1	37	1100	0.003	0.039	< 2	< 2
13:03:00	8	105	-	<0.5	-	<2	<2	7.3	-	-	-	3.1	-	2.6	-	9	-	<0.001	0.023	< 2	< 2
13:03:30	8	-	-	-	<0.5	<2	<2	-	-	-	2.4	-	-	-	7.2	-	480	<0.001	0.003	< 2	< 2
13:03:50	14	105	182	<0.5	<0.5	<2	<2	8.5	59.9	0.7	16.8	3.1	37.9	3.5	21.2	25	1700	0.003	0.016	< 2	< 2
13:04:15	8	88	111	<0.5	<0.5	<2	<2	9.6	30.9	6.6	-	2.0	88.0	3.5	12.7	13	900	0.016	-	< 2	< 2
13:04:30	14	-	147	<0.5	2.2	<2	<2	7.0	22.0	3.3	5.9	4.0	14.6	2.6	6.7	227	900	0.010	-	< 2	< 2
13:05:30	8	35	200	<0.5	<0.5	<2	<2	7.9	24.7	2.7	4.5	1.7	13.1	5.7	8.2	155	900	0.048	-	< 2	< 2
13:06:00	14	18	200	<0.5	<0.5	<2	<2	2.5	44.2	4.1	12.9	<1	26.3	2.8	15.2	<5	1100	0.023	0.023	< 2	< 2
13:06:30	1	14	126	0.7	-	<2	<2	2.4	10.8	3.6	-	<1	7.3	4.0	4.2	<5	-	0.006	0.010	< 2	< 2
13:07:15	14	25	200	0.6	-	<2	<2	1.4	54.3	2.8	14.0	<1	30.6	2.8	18.7	8	1100	0.006	0.016	< 2	< 2
13:09:45	14	56	165	0.7	-	<2	<2	2.3	18.8	3.6	7.7	<1	14.6	3.6	7.2	15	1000	0.006	0.006	< 2	< 2
13:11:30	8	29	108	<0.5	<0.5	<2	<2	2.0	5.4	2.8	-	<1	5.8	2.8	-	<5	22	0.006	0.026	< 2	< 2
13:12:15	1	40	133	<0.5	<0.5	<2	<2	1.6	3.7	4.1	-	<1	5.8	2.3	3.7	<5	55	0.003	0.023	< 2	< 2

*For explanation of SOL and TOT see Table 208.

Dash (-) indicates no data available.

Table 273

Nitrogen Compound Data: Galveston Dump No. 4 near Buoy D, Dredged Materials from Galveston Bay Entrance Channel Buoys 1 through 3

(August 29, 1975)

Time of Collection (hr:min:sec)	Depth (m)	Organic N (mg N/l)	Ammonium (mg N/l)	Nitrate (mg N/l)
12:52:00	1	-	0.01	-
12:53:00	8	-	0.01	-
12:54:00	14	0.30	0.02	0.05
	12:58 - Disposal occurred.			
12:58:30	1	-	0.01	-
12:58:45	8	-	0.02	-
12:59:30	14	0.35	0.01	0.10
	13:00 - Surface turbid plume arrived at sampling location.			
13:00:30	1	0.87	0.01	0.06
13:01:30	8	0.30	0.06	0.05
	13:02 - Surface turbid plume passed sampling location.			
13:02:30	1	7.24	0.36	0.09
13:03:00	8	-	0.15	0.06
13:03:30	8	0.27	0.01	0.05
13:03:45	1	-	0.01	-
13:03:50	14	1.31	0.01	0.05
13:04:00	1	-	0.01	-
13:04:15	8	0.66	0.02	0.07
13:04:30	14	0.65	0.03	0.08
13:05:30	8	0.63	0.01	0.08
13:06:00	14	2.05	0.01	0.05
13:06:30	1	0.39	0.01	0.13

Table 273 (Concluded)

Time of Collection (hr:min:sec)	Depth (m)	Organic N (mg N/l)	Ammonium (mg N/l)	Nitrate (mg N/l)
13:06:45	8	-	0.01	-
13:07:15	14	2.07	0.01	0.10
13:08:30	1	-	0.02	-
13:09:00	8	-	0.01	-
13:09:45	14	1.02	0.02	0.07
13:11:00	14	-	0.01	-
13:11:30	8	0.26	0.02	0.07
13:12:15	1	0.43	<0.01	0.05

Dash (-) indicates no analysis made.

In the bottom water, organic N concentrations showed at least two maxima. There was a sharp increase (to 1.31 mg N/l) five minutes after the disposal, followed by a decrease. Eight minutes after the disposal, a second increase (to 2.07 mg N/l) was observed. Nitrate concentrations started increasing in the surface water about five minutes after disposal but returned to ambient concentrations by 14 minutes after the dump. In the bottom and mid-depth water, nitrate concentrations did not show any clear pattern of variation, although concentrations at both depths exhibited several maxima.

Phosphorus compounds. Data in Table 274 show that the soluble ortho P concentrations during Dump No. 4 appeared to increase at all three depths during this disposal operation. Concentrations increased 25 to 55 fold but returned to ambient levels within a 6 to 8 minute period. These increases occurred shortly after a rapid decrease in light transmission (Figure 88). It appears that the smallest

Table 274

Soluble Orthophosphate Concentrations: Galveston Dump No. 4 near Buoy D, Dredged Materials from Galveston Bay Entrance Channel Buoys 1 through 3

(August 29, 1975)

Time of Collection (hr:min:sec)	Depth (m)	Soluble Orthophosphate (mg P/l)
12:54:00	14	0.447
	12:58 - Dump occurred.	
12:59:30	14	<0.01
	13:00 - Surface turbid plume arrived at sampling location.	
13:00:30	1	0.289
13:01:30	8	<0.01
	13:02 - Surface turbid plume passed sampling location.	
13:02:30	1	0.547
13:03:00	8	0.018
13:03:30	8	<0.01
13:03:50	14	0.254
13:04:15	8	0.077
13:04:30	14	0.186
13:05:30	8	0.261
13:06:00	14	0.013
13:06:30	1	<0.01
13:07:15	14	0.012
13:09:45	14	<0.01
13:11:30	8	<0.01
13:12:15	1	<0.01

Concentration based on one analysis of one sample.

reduction in light transmission and the greatest release of soluble ortho P occurred in the surface waters. The sample taken at 14 m at 12:54 also showed a higher concentration (0.447 mg P/l) of soluble ortho P. This value could be related to residual effects from previous dumps. However, the concentration could be a spurious point, as it was found prior to the dump and most baseline concentrations found were not that erratic.

Organic compounds. Soluble TOC concentrations in composite samples from the fourth dump were 11.2, 23,and 9.8 mg/l, respectively (before, during, and after the turbid plume passage). Total organic carbon in composites of samples taken before, during,and after passage of the surface turbid plume were 25.8, 38.4,and 38.3, respectively. The oil and grease and soluble oil and grease content for these composite samples was < 0.5 mg/l.

Galveston Dump No. 5

The last dump monitored near Buoy D on August 29, 1975, occurred at 14:27. The surface turbid plume arrived at 14:28 and passed at 14:29. The sampling boat was approximately 80 meters from the dump site. The dredge passed between the sampling boat and the buoy, disposing of 1115 cubic yards of the material dredged between Buoys 1 and 3. The pre-disposal currents and other conditions were identical to those for Dump No. 4.

Optical properties. Figure 90 depicts the turbidity data for Galveston Dump No. 5. Percent transmission was monitored at 2 meters (surface), 8 meters (middle), and 14 meters (bottom). The suspended material took one minute (surface), 4 minutes (middle),and 4.5 minutes (bottom) to reach the sampling vessel. Again, the bottom depth showed the greatest turbidity. However, unlike bottom plumes observed in Galveston Dumps No. 3 and 4, the bottom plume in

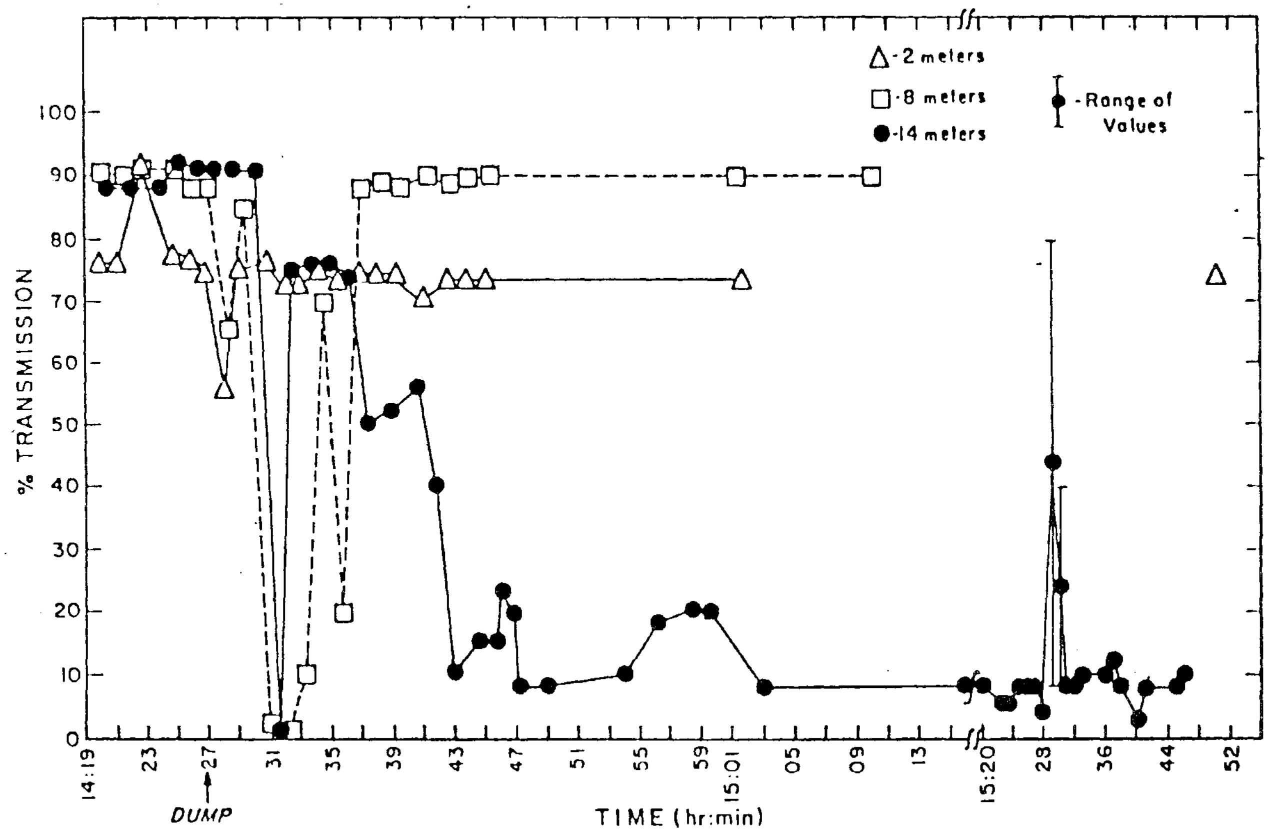

Figure 90

Percent Transmission: Galveston Dump No. 5 near Buoy D, Dredged Material from Galveston Bay Entrance Channel, Buoys 1-3, August 29, 1975 this disposal operation developed after the surface and middle plumes. In addition, the turbidity measured at 14 meters persisted for over one hour. The surface samples showed the same type of turbidity pattern observed during the previous disposal operation.

Dissolved oxygen. Figure 91 presents the plot of the readings of D.O. taken at 14 meters. The figure shows that five minutes after the dump occurred, the D.O. concentrations decreased 1.5 mg/l. Several minutes later another depression in D.O. was seen. Unlike previous dumps, there was not a return to the initial concentrations within ten minutes of disposal. The concentrations did not stay at one level but fluctuated slightly below the pre-disposal levels.

Heavy metals. Table 275 presents water column concentrations of heavy metals for Galveston Dump No. 5. This disposal followed the last one by about 1.5 hours. Due to the larger number of samples analyzed, a well-defined picture of release and sorption was possible. There was an indication of manganese release (about 90 µg/l) in the bottom (16 m) samples. Iron concentrations fluctuated during the sampling period, with several samples showing values above pre-disposal levels. There was no indication of release or sorption of the other metals.

Nitrogen compounds. The ammonium, organic N, and nitrate data for the fifth disposal operation are presented in Table 276. For these and subsequent studies, the detection limit for ammonium was adjusted to <0.05 mg N/l. The ammonium concentrations in the bottom waters and the nitrate concentrations at all three depths are plotted in Figures 92 and 93. These figures indicate that dredged sediment disposal had a significant influence on the bottom waters where very sharp fluctuations in the ammonium concentrations

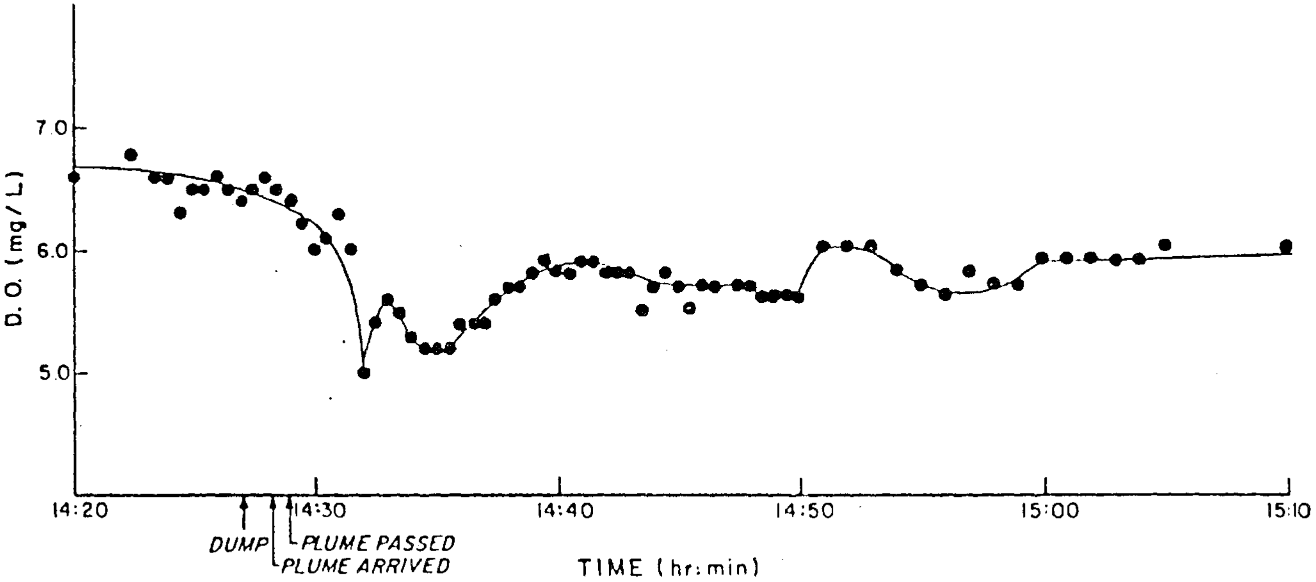

Figure 91

Dissolved Oxygen Concentrations: Galveston Dump No. 5 near Buoy D, Depth 14 m, Dredged Material from Galveston Bay Entrance Channel, Buoys 1-3, August 29,1975

Table 275

Heavy Metal Concentrations: Galveston Dump No. 5 Near Buoy D, Dredged Materials from Galveston Bay Entrance Channel

Buoys 1 through 3

(August 29, 1975)

(μg/l)

Time of Collection (hr:min:sec)	Depth (m)	Mn		Cd		Cr		Zn		Ni		Pb		Cu		Fe		Hg		As	
		SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT
14:26:30	2	96	-	1.1	-	<2	<2	1.5	7.9	8.1	-	7.5	-	4.1	-	<5	72	0.016	-	<2	<2
14:27:00 - Dump occurred.																					
14:27:00	8	69	-	1.1	-	<2	<2	3.5	5.2	9.0	-	10.0	-	3.2	-	<5	19	0.006	0.006	<2	<2
14:28:00 - Surface turbid plume arrived at sampling location.																					
14:28:00	16	48	-	0.9	0.9	<2	<2	1.2	6.8	9.0	-	8.8	-	3.6	-	<5	54	0.006	0.023	<2	<2
14:28:30	2	89	-	0.9	0.8	<2	<2	<0.5	5.4	8.1	-	7.5	-	3.6	-	6	66	0.003	0.006	<2	<2
14:29:00 - Turbid plume passed sampling location.																					
14:29:45	8	140	-	1.1	1.7	2	2	3.3	17.9	0.0	12.2	17.7	-	6.2	7.4	17	17	0.006	0.023	<2	<2
14:30:30	16	82	-	1.4	-	<2	<2	4.8	17.5	6.7	7.1	7.5	-	4.5	-	<5	920	0.003	0.010	<2	<2
14:30:45	2	115	123	1.0	1.2	<2	<2	3.3	18.4	2.3	12.4	7.3	23.3	3.0	8.0	11	63	0.003	0.006	<2	<2
14:31:15	16	140	-	1.5	-	<2	<2	2.2	4.0	7.3	8.3	16.4	16.4	8.2	-	9	390	0.003	0.006	<2	<2
14:31:30	8	81	-	0.9	-	<2	<2	12.5	-	3.6	4.9	13.3	-	3.1	-	11	27	0.003	0.006	<2	<2
14:32:00	16	55	89	1.2	1.3	<2	<2	4.5	42.1	9.5	28.5	6.3	12.4	5.0	10.0	<5	1200	0.006	0.010	<2	<2
14:32:30	8	156	210	1.4	1.8	<2	<2	4.0	16.5	7.3	11.9	15.0	-	6.5	7.4	<5	21	0.006	0.006	<2	<2
14:32:45	16	29	280	1.7	-	<2	<2	3.4	33.9	2.5	23.8	13.3	38.9	1.8	26.8	<5	16,300	0.006	0.030	<2	<2
14:33:00	2	89	-	1.1	-	<2	<2	2.7	6.3	8.1	-	56.9	-	4.5	4.0	<5	85	0.006	0.006	<2	<2
14:33:30	16	41	123	1.1	-	<2	<2	4.1	62.3	9.5	12.8	10.0	44.3	5.0	22.8	<5	1500	0.003	0.023	<2	<2
14:33:45	16	135	-	0.7	-	<2	<2	5.1	49.8	5.2	22.8	12.4	52.6	2.8	19.8	35	10,700	0.006	0.020	<2	<2

(Continued)

Table 275 (Continued)

Time of Collection (hr:min:sec)	Depth (m)	Mn		Cd		Cr		Zn		Ni		Pb		Cu		Fe		Hg		As	
		SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT
13:34:30	16	123	144	1.1	1.5	<2	<2	2.0	40.1	9.5	14.0	11.3	35.2	3.6	14.1	<5	6800	0.006	0.016	<2	<2
14:35:15	16	175	263	1.5	1.6	<2	<2	4.9	33.1	9.0	17.8	11.1	24.7	7.5	15.3	30	10200	0.003	0.049	<2	<2
14:35:30	16	171	-	0.6	1.7	<2	<2	10.8	36.1	12.4	14.8	12.4	33.4	6.9	13.1	639	6900	0.003	0.023	<2	<2
14:36:15	16	55	171	1.1	-	<2	<2	4.7	30.7	7.1	21.2	10.0	29.7	4.1	11.1	17	6600	0.003	0.010	<2	<2
14:36:30	16	69	-	0.9	-	<2	<2	2.4	39.6	10.5	19.6	8.8	32.5	4.1	13.1	<5	6800	0.003	0.010	<2	<2
14:37:00	16	-	245	-	1.2	-	<2	-	22.7	-	18.6	-	37.5	-	18.3	-	10200	<0.001	0.043	<2	<2
14:37:30	8	140	162	1.5	1.8	<2	<2	5.6	10.5	9.7	-	13.7	16.9	6.2	-	9	2700	0.006	-	<2	<2
14:37:45	16	189	-	0.9	-	<2	<2	13.3	27.5	17.2	-	16.9	21.5	6.7	8.1	2300	4800	0.006	0.023	<2	<2
14:39:45	8	123	245	1.4	1.6	<2	<2	2.9	17.7	8.0	12.7	15.0	16.3	7.5	8.3	10	4100	0.003	0.016	<2	<2
14:40:20	16	140	103	1.5	1.7	<2	<2	1.6	15.4	8.7	15.1	15.0	20.5	5.5	10.7	6	6200	0.003	0.030	<2	<2
14:42:00	16	129	210	1.6	-	<2	<2	11.7	22.6	1.0	14.6	8.0	29.0	2.8	10.1	32	4200	0.023	-	<2	<2
14:43:45	16	123	103	1.7	-	<2	<2	2.0	17.2	8.0	13.5	20.3	14.8	6.2	9.8	9	4700	0.006	0.006	<2	<2
14:45:45	16	105	158	1.7	-	<2	<2	7.9	31.3	8.7	14.1	19.0	21.9	5.8	10.7	9	4100	0.010	0.010	<2	<2
14:46:30	2	100	158	1.4	1.6	<2	<2	4.5	14.8	2.1	13.0	8.7	19.1	2.2	8.3	<5	53	0.006	0.010	<2	<2
14:47:15	8	123	210	1.4	-	<2	<2	7.0	36.6	6.7	11.9	19.0	21.9	6.5	6.8	12	19	0.016	0.006	<2	<2

(Continued)

Table 275 (Concluded)

Time of Collection (hr:min:sec)	Depth (m)	Mn		Cd		Cr		Zn		Ni		Pb		Cu		Fe		Hg		As	
		SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT	TOT	SOL	SOL	TOT
14:47:45	16	140	175	1.4	-	< 2	< 2	4.0	20.9	7.7	16.5	15.0	30.4	7.2	13.5	161	7700	0.003	0.016	<2	<2
14:50:15	16	156	158	1.2	1.3	< 2	< 2	11.6	18.6	8.3	13.8	12.4	19.1	6.5	8.3	13	3700	0.016	0.016	<2	<2
14:53:15	16	-	228	-	1.7	-	< 2	-	12.6	-	12.2	-	16.3	-	7.4	-	2700	0.006	0.006	<2	<2
15:02:12	16	193	210	1.4	1.5	< 2	< 2	9.6	12.6	8.0	12.2	15.0	-	6.2	7.4	58	3200	0.006	0.010	<2	<2
15:11:45	16	29	158	1.3	-	< 2	< 2	3.3	17.6	1.4	13.5	8.0	26.2	1.2	7.7	<5	2700	0.006	0.006	<2	<2
15:16:45	2	14	140	1.3	1.8	< 2	< 2	2.1	16.9	1.6	11.9	8.0	10.6	2.8	8.3	10	60	0.010	-	<2	<2
15:17:30	8	71	175	1.1	-	< 2	< 2	7.7	-	1.9	8.0	8.7	19.0	1.6	5.8	175	-	0.006	0.010	<2	<2
15:18:30	16	175	193	1.5	-	< 2	< 2	5.2	16.0	9.0	13.0	15.0	17.7	6.5	8.0	6	3200	0.006	0.006	<2	<2

For explanation of SOL and TOT see Table 208.

Dash (-) indicates no data available.

Table 276

Nitrogen Compound Data: Galveston Dump No. 5 near Buoy D
Dredged Materials from Galveston Bay Entrance
Channel Buoys 1 through 3

(August 29, 1975)

(mg N/l)

Time of Collection (hr:min:sec)	Depth (m)	Organic N	Ammonium*	Nitrate
14:26:30	2	0.34	<0.05	-
	14:27:00 - Dump occurred.			
14:27:00	8	0.25	<0.05	-
	14:28:00 - Surface turbid plume arrived at sampling location.			
14:28:00	16	0.36	<0.05	0.05
14:28:30	2	0.40	<0.05	0.06
	14:29:00 - Surface turbid plume passed sampling location.			
14:29:30	2	-	<0.05	-
14:29:45	16	-	<0.05	-
14:29:45	8	-	<0.05	0.09
14:30:45	2	0.27	<0.05	0.08
14:31:15	16	0.27	<0.05	0.08
14:31:30	8	0.31	<0.05	-
14:32:00	16	-	<0.05	0.22
14:32:30	8	0.38	<0.05	0.09
14:32:45	16	2.67	<0.05	<0.04
14:33:00	2	0.42	<0.05	0.09
14:33:30	16	1.25	0.11	0.10
14:33:45	16	2.32	0.16	0.04
14:34:30	16	-	<0.05	<0.04
14:34:45	2	-	<0.05	-
14:35:15	16	-	<0.05	<0.04
14:35:30	16	0.87	<0.05	-

(Continued)

Table 276 (Continued)

Time of Collection (hr:min:sec)	Depth (m)	Organic N	Ammonium*	Nitrate
14:36:15	16	1.35	<0.05	0.09
14:36:30	16	-	0.38	0.12
14:36:45	2	-	<0.05	-
14:37:00	16	-	<0.05	0.71
14:37:30	8	0.42	<0.05	<0.04
14:37:45	16	0.74	0.10	0.12
14:39:45	8	0.35	<0.05	0.12
14:40:20	16	0.50	<0.05	-
14:41:00	2	-	<0.05	-
14:42:00	16	0.47	<0.05	0.12
14:42:45	2	-	<0.05	-
14:43:30	8	-	<0.05	-
14:43:45	16	0.47	<0.05	0.13
14:44:30	2	-	<0.05	-
14:45:15	8	-	<0.05	-
14:45:45	16	0.42	<0.05	<0.04
14:46:30	2	-	<0.05	0.11
14:47:15	8	0.35	<0.05	0.14
14:47:45	16	0.90	<0.05	0.12
14:48:30	2	-	<0.05	-
14:49:30	8	-	<0.05	-
14:50:15	16	0.32	<0.05	0.09
14:51:45	2	-	<0.05	-
14:53:15	8	0.09	<0.05	0.11
14:55:30	16	-	<0.05	-
15:00:30	2	-	<0.05	-
15:01:15	8	-	<0.05	-
15:02:15	16	0.31	<0.05	0.09

(Continued)

Table 276 (Concluded)

Time of Collection (hr:min:sec)	Depth (m)	Organic N	Ammonium*	Nitrate
15:10:30	2	-	<0.05	-
15:11:00	8	-	<0.05	-
15:11:45	16	0.27	<0.05	0.08
15:16:45	2	0.47	<0.05	-
15:17:30	8	0.43	<0.05	0.11
15:18:30	16	0.74	<0.05	0.09
15:23:00	2	-	<0.05	-
15:23:30	8	-	<0.05	-
15:24:30	16	-	<0.05	-
15:28:45	2	-	<0.05	-
15:29:30	8	-	<0.05	-
15:30:15	16	-	<0.05	-
15:36:30	2	-	<0.05	-
15:37:45	8	-	<0.05	-

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*For this and subsequent disposal operations, the analytical detection limit for ammonium was adjusted to <0.05 mg N/1. For further discussion, see Part II.

Dash (-) indicates no analysis made.

are seen. Ammonium concentrations in the surface and mid-depth waters remained below the <0.05 mg N/1 detection limit.

Nitrate concentrations in surface and mid-depth water also increased little as a result of disposal. Concentrations in the bottom water increased sharply five minutes after the dump but decreased immediately. They returned to the pre-disposal level after about 35 minutes.

Disposal apparently had no effect on organic nitrogen at surface and mid-depth waters. However, organic N concentrations in the bottom waters increased sharply (to 2.67 mg N/1)

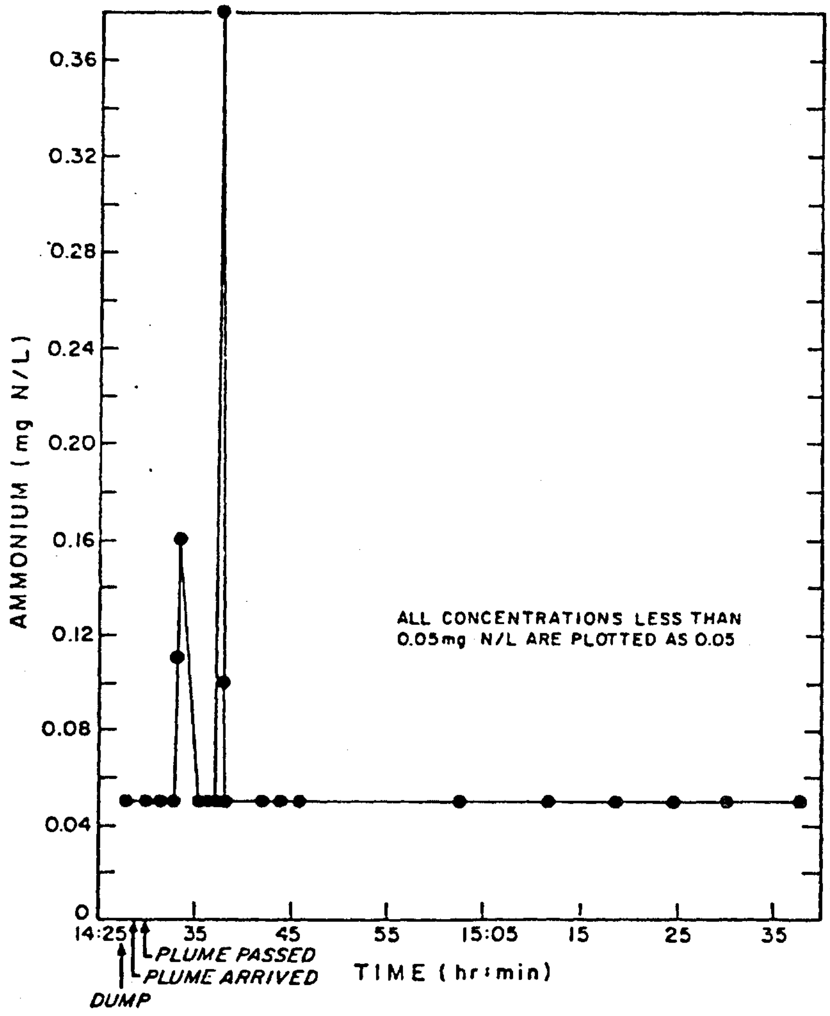

Figure 92

Ammonium Concentrations in Bottom Waters, Galveston Dump No. 5 near Buoy D, August 29, 1975

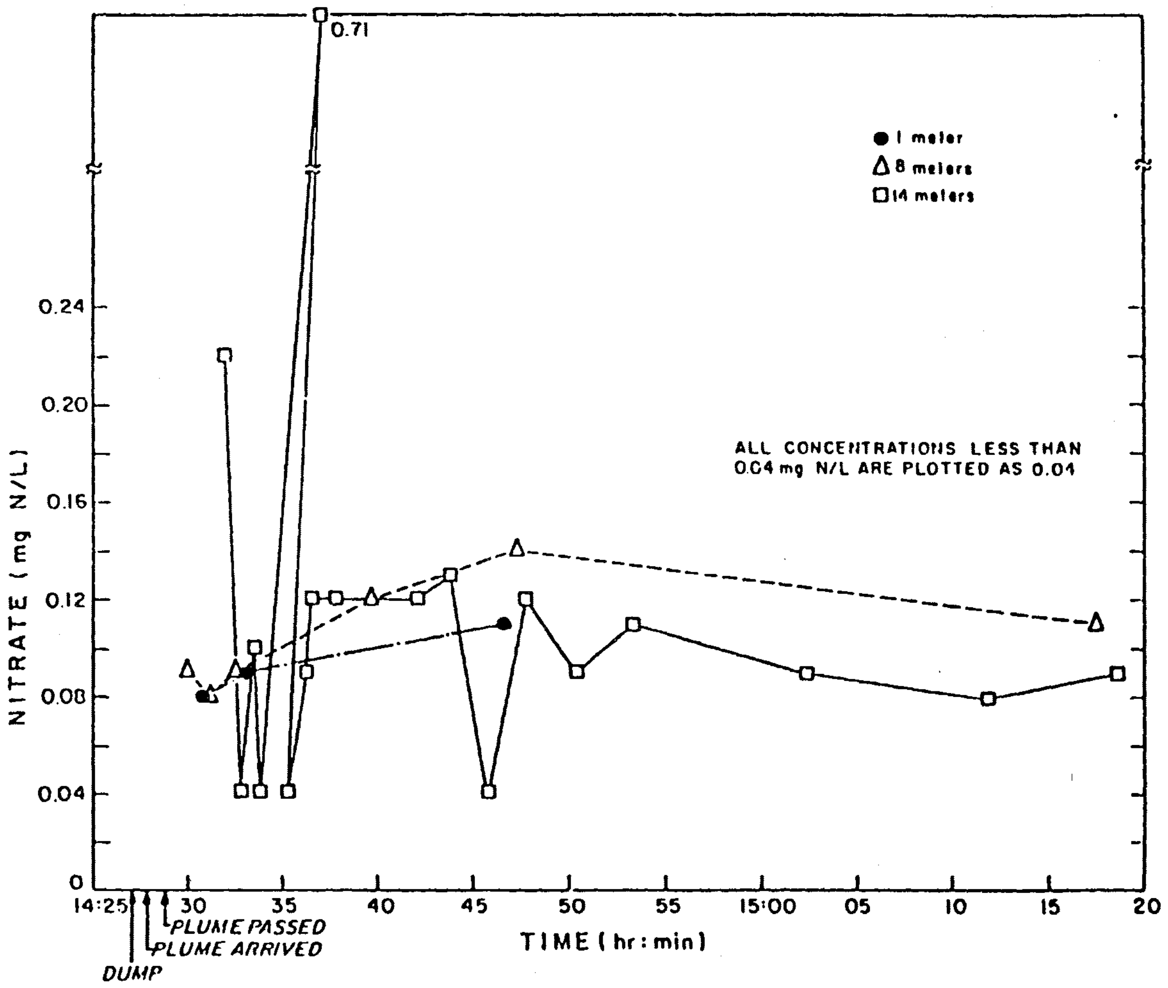

Figure 93
Nitrate Concentrations: Galveston Dump No. 5
near Buoy D, August 29, 1975

four minutes after the plume passed the sampling ship. About ten minutes after disposal, the concentrations in the bottom waters decreased a little but were still higher than in the samples collected prior to the arrival of the turbid plume.

Phosphorus compounds. The concentrations of soluble orthophosphate are listed in Table 277. There was no release of soluble ortho P apparent in the surface waters. At mid-depth (approximately 8 m), soluble ortho P concentrations doubled, but they returned to ambient levels within 10 minutes. The soluble ortho P concentrations near the bottom followed a somewhat irregular pattern, showing two maxima. Concentrations were just slightly above ambient and then increased 12-fold. Rapid recovery to ambient was followed by a 5.5 fold increase and another recovery to ambient about 10 minutes later.

Organic compounds. In the fifth dump, soluble TOC concentrations were 15.4, 28.3, and 15.3 mg/l before, during, and after the passage of the turbid plume, respectively. The concentrations of TOC in the fifth dump were 19.8, 32.6, and 16.2 mg/l, respectively. Soluble oil and grease were below the detection limit of 0.5 mg/l.

Galveston Dump No. 6

The next disposal operation monitored took place at 12:50 on September 9, 1975. The surface turbid plume arrived at 13:02 and passed at 13:04. Material dredged from the GBEC (Buoys 3 through 7A) was dumped near Buoy D at 12:50. The water column depth was 15 meters. The sampling boat was positioned approximately 240 meters from the dump site. Approximately 1500 cubic yards of material were dumped. The surface current was 0.3 knots (15 cm/sec).

Optical properties. Figure 94 shows the percent transmission during Galveston Dump No. 6. Percent transmission was measured at 2 meters (surface), 9 meters (middle), and 15 meters (bottom). The presence of suspended dredged

Table 277

Soluble Orthophosphate Concentrations: Galveston Dump No. 5 near Buoy D, Dredged Materials from Galveston Bay Entrance Channel Buoys 1 through 3

(August 29, 1975)

Time of Collection (hr:min:sec)	Depth (m)	Soluble Orthophosphate (mg P/l)
14:26:30	2	<0.01
14:27 - Dump occurred.		
14:27:00	8	<0.01
14:28 - Surface turbid plume arrived at sampling location.		
14:28:00	16	0.018
14:28:30	2	<0.01
14:29 - Surface turbid plume passed sampling location.		
14:29:45	8	<0.01
14:30:30	16	0.024
14:30:45	2	<0.01
14:31:15	16	<0.01
14:31:30	8	<0.01
14:32:00	16	<0.01
14:32:30	8	0.012
14:32:45	16	<0.01
14:33:00	2	<0.01
14:33:30	16	0.010
14:33:45	16	0.010
14:34:30	16	<0.01
14:35:15	16	<0.01
14:35:30	16	0.018
14:36:15	16	0.014

(Continued)

Table 277 (Concluded)

Time of Collection (hr:min:sec)	Depth (m)	Soluble Orthophosphate (mg P/l)
14:36:30	16	<0.01
14:37:00	16	0.128
14:37:30	8	0.020
14:37:45	16	<0.01
14:39:45	8	0.015
14:40:20	16	0.018
14:42:00	16	0.038
14:43:45	16	<0.01
14:45:45	16	<0.01
14:46:30	2	<0.01
14:47:15	8	0.013
14:47:45	16	0.056
14:50:15	16	0.017
14:53:15	16	0.018
15:02:15	16	<0.01
15:11:45	16	0.017
15:16:45	2	0.011
15:17:30	8	0.011
15:18:30	16	0.011

Concentrations based on one analysis of one sample.

material at the surface, middle, and bottom depths was first observed within 11.57 minutes, 8.08 minutes, and 5.67 minutes, respectively, of the dump. The region of most intense turbidity was again the bottom, although this time at mid-depth the plume was of relatively long duration, some 13 minutes.

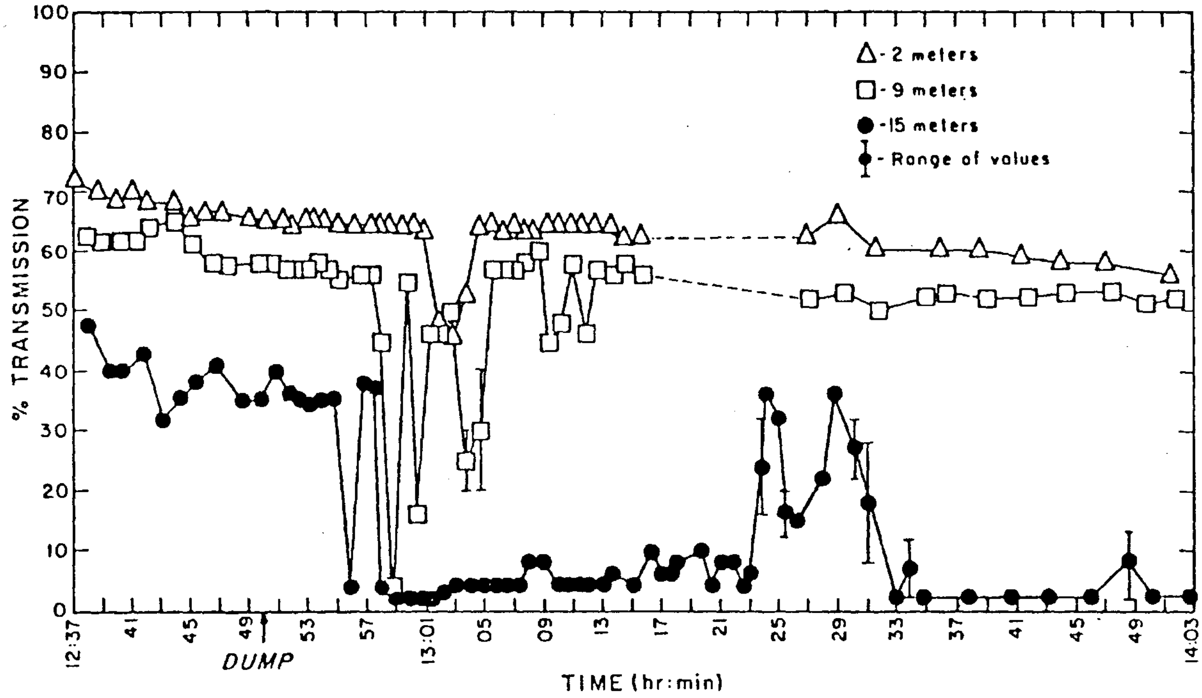

Figure 94

Percent Transmission: Galveston Dump No. 6 near Buoy D, Dredged Material from Galveston Bay Entrance Channel Buoys 3-7A, September 9, 1975

Dissolved oxygen. Dissolved oxygen concentrations for Dump No. 6 are presented in Figure 95. The D.O. reading was taken at a depth of 15 meters. There was a decrease of approximately 0.5 mg/l just after the surface turbid plume arrived at the sampling boat. The D.O. concentration returned to a level of 0.1 mg/l below the pre-disposal concentration within ten minutes of the dump.

Heavy metals. Results of analysis for heavy metals are presented in Table 278. There were no changes in ranges of chromium, arsenic, lead, copper, and zinc concentrations found at the 1, 9, or 15 meter depth during or after the passage of the turbid plume. Further examination of the concentration ranges seen for nickel and manganese show that there was an increase in the levels of these metals seen after the plume passed from those seen before and during the passage of the plume. Cadmium concentrations showed the same pattern of apparent release after the passage of the plume. Mercury increased during the passage of the plume (0.006 μg/l at 1 m and 0.016 μg/l at 9 m). These values were declining at the end of the sampling period.

Nitrogen compounds. Ammonium data presented in Table 279 show that ammonium concentrations for all samples processed from Dump No. 6 were below the detection limit of 0.05 mg N/l.

Phosphorus compounds. Concentrations of soluble orthophosphate are presented in Table 280. Soluble ortho P concentrations appeared to increase at all three depths, but the increases did not appear to be as great as those found during the previous disposal operations near Buoy D. Ambient soluble ortho P concentrations in the surface water were between <0.01 mg P/l (detection limit) and 0.012 mg P/l. During the passage of the surface turbid plume, the concentrations did not rise above this level. The sample taken 11

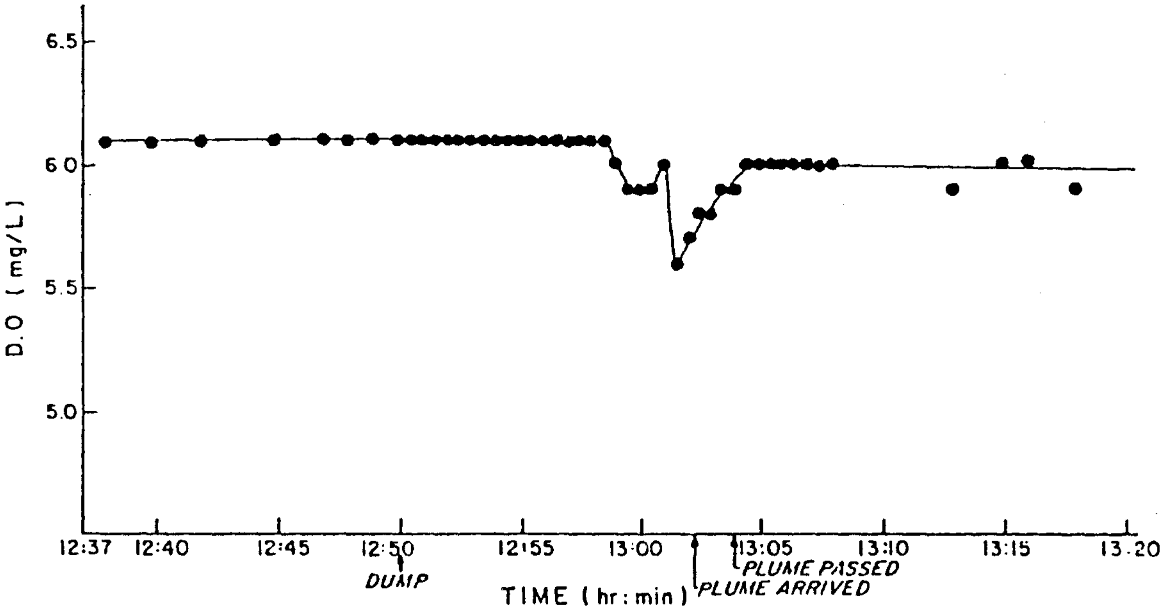

Figure 95

Dissolved Oxygen Concentrations: Galveston Dump
No. 6 near Buoy D, Depth 15 m, Dredged Material
from Galveston Bay Entrance Channel
Buoys 3-7A, September 9, 1975

Table 278

Soluble Heavy Metal Concentrations: Galveston Dump No. 6 near Buoy D, Dredged Materials from Galveston Bay Entrance Channel, Buoys 3 through 7A

(September 9, 1975)

(g/l)

Time of Collection (hr:min:sec)	Depth (m)	Mn	Cd	Cr	Zn	Ni	Pb	Cu	Fe	Hg	As
11:41:00	1	5	<0.5	<2	4.4	2.7	3.6	5.0	40	0.016	<2
11:42:00	9	42	0.8	<2	5.7	5.8	4.8	2.4	22	0.013	<2
11:42:30	15	<5	<0.5	<2	1.6	2.3	3.6	30.0*	29	0.015	<2
12:38:30	1	12	0.5	<2	1.6	2.7	3.6	25.0*	35	0.015	<2
12:39:00	9	5	<0.5	<2	2.9	2.0	1.8	4.1	16	0.005	<2
12:39:30	15	5	0.5	<2	14.7	3.0	4.3	2.2	50	0.013	<2
		12:50 - Dump occurred.									
12:50:15	1	<5	<0.5	<2	11.3	3.0	3.6	3.7	18	0.016	<2
12:50:30	9	18	<0.5	<2	5.6	3.7	4.5	4.1	51	0.013	<2
12:50:45	15	18	<0.5	<2	5.8	3.0	4.5	5.0	38	0.016	<2
12:55:45	15	5	<0.5	<2	1.3	2.7	6.3	3.6	46	0.013	<2
12:59:50	9	<5	<0.5	<2	13.8	2.6	4.3	2.4	40	0.013	<2
13:00:15	15	<5	<0.5	<2	9.3	3.4	3.6	5.0	151*	0.016	<2
13:00:30	1	5	0.5	<2	1.8	2.0	2.7	4.8	46	0.019	<2

(Continued)

Table 278 (Continued)

Time of Collection (hr:min:sec)	Depth (m)	Mn	Cd	Cr	Zn	Ni	Pb	Cu	Fe	Hg	As
13:00:45	9	<5	<0.5	<2	9.0	1.8	4.6	4.0	22	0.017	<2
13:01:15	15	<5	<0.5	<2	15.6	5.4	2.9	3.0	77	0.014	<2
13:02 - Surface trubid plume arrived at sampling location.											
13:02:00	1	12	<0.5	<2	4.6	3.3	4.5	5.5	11	0.017	<2
13:02:15	9	<5	<0.5	<2	7.0	3.0	2.9	5.0	25	0.021	<2
13:02:45	1	<5	<0.5	<2	6.5	2.2	2.1	1.2	21	0.014	<2
13:03:30	1	<5	<0.5	<2	6.3	2.6	3.6	2.5	17	0.021	<2
13:03:45	9	5	<0.5	<2	5.6	3.3	4.5	4.7	29	0.012	<2
13:04 - Surface turbid plume passed sampling location.											
13:04:00	15	12	<0.5	<2	20.7	4.7	1.8	5.0	22	0.010	<2
13:04:30	1	<5	<0.5	<2	14.3	3.0	3.6	2.0	18	0.017	<2
13:05:15	9	42	1.2	<2	5.5	5.8	4.1	2.7	19	0.001	<2
13:05:55	1	33	1.1	<2	6.5	5.5	4.8	2.6	22	0.001	<2
13:06:50	15	150*	0.8	<2	5.4	6.5	3.3	2.2	22	0.001	<2
13:08:10	9	42	1.1	<2	9.7	6.5	4.1	2.4	17	0.001	<2
13:10:00	9	42	1.0	<2	11.4	4.8	4.1	2.3	16	0.001	<2
13:10:45	1	42	2.4	<2	9.8	10.2	4.8	68.1*	21	0.007	<2
13:13:45	9	33	1.2	<2	8.2	6.5	3.3	2.6	282*	0.001	<2

(Continued)

Table 278 (Concluded)

Time of Collection (hr:min:sec)	Depth (m)	Mn	Cd	Cr	Zn	Ni	Pb	Cu	Fe	Hg	As
13:15:00	1	50	1.2	<2	4.4	5.5	3.3	2.4	11	0.003	<2
13:15:20	9	25	1.0	<2	10.7	5.8	2.6	2.8	14	0.003	<2
13:15:35	15	33	1.0	<2	7.9	6.8	2.6	2.7	27	0.024	<2
13:21:15	15	58	0.8	<2	5.7	4.8	2.6	2.4	26	0.003	<2
13:30:30	1	50	1.1	<2	5.3	5.8	2.6	2.3	11	0.006	<2
13:31:00	9	25	1.1	<2	4.8	6.2	3.3	2.2	22	0.018	<2
13:31:35	15	50	1.0	<2	4.3	6.2	2.6	2.2	22	0.003	<2
14:16:15	1	58	1.1	<2	5.9	4.5	4.1	6.4	42	0.003	<2
14:16:30	9	33	0.9	<2	8.6	4.5	2.6	2.7	57	0.003	<2
14:16:45	15	50	0.5	<2	6.4	5.8	2.6	2.2	36	0.012	<2

*There were unusually high values of copper encountered at 11:42:30, 12:38:30 and 13:10:45, ranging from 25 to 68 µg/l. Two high values of iron, 151 µg/l at 13:00:15 and 282 µg/l at 13:13:45 were seen. One manganese value of 150 µg/l at 13:06:50 was also quite high. These high values do not correlate with depth (i.e., they are not all bottom samples), and it is thought that they are probably due to analytical error or sample contamination.

Table 279

Ammonium Concentrations: Galveston Dump No. 6 near Buoy D, Dredged Materials from Galveston Bay Entrance Channel Buoys 3 through 7A

(September 9, 1975)

Time of Collection (hr:min:sec)	Depth (m)	Ammonium (mg N/l)
11:41:00	1	<0.05
11:42:00	9	<0.05
11:42:30	15	<0.05
12:38:30	1	<0.05
12:39:00	9	-
12:39:30	15	<0.05
	12:50 - Dump occurred.	
12:50:15	1	<0.05
12:50:30	9	-
12:50:45	15	<0.05
12:55:45	15	<0.05
12:59:50	9	<0.05
13:00:15	15	<0.05
13:00:30	1	<0.05
13:00:45	9	<0.05
13:01:15	15	<0.05
	13:02 - Surface turbid plume arrived at sampling location.	
13:02:00	1	<0.05
13:02:15	9	<0.05
13:02:45	1	<0.05
13:03:30	1	<0.05
13:03:45	9	<0.05
13:04:00	15	<0.05

(Continued)

Table 279 (Concluded)

Time of Collection (hr:min:sec)	Depth (m)	Ammonium (mg N/l)
13:04:30	1	<0.05
13:05:15	9	<0.05
13:05:55	1	<0.05
13:06:50	15	<0.05
13:08:10	9	<0.05
13:10:00	9	<0.05
13:10:15	1	<0.05
13:13:45	9	<0.05
13:13:45	15	<0.05
13:15:00	1	<0.05
13:15:20	9	<0.05
13:15:35	15	<0.05
13:21:15	15	<0.05
13:30:30	1	<0.05
13:31:00	9	<0.05
13:31:35	15	<0.05
13:40:00	9	<0.05
13:40:35	15	<0.05
14:16:15	1	<0.05
14:16:30	9	<0.05
14:16:45	15	<0.05

Table 280

Soluble Orthophosphate Concentrations: Galveston Dump No. 6 near Buoy D, Dredged Materials from Galveston Bay Entrance Channel Buoys 3 through 7A

(September 9, 1975)

Time of Collection (hr:min:sec)	Depth (m)	Soluble Orthophosphate (mg P/l)	
		$\bar{X}$	SD
11:41:00	1	<0.01	∿0
11:42:00	9	0.015	0
11:42:30	15	<0.01	∿0
12:38:30	1	0.012	0.001
12:39:00	9	0.018	0.001
12:39:30	15	0.013	0
	12:50 - Dump occurred.		
12:50:15	1	0.01	0.001
12:50:30	9	<0.01	∿0
12:50:45	15	<0.01	∿0.003
12:55:45	15	<0.01	∿0.001
12:59:50	9	<0.01	∿ 0
13:00:15	15	0.023	0
13:00:30	1	0.013	0.001
13:00:45	9	<0.01	∿ 0
13:01:15	15	0.019	0.001
	13:02 - Surface turbid plume arrived at sampling location.		
13:02:00	1	<0.01	0.001
13:02:15	9	0.012	0
13:02:45	1	0.011	0.002
13:03:30	1	<0.01	0.001
13:03:45	9	<0.01	∿0.001
	13:04 - Surface turbid plume passed sampling location.		

(Continued)

Table 280 (Concluded)

Time of Collection (hr:min:sec)	Depth (m)	Soluble Orthophosphate (mg P/l)	
		$\bar{X}$	SD
13:04:00	15	<0.01	∿0.001
13:04:30	1	<0.01	∿0.001
13:05:15	9	<0.01	∿0
13:05:55	1	0.012	0
13:06:50	15	0.022	0.001
13:08:10	9	0.013	0.001
13:10:00	9	0.018	0.001
13:10:15	1	<0.01	∿0
13:13:45	9	0.022	0
13:13:45	15	0.024	0.002
13:15:00	1	0.022	0
13:15:20	9	0.015	0.001
13:15:35	15	<0.01	∿0
13:21:15	15	0.020	0.001
13:30:30	1	0.014	0
13:31:00	9	0.018	0.001
13:31:35	15	0.023	0.001
13:40:00	9	<0.01	∿ 0
13:40:35	15	0.02	0
14:16:15	1	0.016	0.001
14:16:30	9	<0.01	∿0.001
14:16:45	15	0.011	0

Mean and standard deviations calculated from duplicate analyses of one sample.

minutes after the plume passed showed an approximately two-fold increase (to 0.022 mg P/1) over ambient soluble ortho P concentrations. A sample taken 15 minutes later showed a decrease in concentration to 0.014 mg P/1. About 45 minutes later, the concentration was slightly above ambient levels (0.016 mg P/1).

Soluble ortho P concentrations at mid-depth (9 m) varied between < 0.01 mg P/1 (detection limit) and 0.019 mg P/1 before arrival of the turbid plume. When the mid-depth percent light transmission was lowest, the soluble ortho P concentration was below 0.01 mg P/1 (detection limit). It then appeared to rise steadily to 0.022 mg P/1 about 14 minutes later. About 25 minutes after the apparent maximum, the soluble ortho P concentrations had returned to ambient levels.

As the percent light transmission in the near-bottom waters dropped to 1 percent, the soluble ortho P increased from < 0.01 to 0.023 mg P/1. It dropped back to ambient levels about 4 minutes later, and fluctuated between < 0.01 and 0.024 mg P/1 for the duration of the sampling period.

Texas City Channel Sediment Elutriate Tests

Two sets of sediment and water samples were collected by UTD personnel in the Texas City Ship Channel for elutriate tests. The sediments were all collected with a Ponar grab sampler and stored in 5-gallon plastic pails. The water samples from the same sites were collected from the surface with a rope and bucket and stored in 13.5-gallon polyethylene bottles. After collection, all of the samples were cooled with ice in insulated boxes and transported to the UTD laboratory, where they were stored at 4°C until elutriation.

The first set of Texas City samples was collected on March 28, 1975, at sites designated as TCC-1, 2, and 3. Their locations are shown in Figure 96. The second set of three sites (TCC-4, 5, and 6) was sampled September 20, 1975; these sites are also shown in the figure.

General Sediment Characteristics and Oxygen Demand

The oxidation reduction potential (Eh), sulfide concentration, and percent dry weight were determined for sediment samples from Texas City Sites 1, 2, 4, 5, and 6. The data are presented in Table 281. The first two sites (TCC-1 and 2) showed a similarity in Eh (-38 versus -20 mv), sulfide concentration (1205 mg/kg versus 1251 mg/kg) and also dry weight (53 percent versus 51 percent). There was also a general similarity between the samples from TCC-4, 5, and 6 in Eh and percent dry weight. The Eh readings were -100, -136, and -124 mv, respectively. The percent dry weight results were 38, 44, and 40 percent, respectively. However, the sulfide concentrations did not show the same trend; in fact, the three readings were quite dissimilar: 2519, 237, and 1557 mg/kg for TCC-4, 5, and 6, respectively.

The oxygen demand test was run with sediment from all six Texas City sites except Site 3. Tables A24 and A25 of Appendix A present the data from the tests of 5 cc samples of sediment from TCC-1 and TCC-2. The standard deviations between runs ranged from 0.1 to 0.5 mg/l, indicating fair reproducibility. The oxygen uptake values (Table 281) in the first hour for a cubic meter and one gram dry weight of TCC-1 sediment were 5.0×10^2 g O_2 and 0.66 mg O_2, respectively. Similar uptakes were measured in the first hour for TCC-2, 4.8×10^2 g O_2 for a cubic meter and 0.64 mg O_2 for one gram dry weight of sediment.

The data from the oxygen demand test of TCC-1 and TCC-2 sediment are plotted in Figures 97 and 98. The

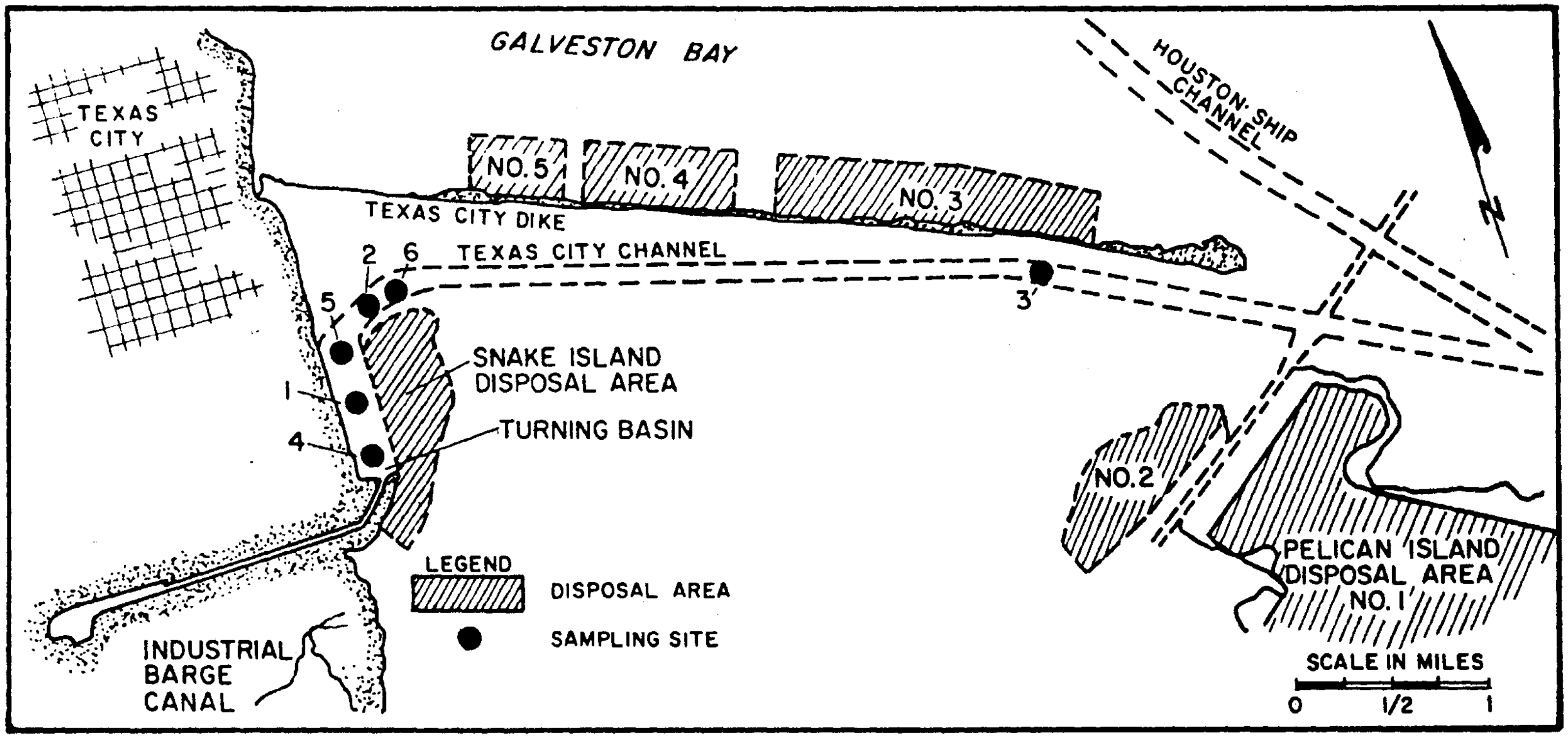

Figure 96

Texas City Channel and Turning Basin Sampling Locations

Table 281

General Sediment Characteristics: Texas City Sediments

Sampling Location* (TCC Site)	Eh (mv)	Sulfide (mg/kg)		Percent Dry Weight		Oxygen Uptake First Hour	
		$\bar{X}$	SD	$\bar{X}$	SD	Per Cubic Meter ($g\ O_2$)	Per Gram Dry Wt. ($mg\ O_2$)
1	- 38	1205	108	53	0.7	5.0×10^2	0.66
2	- 20	1251	95	51	2.1	4.8×10^2	0.64
4	-100	2519	10	38	0.3	6.0×10^2	1.21
5	-136	237	10	44	0.9	4.5×10^2	1.17
6	-124	1557	140	40	0.1	6.1×10^2	0.76

Mean and standard deviation calculated from triplicate analysis.

*Site 3 sediment was not available for sediment analysis.

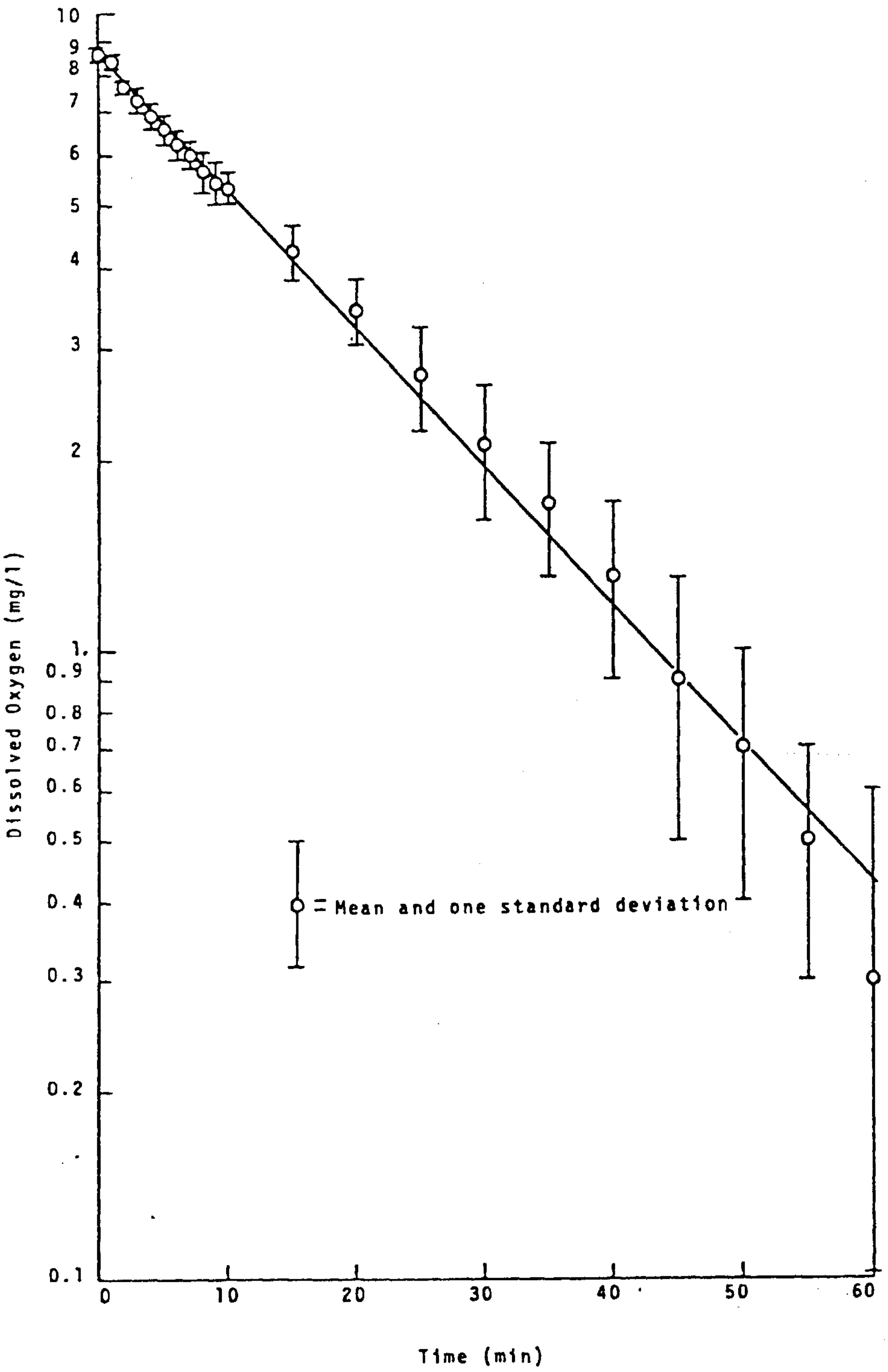

Figure 97
Oxygen Demand Test: Texas City Site 1 Sediment
(Sample Size - 5 cc)

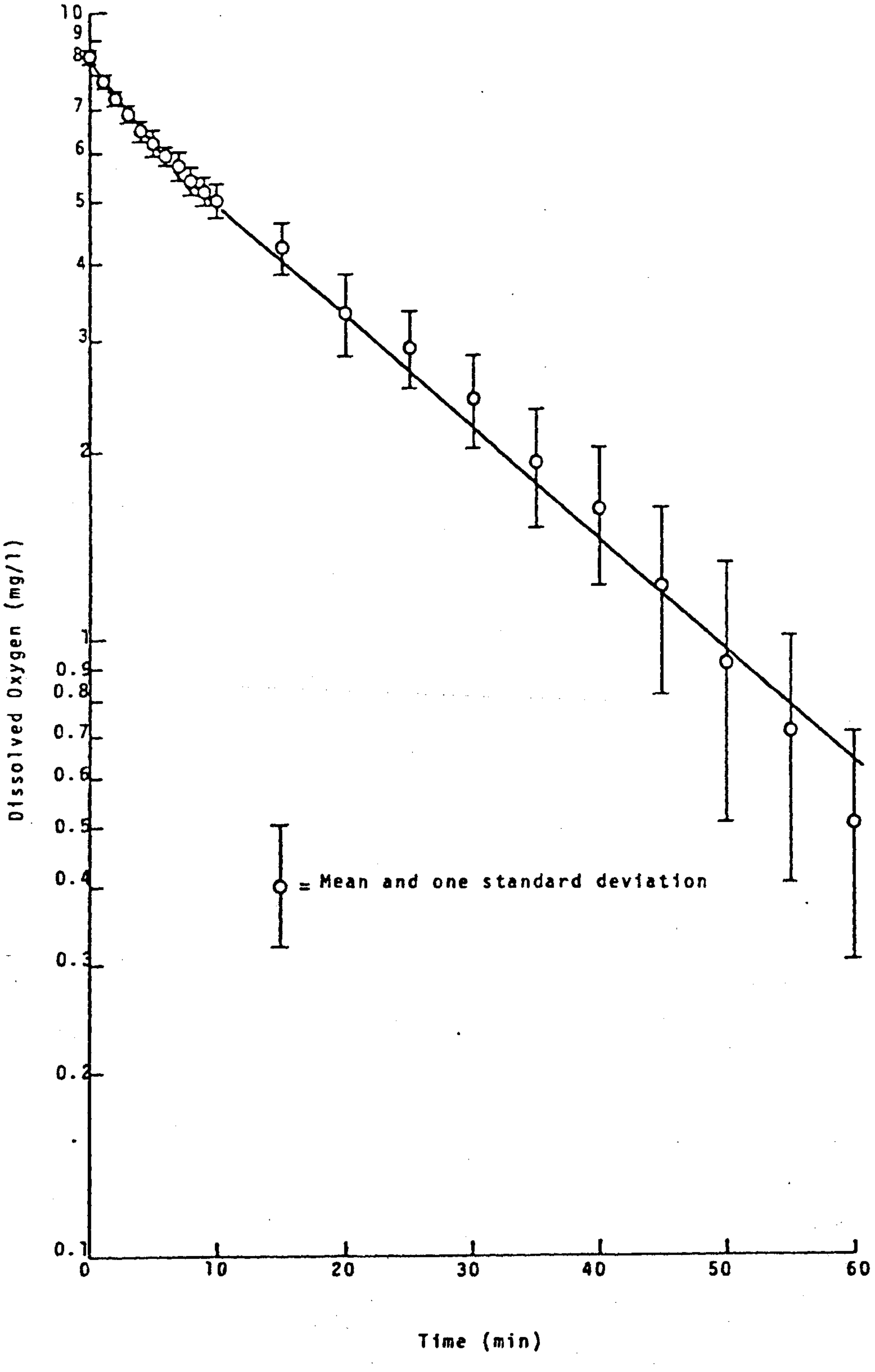

Figure 98
Oxygen Demand Test: Texas City Site 2 Sediment
(Sample size - 5 cc)

slope was -0.020 mg/l O_2min^{-1} for TCC-1 sediment. The slope of the fast component of the TCC-2 plot was -0.026 mg/l O_2 min^{-1}; the slow component slope was -0.017 mg/l O_2 min^{-1}.

Tables A26, A27, and A28 of Appendix A present the data obtained during oxygen demand tests of the samples from TCC-4, 5, and 6. The standard deviations between the runs in each test ranged from 0.1 to 0.5 mg/l, indicating fair reproducibility. The oxygen uptake values (presented in Table 284) for the first hour per cubic meter were 6.0 x 10^2 g O_2 (TCC-4), 4.5 x 10^2g O_2 (TCC-5), and 6.1 x 10^2g O_2 (TCC-6). Again, TCC-4 and 6 had similar results (for uptake per gram dry weight), with 1.21 mg O_2 and 1.17 mg O_2, respectively. The TCC-5 samples had an uptake of 0.76 mg O_2.

The data from these tests were plotted; Figures 99, 100, and 101 present the results. All three samples exhibited a two-component system for the first hour. The slopes of the fast components of TCC-4 and 5 were similar (-0.023 mg/l O_2 min^{-1} and -0.024 mg/l O_2 min^{-1}, respectively), while the TCC-6 fast component had a slope of -0.064 mg/l O_2 min^{-1}. However, it was the TCC-4 and 6 slopes which had similar slow components; these slopes were -0.011 mg/l O_2 min^{-1} and -0.010 mg/l O_2 min^{-1}, respectively. The TCC-5 sample had a slope of -0.004 mg/l O_2 min^{-1}.

Elutriate Test General Parameters

On April 8, 1975, two 5 percent oxic and two 20 percent oxic elutriate tests were run on the TCC-1 samples; one of each pair was allowed to settle for one hour, the other for 24 hours. The unused sediment and site water were stored in the dark at 4°C for future testing. Also on April 8, one 5 percent and one 20 percent oxic elutriate test were run on both TCC-2 and 3 sediment and water.

To assess the effects of extended storage of sediment and water prior to elutriation, standard 5 percent

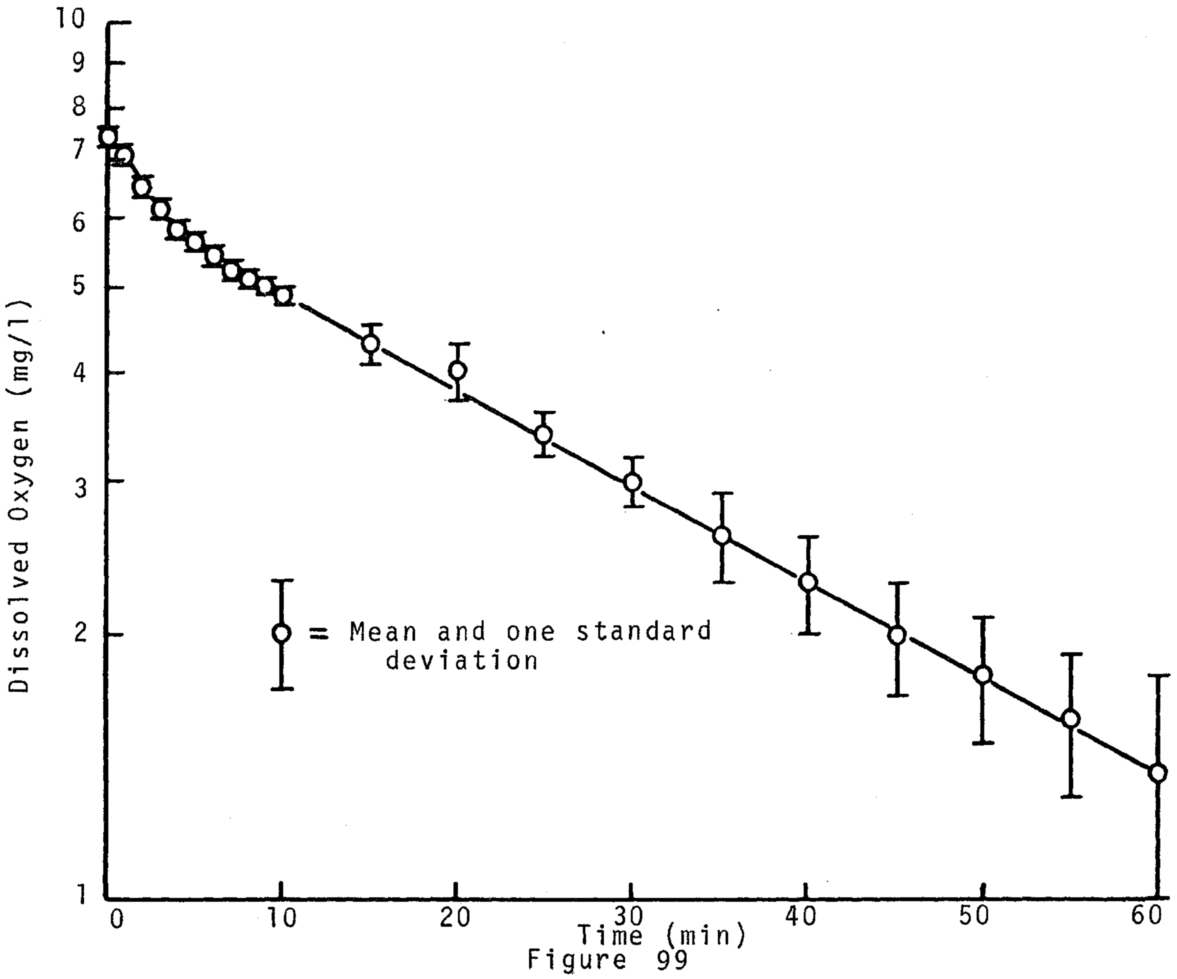

Figure 99

Oxygen Demand Test: Texas City Channel Site 4 Sediment
(Sample size - 3 cc)

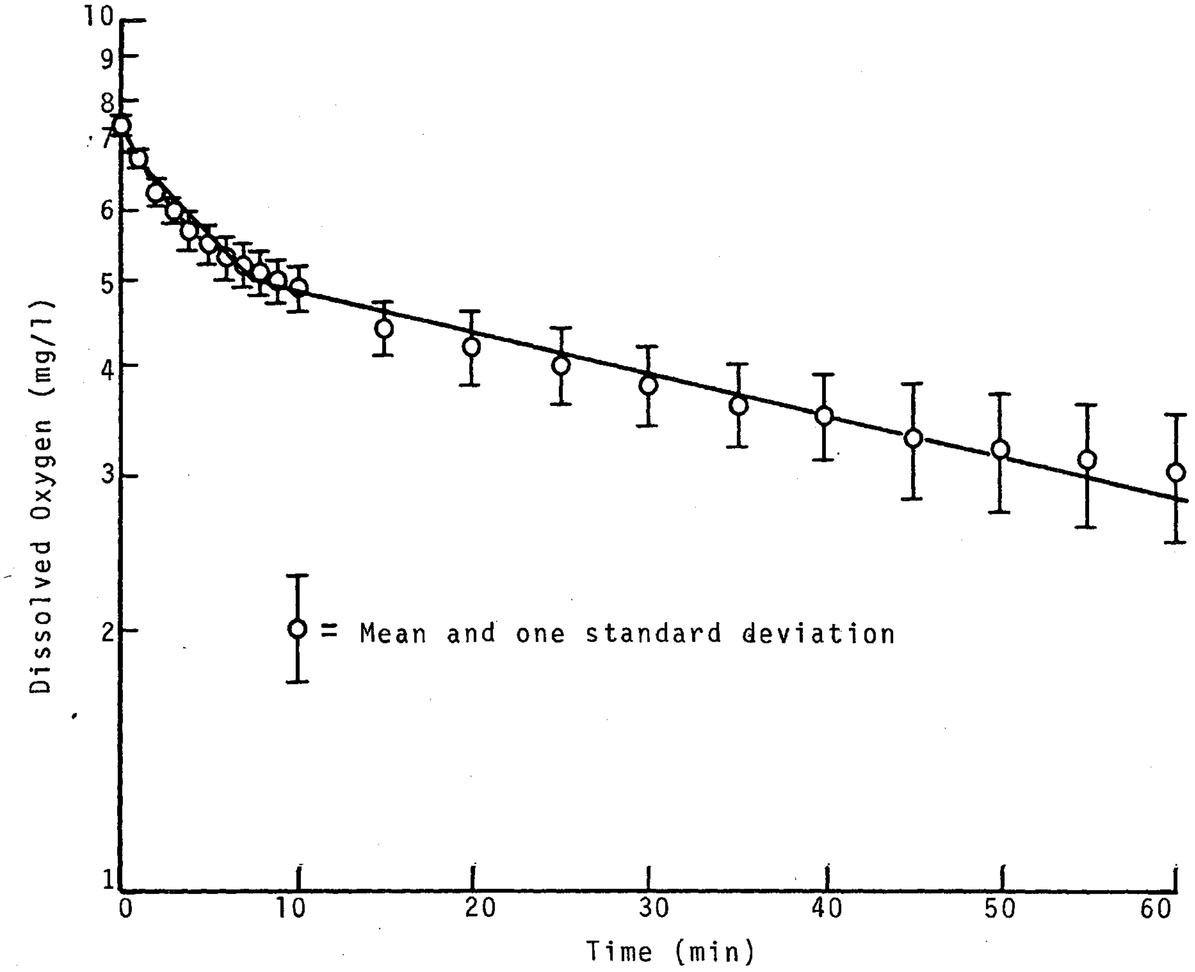

Figure 100

Oxygen Demand Test: Texas City Channel Site 5 Sediment
(Sample size - 3 cc)

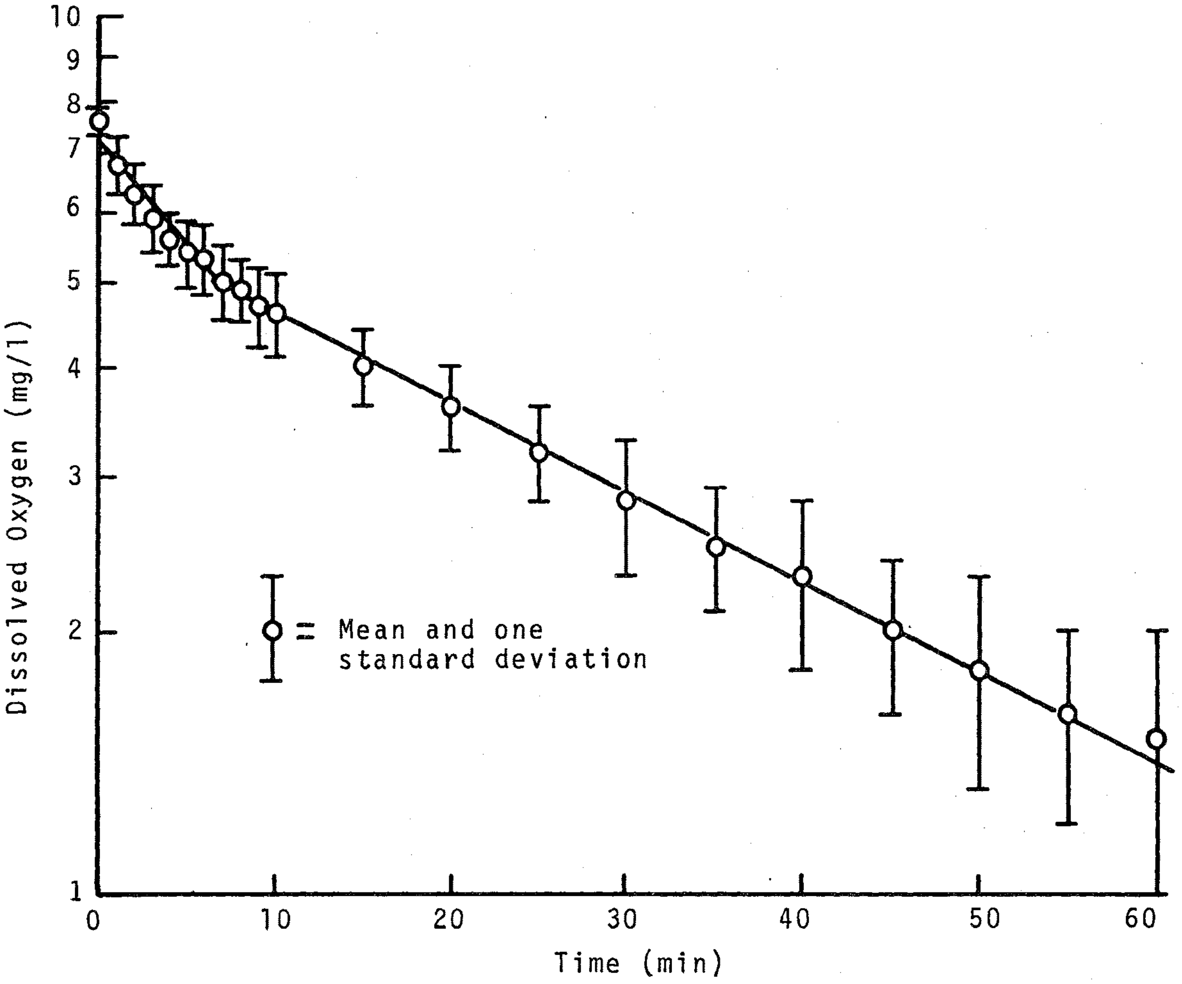

Figure 101
Oxygen Demand Test: Texas City Channel Site 6 Sediment
(Sample size - 3 cc)

and 20 percent oxic elutriate tests were run on the TCC-1 sediment and water on June 17, 70 days after the first tests. Elutriates were centrifuged prior to analysis for general parameters and total constituents.

On June 19, 1975, variations of the anoxic/oxic elutriate tests were run on TCC-1, 2, and 3 sediments. One test contained 20 percent sediment by volume, the other, 25 percent. A 20-minute nitrogen mixing period was used, followed by 10 minutes of compressed air mixing. The elutriates were allowed to settle for one hour in air. The elutriates were centrifuged (5 min. @ 9000 rpm) prior to filtration.

Sediment and water samples collected from Texas City Sites 4, 5, and 6 on September 20 were subjected to single standard 5 and 20 percent oxic elutriate tests on September 24 and 25. After these tests were run, the sediment and site water samples were stored in the dark at 4°C until October 31 (40 days after collection). On that date, duplicate 20 percent oxic tests were run on the TCC-4 samples, and single 20 percent oxic tests were run on TCC-5 and 6 samples to assess the effects of extended sample storage on elutriate test results.

Table 282 presents the values for the general physical and chemical parameters measured during tests on Texas City Channel Sites 1, 2, and 3 samples. In general, site water D.O., turbidity, and specific conductance values were greatest at the most seaward sampling site; pH showed an opposite pattern.

Two 5 percent oxic and two 20 percent oxic elutriate tests were run on TCC-1 samples; one of each set was allowed to settle for one hour, the other for 24 hours (Table 282). The 20 percent tests consistently had lower

Table 282

General Physical and Chemical Parameters: Texas City Sites 1, 2 and 3 Oxic Elutriate Tests

Sample Designation	Dissolved Oxygen (mg/l @ °C) Initial	After Mixing	After Settling	pH	Turbidity (NTU)	Specific Conductance (μmhos/cm @ 25°C)	Salinity (°/oo)
TCC-1:							
Site Water	7.9@23.5°	-	-	8.3	1	27,300	16.8
5% (1 hr)*	-	9.8@16.0°	8.7@17.0°	8.2	49	22,700	13.5
(24 hr)	-	9.5@14.0°	4.7@24.0°	8.1	8	25,300	15.5
20% (1 hr)	-	8.3@17.0°	6.3@21.0°	8.4	28	26,000	15.8
(24 hr)	-	7.1@14.0°	4.2@24.0°	8.1	1	26,700	16.5
TCC-2:							
Site Water	7.8@10.5°	-	-	7.8	5	27,500	16.8
5% (1 hr)	-	9.8@16.0°	8.7@19.0°	8.2	52	26,500	16.5
20% (1 hr)	-	6.2@17.0°	2.5@19.0°	8.5	55	24,500	14.8
TCC-3							
Site Water	11.4@10.5°	-	-	8.0	10	30,000	18.5
5% (1 hr)	-	9.7@15.0°	8.5@18.5°	8.0	66	30,500	19.0
20% (1 hr)	-	8.6@17.0°	7.3@17.0°	8.0	69	30,000	18.5

Dash (-) indicates not applicable.

*Time in parentheses indicates duration of settling period.

D.O. than the 5 percent tests. The D.O. after the 24-hour settling period was lower than it had been after one hour's settling. In addition, the difference in D.O. between the 5 and 20 percent (24 hour) tests was less after the extended settling periods. The pH showed little change upon elutriation. The turbidity was greater in the 5 percent elutriates than in the 20 percent elutriates; turbidities were considerably lower after the additional settling time. Specific conductance and salinity appear to have decreased after standard elutriation. The decrease was less after the extended settling period.

General parameter results from TCC-2 elutriate tests (Table 282) showed the D.O. concentrations in the 5 percent test after settling to have been the same as in the TCC-1 elutriate. The D.O. after settling of the TCC-2 20 percent test, however, was considerably lower than it had been in the corresponding TCC-1 test. The pH increased slightly upon elutriation. The values were about the same as they had been in corresponding TCC-1 elutriates. Turbidity increased from 5 NTU in the site water to about 55 NTU. The specific conductance decreased upon elutriation. It decreased to a greater degree in the 20 percent test than in the 5 percent one; this pattern was opposite that of the TCC-1 elutriates.

The values of D.O. during elutriation with TCC Site 3 samples was about the same as it had been during TCC-1 tests. The final D.O. of the TCC-3 5 percent elutriate was slightly higher than in the corresponding Site 1 elutriate, however. The pH did not change as a result of elutriation. Turbidity increased from 10 NTU in the site water to about 70 NTU in both 5 and 20 percent oxic elutriates. The specific conductance rose slightly after the 5 percent test, but remained at 30,000 μmhos/cm @ 25°C in the 20 percent oxic elutriate. (All specific conductance values are corrected to and reported at 25°C). The salinities of the TCC-3 sample site water and elutriates were greater than those of the other TCC locations.

After the TCC-1 sediment and water were stored in the dark at 4°C for 70 days more, they were subjected to additional 5 percent and 20 percent oxic tests. Total elutriate volume was four liters (total volume was three liters in the earlier tests on these samples). The general and physical parameter results of these tests are presented in Table 283.

The site water D.O. level was higher and pH value slightly lower after storage. Values of the other parameters were the same as they had been prior to storage. The oxygen demand of the sediment appeared to be somewhat greater after storage as reflected in the 20 percent elutriate (after settling) D.O. The pH values in the elutriates were no different from those in the elutriates of fresher sediment. Turbidity in the 5 percent elutriate (after storage) was greater than that in the corresponding elutriate before sample storage, although storage did not appear to affect 20 percent elutriate turbidity. The specific conductance was greater in the 20 percent oxic elutriate than in the 5 percent elutriate, as was seen in pre-storage elutriate tests. However, pre-storage elutriation caused a decrease in specific conductance, whereas the tests run after storage showed a slight increase.

The results of the 20 and 25 percent anoxic/oxic tests are presented in Table 284. After nitrogen mixing D.O. was less than 0.5 mg/l in the 20 percent test and 0.7 mg/l in the 25 percent test. During air-mixing, D.O. rose to about 6 mg/l in both the 20 and 25 percent tests. Following settling, D.O. was higher in the 25 percent elutriate (4.7 mg/l) than in the 20 percent elutriate (1.0 mg/l). This may have been related to the intensity of air stirring and/or the variability in the oxygen demand of the subsamples of sediments. Both pH values increased upon elutriation to about the same value as that of the 20 percent oxic elutriate (Table 283). Turbidity

Table 283

General Physical and Chemical Parameters: Texas City Site 1

Elutriate Tests Performed June 17, 1975*

Sample Designation	Dissolved Oxygen (mg/l @ 14-17°C)			pH	Turbidity (NTU)	Specific Conductance (μmhos/cm @ 25°C)	Salinity (°/oo)
	Initial	After Mixing	After Settling				
Site Water	9.6	-	-	7.9	1	27,200	16.6
5% Oxic	-	9.8	8.5	8.3	81	27,600	16.8
20% Oxic	-	8.2	3.6	8.5	28	28,200	17.3

Dash (-) indicates not applicable.
*Samples collected March 28, 1975. A one-hour settling period was used.

Table 284

General Physical and Chemical Parameters: Texas City Site 1 Anoxic/Oxic* Elutriate Tests Performed June 19, 1975**

Sample Designation	Dissolved Oxygen (mg/l @ °C)				pH	Turbidity (NTU)	Specific Conductance (µmhos/cm @ 25°C)	Salinity (°/oo)
	Initial	After N_2 Mixing	After Air Mixing	After Settling				
Site Water	10.6@14.5°	-	-	-	7.7	6	27,600	16.8
20% Anoxic/ Oxic	7.5@12.5°	< 0.5@13.0°	6.2@13.0°	1.0@16.0°	8.5	46	28,800	17.8
25% Anoxic/ Oxic	7.0@13.5°	0.7@15.0°	5.9@15.5°	4.7@20.0°	8.4	150	27,400	16.9

Dash (-) indicates not applicable.

*20 min. N_2 mixing followed by 10 min. air mixing.

**Samples were collected March 28, 1975.

was higher in the 25 percent anoxic/oxic elutriate than in the 20 percent anoxic/oxic elutriate. Both of these turbidity values were higher than they were in the 20 percent oxic elutriate. The specific conductance increased after 20 percent elutriation but decreased slightly after 25 percent elutriation.

The values for the TCC-4, 5, and 6 general physical and chemical parameters measured are presented in Table 285. With the exception of the lower D.O. in TCC-6 site water, the general characteristics were about the same in each of the three site water samples. The TCC-6 sediment appeared to have the greatest oxygen demand, judging from both 5 and 20 percent tests; the D.O. levels in TCC-4 and 5 elutriates were greater than concentrations in the TCC-6 elutriates. Site 6 was located near TCC Site 2; Site 2 sediments had appeared to exert the greatest oxygen demand in the earlier set of Texas City tests.

Values for other general parameters measured appeared fairly consistent between sites. The pH appears to have decreased slightly after elutriation of TCC-4 sediments but apparently remained unchanged after elutriation of TCC-5 and 6 sediments. There did not appear to be a consistent change in turbidity with percent sediment; values were about the same in tests on the same sediment. TCC-6 elutriates had noticeably less turbidity than did the other elutriates. There was no consistent pattern of changes in the observed specific conductance values for the three sets of elutriates.

The values for the general physical and chemical parameters from elutriate tests run after 36 days of sample storage are presented in Table 286. In most cases, the oxygen demand of the sediments appeared to be greater after storage, as was found in the TCC-1 storage tests. The D.O. values of nearly all of the later elutriates were lower than those of the earlier elutriates. The storage period seems to have

Table 285

General Physical and Chemical Parameters: Texas City Sites 4, 5 and 6

Elutriate Tests

Sample Designation	Dissolved Oxygen (mg/l@ 17.5-20.9°C)					Specific	
	Initial	After Mixing	After Settling	pH	Turbidity (NTU)	Conductance (μmhos/cm @ 25°C)	Salinity (°/oo)
TCC-4:							
Site Water	7.7	-	-	8.3	4	27,800	17.0
5% Oxic	-	8.9	8.1	7.8	110	28,000	17.2
20% Oxic	-	8.7	7.2	8.1	125	28,500	17.5
TCC-5:							
Site Water	7.3	-	-	8.2	4	27,700	17.0
5% Oxic	-	8.8	7.7	8.2	150	28,500	17.5
20% Oxic	-	8.8	7.9	8.1	150	27,000	16.5
TCC-6:							
Site Water	5.7	-	-	8.2	5	28,000	17.2
5% Oxic	4.3	6.6	5.8	8.2	61	28,000	17.2
20% Oxic	< 0.5	4.6	1.3	8.3	46	27,000	16.5

Dash (-) indicates not applicable or not measured.

Table 286

General Physical and Chemical Parameters: Texas City Sites 4, 5 and 6

Elutriate Tests Performed October 31, 1975*

Sample Designation	Dissolved Oxygen (mg/l @ $22^{\circ}C$)			pH	Turbidity (NTU)	Specific Conductance (μmhos/cm @ $25^{\circ}C$)	Salinity ($^{\circ}/oo$)
	Initial	After Mixing	After Settling				
TCC-4:							
Site Water	7.8	-	-	7.6	1	28,000	17.2
20% Oxic A	4.6	6.1	4.8	8.2	78	27,600	17.0
B	4.1	5.1	2.6	8.3	25	25,500	15.5
TCC-5:							
Site Water	7.2	-	-	8.1	3	28,000	17.2
20% Oxic	3.0	5.6	4.0	8.2	47	25,000	15.0
TCC-6:							
Site Water	7.2	-	-	8.0	2	26,800	16.5
20% Oxic	1.8	4.8	2.1	8.0	32	27,700	17.0

A and B are replicates.

Dash (-) indicates not applicable.

*Samples were collected September 20, 1975.

had variable effects on the other parameters. The pH of the TCC-4 site water appeared to have decreased over the storage period. The TCC-4 elutriates showed increases in pH over that of the site water; prior to storage, the opposite effect was observed. The TCC-5 and 6 elutriates had about the same pH values in both pre- and post-storage studies. The specific conductance of the site waters from TCC-4 and 5 increased slightly during storage; that of TCC-6 appears to have decreased. Direction of changes in specific conductance upon elutriation of stored TCC-4 and 6 samples appeared to be opposite of those found prior to storage. The TCC-5 tests showed a greater decrease in specific conductance upon elutriation after storage than it had before storage.

Heavy Metals

Table 287 shows that there were some major differences between the two sets of Texas City sediments. The TCC-1, 2, and 3 sediment samples collected on March 28 contained 3.3 to 4.5 mg/kg cadmium and 59 to 90 mg/kg lead. In the samples collected in September, concentrations of these metals were below the detection limits. The TCC-1, 2, and 3 samples exceeded the US EPA criterion[10] for cadmium, chromium, zinc, and lead. The ranges of concentrations seen were 3.3 to 4.5 mg/kg cadmium, 170 to 650 mg/kg chromium, 50 to 240 mg/kg zinc, 50 to 90 mg/kg lead, and 10 to 720 mg/kg nickel. Manganese, iron, and mercury concentrations were also high. The set collected from Sites 4, 5, and 6 had values exceeding the criterion[10] for zinc, copper, and arsenic. The ranges of these metals were 114 to 160 mg/kg, 43 to 83 mg/kg, and 11.8 to 13 mg/kg, respectively. Manganese and iron concentrations were again high. Manganese and iron concentrations were 556 to 671 mg/kg and 25.8 to 26.3 g/kg, respectively.

The variability of metals concentrations between March and September sets of sediment samples was considerable.

Table 287

Total Heavy Metal Concentrations: Texas City Channel and Turning Basin Sediment Samples

(mg/kg)*

Sampling Location and Date Collected (1975)	Mn		Cd		Cr		Zn		Ni		Pb		Cu		Fe*		Hg		As	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
March 28:																				
TCC-1	840	40	4.3	0.6	650	20	240	60	720	20	50	30	40	1	23.2	0.3	0.68	0.04	**	
TCC-2	400	20	4.5	1.3	340	180	80	10	10	1	60	20	30	10	17.4	4.7	0.68	0.04	**	
TCC-3	4680	150	3.3	0.3	170	90	50	10	20	1	90	20	10	1	33.3	2.3	0.40	0.07	**	
September 20:																				
TCC-4	556	8	<0.5	-	77	5	160	3	24	4	< 1	-	83	1	26.3	0.3	0.041	0.002	12.8	0
TCC-5	557	21	<0.5	-	58	4	114	6	21	2	< 1	-	43	1	26.0	0.3	0.031	0.002	11.8	0
TCC-6	671	13	<0.5	-	90	3	141	2	25	1	< 1	-	60	1	25.8	0.5	0.032	0	13.0	0.2

Dash (-) indicates single analysis.

Mean and standard deviation calculated from triplicate analyses.

*Iron concentrations in g/kg.

**Analyses not performed.

However, the ranges of manganese, zinc, and iron were quite similar at the two sampling periods. The concentrations of mercury appeared to have decreased 10 to 20 fold in the time between the sampling periods.

Table 288 contains the results of the soluble heavy metals analyses for the TCC-1, 2, and 3 elutriate tests. In the 20 percent tests of TCC-1 and 3 sediment, large amounts of manganese (1063 and 5760 µg/l, respectively) were released. In the TCC-2 tests, only moderate manganese release was seen, but that of the 20 percent test was nearly double that seen in the 5 percent test. Elutriates of TCC-1 sediment which were allowed to settle for 24 hours showed nearly twice the manganese release seen in the one-hour settling test.

There was removal of zinc from the site water in the Sites 1 and 3 tests (approximately 50 and 20 percent, respectively) and what appeared to be slight release (14.3 µg/l over 8.7 µg/l found in the test water) in tests with the TCC-2 sediment. There was small release of iron, 27 µg/l, in the tests on Site 1 sediment. The iron concentration of the TCC-1 site water was 5 µg/l. There was little change with variation in settling time. Concentrations in site and elutriate waters from TCC-2 and 3 were consistently low.

There were indications of copper uptake in TCC-1 elutriates. The site water contained 5.4 µg/l, and the elutriates contained 1.8 to 4.6 µg/l. Concentrations were lower in the 20 percent elutriates. Concentrations in TCC-2 and 3 tests were low and showed no change.

There was a slight release of nickel by all three sediments. No general pattern was seen with variation of percent sediment, but the observed release was lower in the TCC-1 elutriates settled for 24 hours than in the ones

Table 288

Soluble Heavy Metal Concentrations: Texas City

Sites 1, 2 and 3 Elutriate Tests

(μg/l)

Sample	Mn		Cd		Cr		Zn		Ni		Pb		Cu		Fe		Hg	
Designation	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
TCC-1:																		
Site Water	52	8	1.8	0.1	11.1	2.5	13.3	0.6	4.1	1.5	3.6	1.2	5.4	0	5	3	0.27	0.01
5% (1 hr)	262	52	5.5	1.9	108.4	8.1	4.8	3.9	11.4	3.1	3.9	2.4	4.6	4.0	18	1	0.08	0.01
(24 hr)	551	13	3.8	0.6	41.4	5.6	5.1	0.9	9.5	1.9	4.1	0.7	4.2	1.6	15	8	0.01	0.01
20% (1 hr)	626	48	5.9	1.1	159	10	4.7	2.6	14.7	0.6	4.5	1.9	2.2	0.2	20	5	0.22	0.01
(24 hr)	1063	35	3.9	1.2	134.9	14	3.2	1.0	9.5	1.9	5.2	2.9	1.8	0.4	27	5	0.10	0.01
TCC-2:																		
Site Water	5	-	<0.3	-	<2.0	-	8.7	-	7.8	-	<1.0	-	<1.0	-	< 1	-	0.028	-
5%	296	11	<0.3	∿0	10.3	7.0	14.3	0.6	12.9	0.3	2.0	0	<1.0	∿0	2	1	0.048	-
10%	472	53	<0.3	∿0	3.7	2.3	10.7	0.8	9.8	0	2.0	0	<1.0	∿0	2	0	0.014	-
TCC-3:																		
Site Water	12	-	<0.3	-	<2.0	-	19.3	-	4.6	-	1.0	-	1.7	-	< 1	-	0.099	-
5%	3970	17	<0.3	∿0	<2.0	∿0	15.7	0.4	6.9	1.1	3.2	2.3	<1.0	∿0	< 1	∿ 0	0.034	-
20%	5760	170	<0.3	∿0	4.0	0	17.0	2.7	8.1	0	1.6	0	1.2	0.8	< 1	∿ 0	0.034	-

Mean and standard deviation calculated from duplicate analyses.

Dash (-) indicates that standard deviation could not be computed.

settled for one hour. Chromium was also released by all three sediments. The TCC-1 site water contained 11 µg/l chromium and the 20 percent, one-hour settled elutriate contained 159 µg/l. Increases were small in the TCC-2 and 3 tests and as initial concentrations were low, the increases were probably insignificant. The same is true of apparent increases in lead in all tests. Cadmium concentrations in TCC-1 elutriate were small, but there appeared to be an increase over the site water concentration (1.8 µg/l). Concentrations in all samples with TCC-2 and 3 sediment were below the detection limit (0.3 µg/l).

There appeared to be removal of mercury from site waters by all three sediments. Removal of mercury from the TCC-1 site water was highest (0.27 µg/l) in the 5 percent test with 24 hour settling and lowest in the 20 percent test with 1-hour settling. There was no pattern with the other sediments. Mercury concentrations in TCC-2 and 3 elutriates were considerably higher than those in Site 1 elutriates. This may be due to the changes in analytical procedures for mercury concentrations, which were discussed in Part II.

Table 289 shows the results of metals analyses of the site water and elutriates from tests performed with the TCC-1 samples after storage. Manganese was released as a function of increased sediment percentage of the total elutriate volume. The trend and amount of manganese release were similar to those observed in the previous tests. In these later tests, zinc concentrations showed no change, while in the previous tests (April 8, 1975) zinc removal had been apparent.

No change in the copper, cadmium, chromium, and lead concentrations were observed in the June test. In the

Table 289

Soluble Heavy Metal Concentrations: Texas City Site 1 Elutriate Test

Performed June 17, 1975*

(μg/l)

Sample	Mn		Cd		Cr		Zn		Ni		Pb		Cu		Fe		Hg	
Designation	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Site Water	<2	~0	0.9	0.0	2.9	0.3	8.2	4.7	5.3	0.2	<1.0	~0	3.0	3.1	8.5	2.3	0.009	0.004
5%	269	26	1.1	0.1	2.6	0.2	9.5	5.0	6.3	1.1	<1.0	~0	3.3	0.2	34.6	1.1	0.026	0.004
20%	539	26	1.0	0.0	3.7	0.1	10.9	0.4	9.5	2.5	<1.0	~0	3.5	0.4	20.2	0.7	0.035	0.004

Mean and standard deviation calculated from duplicate analyses.

*Samples were collected March 28, 1975.

earlier tests, however, increases indicating release were noted for cadmium, nickel, and chromium. In the original tests the most significant release was that of chromium, with concentrations reaching 159 μg/l. In the June test chromium concentrations remained below 4 μg/l. Moderate iron release occurred in both sets of tests. Mercury release was apparent in the later tests, with increasing release as percentage of sediment content increased. In the early tests mercury appeared to be removed in the 5 percent sediment test; no change was noticed in the 20 percent test.

Overall, the results from the two sets of tests did not agree well, except for manganese and lead release. Sample storage resulted in elutriate test results which gave a comparative underestimation of the potential of sediments to release metals.

Table 290 presents the metal analyses of the modified anoxic/oxic elutriate tests performed with TCC-1 sediment and water on June 19. Statistically significant release of manganese was seen in both elutriates. Release was greater in the 20 percent sediment content test (1551 μg/l). There was no statistical difference in the concentrations of zinc, copper, chromium, cadmium, or lead in the elutriates and the test water. Apparent release of nickel occurred, the amount being the same in both tests. Similar small apparent releases of iron were also observed in the two elutriates.

Table 291 presents the results of heavy metal analyses for TCC-4, 5, and 6 elutriate tests. Substantial release of manganese occurred with TCC-4. The amount released increased with increasing sediment content of the test in a linear manner. Manganese levels reached 1,200 μg/l in the 20 percent sediment test, which was four times the amount found in the 5 percent elutriate. A very small

Table 290

Soluble Heavy Metal Concentrations: Texas City Site 1

Anoxic/Oxic Elutriate Tests[*]

(μg/l)

Sample Designation	Mn		Cd		Cr		Zn		Ni		Pb		Cu		Fe	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Site Water	209	22	1.8	0.1	<1	∿0	13.5	1.0	4.3	0.0	8.3	1.2	2.5	0.2	6.1	0.0
20%	1551	42	2.3	0.2	<1	∿0	9.1	-	18.6	3.4	11.2	2.1	2.6	0.8	14.7	1.1
25%	475	-	2.1	-	<1	∿0	14.0	2.8	18.5	-	9.8	-	1.7	-	19.2	-

Mean and standard deviation calculated from duplicate analyses.

Dash (-) indicates single determination.

[*] Samples were stirred with nitrogen gas 20 minutes, then with air 10 minutes.

Table 291

Soluble Heavy Metal Concentrations: Texas City Sites 4, 5 and 6

Oxic Elutriate Tests

(μg/l)

Sample Designation	Mn		Cd		Cr		Zn		Ni		Pb		Cu		Fe		Hg		As	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
TCC-4:																				
Site Water	74	7.8	1.1	0	<2	-	1.3	-	4.9	0.7	7.2	1.1	5.7	0.2	5	1.0	0.007	0	<2	-
5%	315	79	1.5	0.1	<2	-	1.4	-	6.8	0.9	8.6	1.0	4.2	0.1	12	0.9	0.009	0.002	<2	-
20%	1200	200	1.5	0.1	<2	-	< 1	-	5.4	0.4	8.6	1.0	3.8	0.4	10	1.3	0.007	0	<2	-
TCC-5:																				
Site Water	68	0	0.8	0.2	<2	-	1.3	0.3	5.1	0.4	15.0	1.0	5.7	0.5	10	2.9	0.003	0	<2	-
5%	2750	495	0.6	0.1	<2	-	< 1	-	8.2	0.3	13.9	0.6	3.6	0.3	10	0.2	0.003	0	<2	-
20%	1200	2828	0.6	0.1	<2	-	< 1	-	7.1	0.5	16.4	1.0	6.4	2.3	16	1.3	0.009	0.002	<2	-
TCC-6:																				
Site Water	51	7.8	1.4	0.1	<2	-	3.0	0.6	4.8	0	9.7	0.5	5.4	0.3	5	1.0	0.007	-	<2	-
5%	905	134	0.7	0.1	<2	-	< 1	-	5.3	1.2	10.7	1.0	4.1	0.5	8	1.6	0.007	-	<2	-
20%	1600	-	0.5	-	<2	-	< 1	-	5.7	-	12.1	-	3.7	-	20	-	0.007	-	<2	-

Mean and standard deviation calculated from duplicate analyses.

Dash (-) indicates standard deviation could not be calculated.

increase in iron, from 5 µg/l to about 10 µg/l was noted. No significant change from site water concentrations of chromium, cadmium, zinc, nickel, lead, copper, mercury, or arsenic was detected in the elutriate.

Very large quantities of manganese were released in TCC-5 tests. Concentrations reached 2,750 µg/l in the 5 percent test. Nickel was observed to increase from 5 to 8 µg/l. A small decrease in zinc was also noted. No statistically significant change was observed for other metals monitored.

In tests with TCC-6 sediment, there was again substantial manganese release, only in this case it was in proportion to sediment content of the test. The 5 percent elutriate concentration (905 µg/l) and 20 percent concentration (1600 µg/l) were, respectively, lower and higher than the concentrations in the corresponding TCC-5 elutriates. There was a small but statistically significant decrease in the zinc concentration, from 3.0 µg/l to less than 1 µg/l. Also, small increases in iron concentrations, from 5 µg/l to 20 µg/l, were observed. TCC-6 site water and elutriate concentrations of other metals determined were statistically identical.

Data on release of heavy metals during elutriation of TCC-4, 5, and 6 samples after one month of storage are presented in Table 292. Manganese and iron were released from all three sediments as they had been in the previous elutriate tests. Manganese and iron releases seen in the previous TCC-4, 5, and 6 elutriate tests and storage tests were qualitatively the same. There was a dramatic increase in zinc and nickel concentrations in the elutriates of stored samples. Although this may reflect some chemical change during storage (at 4°C), it may also be the result of handling and analysis. In the later tests, there was some uptake of nickel although release had been seen earlier. All

Table 292

Soluble Heavy Metal Concentrations: Texas City Sites 4, 5 and 6

Elutriate Tests Performed October 31, 1975*

(µg/l)

Sample Designation	Mn		Cd		Cr		Zn		Ni		Pb		Cu		Fe		Hg		As	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
TCC-4:																				
Site Water	67	8	1.0	0	<2	-	21.1	11.1	43.0	3.4	5.6	0.4	9.5	0.2	8	1.4	0.010	0.004	<2	-
20% Oxic A	1650	350	1.3	0.2	<2	-	16.8	7.1	35.0	14.1	5.6	0.4	6.6	0.2	15	7.1	0.010	0.004	<2	-
B	3000	424	<0.5	-	<2	-	20.6	11.5	45.0	7.0	6.2	0.4	7.1	0.9	17	2.1	0.015	0	<2	-
TCC-5:																				
Site Water	50	0	1.0	0.1	<2	-	20.1	3.6	40.0	0	20.0	0.8	9.3	0.4	6	0.7	0.013	0	<2	-
20% Oxic	1950	71	0.7	0	<2	-	22.8	3.1	37.5	3.5	5.9	0.8	8.1	1.7	10	2.1	0.025	0	<2	-
TCC-6:																				
Site Water	50	0	1.0	0.1	<2	-	19.9	2.8	40.0	0	5.0	0.4	12.6	0.6	5	0.7	0.007	0.002	<2	-
20% Oxic	6100	990	1.3	0.1	<2	-	17.0	0	30.0	0	5.9	0.8	7.1	1.3	63	6.4	0.018	0	<2	-

A and B are replicates.
Mean and standard deviation calculated from duplicate analyses.
Dash (-) indicates not applicable.
* Samples collected on September 20, 1975.

other metals determined showed almost identical concentrations before and after the storage period.

Nitrogen Compounds

Total Kjeldahl nitrogen concentrations were determinted for each of the Texas City sediments; ammonium and organic N were determined for TCC-4, 5, and 6 samples only. The data shown in Table 293 indicate that total Kjeldahl nitrogen concentrations ranged from 643 mg N/kg for TCC-2 sediment to 1820 mg N/kg for the TCC-3 sediment. Except for the sediments from TCC-2 and TCC-5, all other Texas City sediments had TKN concentrations above 1000 mg N/kg. The highest ammonium and organic N concentrations were in the TCC-4 sediment sample.

Nitrogen compound release data in Table 294 show that ammonium release in the April 8 TCC-1 oxic tests was higher in the 24 hour elutriates. Further, ammonium release was greater with increased sediment percentage in the elutriate. Organic N concentrations decreased and appeared to vary inversely with the percent sediment in the total elutriate volume. Nitrate concentrations apparently did not change in the elutriates.

Table 295 presents nitrogen data for elutriate tests of sediment samples from Sites 2 and 3. Because the samples had to be centrifuged, the organic N concentrations do not represent total values, but rather the combined dissolved and fine particulate nitrogen fractions. Site water was not centrifuged prior to analysis.

Nitrate concentrations decreased slightly or remained unchanged in all elutriates. Ammonium release, which was in readily measurable amounts, was a function of the percent sediment in the total elutriate volume. Release was greatest in the Site 2 20 percent elutriate, but still below

Table 293

Nitrogen Compound Concentrations: Texas City Channel Sediment Samples

(mg N/kg)

Sample Designation	Total Kjeldahl Nitrogen		Organic N		Ammonium	
	X	SD	X	SD	X	SD
TCC-1	1670	47	-	-	-	-
TCC-2	643	12	-	-	-	-
TCC-3	1820	432	-	-	-	-
TCC-4	1670	47	1376	159	294	112
TCC-5	654	35	618	35	36	0
TCC-6	1249	116	1027	143	222	27

Mean and standard deviation calculated from duplicate analyses.

Dash (-) indicates data not available.

Table 294

Nitrogen Compound Concentrations: Texas City Channel Site 1 Oxic Elutriate Tests

(mg N/l)

Sample Designation	Organic N		Ammonium		Nitrate	
	$\bar{X}$	SD*	$\bar{X}$	SD*	$\bar{X}$	SD**
Site Water	5.0	1.0	0.59	0.04	0.08	0.01
5% (1 hr)	3.2	1.3	3.06	0.18	0.05	0.01
(24 hr)	2.2	0.7	3.84	0.2	0.06	0.02
20% (1 hr)	0.2	1.5	7.5	0.1	0.05	0
(24 hr)	0.6	0.6	10.3	-	0.07	0.02

Dash (-) indicates that only one sample was analyzed.

*Mean and standard deviation calculated from duplicate analyses.

**Mean and standard deviation calculated from triplicate analyses.

Table 295

Nitrogen Compound Concentrations: Texas City Sites 2 and 3
Oxic Elutriate Tests with One-Hour Settling
(mg N/l)

Sample Designation	Organic N		Ammonium		Nitrate	
	$\bar{X}$	SD*	$\bar{X}$	SD*	$\bar{X}$	SD**
TCC-2:						
Site Water	0.25	0.02	0.15	0.01	0.11	0.01
5%	<0.05	0.08	1.59	0	0.11	0.01
20%	<0.05	0.68	6.02	0.08	0.09	0.01
TCC-3:						
Site Water	0.30	0.21	0.22	0.01	0.11	0.01
5%	<0.05	0.21	2.98	0.01	0.09	0.01
20%	<0.05	0.23	4.66	0.23	0.11	0.01

Samples centrifuged prior to analysis.

*Mean and standard deviation calculated from duplicate analyses.

**Mean and standard deviation calculated from triplicate analyses.

that of the Site 1 elutriates. Organic N concentrations in the elutriates were generally lower than those in the site water, but this was probably due to the centrifugation step.

Table 296 shows results of tests run on Site 1 sediment on June 17 (81 days after sample collection). Organic N data again reflect less than total values because samples were centrifuged for 5 minutes at 9000 RPM prior to analysis. Results of nitrogen analysis show that nitrate increased in the June tests; it had decreased in the April tests. The increase was substantial (5-fold) in the 20 percent elutriate. Ammonium release was similar in both sets of elutriates.

Replicate 20 and 25 percent TCC-1 anoxic/oxic elutriates were prepared and subjected to nitrogen compound analysis. Organic N samples were centrifuged. Nitrogen data (Table 297) show major increases in nitrate and organic N concentrations in the 25 percent elutriates. A smaller increase, about 50 percent, was apparent in ammonium concentrations.

Table 296

Nitrogen Compound Concentrations: Texas City Channel Site 1

Oxic Elutriate Tests Performed June 17, 1975

(mg N/l)

Sample Designation	Organic N		Ammonium		Nitrate	
	$\bar{X}$	SD*	$\bar{X}$	SD*	$\bar{X}$	SD**
Site Water	0.23	0.02	<0.05	0	0.08	0.01
5%	< 0.05	0.06	2.42	0.02	0.10	0.01
20%	< 0.05	0.53	8.34	0.17	0.43	0.02

Samples centrifuged prior to analysis.

*Mean and standard deviation calculated from duplicate analyses.

**Mean and standard deviation calculated from triplicate analyses.

Table 297

Nitrogen Compound Concentrations: Texas City Channel Site 1

Anoxic/Oxic Elutriate Tests Performed June 19, 1975

(mg N/l)

Sample Designation	Organic N		Ammonium		Nitrate	
	$\bar{X}$	SD*	$\bar{X}$	SD*	$\bar{X}$	SD**
Site Water	0.27	0.04	<0.05	0	0.10	0.01
20%	0.05	0.5	12.3	0.1	0.12	0.01
25%	1.01	0.29	12.8	0.07	0.50	0.01

Samples were centrifuged before analysis.

*Mean and standard deviation calculated from duplicate analyses.

**Mean and standard deviation calculated from triplicate analyses.

The nitrogen data for elutriate tests on samples collected from Sites 4, 5, and 6 in September are presented in Table 298. Only 5 and 20 percent oxic elutriate tests were performed. All site water samples showed 0.12 mg N/l ammonium nitrogen. Site 6 site water showed the lowest organic N and nitrate concentrations. Compared to site water levels, nitrate concentrations increased in the TCC-4 and TCC-6 elutriates and decreased in the TCC-5 elutriates. Nitrate release did not appear to depend upon the percent sediment in the elutriate mixture. Although TCC-6 site water had lowest organic N concentrations, TCC-6 elutriates had the highest organic N release.

Ammonium concentrations in all elutriates increased as a function of percent sediment. The ammonium increase in the 20 percent TCC-6 elutriate was over twice that in the 20 percent TCC-2 elutriate, even though these two samples were collected from the same general location. Ammonium release was also considerable in the TCC-4 elutriate.

Additional elutriate tests were conducted on October 31, and the data are presented in Table 299. The nitrogen data for site water organic N are considerably different from those found in September. The October organic N and nitrate values were higher in the TCC-4 and 6 site water samples but lower in the TCC-5 sample. In the later tests, organic N release in TCC-5 elutriates was higher than that in the September TCC-6 elutriates. Ammonium concentrations of site water showed a two-fold increase with storage. Again there was considerable ammonium release from the TCC-4 and 6 sediments. Nitrate concentrations decreased in all the elutriates in the later tests, although only the TCC-5 elutriate had shown a nitrate decrease previously.

Table 298

Nitrogen Compound Concentrations: Texas City Sites 4, 5, and 6

Oxic Elutriate Tests

(mg N/l)

Sample Designation	Organic N		Ammonium		Nitrate	
	$\bar{X}$	SD*	$\bar{X}$	SD*	$\bar{X}$	SD**
TCC-4:						
Site Water	0.84	0.30	0.12	0	0.10	0.01
5%	<0.05	∿0	4.50	0.09	0.42	0.01
20%	<0.05	∿0	10.25	0.25	0.74	0.02
TCC-5:						
Site Water	0.79	0.22	0.12	0	0.11	0.01
5%	0.93	0.16	1.63	0.01	0.05	0.01
20%	<0.05	∿0	2.95	0.02	0.09	0.01
TCC-6:						
Site Water	0.15	0.09	0.12	0.01	0.04	0.01
5%	0.91	0.01	4.41	0.01	0.50	0.01
20%	2.65	2.30	15.70	0.42	0.31	0.02

*Mean and standard deviation calculated from duplicate analyses.

**Mean and standard deviation calculated from triplicate analyses

Phosphorus Compounds

The total phosphorus content of the Texas City Channel sediments is presented in Table 300. There does not appear to be an overall pattern (considering all six locations) of concentration with regard to sampling location. In the first sampling series (TCC-1, 2,and 3), the greatest concentration was found at TCC-1 (farthest up the turning basin), the lowest at TCC-2, and an intermediate value at TCC-3 (the most seaward site). Concentrations at TCC-4, 5, and 6 were all greater than those from the other TCC sites,

Table 299

Nitrogen Compound Concentrations: Texas City Sites 4, 5 and 6 Oxic Elutriate Tests Performed October 31, 1975

(mg N/1)

Sample Designation	Organic N		Ammonium	Nitrate	
	$\bar{X}$	SD*	$\bar{X}$	$\bar{X}$	SD**
TCC-4:					
Site Water	1.89	0.30	0.24	0.19	0.01
20% Oxic A	<0.05	∿0	9.38	0.10	0.02
B	0.32	0	15.1	<0.04	∿0
TCC-5:					
Site Water	0.31	0	0.22	0.09	0.01
20% Oxic	1.17	0.52	4.31	0.05	0.01
TCC-6:					
Site Water	0.85	0	0.21	0.08	0.01
20% Oxic	<0.05	∿0	11.3	0.07	0.01

A and B are replicates.

*Mean and standard deviation calculated from duplicate analyses.

**Mean and standard deviation calculated from triplicate analyses.

Table 300

Total Phosphorus Concentrations: Texas City Channel Sediment

(mg P/kg dry weight)

Sample Designation (TCC Site)	Total Phosphorus	
	$\bar{X}$	SD
1	750	70
2	473	59
3	644	23
4	1468	34
5	937	7
6	1232	14

Mean and standard deviation calculated from duplicate analyses of one sediment sample.

but showed a similar pattern, i.e., the greatest concentration was found farthest up the turning basin (TCC-4), the lowest was found at the mouth of the turning basin (between TCC-1 and 2), and the intermediate concentration at TCC-6, the most seaward site.

The mean soluble orthophosphate and total phosphorus concentrations found in Texas City Channel Sites 1, 2 and 3 elutriates are presented in Table 301. The site waters from all three locations had essentially the same concentrations of soluble ortho P and total P. The fresh Site 1 sediment released about the same amount of soluble ortho P in both the 5 percent and 20 percent (one hour) tests; it released greater amounts after the 24-hour settling period than after the one-hour period. The total P release was also about the same in the 5 and 20 percent elutriates settled for one hour. The settling time did not appear to affect the total P concentration in the 5 percent elutriate. However, the 20 percent elutriate settled for 24 hours had a phosphorus concentration four times greater than that settled for one hour.

The TCC-2 five percent elutriate (also in Table 301) showed a 50 percent reduction in soluble orthophosphate concentration to 0.048 mg P/l. The 20 percent elutriate had the same concentration as the site water. The total P concentration of the 5 percent elutriate was slightly lower than that of the site water; however, the 20 percent elutriate showed a two-fold increase over the site water concentration of 0.12 mg P/l.

The TCC-3 five and 20 percent elutriates showed reductions in soluble orthophosphate concentration to 0.054 and 0.074 mg P/l, respectively,from the 0.10 mg P/l concentration in the site water. The total P content remained virtually unaffected by oxic elutriation. Table 301 also presents phosphorus concentrations in TCC-1 elutriates which were run on samples that had been stored for 83 days. The site water

Table 301

Soluble Orthophosphate and Total Phosphorus Concentrations: Texas City Channel Sites 1, 2, and 3 Oxic Elutriate Tests

(mg P/l)

Sample Designation (1975)	Soluble Ortho P		Total P	
	$\bar{X}$	SD	$\bar{X}$	SD
TCC-1 (April 8):				
Site Water	0.095	0.021	0.10	0
5% (1 hr)	0.24	0.005	0.27	0.01
(24 hr)	0.30	0.008	0.30	0.01
20% (1 hr)	0.22	0.008	0.24	0.01
(24 hr)	1.3	0.03	>1.0*	-
TCC-1 (June 17):				
Site Water	0.082	0.003	-	
5% (1 hr)	0.15	0.004	-	
20% (1 hr)	0.36	0.003	-	
TCC-2 (April 8):				
Site Water	0.11	0.006	0.12	0.01
5% (1 hr)	0.048	0.002	0.09	0.01
20% (1 hr)	0.11	0	0.24	0.01
TCC-3 (April 8):				
Site Water	0.10	0.003	0.13	0.01
5% (1 hr)	0.054	0.005	0.13	0.01
20% (1 hr)	0.074	0.003	0.15	0.01

Dash (-) indicates no analysis made.

Mean and standard deviation calculated from duplicate or triplicate analyses of one sample

*Sample absorbance exceeded that of highest standard; insufficient sample remained to rerun analysis.

soluble orthophosphate concentration was slightly lower after storage. The release of soluble ortho P in the 5 percent test was less than it had been prior to storage; the release in the 20 percent elutriate was greater after storage, however.

The soluble orthophosphate concentrations in TCC-1 anoxic/oxic elutriates (Table 302) were nearly six times greater than the concentration found in the 20 percent oxic stored elutriate (Table 301). (Stored elutriate was used for comparison since it was tested on July 17; the anoxic/oxic tests were run June 19.) There were no differences between soluble ortho P or total P concentrations in the 20 and 25 percent elutriates.

Orthophosphate data from oxic elutriate tests on sediment and water collected in September from Texas City Sites 4, 5, and 6 are presented in Table 303. Soluble orthophosphate concentrations in the three site waters appeared to increase slightly from TCC-4 to 5 to 6. These concentrations were about two times greater than they had been in the same general area six months earlier (Table 301). Sediment from TCC-4 released soluble ortho P upon elutriation; the increase (1.5-fold) was approximately the same in both the 5 and 20 percent elutriates. The TCC-5 elutriates showed slightly decreased soluble ortho P concentrations following elutriation; the reduction was less in the 5 percent elutriate. The TCC-6 five percent elutriate also showed a reduction in the soluble ortho P concentration below that of the site water, whereas the 20 percent elutriate showed a slight increase in concentration. The difference in behavior between the two TCC-6 elutriates may be related to the difference in percent sediment used and/or the difference in D.O. concentrations after settling; the 5 percent elutriate had 5.8 mg/l D.O., whereas the 20 percent elutriate D.O. had 1.3 mg/l.

Table 302

Soluble Orthophosphate and Total Phosphorus Concentrations: Texas City Channel Site 1 Anoxic/Oxic Elutriate Tests Performed June 19, 1975

(mg P/l)

Sample Designation	Soluble Ortho P		Total P	
	$\bar{X}$	SD	$\bar{X}$	SD
Site Water	0.11	0.002	0.11	0
20%	2.1	0	1.6	0.03
25%	2.1	0	1.8	0.03

Mean and standard deviation calculated from duplicate or triplicate analyses of one sample.

Elutriates were centrifuged at 9000 rpm for 5 minutes prior to analysis.

Table 303

Soluble Orthophosphate Concentrations: Texas City Channel Sites 4, 5 and 6 Oxic Elutriate Tests

(mg P/l)

Sample Designation	Soluble Ortho P	
	$\bar{X}$	SD
TCC-4:		
Site Water	0.17	0
5%	0.28	0.018
20%	0.26	0.001
TCC-5:		
Site Water	0.18	0.003
5%	0.13	0.003
20%	0.15	0.001
TCC-6:		
Site Water	0.20	0.002
5%	0.12	0.001
20%	0.22	0

Mean and standard deviation calculated from triplicate analyses of one sample.

Table 304 presents the orthophosphate results for TCC-4, 5, and 6 samples stored 40 days and then elutriated. Following the storage period, soluble ortho P concentrations in TCC-4 and 5 site waters were 34 and 15 percent greater, respectively. TCC-6 site water soluble ortho P was 11 percent lower than it had been prior to storage. After storage, the direction of concentration change as a result of elutriation was exactly opposite that found in earlier tests; where release of soluble ortho P in elutriates had been found before sample storage (TCC-4 and 6), uptake was found in elutriate tests after storage. Where uptake was found before storage (TCC-5), release was found afterwards.

Table 304

Soluble Orthophosphate Concentrations: Texas City Sites 4, 5 and 6 Oxic Elutriate Tests Performed October 31, 1975*

(mg P/l)

Sample Designation	Soluble Ortho P	
	$\bar{X}$	SD
TCC-4:		
Site Water	0.23	0.001
20% Oxic A	0.17	0.002
B	0.10	0.001
TCC-5:		
Site Water	0.21	0
20% Oxic	0.27	0
TCC-6:		
Site Water	0.18	0
20% Oxic	0.042	0.002

A and B are replicates.

Mean and standard deviation calculated from triplicate analyses of one sample.

*Samples collected September 20.

Organic Compounds

A 5 percent elutriate test was run on samples from Texas City Site 1. Figure 102A shows resolution of 31 peaks on the EC chromatograms of TCC-1 sediment. Aldrin, pp'DDT, dieldrin, lindane, and PCBs were detected in the sediment. The PCB value of 7426 µg/kg is one of the highest sediment concentrations found in this study. This could be due to a possible point source discharge.

Sixteen of the peaks present in the sediment were detected in the water sample (Figure 102B). The same chlorinated hydrocarbons detected in the sediment were detected in the water, but only the aldrin concentration was above the detection limit.

The profile of organic residue of the elutriate shows five peaks in addition to the 16 peaks detected in the water. Generally, the magnitude of these peaks is higher than that of the water, indicating a tendency for release of organic residues. Table 305 lists the relative retention time correlation values of sediment, water, and elutriate derived from Figure 102.

The concentrations of chlorinated hydrocarbon pesticides and PCBs are presented in Table 306. The oil and grease of the sediment (304 mg/kg) is in a low concentration range, which would indicate a low affinity for sorption of PCBs and chlorinated hydrocarbon pesticides. The results of the elutriate test show a release of lindane, aldrin, and PCBs.

A 20 percent elutriate was run on samples from Texas City Site 4. The profile of organic residues on the EC chromatograms of the sediment and water showed essentially the same fingerprints detected in the TCC-1 sediment and water samples (Figure 102). The EC chromatograms of the elutriate showed significant release for most of the peaks detected in the sediment.

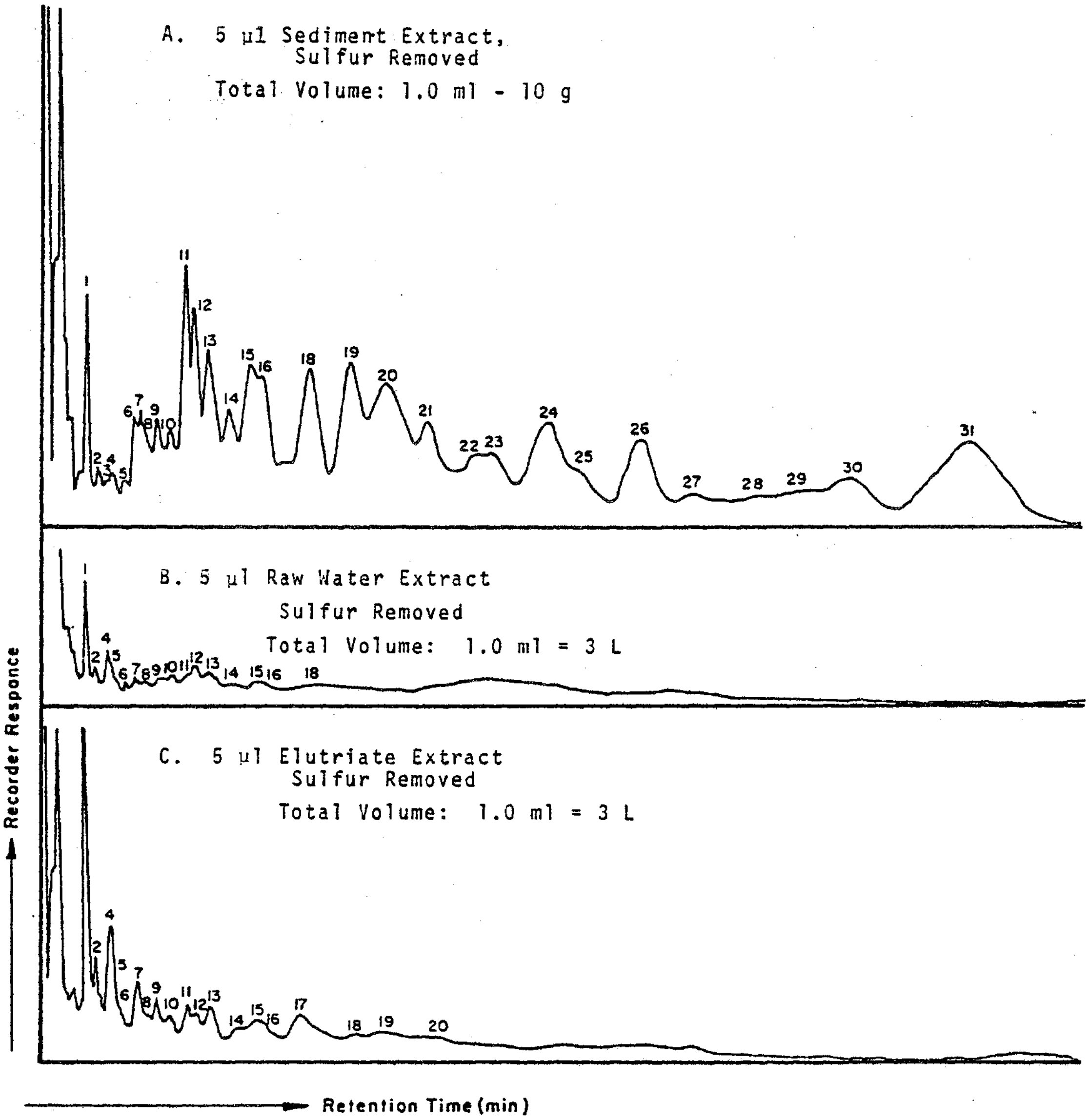

Figure 102

Profile of Organic Residues on EC Chromatograms: Texas City Channel Site 1 Sediment, Water and Elutriate

Table 305

Relative Retention Correlation Data: Texas City Site 1 Elutriate Test

Peak Number	Organic Compound	X_{mm}	R_r	Sediment	Water	Elutriate
1	Lindane	18	0.22	✓✓	✓✓	✓✓
2		23	0.28	✓	✓	✓
3		25	0.30	✓		✓
4		28	0.33	✓	✓	✓
5		32	0.39	✓	✓	✓
6		36	0.43	✓	✓	✓
7		39	0.47	✓	✓	✓
8		41	0.49	✓	✓	✓
9		46	0.55	✓	✓	✓
10		51	0.61	✓	✓	✓
11		56	0.67	✓	✓	✓
12		60	0.72	✓	✓	✓
13		66	0.78	✓	✓	✓
14		73	0.87	✓	✓	✓
15	Aldrin	83	1.00	✓✓	✓✓	✓✓
16		86	1.04	✓	✓	✓
17		95	1.14	✓		
18		103	1.27	✓	✓	✓
19		120	1.45	✓		✓
20		134	1.61	✓		✓
21		152	1.83	✓		✓
22	Dieldrin	169	2.04	✓✓		
23		177	2.13	✓		
24		197	2.37	✓		✓
25		209	2.52	✓		
26	pp'DDT	234	2.81	✓✓	✓✓	✓✓
27		255	3.07	✓		
28		280	3.37	✓		
29		295	3.55	✓		
30		311	3.75	✓		
31		356	4.29	✓		

✓ = Compound indicated on one column.
✓✓ = Compound indicated on two columns.

Table 306

Data for Organic Compounds and Related Parameters: Texas City Site 1 Elutriate Test

Parameter	Sediment (µg/kg)	Water (ng/l)	Elutriate (ng/l)
Chlorinated Hydrocarbons:			
Aldrin	3.4	1.4	3.6
op'DDT	<1.6	<3.0	<3.0
pp'DDT	8.4	<3.0*	<3.0*
op'DDD	<2.0	<2.0	<2.0
pp'DDD	<2.0	<2.0	<2.0
op'DDE	<1.4	<2.0	<2.0
pp'DDE	<1.4	<2.0	<2.0
Dieldrin	2.7	<1.2*	<1.2*
Endosulfan I	<0.9	<1.2	<1.2
Endosulfan II	<3.4	<4.4	<4.4
Endrin	<1.2	<1.6	<1.6
Heptachlor	<0.3	<0.4	<0.4
Lindane	1.0	<0.3*	1.5
PCBs	7426	130	150
Other Organic Compounds			
Oil and Grease	304 mg/kg	NT	NT
Total Organic Carbon	NT	NT	NT
Total Inorganic Carbon	1.8%	NT	NT

*Compound indicated on two columns, but below detection limit.

NT = not tested.

Measurable amounts of aldrin, pp'DDT, pp'DDE, lindane, and PCBs were detected in the sediment. Only lindane, aldrin, and PCBs were detected in the water. In the elutriate there was release of aldrin, pp'DDT, pp'DDE, lindane, and PCBs.

Table 307 presents the results of the organic analyses. The quality of the sediment in terms of percent total carbon and oil and grease content was comparable to that of the TCC-1 sediment. The concentrations of chlorinated hydrocarbon pesticides were similar to those in the Site 1 sediment, except that dieldrin was not detected. The value of PCBs (3010 μg/kg) was less than half of the value reported for the TCC-1 sample.

The water contained aldrin, lindane, and PCBs at concentrations of 1.4 and 1.0 and 52 ng/l, respectively. Release was found in the elutriate. Concentrations of aldrin (8.9 ng/l), pp'DDE (5.6 ng/l), lindane (1.6 ng/l), and PCBs (9619 ng/l) were higher than those found in the water. The PCB release was one of the largest releases found in this study.

Bioassays

Elutriates of sediment from each Texas City site and US EPA Reconstituted Sea Water[22] were used in a series of bioassays. Table 308, which presents the characteristics of the bioassay elutriates of Texas City Site 1 sediments, shows that the total ammonium nitrogen content for the 20 percent sediment test was approximately 7 mg N/l, of which approximately 0.47 mg/l was unionized ammonia. In addition, there were decreases in the D.O. and specific conductance

Table 307

Data for Organic Compounds: Texas City

Site 4 Elutriate Tests

Parameter	Sediment	Water	Elutriate
	(μg/kg)	(ng/l)	(ng/l)
Chlorinated Hydrocarbons:			
Aldrin	2.6	1.4	8.9
op'DDT	<1.6	<3.0	<3.0
pp'DDT	6.2	<3.0	12.0
op'DDD	<1.4	<2.0	<2.0
pp'DDD	<1.4	<2.0	<2.0
op'DDE	<1.4	<2.0	<2.0
pp'DDE	3.3	<2.0	5.6
Dieldrin	<0.8	<1.2	<1.2
Endosulfan I	<0.9	<1.2	<1.2
Endosulfan II	<3.4	<4.4	<4.4
Endrin	<1.2	<1.6	<1.6
Heptachlor	<0.3	<0.4	<0.4
Lindane	0.4	1.0	1.6
PCBs	3010	52	9619
Other Organic Compounds			
Oil and Grease	533 mg/kg	0.92 mg/l	147 mg/l
Total Organic Carbon	0.8 %	NT	NT
Total Inorganic Carbon	1.5 %	NT	NT

NT - not tested

Table 308

Chemical and Physical Characteristics: Texas City Site 1

Bioassay Elutriates*

Sample Designation		pH	D.O. (mg/l @ 21-23.5°C)	Specific Conductance (μmhos/cm @ 21-23.5°C)	Total Ammonium (mg N/l)	Unionized** Ammonia (mg N/l)	Turbidity (NTU)
Control	A	8.1	7.0	46,100	0.03	<0.01	2
	B	8.1	7.0	46,000	0.05	<0.01	2
5%	A	8.1	3.9	30,800	4.03	0.22	33
	B	8.1	3.9	30,700	4.00	0.22	33
10%	A	8.2	2.6	24,800	5.46	0.37	30
	B	8.2	2.6	24,900	5.60	0.38	29
20%	A	8.2	2.2	24,200	7.31	0.46	26
	B	8.2	2.2	24,200	7.71	0.49	27

A and B are replicates.

*Measurements taken after the one-hour settling period.

**For all bioassay elutriates, unionized ammonia calculated from Skarheim's[9] tables for fractions of ammonia in the undissociated form.

and increases in turbidity. The decreases in specific conductance reflect the lower salinity periodically found in a system affected by fluctuations in seasonal rainfall. Table 309 shows manganese concentrations over 100 mg/l in the 5 percent sediment test and lower concentrations in the 10 and 20 percent tests. Small amounts of iron were released, while mercury and chromium were removed. Other metals monitored showed no statistically significant changes.

Table 310 presents the results of the 96-hour bioassay on _P_. _pugio_ in these elutriates. Examination of the data shows that no toxicity to _P_. _pugio_ was found for the 5 and 10 percent sediment elutriates. Ten percent toxicity was observed after 24 hours and 20 percent toxicity after 36 hours for the 20 percent sediment elutriates.

The chemical characteristics, heavy metal, and bioassay results for Texas City Site 2 bioassay elutriates are presented in Tables 311, 312, and 313, respectively. The chemical changes were similar to those observed for TCC Site 1 elutriates (Table 308), except that total ammonium nitrogen concentrations were considerably lower. Heavy metal behavior was also comparable to that found for the Site 1 bioassay elutriates. Site 2 sediments showed limited toxicity (10 to 20 percent mortality) to _P_. _pugio_.

Tables 314 and 315 show that Texas City Site 3 elutriates were similar to those of Site 1 in both general physiochemical parameters and heavy metals, except that manganese was higher with 20 percent sediment tests than in the 5 percent sediment tests. Toxicity results for Site 3 elutriates (Table 316) were also similar in that there was limited toxicity (10 to 20 percent mortality) to _P_. _pugio_.

Table 309

Release of Heavy Metals: Texas City Site 1

Bioassay Elutriates

(μg/l)

Sample Designation		Mn*	Cd	Cr	Zn	Ni	Pb	Cu	Fe	Hg
Control	A	1.1	0.9	0.6	11.6	7.5	6.3	5.8	1	2.1
	B	1.1	0.9	0.6	11.6	7.5	6.3	5.8	1	2.1
5%	A	107	0.2	<0.1	13.4	4.5	7.3	4.6	27	0.4
	B	100	0.3	<0.1	12.6	5.3	7.9	4.1	5	0.4
10%	A	22	0.5	<0.1	12.7	<0.1	6.5	4.1	4	0.4
	B	23	0.3	<0.1	12.3	1.5	6.8	3.8	4	0.4
20%	A	37	0.7	<0.1	8.9	8.3	5.5	3.5	4	0.6
	B	48	0.6	<0.1	9.1	3.8	6.3	4.1	5	0.6

A and B are replicates.

*Manganese concentrations in mg/l.

Table 310

Response of P. pugio to Varying Sediment Percent of Total Elutriate Volume as a Function of Time: Texas City Site 1 Bioassay Elutriate

Time (hr)	Number of *P. pugio* Living at Varying Sediment Percentages							
	Control		5%		10%		20%	
	A	B	A	B	A	B	A	B
0	10	10	10	10	10	10	10	10
12	10	10	10	10	10	10	10	10
24	10	10	10	10	10	10	9	9
36	10	10	10	10	10	10	8	8
48	10	10	10	10	10	10	8	8
60	10	10	10	10	10	10	8	8
72	10	10	10	10	10	10	8	8
84	10	10	10	10	10	10	8	8
96	10	10	10	10	10	10	8	8

A and B are replicates.

Table 311

Chemical and Physical Characteristics: Texas City Site 2

Bioassay Elutriates*

Sample Designation		pH	D.O. (mg/l @ 21.6-23.5°C)	Specific Conductance (µmhos/cm @ 21.6-23.5°C)	Total Ammonium (mg N/l)	Unionized Ammonia	Turbidity (NTU)
Control	A	8.1	7.0	46,100	0.03	< 0.01	2
	B	8.1	7.0	46,000	0.05	< 0.01	2
5%	A	8.2	3.7	24,200	2.25	0.15	48
	B	8.2	3.66	24,200	2.25	0.15	48
10%	A	8.3	2.0	24,000	3.12	0.21	26
	B	8.3	2.0	24,000	3.20	0.22	26
5%	A	8.3	1.8	29,000	3.74	0.25	23
	B	8.3	1.7	29,000	3.65	0.25	22

A and B are replicates.

*Measurements taken after the one-hour settling period.

Table 312

Release of Heavy Metals : Texas City Site 2

Bioassay Elutriates

(µg/l)

Sample Designation		Mn*	Cd	Cr	Zn	Ni	Pb	Cu	Fe	Hg
Control	A	1.1	0.9	0.6	11.6	7.5	6.3	5.8	1	2.1
	B	1.1	0.9	0.6	11.6	7.5	6.3	5.8	1	2.1
5%	A	79	0.8	0.3	9.5	<0.1	5.2	0.9	9	0.4
	B	82	0.4	<0.1	9.2	<0.1	5.7	0.9	8	0.4
10%	A	94	0.8	0.3	9.7	<0.1	6.8	2.9	3	0.5
	B	86	0.4	0.1	8.9	0.8	6.5	2.9	4	0.5
20%	A	19	0.7	<0.1	18.5	6.0	3.0	2.9	10	0.5
	B	22	0.7	0.3	7.8	6.0	4.6	2.6	8	0.5

A and B are replicates.

*Manganese concentrations in mg/l.

Table 313

Response of P. pugio to Varying Sediment Percent of Total Elutriate Volume as a Function of Time: Texas City Site 2 Bioassay Elutriates

Time (hr)	Control		Number of *P. pugio* Living at Varying Sediment Percentages					
			5%		10%		20%	
	A	B	A	B	A	B	A	B
0	10	10	10	10	10	10	10	10
12	10	10	10	10	10	10	10	10
24	10	10	10	10	9	10	10	9
36	10	10	10	10	9	10	9	9
48	10	10	9	10	9	9	9	8
60	10	10	9	10	9	9	8	8
72	10	10	9	9	9	9	8	8
84	10	10	9	9	9	9	8	8
96	10	10	9	9	9	9	8	8

A and B are replicates.

Table 314

Chemical and Physical Characteristics: Texas City Site 3 Bioassay Elutriates*

Sample Designation		pH	D.O. (mg/1 @ 20°C)	Specific Conductance (μmhos/cm @ 20°C)	Total Ammonium (mg N/1)	Unionized Ammonia (mg N/1)	Turbidity (NTU)
Control	A	8.1	6.5	39,000	0.04	<0.01	<0.1
	B	8.1	6.5	39,000	0.04	<0.01	<0.1
5%	A	8.0	4.2	31,800	2.64	0.12	53
	B	8.0	4.2	36,500	2.64	0.12	53
10%	A	7.8	1.6	37,800	4.12	0.12	58
	B	7.8	1.5	33,000	4.10	0.12	58
20%	A	7.8	1.3	30,800	6.06	0.18	52
	B	7.8	1.3	38,500	6.10	0.18	52

A and B are replicates.

*Measurements taken after the one-hour settling period.

Table 315

Release of Heavy Metals: Texas City Site 3

Bioassay Elutriates

(μg/l)

Sample Designation	Mn*	Cd	Cr	Zn	Ni	Pb	Cu	Fe
Control A	0.4	<0.1	4.7	17.9	16.5	<1.0	3.8	5
B	0.4	<0.1	4.7	18.0	16.5	<1.0	3.7	5
5% A	2.4	<0.1	6.1	5.9	8.4	<1.0	2.16	29
B	2.5	<0.1	7.4	5.7	8.4	<1.0	2.16	56
10% A	6.2	<0.1	7.4	5.6	10.5	<1.0	2.7	33
B	6.2	<0.1	8.8	4.6	10.5	<1.0	2.7	45
20% A	8.6	<0.1	8.8	5.6	11.5	<1.0	3.2	75
B	8.3	<0.1	8.8	4.6	12.5	<1.0	3.7	91

A and B are replicates.

*Manganese concentrations in mg/l.

Table 316

Response of P. pugio to Varying Sediment Percent of Total Elutriate Volume as a Function of Time: Texas City Site 3 Bioassay Elutriates

Time (hr)	Control		Number of *P. pugio* Living at Varying Sediment Percentages					
			5%		10%		20%	
	A	B	A	B	A	B	A	B
0	10	10	10	10	10	10	10	10
12	10	10	10	10	9	9	9	8
24	10	10	9	10	9	9	8	8
36	10	10	9	10	9	9	8	8
48	10	10	9	9	9	9	8	8
60	10	10	9	9	9	9	8	8
72	10	10	9	9	9	9	8	8
84	10	10	9	9	9	9	8	8
96	10	10	9	9	9	9	8	8

A and B are replicates.

The chemical characteristic data for Site 4 samples presented in Table 317 show that the total ammonium nitrogen for the 20 percent sediment test was 8 to 10 mg N/l, with approximately 0.35 mg/l present as unionized ammonia. In addition, there were decreases in D.O. and increases in turbidity.

The results of the heavy metal analysis of the Site 4 bioassay elutriates are presented in Table 318. Increased manganese release was observed with increased sediment percentage in the elutriates. Manganese concentrations over 1000 μg/l were observed in the 20 percent sediment tests. Iron release ranged from approximately 2300 μg/l in one 20 percent replicate to 3300 μg/l in a 10 percent test. Release of zinc generally increased with increasing sediment percentage elutriates. Slight release of lead occurred, while no significant changes were observed for cadmium, copper, chromium, nickel, and mercury.

Bioassays of P. pugio in these elutriates showed limited toxicity. Table 319 shows that the maximum kill (30 percent) occurred in 10 percent sediment replicate B after 60 hours of exposure.

Chemical characteristics and metal results for Texas City Channel Site 5 sediment elutriates are presented in Tables 320 and 321; the corresponding bioassay data are in Table 322. The results presented in Table 320 are similar to those of Site 4 sediments. The 20 percent sediment test total ammonium content was approximately 4.7 mg/l as nitrogen. The heavy metal data also follow the same general trends found for Site 4. Large amounts of manganese and iron were released with smaller zinc release and slight increases in lead concentrations. Examination of Table 322 shows no toxicity of Site 5 sediments to P. pugio over the entire 96-hour test period.

The chemical characteristics data in Table 323 show large amounts of total ammonium nitrogen release in

Table 317

Chemical and Physical Characteristics: Texas City Site 4 Bioassay Elutriates*

Sample Designation		pH	D.O. (mg/l @ 19.5-20.2°C)	Specific Conductance (μmhos/cm @ 19.5-20.2°C)	Total Ammonium (mg N/l)	Unionized Ammonia (mg N/l)	Turbidity (NTU)
Control	A	7.9	7.5	35,000	0.05	<0.01	<1
	B	7.9	7.5	35,000	0.05	<0.01	<1
5%	A	8.1	4.6	37,000	5.91	0.28	185
	B	8.0	5.3	35,000	5.69	0.22	245
10%	A	8.0	4.3	35,000	6.71	0.26	270
	B	8.0	3.7	38,000	7.60	0.29	195
20%	A	8.0	2.4	38,000	8.52	0.33	160
	B	8.0	2.2	38,000	10.13	0.37	140

A and B are replicates.

*Measurements taken after the one-hour settling period.

Table 318

Release of Heavy Metals: Texas City Site 4 Bioassay Elutriates

Sample Designation		Mn	Cd	Cr	Zn	Ni	Pb	Cu	Fe	Hg
Control	A	84	<2.7	2.0	16.3	8.2	13.8	12.1	11	0.018
	B	68	<2.7	2.0	19.5	8.5	16.3	15.3	11	0.028
5%	A	700	<2.5	2.0	39.0	8.8	27.5	14.7	2500	0.018
	B	700	<3.0	2.0	53.2	9.7	31.3	24.7	3000	0.025
10%	A	700	<2.6	2.0	40.8	9.1	30.0	18.2	3300	0.018
	B	800	<2.6	2.0	66.0	9.4	31.3	22.0	3300	0.023
20%	A	1000	<2.7	2.0	32.3	9.1	30.0	14.2	2300	0.075
	B	1200	<2.6	2.0	44.0	9.1	31.3	15.3	2600	0.015

A and B are replicates.

Table 319

Response of P. pugio to Varying Sediment Percent of Total Elutriate Volume as a Function of Time: Texas City Site 4 Bioassay Elutriates

Time (hr)	Control		Number of *P. pugio* Living at Varying Sediment Percentages					
			5%		10%		20%	
	A	B	A	B	A	B	A	B
0	10	10	10	10	10	10	10	10
12	10	10	10	10	9	10	9	9
24	10	10	10	10	9	10	9	9
36	10	10	10	10	9	8	9	9
48	10	10	10	10	9	8	9	9
60	10	10	9	10	9	7	9	9
72	10	10	8	10	9	7	9	8
84	10	10	8	10	9	7	9	8
96	10	10	8	10	9	7	9	8

A and B are replicates.

Table 320

Chemical and Physical Characteristics: Texas City Site 5

Bioassay Elutriates*

Sample Designation		pH	D.O. (mg/l@20°C)	Specific Conductance (μmhos/cm @ 20°C)	Total Ammonium (mg N/l)	Unionized Ammonia (mg N/l)	Turbidity (NTU)
Control	A	7.9	7.5	35,000	0.05	<0.01	< 1
	B	7.9	7.5	35,000	0.05	<0.01	< 1
5%	A	8.1	4.7	35,000	2.57	0.12	340
	B	8.1	4.9	36,000	2.36	0.11	295
10%	A	8.2	2.8	35,000	3.19	0.19	240
	B	8.2	2.5	35,000	3.46	0.20	260
20%	A	8.2	1.1	35,000	4.68	0.28	175
	B	8.2	1.2	37,000	4.82	0.29	155

A and B are replicates.

*Measurements taken after the one-hour settling period.

Table 321

Release of Heavy Metals: Texas City Site 5 Bioassay Elutriates

(μg/l)

Sample Designation		Mn	Cd	Cr	Zn	Ni	Pb	Cu	Fe	Hg
Control	A	84	2.7	<2.0	16.3	8.2	13.8	12.5	11	0.018
	B	68	2.7	<2.0	19.5	8.5	16.3	15.3	11	0.028
5%	A	1700	3.2	<2.0	34.8	7.0	20.0	10.9	7000	0.028
	B	600	2.7	<2.0	35.8	7.9	20.0	14.9	3000	0.015
10%	A	1000	2.6	<2.0	41.9	9.7	20.0	14.0	2500	0.013
	B	1000	2.5	<2.0	47.5	8.5	20.0	13.6	2700	0.018
20%	A	1700	2.5	<2.0	60.0	7.0	25.0	16.2	2500	0.018
	B	1700	2.6	<2.0	57.8	7.6	25.0	21.3	3900	0.018

A and B are replicates.

Table 322

Response of P. pugio To Varying Sediment Percent of Total Elutriate Volume As A Function of Time: Texas City Site 5 Bioassay Elutriates

Time	Number of P. pugio Living at Varying Sediment Percentages							
	Control		5%		10%		20%	
(hr)	A	B	A	B	A	B	A	B
0	10	10	10	10	10	10	10	10
12	10	10	10	10	10	10	10	10
24	10	10	10	10	10	10	10	10
36	10	10	10	10	10	10	10	10
48	10	10	10	10	10	10	10	10
60	10	10	10	10	10	10	10	10
72	10	10	10	10	10	10	10	10
84	10	10	10	10	10	10	10	10
96	10	10	10	10	10	10	10	10

A and B are replicates.

Table 323

Chemical and Physical Characteristics: Texas City Site 6

Bioassay Elutriates*

Sample Designation		pH	D.O. (mg/l@21.5°C)	Specific Conductance (µmhos/cm @ 21.5°C)	Total Ammonium (mg N/l)	Unionized Ammonia (mg N/l)	Turbidity (NTU)
Control	A	8.15	7.1	35,000	0.05	<0.01	5
	B	8.10	7.1	35,000	0.05	<0.01	2
5%	A	8.15	4.4	35,000	3.42	0.23	32
	B	8.10	4.2	35,000	2.92	0.16	35
20%	A	8.00	2.1	35,000	0.40	0.40	29
	B	8.00	2.5	36,000	10.60	0.47	30

A and B are replicates.

*Measurements taken after the one-hour settling period.

Texas City Site 6 sediment elutriates. The increases in turbidity were not as pronounced as those observed in elutriates of Sites 4 and 5 sediments. Table 324 shows the concentrations of D.O. in the Site 6 bioassay elutriates over the 96-hour test period. The data indicate that the method of aeration was sufficient to keep D.O. levels above 4 mg/l for the duration of the test.

The results of the heavy metal analyses of these solutions are presented in Table 325. Only the 20 percent sediment elutriates were analyzed. Large quantities of manganese and iron were released. The concentrations of other metals monitored did not change much from the concentrations observed in the control.

Table 326 presents the bioassay results for these elutriates. Examination of the table shows only slight toxicity of Site 6 sediment to <u>P</u>. <u>pugio</u> after 36 hours. One grass shrimp died in one 20 percent replicate.

Table 324

Dissolved Oxygen Concentrations over Test Period:

Texas City Site 6 Bioassay Elutriates

(mg/l @ 21°C)

Time (hr)	Control		5%		20%	
	A	B	A	B	A	B
0	7.1	7.1	4.4	4.2	2.1	2.5
1*	7.2	7.2	4.5	4.2	4.4	4.2
24	6.2	6.2	4.7	4.9	4.4	4.2
48	6.4	6.4	4.7	4.9	4.5	4.5
72	6.3	6.3	4.7	4.8	4.5	4.7
96	6.3	6.3	4.8	4.8	4.5	4.5

A and B are replicates.

*Measurements taken after first hour of aeration.

Table 325

Release of Heavy Metals: Texas City Site 6 Bioassay Elutriates

(μg/l)

Sample Designation*	Mn	Cd	Cr	Zn	Ni	Pb	Cu	Fe	Hg
Control A	270	2.8	3.0	23.7	19.1	17.8	12.7	27	0.023
B	248	2.3	3.0	22.4	19.1	17.8	14.0	17	0.013
20% A	3700	1.1	< 2.0	24.9	14.3	12.4	12.0	227	0.018
B	3500	2.4	< 2.0	26.9	17.4	16.5	6.7	143	0.015

A and B are replicates.

*Five percent sediment elutriates were lost.

Table 326

Response of *P. pugio* To Varying Sediment Percent of Total Elutriate Volume As A Function of Time: Texas City Site 6 Bioassay Elutriates

Time	Number of *P. pugio* Living at Various Sediment Percentages							
	Control		5%		10%		20%	
(hr)	A	B	A	B	A	B	A	B
0	10	10	10	10	10	10	10	10
12	10	10	10	10	10	10	10	10
24	10	10	10	10	10	10	10	10
36	10	10	10	10	10	10	9	10
48	10	10	10	10	10	10	9	10
60	10	10	10	10	10	10	9	10
72	10	10	10	10	10	10	9	10
84	10	10	10	10	10	10	9	10
96	10	10	10	10	10	10	9	10

A and B are replicates.

Texas City Hopper Dredge

In the Texas City Channel, dredging was begun immediately as the hopper dredge entered the Texas City Channel Turning Basin (TCCTB). The sidearms were lowered, and the dredged material was pumped through them and back to the rear of the hopper through the two exit ports. Approximately 90 percent of the material entered the hopper this way, with the remaining 10 percent entering as a spray off the main conduit.

The dredging continued for the length of the turning basin. At that point, the sidearms were raised out of the sediment, and the dredge was turned back toward the entrance of the turning basin. The sidearms were again lowered into the sediment and dredging was recommenced. This procedure was continued until the captain decided that the hopper was full.

An overflow system was used during dredging operations. Before dredging, the hopper had contained several feet of residual water which had either been trapped when the hopper doors closed during a previous dump or had seeped into the hopper while the dredge was in transit. During dredging, some TCCTB water entered the hopper when the sidearms were raised at each turn of the dredging run. As the hopper filled, the solid material tended to settle to the bottom, and apparently, as a normal procedure, an overflow system discharged the supernatant water via ports on both sides of the dredge. This procedure was apparently continuous.

The intake into the hopper of the dredge McFarland was sampled in October, 1975 during dredging operations in the TCCTB. Table 327 presents percent settleable solids data for the three dredging runs in the turning basin. Figure 103 shows the highest overall variability for Run 1. Readings fluctuated, ranging from <9 to 100 percent. In both runs,

Table 327

Percent Settleable Solids: Texas City Hopper Dredge Samples

Dredging Location and Date (1975)	Time (hr :min)	Sample Source*	Percent Settleable Solids
October 9:			
	9:02-Dredging Began.		
Run 1	9:02	D	90
	9:07	D	97
	9:12	D	22
	9:12	D	10
	9:17	D	42
	9:22	D	14
	9:27	S	9
	9:30	O	1
	9:33	D	94
	9:40	D	100
	9:47	S	20
	9:47-Dredging Stopped.		
	10:21	S	22
	11:24	S	15
Run 2 (Texas City Dump No. 1)	14:31 Dredging Began.		
	14:33	D	94
	14:36	O	0.8
	14:39	D	19
	14:50	S	27
	14:52	O	33
	14:55	O	13
	15:02	D	12
	15:06	D	36
	15:06-Dredging Stopped.		
	15:24	S	31
	16:12	S	10
	16:22	S	21

(Continued)

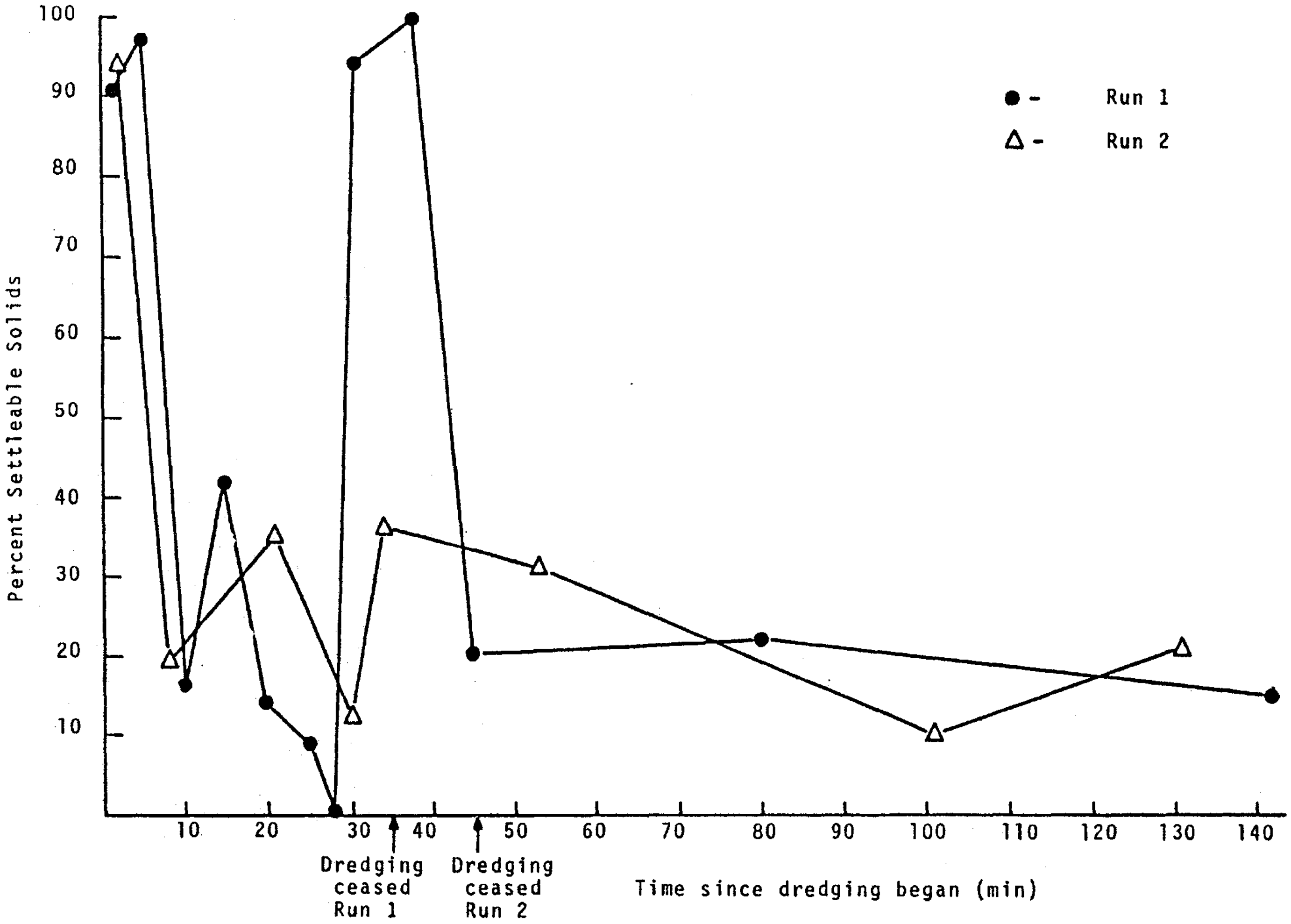

Figure 103

Changes in Percent Settleable Solids: Hopper Dredge Samples Dredged from Texas City Channel and Turning Basin (October 9, 1975)

Table 327 (Concluded)

Dredging Location and Date (1975)	Time (hr :min)	Sample Source*	Percent Settleable Solids
October 10:			
	7:15-Dredging Began.		
Run 1 (Texas City Dump No. 2)	7:24	D	9
	7:30	D	34
	7:33	O	6
	7:38	S	4
	7:42	D	41
	7:45	O	11
	7:45-Dredging Stopped.		
	7:51	D	28
	7:57	D	20
	8:01	S	9
	8:37	S	8
	9:11	S	6
	10:13	S	13

*D = Dredging pump discharge
O = Overflow
S = Supernatant

after the initial high reading, the readings dropped off and stayed below the 35 percent level.

The data from the dredging run on October 10 are presented in Figure 104. For this run, the maximum (41 percent) was found in a sample taken 27 minutes after dredging started. After dredging ceased, settleable solids in the supernatant ranged from 6 to 13 percent.

The most important conclusion from hopper sampling is that the system is highly variable during dreding. This is most likely due to the variability in the contours of the

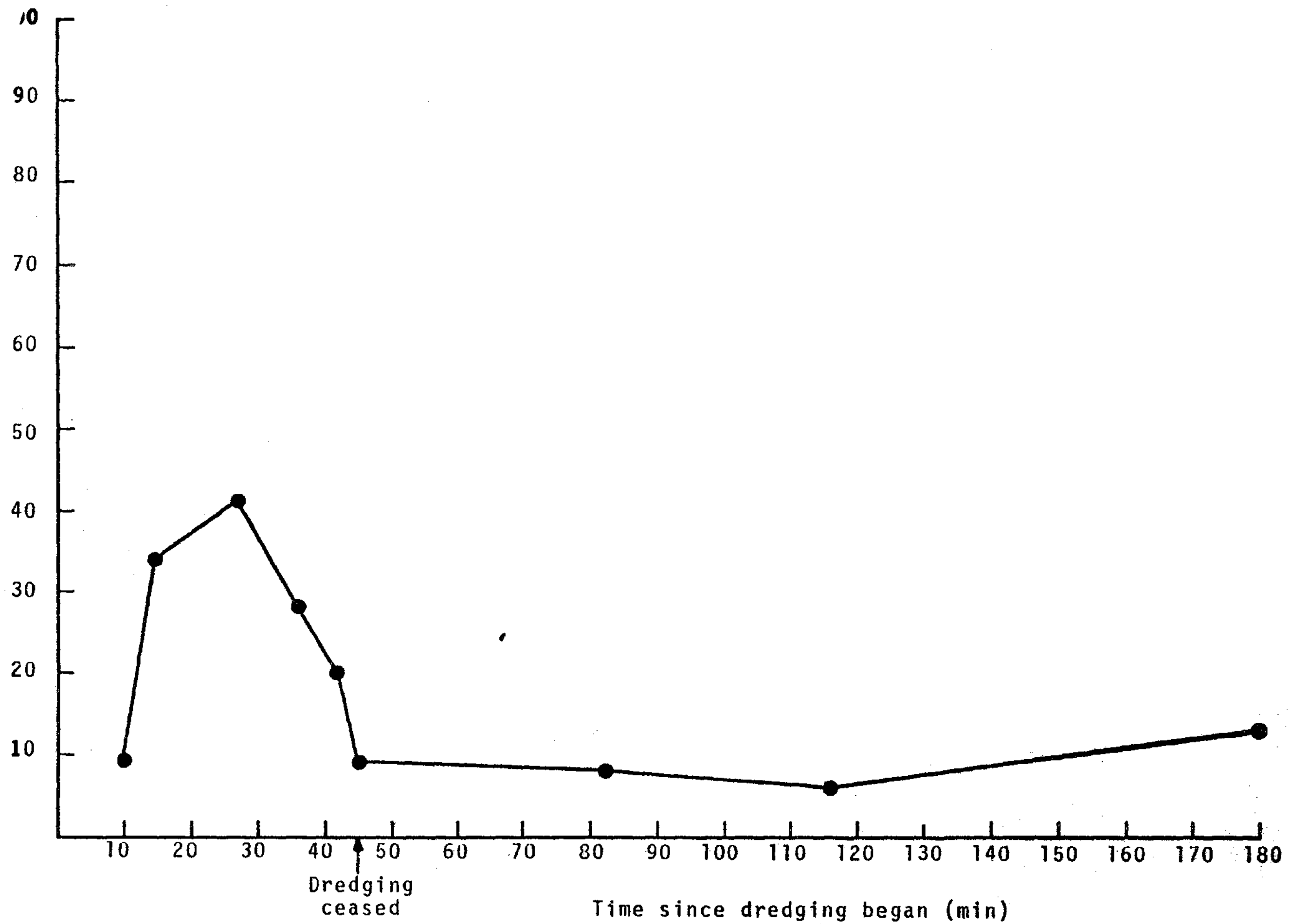

Figure 104

Changes in Percent Settleable Solids: Hopper Dredge Samples
Dredged from Texas City Channel and Turning Basin
(October 10, 1975)

channel floor being dredged. Since the bottom is not level, the amount of sediment taken up varies as the hopper arm moves through sediment at a fixed depth. There was a general trend for the percent settleable solids to decrease during dredging and stabilize after dredging ceased.

Heavy Metals

During Run 1 on October 9, the hopper was sampled from 9:02 to 11:24; results of heavy metals analyses are shown in Table 328. The metal concentrations in the hopper were comparable to ambient levels. The exception was manganese, of which concentrations varied from 138 to 3,710 µg/l. The early samples, collected while dredging was in progress, showed higher manganese concentrations than samples collected after dredging.

From 14:33 to 16:42 that day another dredging operation was monitored. Again, only manganese concentrations exceeded ambient levels. As Table 329 shows, manganese ranged from 100 to 700 µg/l, which is low compared to levels in samples taken from the hopper.

Table 330 shows the results of analyses of samples collected during Run 1 on October 10. As before, only manganese was significantly released in the hopper samples. Levels were found to range from 129 to 2,220 µg/l. Another overflow sample was collected and showed a soluble manganese concentration of 200 µg/l. As in the previous operation, the overflow concentration of manganese was generally lower than the concentrations observed in the hopper samples.

The hopper dredge studies indicate the ability of the elutriate test to qualitatively predict release of heavy metals. The elutriate test did seem to overestimate the magnitude of the manganese release. The concentrations of soluble manganese observed in the elutriate were generally much higher than those typically found in the hopper samples.

Table 328

Soluble Heavy Metal Composition: Texas City* Hopper Dredge Samples Collected During Run 1 on October 9, 1975

(μg/l)

Time of Collection	Percent Sediment	Mn	Cd	Cr	Zn	Ni	Pb	Cu	Fe	Hg	As
			9:02 - Dredging Began.								
9:02	90	1,180	2.3	< 2	26.1	13.9	2.4	7.0	59	0.012	< 2
9:07	97	495	2.5	< 2	30.1	10.1	3.6	8.7	59	–	< 2
9:12	16	510	3.1	< 2	46.9	12.9	2.9	7.3	15	0.028	< 2
9:27	9	342	3.8	< 2	59.2	16.2	3.6	7.6	25	–	< 2
9:30	<1	221	2.8	< 2	19.0	9.6	3.1	10.7	28	0.044	< 2
9:33	94	940	2.5	< 2	31.1	13.4	2.9	5.9	48	–	< 2
9:40	100	3,710	2.2	< 2	17.4	13.9	2.9	5.4	81	0.012	< 2
9:47	20	160	3.4	< 2	58.1	12.9	3.6	9.2	23	0.028	< 2
			9:47 - Dredging Stopped.								
10:21	22**	138	2.1	< 2	42.5	10.8	1.7	5.9	19	0.028	< 2
11:24	15**	263	2.7	< 2	73.0	15.5	2.1	7.8	29	0.028	< 2
			11:24 - Dump Occurred.				2.9				
Mean		796	2.7	< 2	40.3	12.9	0.7	7.6	39	0.026	< 2
Standard deviation		1080	0.5	0	18.7	2.2	22.7	1.6	22	0.011	0
Coefficient of variation, V(%)		135.6	20.0	–	46.5	16.9		21.8	56.6	42.9	–

Dash (-) indicates no analaysis.

*All Texas City hopper dredge samples were collected in Texas City Channel Turning Basin.

**Supernatant percent sediment.

Table 329

Soluble Heavy Metal Composition: Texas City Hopper Dredge Samples Collected During Run 2 on October 9, 1975

(μg/l)

Time of Collection	Percent Sediment	Mn	Cd	Cr	Zn	Ni	Pb	Cu	Fe	Hg	As
						14:31 - Dredging Began.					
14:33	94	175	2.2	< 2	26.4	10.8	1.9	6.7	34	0.028	< 2
14:39	19	100	2.6	< 2	30.1	10.8	2.1	4.5	14	0.012	< 2
14:50	27*	700	2.5	< 2	52.9	12.9	2.2	4.3	30	0.044	< 2
14:52	35	342	2.8	< 2	40.4	13.4	2.4	5.6	18	-	< 2
14:55	13**	175	2.4	< 2	43.6	11.1	1.9	6.7	11	0.028	< 2
15:02	12	225	3.4	< 2	56.8	16.2	2.1	8.6	18	0.028	< 2
15:06	36	675	2.1	< 2	48.8	13.5	1.9	3.7	177	-	< 2
						15:06 - Dredging Stopped.					
15:24	31*	297	3.5	< 2	46.7	12.5	2.9	5.1	41	0.028	< 2
16:12	10*	175	3.7	< 2	65.0	13.9	2.9	9.9	20	0.028	< 2
16:42	21*	525	3.2	< 2	68.6	12.5	2.9	9.8	23	0.028	< 2
						16:42 - Dump Occurred.					
Mean		339	2.8	< 2	47.9	12.8	2.3	6.5	39	0.028	< 2
Standard deviation		219	0.6	0	13.7	1.7	0.4	2.3	50	0.009	0
Coefficient of variation V(%)		64.5	20.1	-	28.5	13.0	18.5	35.0	128.2	30.5	-

Dash (-) indicates not applicable.

*Supernatant percent sediment.

**Overflow percent sediment.

Table 330

Soluble Heavy Metal Compositions: Texas City Hopper Dredge Samples Collected During Run 1 on October 10, 1975

(µg/l)

Time of Collection	Percent Sediment	Mn	Cd	Cr	Zn	Ni	Pb	Cu	Fe	Hg	As
7:15 - Dredging Began.											
7:24	9	160	3.5	< 2	42.2	13.4	2.7	9.6	24	0.028	< 2
7:30	34	2,220	2.6	< 2	35.6	11.5	2.4	5.1	33	-	< 2
7:38	8*	129	5.2	< 2	65.8	14.8	2.2	10.1	20	0.028	< 2
7:42	41	571	2.2	< 2	41.6	12.0	2.4	5.6	30	0.028	< 2
7:45	11 **	200	3.0	< 2	41.6	11.1	1.7	8.2	17	0.044	< 2
7:45 - Dredging Stopped.											
8:01	9*	640	2.8	< 2	53.3	12.0	2.4	5.1	23	0.028	< 2
8:37	8*	190	2.9	< 2	42.2	11.1	2.2	9.6	26	0.028	< 2
10:13	13*	190	2.8	< 2	43.6	11.1	2.4	10.9	20	0.028	< 2
10:15 - Dump Occurred.											
Mean		538	3.1	< 2	42.4	12.1	2.3	8.0	24	0.030	< 2
Standard deviation		708	0.9	0	12.1	1.3	0.3	2.4	5	0.006	0
Coefficient of variation, V(%)		131.7	29.3	-	28.5	11.0	12.5	30.0	22.3	20.0	-

Dash (-) indicates not applicable.

*Supernatant percent sediment.

**Overflow percent sediment.

The variability of concentrations of soluble metals associated with the sediment from the TCCTB in the hopper was similar to that seen in the Galveston dredging runs. Manganese concentrations varied widely in all three Texas City runs. In the analyses for Run 1 on October 9 (Table 328), the coefficients of variation ranged from 20.0 percent (cadmium) to 135.6 percent (manganese). The V's for the second and third Texas City dredging runs ranged from 13.0 (nickel) to 128.2 percent (iron) and from 11.0 (nickel) to 131.7 percent (manganese). No attempt was made to separate supernatant and overflow samples from dredged material discharge samples for statistical analyses because metals concentrations were generally in the same range regardless of the sample source.

Nitrogen Compounds

Hopper dredge samples collected during the Texas City Channel dredging were analyzed for ammonium. The results are presented in Table 331. The concentrations observed were much higher than those found in the samples collected in late August. Very high concentrations were observed in the samples collected from the pump discharge. A graphical representation of ammonium concentrations versus percent settleable solids (Figure 105) shows them to have a high positive correlation (r = 0.87). The ammonium concentrations increased steadily with increased percent settleable solids.

Phosphorus Compounds

Concentrations of soluble orthophosphate found in hopper dredge samples connected with dredging runs in the TCCTB are presented in Table 332. Concentrations in the pump discharge material during the first dredging run ranged from 0.10 to 0.45 mg P/l; they appeared to decrease and then increase with time. The hopper supernatant concentrations were generally at the lower end of the range found in the discharge material and fluctuated seemingly without pattern.

Table 331

Ammonium Concentrations: Texas City Hopper Dredge Samples

Dredging Location and Date (1975)	Time (hr:min)	Ammonium (mg N/1)	
		$\bar{X}$	SD
October 9:	9:02 - Dredging began.		
Run 1	9:02	104	2.5
	9:07	107	1.4
	9:12	10.0	0.7
	9:12	6.8	1.1
	9:17	27.5	1.4
	9:22	13.0	0
	9:27	10.2	0.4
	9:30	1.4	0.2
	9:33	75.1	3.4
	9:40	92.5	3.5
	9:47 - Dredging stopped.		
	9:47	16.0	0.7
	10:21	28.5	0.7
	11:24	25.5	0.7
	11:24 - Unmonitored dump occurred.		
	14:31 - Dredging began.		
Run 2 (TCC Dump No. 1)	14:33	78.8	5.3
	14:36	1.2	0.2
	14:39	18.5	0.7
	14:50	17.0	0.7
	14:52	17.0	1.4
	14:55	10.0	0.7
	15:02	12.8	0.4
	15:06	15.2	0.4
	15:06 - Dredging stopped.		

(Continued)

Table 331 (Concluded)

Dredging Locaton and Date (1975)	Time (hr:min)	Ammonium (mg N/1)	
		$\bar{X}$	SD
	15:24	25.0	1.4
	16:12	26.2	1.8
	16:42	32.2	0.9
	16:42 - Dump occurred.		
October 10:			
Run 1 (TCC Dump No. 2)	7:15 - Dredging began.		
	7:24	4.2	0.4
	7:30	31.5	1.4
	7:33	16.3	0.8
	7:38	2.2	0.5
	7:42	36.2	0.4
	7:45	11.0	1.4
	7:45 - Dredging stopped.		
	7:51	56.0	1.4
	7:57	79.5	0.7
	8:01	9.2	0.4
	8:37	25.5	0.7
	9:11	19.5	0.7
	10:13	32.8	0.4
	10:14 - Dump occurred.		

Mean and standard deviation calculated from duplicate analyses.

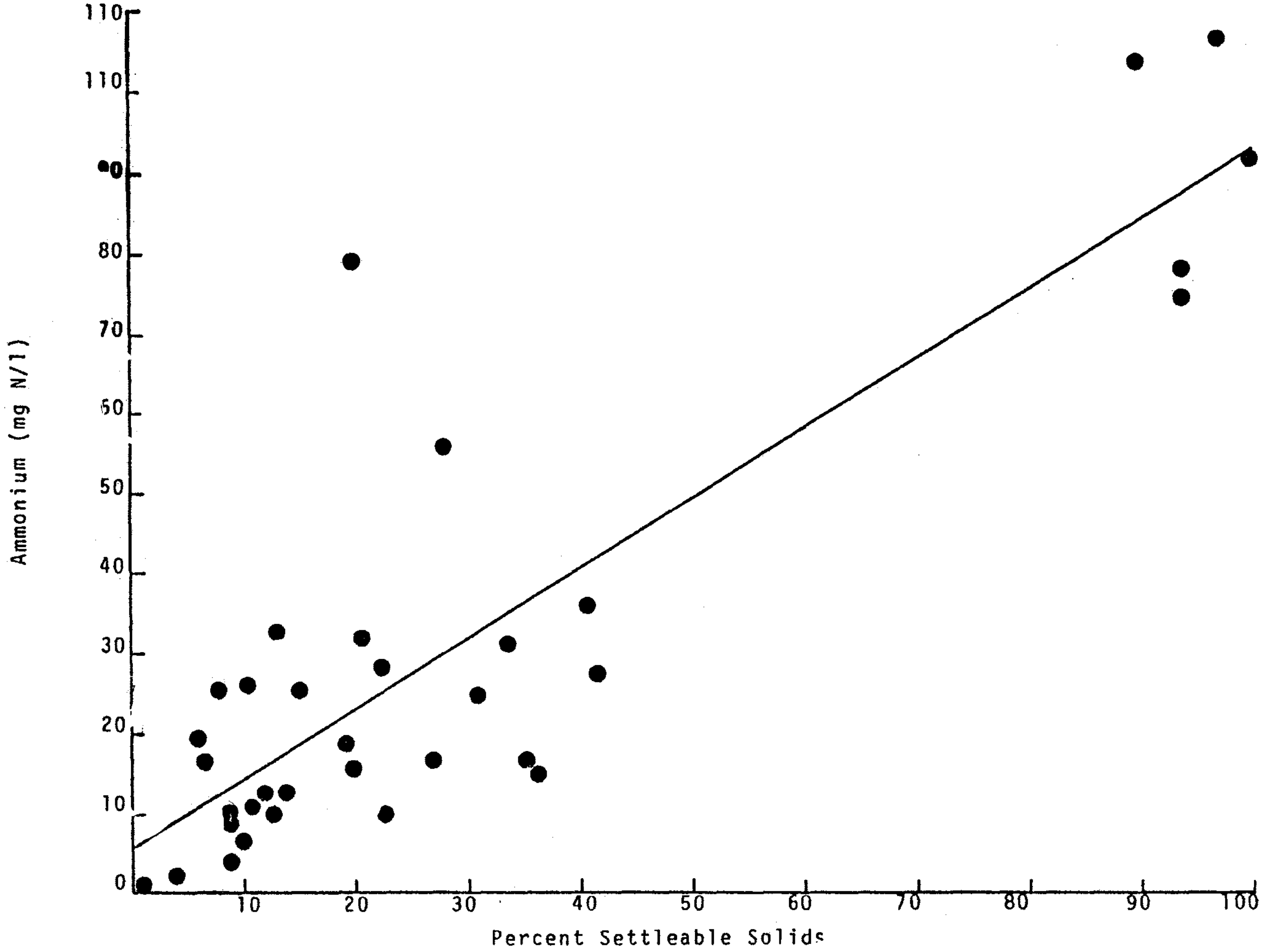

Figure 105
Percent Settleable Solids vs Ammonium Concentrations: Texas City Channel Hopper Dredge Samples

Table 332

Soluble Orthophosphate Concentrations: Texas City Hopper Dredge Samples

Dredging Location and Date (1975)	Time (hrs:min)	Sample Source*	Soluble Ortho P (mg P/l)	
			X̄	SD
October 9:		9:02 - Dredging began.		
Run 1	9:02	D	0.45	0
	9:07	D	0.25	0.001
	9:12	D	0.10	0.001
	9:12	D	-	-
	9:17	D	-	-
	9:22	D	-	-
	9:27	S	0.068	0
	9:30	O	0.23	0.001
	9:33	D	0.38	0
	9:40	D	0.38	0.002
	9:47	S	0.11	0.001
		9:47 - Dredging stopped.		
	10:21	S	0.25	0.001
	11:24	S	0.16	0.001
Run 2 (TCC Dump No. 2)		14:31 - Dredging began.		
	14:33	D	0.38	0.001
	14:36	O	-	-
	14:39	D	0.22	0.001
	14:50	S	0.052	0.001
	14:52	D	0.13	0
	14:55	O	0.25	0
	15:02	D	0.056	0
	15:06	D	0.15	0.002
		15:06 - Dredging stopped.		
	15:24	S	0.14	0.001

(Continued)

Table 332 (Concluded)

Dredging Location and Date (1975)	Time (hrs:min)	Sample Source	Soluble Ortho P (mg P/1)	
			$\bar{X}$	SD
	16:12	S	0.18	0.001
	16:42	S	0.14	0
October 10:				
Run 1 (TCC Dump No. 2)		7:15 - Dredging began.		
	7:24	D	0.20	0.001
	7:30	D	0.20	0.010
	7:33	O	-	-
	7:38	S	0.16	0
	7:42	D	0.17	0.001
	7:45	O	0.18	0.001
		7:45 - Dredging stopped.		
	8:01	S	0.24	0
	8:37	S	0.16	0.001
	9:11	S	-	-
	10:13	S	0.19	0.002

Mean and standard deviation calculated from duplicate analyses of one sample.

*D - Dredging pump discharge

O = Overflow

S - Supernatant

Run 2 samples were collected from material dumped during Texas City Dump No. 1. The soluble orthophosphate concentrations in dredging pump discharge during dredging for Texas City Dump No. 1 ranged from 0.052 (at 14:50) to 0.38 mg P/l (at 14:33) and generally appeared to decrease with time. Concentrations in the supernatant after the dredging had ceased (15:24 to 16:42) ranged from 0.14 to 0.18 mg P/l.

During dredging on October 10 for TCC Dump No. 2, the soluble orthophosphate concentrations in the dredging pump discharge ranged from 0.17 to 0.20 mg P/l, again showing a pattern of decreasing concentration with time. After dredging ceased, the supernatant concentration was 0.24 mg P/l (at 8:01). The water level in the hopper dropped about 6 feet after the 8:01 sampling; hopper concentrations then were 0.16 and 0.19 mg P/l.

The general pattern of concentrations in the dredging pump discharge seemed to be one of decreasing concentration with time. In general, the first few soluble ortho P concentrations in the pump discharge appeared to decrease with each subsequent dredging run; the initial concentration during the first dredging run was greater than that of the second, which in turn was greater than the Texas City Dump No. 2 dredging run. Concentrations found in the dredging pump discharge and supernatant during these dredging operations were generally higher (by a factor of about 10) than those found during GBEC dredging. The phosphorus concentrations of the TCCTB sediments were also greater than those of the GBEC sediments.

Texas City Channel Disposal Operations

In October 1975, Lee et al.[31] monitored two disposal operations in which sediment dredged from the TCCTB was dumped near Buoy B (located about 500 meters from Buoy B) in the GBEC Disposal Site. Both sampling and disposal sites can be found in Figure 79 . Although two operations were studied, only one (Dump No. 2) provided the data needed for a comparison of elutriate test results with those of the disposal operation. The results of that operation, taken from Lee et al.[31] are presented below.

Texas City Dump No. 2

Texas City Channel Dump No. 2 occurred at 10:14 on October 10, 1975. The surface turbid plume arrived at 10:18 and passed at 10:21. Disposal occurred approximately 40 meters off the bow of the sampling vessel. The current readings were 0.1 knots (5 cm/sec) and 0.2 knots (10 cm/sec) in surface and bottom waters, respectively. Approximately 765 cubic yards of material was dumped.

Optical properties. Figure 106 presents percent transmission data from the second Texas City disposal operation. The suspended material was present at each depth monitored; the turbid plume took 4, 5, and 3 minutes to reach the sampling vessel at surface, mid-, and bottom depths, respectively. Turbidity at the 10 meter depth gradually began to increase 16 minutes after disposal and persisted for over an hour. Secchi depths were recorded at 9:22 (prior to disposal) and 22 minutes after Texas City Dump No. 2. The initial Secchi depth was 3.0 meters; after disposal it was 2.5 meters.

Dissolved oxygen. Figure 107 shows that D.O. decreased at 2 and 10 meters just after the second Texas City dump. At the other depths there was no detectable change in the D.O. levels. The concentration at the 2 meter depth returned to pre-disposal level minutes after disposal, while at the 10 meter depth it stayed below the pre-disposal level.

Readings were taken only twice at the 9 meter depth and are not depicted on the figure. At 10:07 the reading was 6.9 mg/l at 9 meters. At 11:07 it was found to be 5.5 mg/l. Dissolved oxygen levels at 10 meters at those times were 5.2 and 4.6 mg/l, respectively. These readings indicate that depletion of oxygen occurs in the bottom two meters of the water column.

Heavy metals. Analytical results for heavy metals are presented in Table 333. With the exception of nickel,

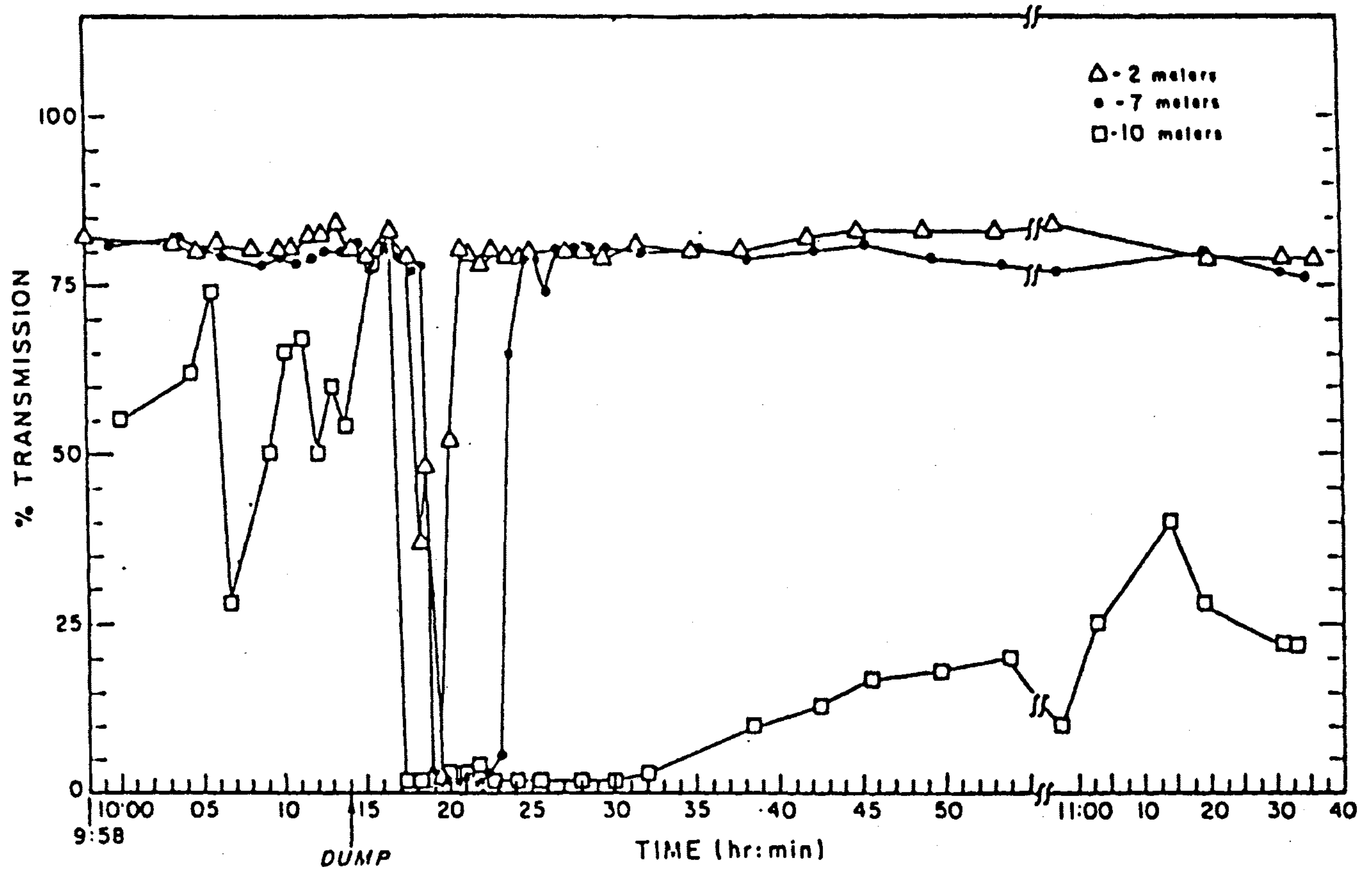

Figure 106

Percent Transmission: Texas City Dump No. 2 near Buoy B_1
Dredged Material from Texas City Channel Turning Basin
(October 10, 1975)

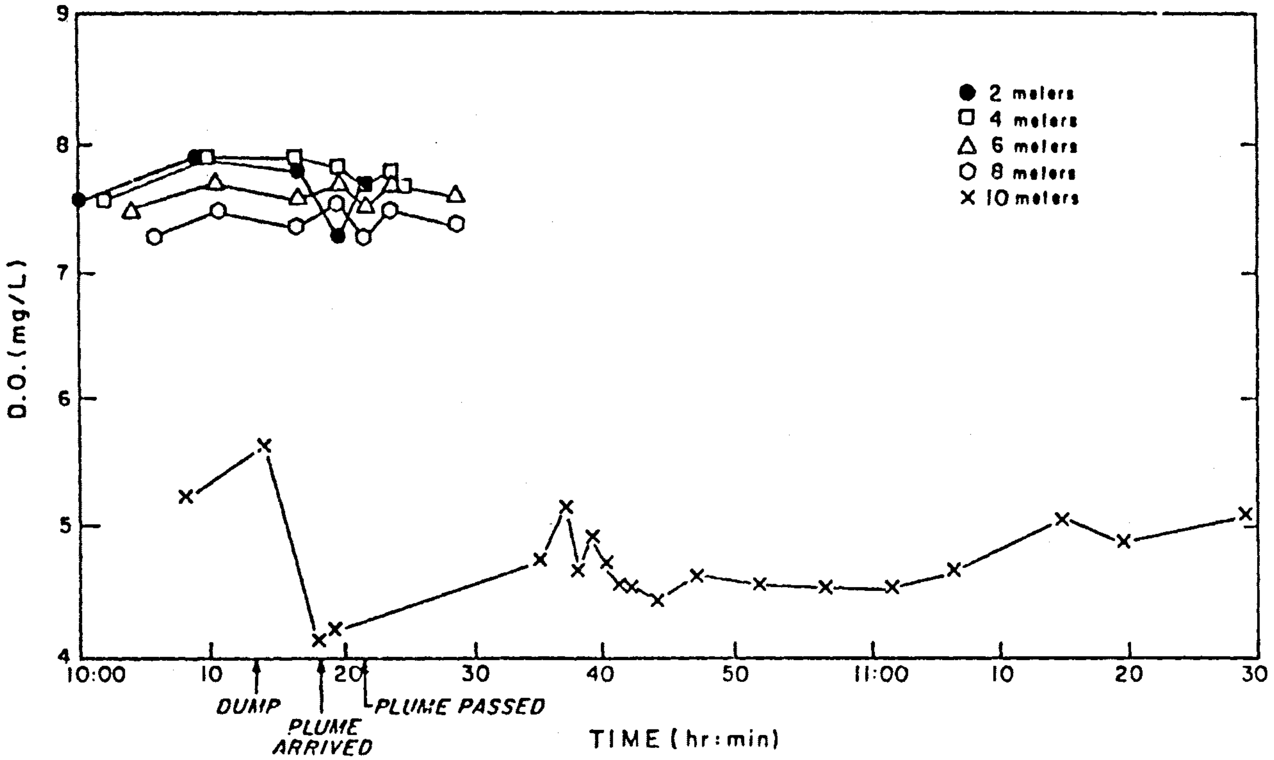

Figure 107

Dissolved Oxygen Concentration: Texas City Dump No. 2 near Buoy B_1
Dredged Material from Texas City Channel Turning Basin
(October 10, 1975)

Table 333

Soluble Heavy Metal Concentrations: Texas City Dump No. 2 near Buoy B_1, Dredged Materials from Texas City Channel Turning Basin

(October 10, 1975)

(g/l)

Time of Collection (hr:min:sec)	Depth (m)	Mn	Cd	Cr	Zn	Ni	Pb	Cu	Fe	Hg	As
9:58:30	1.5	14	0.8	<2	9.7	14.5	1.9	2.9	< 5	0.002	<2
9:58:45	8	14	0.8	<2	5.3	14.5	2.4	2.5	11	0.002	<2
10:01:45	1.5	30	0.8	<2	2.3	14.5	1.9	2.5	5	0.006	<2
10:02:25	10.5	25	0.8	<2	13.1	3.1	2.4	3.0	18	0.016	<2
10:14 - Dump occurred.											
10:14:15	8	<5	0.6	<2	12.9	12.2	6.8	4.8	459	0.002	<2
10:15:50	10.5	838	0.9	<2	22.7	6.8	0.9	2.6	13	0.002	<2
10:16:60	8	<5	0.6	<2	7.2	10.5	1.9	2.8	40	0.002	<2
10:16:45	8	14	0.7	<2	15.8	14.5	6.8	4.6	37	0.006	<2
10:18 - Surface turbid plume arrived at sampling location.											
10:18:00	1.5	16	0.8	<2	4.2	4.1	0.9	4.3	17	0.002	<2
10:18:25	10.5	25	1.1	<2	16.9	4.7	2.4	6.1	9	0.002	<2
10:19:10	10.5	14	1.0	<2	8.7	12.9	1.9	6.0	109	0.016	<2
10:19:40	8	21	0.7	<2	7.4	16.2	2.7	9.4	212	0.006	<2
10:19:55	1.5	<5	0.6	<2	2.2	13.7	1.9	2.8	13	0.002	<2
10:20:10	10.5	14	0.7	<2	8.6	18.6	2.7	2.9	49	0.002	<2

(Continued)

Table 333 (Continued)

Time of Collection (hr:min:sec)	Depth (m)	Mn	Cd	Cr	Zn	Ni	Pb	Cu	Fe	Hg	As
10:20:50	1.5	14	0.9	<2	44.8	15.3	2.4	2.8	20	0.016	<2
10:21 - Surface turbid plume passed sampling location.											
10:21:10	10.5	30	1.2	<2	17.7	15.3	2.4	7.5	74	0.012	<2
10:21:50	1.5	<5	0.8	<2	6.7	12.1	2.7	3.1	50	0.023	<2
10:22:45	1.5	30	0.9	<2	7.7	12.9	2.2	2.9	123	0.012	<2
10:23:45	8	19	0.8	<2	5.0	4.4	2.8	4.6	18	0.006	<2
10:24:35	10.5	31	1.2	<2	17.1	5.6	2.8	9.4	41	0.006	<2
10:25:00	8	14	0.8	<2	2.7	10.5	1.6	2.6	11	0.016	<2
10:26:35	10.5	< 5	1.0	<2	10.2	11.3	2.4	6.8	98	0.016	<2
10:27:55	8	14	0.9	<2	4.8	15.3	2.2	2.5	10	0.016	<2
10:29:45	8	25	0.7	<2	6.5	3.3	2.0	3.5	13	0.016	<2
10:30:50	10.5	21	0.7	<2	9.3	17.0	2.7	8.9	22	0.006	<2
10:31:35	1.5	21	0.8	<2	10.3	12.1	2.2	3.4	5	0.016	<2
10:34:45	8	27	0.7	<2	1.5	3.6	0.9	2.4	< 5	0.002	<2
10:35:10	10.5	10	0.8	<2	30.7	3.6	1.4	4.0	12	0.002	<2
10:39:50	10.5	27	1.0	<2	3.3	4.1	0.9	3.5	5	0.002	<2
10:43:10	8	25	0.8	<2	29.0	3.3	2.8	3.1	7	0.002	<2
10:43:30	10.5	21	1.0	<2	26.2	4.4	0.5	4.3	7	0.002	<2
10:48:00	1.5	32	0.8	<2	7.6	3.1	0.9	2.6	< 5	0.002	<2

(Continued)

Table 333 (Concluded)

Time of Collection (hr:min:sec)	Depth (m)	Mn	Cd	Cr	Zn	Ni	Pb	Cu	Fe	Hg	As
10:48:30	8	25	0.8	<2	11.8	5.0	2.4	3.1	10	0.002	< 2
10:49:00	10.5	21	0.8	<2	4.8	3.4	0.9	3.2	< 5	0.002	< 2
10:55:50	10.5	10	0.9	<2	3.0	4.4	0.9	2.6	< 5	0.002	< 2
11:01:10	10.5	10	0.8	<2	1.8	4.4	0.9	2.6	< 5	0.002	< 2
11:07:25	10.5	19	0.9	<2	7.7	3.6	2.8	3.2	13	0.002	< 2
11:13:30	10.5	10	0.9	<2	3.7	3.6	0.9	3.2	6	0.016	< 2
11:17:30	1.5	25	0.9	<2	6.3	4.2	2.8	3.7	7	0.002	< 2
11:18:00	8	25	1.0	<2	12.7	3.6	2.4	3.7	6	0.002	< 2
11:18:15	10.5	25	0.8	<2	7.0	5.0	2.4	2.8	< 5	0.002	< 2
11:32:40	10.5	15	0.8	<2	12.3	3.3	2.4	3.8	6	0.002	< 2

there were no obvious changes in heavy metal concentrations as a result of disposal. Nickel increases were observed, although only at bottom depths. Elevated nickel levels, however, began to decrease some five minutes after the plume reached the sampling location. In this period, nickel in surface samples also decreased, even though no initial release had been observed. Five minutes after the turbid plume reached the sampling location, concentrations had decreased approximately 9 μg/l from the pre-disposal levels. The concentration of manganese measured at 10:15:50 at 10.5 meters was 838 μg/l, and the concentration of iron at 10:14:15 at 8 meters was 459 μg/l. These values were well outside the concentration ranges of these metals during this dump and, as these samples were not taken in the turbid plume, it is suspected that the high values were due to contamination during collection or handling.

Nitrogen compounds. Table 334 presents the results of organic N and ammonium analyses of TCC Dump No. 2 samples. In Figure 108 ammonium concentrations are plotted against time. Release of ammonium in the bottom water was observed, but the concentrations in the overlying water remained below 0.05 mg N/l except for one sample each of surface and mid-depth water. From the figure, it appears that a statistically significant amount (1.86 mg N/l) of ammonium was present in the water at 10:15:50. However, this concentration persisted at the sampling location for less than one minute. Organic N was apparently released in the bottom waters as a result of the disposal operation but returned to ambient levels 13 minutes after the surface turbid plume arrived at the sampling location. In the surface and mid-depth water, no discernible pattern could be observed.

Phosphorus compounds. Concentrations of soluble orthophosphate are presented in Table 335. There appears

Table 334

Organic N and Ammonium Concentrations: Texas City Dump No. 2 near Buoy B_1, Dredged Materials from Texas City Channel Turning Basin

Time of Collection (hr:min:sec)	Depth (m)	Organic N (mg N/l)	Ammonium (mg N/l)
9:58:30	1.5	0.55	< 0.05
9:58:45	8	0.11	< 0.05
9:59:00	10.5	<0.05	0.11
10:01:45	1.5	0.59	< 0.05
10:02:00	8	0.07	< 0.05
10:06:45	1.5	-	< 0.05
	10:14:00 - Dump occurred.		
10:14:00	1.5	-	< 0.05
10:14:15	8	-	< 0.05
10:14:25	10.5	-	< 0.05
10:15:50	10.5	-	1.86
10:16:10	8	-	< 0.05
10:16:15	1.5	-	< 0.05
10:16:30	10.5	-	0.65
10:16:45	8	-	< 0.05
10:17:25	10.5	-	0.73
	10:18:00 - Surface turbid plume arrived at sampling location.		
10:18:00	1.5	0.31	< 0.05
10:18:25	10.5	0.55	0.27
10:19:00	1.5	-	< 0.05
10:10:10	10.5	1.01	0.77
10:19:40	8	0.11	< 0.05
10:19:55	1.5	0.11	< 0.05
10:20:10	10.5	-	0.81

(Continued)

Table 334 (Continued)

Time of Collection (hr:min:sec)	Depth (m)	Organic N (mg N/l)	Ammonium (mg N/l)
10:20:30	8	-	0.07
10:20:50	1.5	<0.05	0.05
10:21:00 - Surface turbid plume passed sampling location.			
10:21:10	10.5	-	0.57
10:21:50	1.5	-	<0.05
10:22:05	10.5	-	0.18
10:22:45	1.5	-	<0.05
10:23:15	10.5	-	0.31
10:23:45	8	0.11	<0.05
10:24:20	1.5	-	<0.05
10:24:35	10.5	0.67	0.49
10:25:00	8	-	<0.05
10:25:20	1.5	-	<0.05
10:26:10	1.5	-	0.13
10:26:25	8	-	<0.05
10:26:35	10.5	-	0.75
10:27:40	1.5	-	<0.05
10:27:55	8	-	<0.05
10:28:10	10.5	-	0.64
10:29:45	8	-	<0.05
10:30:10	10.5	-	0.44
10:30:50	10.5	< 0.05	0.51
10:31:35	1.5	< 0.05	<0.05
10:31:55	8	-	<0.05
10:32:15	10.5	-	0.52
10:34:45	8	-	<0.05
10:36:49	10.5	-	0.33

(Continued)

Table 334 (Concluded)

Time of Collection (hr:min:sec)	Depth (m)	Organic N (mg N/1)	Ammonium (mg N/1)
10:39:15	1.5	-	<0.05
10:39:30	8	-	<0.05
10:39:50	10.5	-	0.39
10:42:45	1.5	-	<0.05
10:43:10	8	0.07	<0.05
10:43:30	10.5	-	0.25
10:48:00	1.5	0.87	<0.05
10:48:30	8	<0.05	<0.05
10:49:00	10.5	<0.05	0.19
10:54:50	1.5	-	<0.05
10:55:15	8	-	<0.05
10:55:50	10.5	-	0.18
11:01:10	10.5	-	0.10
11:07:25	10.5	-	0.19
11:13:30	10.5	0.08	0.16
11:17:30	1.5	0.07	<0.05
11:18:00	8	0.19	<0.05
11:18:15	10.5	-	0.18
11:32:40	10.5	-	0.25

Dash (-) indicates data not available.

to have been a reduction in the concentration of soluble ortho P in the surface water with the passage of the surface turbid plume. Concentrations appear to have gradually dropped from ambient levels (0.07 mg P/1 to 0.11 mg P/1) to 0.044 mg P/1 about four minutes after the arrival of the surface plume. They increased about 1.8-fold 26 minutes later but decreased to 0.049 mg P/1 in another 30 minutes.

Prior to the decrease in percent light transmission at mid-depth (Figure 106), soluble ortho P concentrations

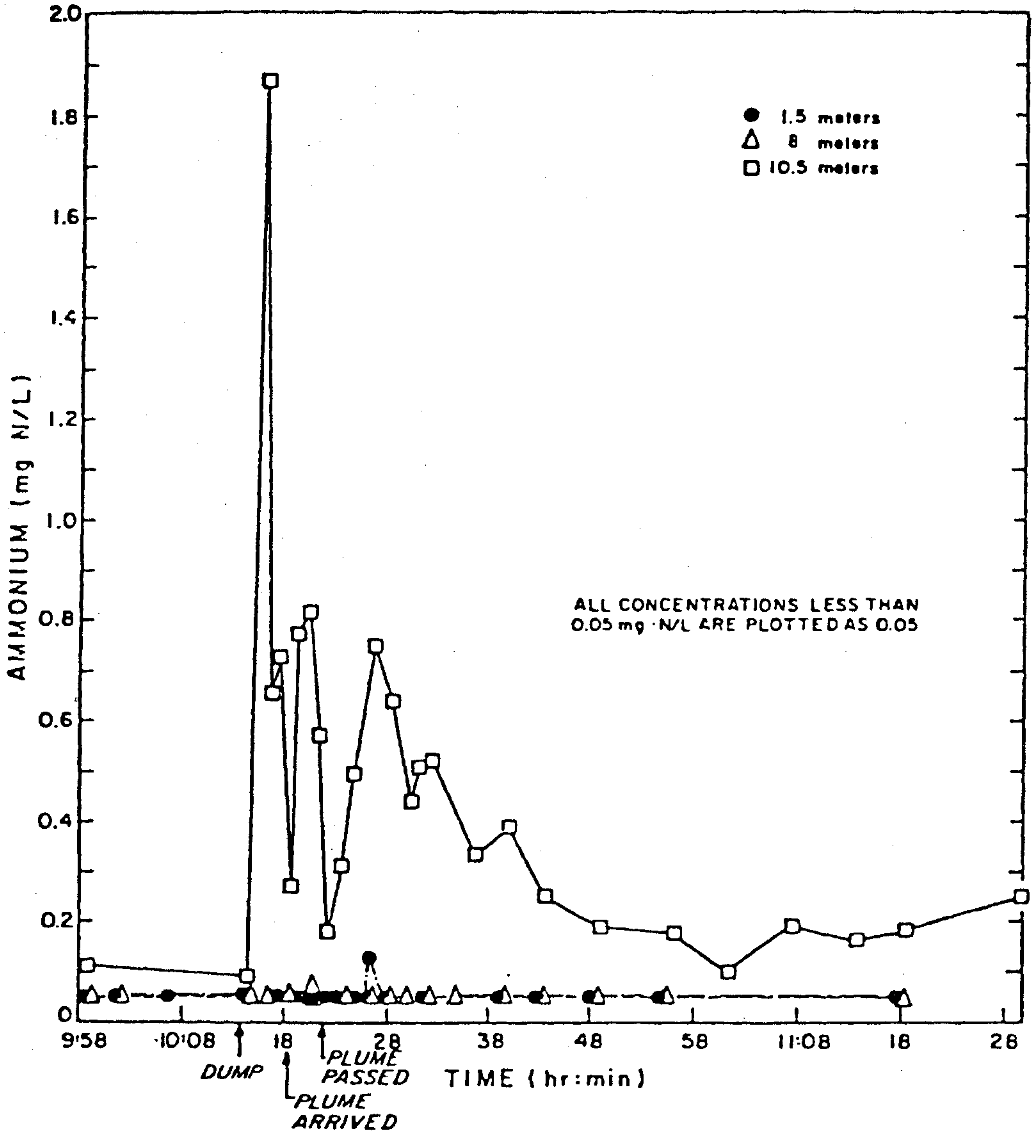

Figure 108

Ammonium Concentrations: Texas City Dump No. 2 near Buoy B_1

(October 10, 1975)

Table 335

Soluble Orthophosphate Concentrations: Texas City Dump No. 2 near Buoy B_1, Dredged Materials from Texas City Channel Turning Basin

(October 10, 1975)

Time of Collection (hr:min:sec)	Depth (m)	Soluble Orthophosphate (mg P/l)
9:58:30	1.5	0.070
9:58:45	8	-
9:59:00	10.5	0.072
10:01:45	1.5	0.101
10:02:00	8	0.108
10:02:25	10.5	0.097
	10:14:00 - Dump occurred.	
10:14:15	8	0.084
10:14:25	10.5	0.067
10:15:50	10.5	0.559
10:16:10	8	0.019
10:16:45	8	0.053
	10:18:00 - Surface turbid plume arrived at sampling location.	
10:18:00	1	0.096
10:18:25	10.5	0.176
10:19:10	10.5	0.084
10:19:40	8	0.141
10:10:55	1	0.061
10:20:10	10.5	0.350
10:20:50	5	0.062
	10:21:00 - Surface turbid plume passed sampling location.	
10:21:10	10.5	0.054
10:21:50	1.5	0.054

(Continued)

Table 335 (Concluded)

Time of Collection (hr:min:sec)	Depth (m)	Soluble Orthophosphate (mg P/l)
10:22:45	1.5	0.044
10:23:45	8	0.076
10:24:35	10.5	0.167
10:25:00	8	0.049
10:26:35	10.5	0.086
10:27:55	8	0.049
10:29:45	8	0.077
10:30:50	10.5	0.139
10:31:35	1.5	0.045
10:34:45	8	0.058
10:35:10	10.5	0.070
10:39:50	10.5	0.069
10:43:10	8	0.105
10:43:30	10.5	0.136
10:48:00	1.5	0.079
10:48:30	8	0.021
10:49:00	10.5	0.041
10:55:50	10.5	0.070
11:01:10	10.5	0.076
11:07:25	10.5	0.072
11:13:30	10.5	0.064
11:17:30	1.5	0.049
11:18:00	8	0.042
11:18:15	10.5	0.026
11:32:40	10.5	0.033

Soluble ortho P concentrations based on a single analysis of one sample.

Dash (-) indicates no data available.

varied between 0.019 and 0.108 mg P/l. The concentration at mid-depth was greatest (0.141 mg P/l) in the sample collected during the lowest percent light transmission. It decreased to 0.049 mg/l when the percent light transmission increased back to ambient levels. After the percent light transmission returned to and remained at ambient levels (∿12:25:00), soluble ortho P fluctuated between 0.021 and 0.105 mg P/l without an apparent pattern.

Before the reduction in percent light transmission in bottom waters, soluble ortho P concentrations varied from 0.067 to 0.097 mg P/l. Coincident with the decrease in percent light transmission, soluble ortho P concentrations increased to 0.559 mg P/l. For the duration of the sampling period, the concentrations fluctuated between 0.041 and 0.350 mg P/l. There was no apparent correlation between these levels and percent light transmission. The final three samples, which were collected about 45 minutes after the disposal, showed about the same concentration as had been found at the onset.

Organic compounds. Seven composites of subsamples collected before, during, and after the passage of the surface turbid plume were analyzed for soluble TOC and oil and grease. One composite was made from subsamples collected before the plume arrived. Subsamples collected during the plume were used for Composites 2 through 5. Two composites were made from subsamples collected after the plume passed. The composites were centrifuged at 9000 rpm for 10 minutes to remove particulate matter but were not subjected to filtration in order to avoid the loss of oil and grease due to adherence to the filter. It is assumed that the TOC and oil and grease concentrations represent the soluble fraction of these two parameters.

Table 336 shows that concentration of TOC in the sample composited before the arrival of the plume was 21.8 mg/l. The TOC concentrations in Composites 2 through 5 ranged from 15.2 to 27.2 mg/l with an average of 20.7. The two post-plume composite samples contained 26.1 and 26.4 mg/l TOC, respectively. The oil and grease content before the plume

Table 336

Carbon and Oil and Grease in the Water Column:

Texas City Dump No. 2* near Buoy B_1

(October 10, 1975)

Composite** Number	Time (hr:sec)	Soluble TOC (mg/l)	Oil and Grease (mg/l)
1	10:06 to 10:16	21.8	5.9
Surface turbid plume arrived at sampling location.			
2	10:16 to 10:17	20.8	7.1
3	10:18 to 10:22	19.7	4.6
4	10:24 to 10:26	15.2	8.6
5	10:27 to 10:31	27.2	6.1
Surface turbid plume passed sampling location.			
6	10:36 to 10:39	26.1	7.5
7	10:42 to 10:55	26.4	5.7

*Dredged material from Texas City Turning Basin.

**Two liters were composited from subsamples collected during the time cited. Composite samples were centrifuged for 10 minutes at 9000 rpm to remove particulate matter. Composites were not filtered.

arrived was 5.9 mg/l. During passage of the plume, oil and grease concentrations fluctuated from 4.6 to 8.6 mg/l with an average of 6.6 mg/l. The two post-plume samples contained 7.5 and 5.7 mg/l, with an average of 6.6 mg/l.

Statistical analysis of variance was run on the Texas City TOC and oil and grease data. The results indicated no significant difference at a 95 percent confidence level between concentrations of these two parameters before, during, or after passage of the surface turbid plume.

Galveston Channel

On August 29, 1975, a sediment sample was collected with a Ponar grab sampler in the Galveston Channel across from the Galveston Channel Yacht Basin. A surface water sample was also obtained from this site. This is an area which is usually maintained by pipeline dredging. Figure 79 shows the sampling location.

On September 10 and September 20, 1975, samples were taken from the pipeline dredge discharge from a dredge operation in the Galveston Channel near the Yacht Basin. Several samples were taken on each day. The samples collected on each of the two days were composited so that there was one composite pipeline discharge sample for each sampling date.

General Sediment Characteristics and Oxygen Demand

Values for Eh and sulfide presented in Table 337 were considerably higher in the Galveston Channel sample than in the GBEC Buoy 1 sample.

Oxygen demand tests were run with three different volumes of Galveston Channel sediment: 5 cc, 3 cc, and 2 cc. The purpose of running three sets on one sediment was to determine the effect of different sediment volumes on the uptake per cc of wet sediment. The time of 30 minutes was used for comparison. Table A29 of Appendix A shows that the 5 cc sample depleted the oxygen in 45 minutes. The oxygen uptake per cc (Table 337) for the 5 cc sample was 0.45 mg O_2; for

Table 337

General Sediment Characteristics and Oxygen Uptake: Galveston Channel Sediment Samples

Sampling Designation	Eh (mv)	Sulfide (mg/kg)	Percent Dry Wt.		Oxygen Uptake First Hour		Uptake/cc First Hr (mg O_2)
			$\bar{X}$	SD*	Per Cubic Meter (mg O_2)	Per Gram Dry Weight (mg O_2)	
GC	-107	1078	36.3	0.6	5.9×10^2	1.28	-
5 cc	-	-	-	-	-	-	0.45
3 cc	-	-	-	-	-	-	0.47
2 cc	-	-	-	-	-	-	0.50

* Mean and standard deviation calculated from triplicate analyses.

Dash (-) indicates not applicable.

the 3 cc sample it was 0.47 mg O_2, and for the 2 cc sample it was 0.50 mg O_2 in the first half hour. This indicates that oxygen uptake should not be noticeably affected by sediment volume tested if it is within the range of 2 to 5 cc. The oxygen demand for a cubic meter was 5.9×10^2 g O_2; for the first hour it was 1.28 mg O_2 per gram dry weight.

Figure 109 is a plot of the data for the oxygen demand test on Galveston Channel sediment. All three sample sizes had slopes with fast and slow components. The fast component slopes were -0.018 mg/l O_2 min^{-1}, -0.025 mg/l O_2 min^{-1}, and 0.060 mg/l O_2 min^{-1} for the 2cc, 3cc, and 5 cc samples, respectively. The slow components were (also respectively) -0.004 mg/l O_2 min^{-1}, -0.008 mg/l O_2 min^{-1}, and -0.028 mg/l O_2 min^{-1}. These slopes showed no correlation between uptake rates and volume of sediment.

Elutriate Test General Parameters

One 20 percent oxic elutriate test was run on Galveston Channel sediment and water collected on August 29, 1975. Values of the general physical and chemical parameters measured during the 20 percent oxic Galveston Channel test are presented in Table 338. The D.O. decreased from 11.2 mg/l in the site water to 4.2 mg/l in the elutriate. Based on elutriate test results, the oxygen demand of this sediment appeared to be similar to that of Morgan's Point and Texas City Channel (TCC) Site 1 sediments (discussed elsewhere in the report). The pH remained unchanged after elutriation. Turbidity increased from 4 NTU (site water) to 38 NTU in the elutriate. This water (and resultant elutriate) was among the most saline of the Texas Gulf Coast samples collected. Specific conductance was 33,000 μmhos/cm in the site water and elutriate.

Heavy Metals

Table 339 shows the total concentrations of selected heavy metals in the sediment sample collected in the Galveston Channel on August 29, 1975. The sediment had particularly

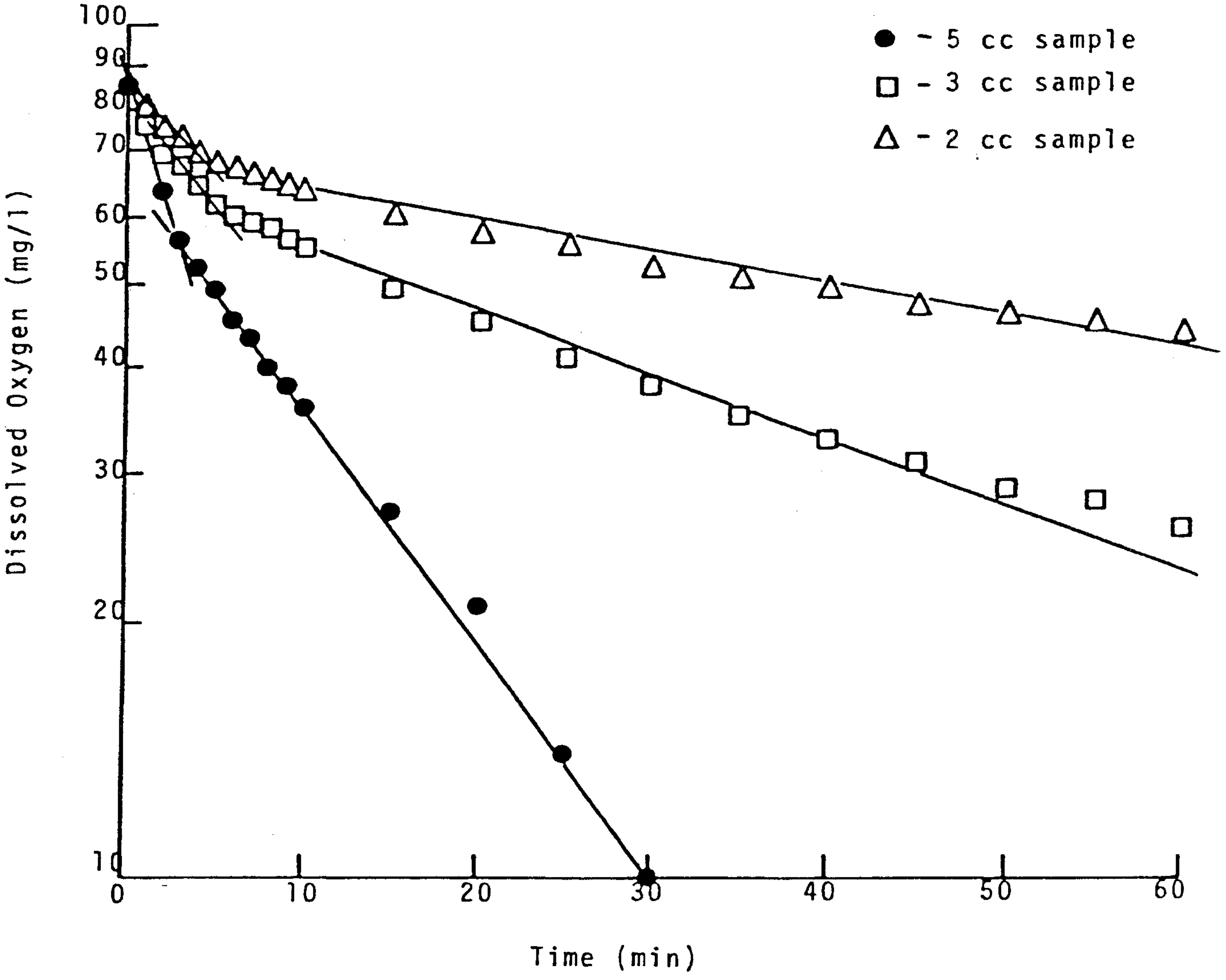

Figure 109

Oxygen Demand Test: Galveston Channel Sediment

Table 338

General Physical and Chemical Parameters: Galveston Channel Elutriate Test

Sample Designation	D.O. (mg/l @ 20-21°C)			pH	Turbidity (NTU)	Specific Conductance (μmhos/cm @ 25°C)	Salinity (°/oo)
	Initial	After Mixing	After Settling				
Site Water	11.2	-	-	8.2	4	33,000	26
20% Oxic	6.4	7.8	4.2	8.2	38	33,000	26

Dash (-) indicates not applicable.

Table 339

Total Heavy Metal Composition: Galveston Channel Sediment and Pipeline Samples

(μg/kg)

Sample Designation and Collection Date (1975)*	Mn		Cd		Cr		Zn		Ni		Pb		Cu		Fe**		Hg		As	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Sediment:																				
August 29	726	44	< 0.5	-	36.5	0.9	96.8	4.4	28.5	2.6	< 1	-	16.4	0.7	27	0.3	0.010	0	11.2	1.1
Pipeline Composite:																				
September 10	358	3	0.6	0.5	25.6	1.3	58	3	17.1	1.2	19.8	2.1	11.7	0.9	20	0.09	0.078	0.010	0.35	0.01
September 20	225	24	< 0.5	0	23.2	5.3	50	5	14.2	0.4	14.8	3.0	11.2	0.7	20	0.03	0.095	0	0.22	0.04

Mean and standard deviation calculated from triplicate analyses.

*Sediment sample analyzed in September 1975. Pipeline disposal composites were analyzed in April, 1976.

**Iron concentration in g/kg.

Dash (-) indicates not calculated.

high manganese, arsenic, zinc, and iron concentrations. Concentrations of zinc and arsenic, 96.8 and 11.2 mg/kg, respectively, were in excess of the US EPA criteria for the acceptability of dredged sediments.[10] These concentrations may be compared with the total heavy metals found in the sediment phase of composite pipeline dredge samples collected from an operation which was working the same part of the channel (Table 339). Concentrations of all metals in these pipeline discharge samples were lower than those found in the sediment sample taken directly from the channel bottom. Manganese and zinc concentrations were half those seen in the sediment, though still high. Arsenic concentrations in the pipeline discharge were a fraction of the sediment concentrations, while mercury concentrations were 8 to 9 times higher than the sediment concentration. These differences may be due to release of metals from the sediment during the dredging operation or to differences in the metals composition of sediments along the channel.

Table 340 shows the results of metals analysis of the site water and elutriate from a 20 percent oxic elutriate test with the sediment collected from the Galveston Channel. There was substantial release of manganese in the test. The site water contained 72 μg/l manganese, and the elutriate contained 1900 μg/l manganese. Zinc and mercury were also released. The site water contained 10.7 μg/l zinc and 0.007 μg/l mercury. There were no significant changes in concentrations of chromium, nickel, cadmium, lead, iron, or arsenic as a result of elutriation of this sediment.

The results of this elutriate test are in agreement with those of others performed in this study. The release of metals during the test did not correspond to the bulk metal composition, in that manganese and zinc, which existed in high concentrations in the sediment, were released, while mercury, which was found in a fairly low concentration in the sediment,

Table 340

Soluble Heavy Metal Concentrations: Galveston Channel

Elutriate Test

(μg/l)

Sample Designation	Mn		Cd		Cr		Zn		Ni		Pb		Cu		Fe		Hg		As	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Site Water	72	5	1.3	0.1	< 2	-	10.7	0.9	9.3	1.0	6.3	0	7.3	0	4	2.0	0.007	0	< 2	-
20% Oxic	1900	-	1.2	0	< 2	-	69.3	1.1	12.2	1.1	7.5	0	3.9	0.4	3	2.3	0.071	0.004	< 2	-

Mean and standard deviation calculated from duplicate analyses.

Dash (-) indicates not calculated.

was also released in the test. Iron content in the sediment was very high, but iron was not released in the test.

Nitrogen Compounds

The results of nitrogen compound analyses for the Galveston Channel elutriate tests are presented in Table 341. Only one 20 percent oxic elutriate test was performed. Organic N and nitrate concentrations decreased as a result of elutriation. Ammonium release was comparable to the release obtained from TCC-1 sediment but higher than the release obtained from Galveston Bay Entrance Channel sediments.

Phosphorus Compounds

Table 342 presents the total phosphorus concentrations of the Galveston Channel sediment samples collected for an elutriate test. The concentrations in the two pipeline samples were approximately the same and contained about half the total P found in the Galveston Channel sediment sample. The Galveston Channel site water orthophosphate concentration (Table 342) was about the same as that found in the Texas City Channel Sites 4, 5, and 6 site waters. It can also be seen that the elutriation with the Galveston Channel sediment caused little change in the soluble orthophosphate concentrations of the water.

Organic Compounds

A 20 percent elutriate test was run on sediments collected from an area in the Galveston Channel near a pipeline dredging operation. An effluent sample from the pipeline discharge was also obtained. Pipeline effluent was centrifuged, and the sediment and water phases were analyzed. The analytical results for the elutriate test and the pipeline samples are presented in Tables 343 and 344. The total organic carbon of the Galveston Channel sediment (0.9 percent) was slightly higher than the 0.8 percent found in the pipeline discharge sediment phase. Both sediments contained aldrin, DDT compounds, and lindane in concentrations of 2.5 μg/kg or

Table 341

Nitrogen Compound Concentrations: Galveston Channel Elutriate Test

(mg N/1)

Sample Designation	Organic N		Ammonium		Nitrate	
	$\bar{X}$	SD*	$\bar{X}$	SD*	$\bar{X}$	SD**
Site Water	0.30	0.08	0.08	0	0.10	0.02
20% Oxic	<0.05	∿0	7.36	0.10	0.09	0.01

*Mean and standard deviation calculated from duplicate analyses.

**Mean and standard deviation calculated from triplicate analyses.

Table 342

Total Phosphorus Concentrations: Galveston Channel Discharge Samples and Elutriate Test

Sample Designation and Collection Date (1975)	Total Phosphorus* (mg P/kg dry wt.)		Soluble Ortho P** (mg P/1)	
	$\bar{X}$	SD	$\bar{X}$	SD
Galveston Channel	696	17	-	-
Pipeline Discharge:				
September 10	362	12	-	-
September 20	340	2	-	-
Elutriate Test:				
Site water	-	-	0.17	0.002
20% oxic	-	-	0.16	0.002

Dash (-) indicates not applicable.

*Mean and standard deviation calculated from duplicate analyses of one sample.

**Mean and standard deviation calculated from triplicate analyses of one sample.

Table 343

Data for Organic Compounds: Galveston Channel Pipeline Dredged Material

Parameter	Sediment	Elutriate
	(µg/kg)	(ng/l)
Chlorinated Hydrocarbons:		
Aldrin	0.9	20
op'DDT	1.7	<3.0
pp'DDT	2.2	<3.0
op'DDD	<1.4	<2.0
pp'DDD	<1.4	<2.0
op'DDE	1.4	<2.0
pp'DDE	0.9	<2.0
Dieldrin	<0.8	<1.2
Endosulfan I	<0.9	<1.2
Endosulfan II	<3.9	<4.4
Endrin	<1.2	<1.6
Heptachlor	<0.3	<0.4
Lindane	0.5	8.7
PCBs	86	78
Other Organic Compounds		
Oil and Grease	194 mg/kg	0.9 mg/l
Total Organic Carbon	0.8 %	NT
Total Inorganic Carbon	0.5 %	NT

NT = not tested.

Table 344

Data for Organic Compounds: Galveston Channel Elutriate Test

Parameter	Sediment	Water	Elutriate
	(μg/kg)	(ng/l)	(ng/l)
Chlorinated Hydrocarbons:			
Aldrin	0.9	6.9	35.1
op'DDT	<1.6	<3.0	< 3.0
pp'DDT	2.5	<3.0	< 3.0
op'DDD	<1.4	<2.0	< 2.0
pp'DDD	<1.4	<2.0	< 2.0
op'DDE	<1.4	<2.0	< 2.0
pp'DDE	2.9	<2.0	< 2.0
Dieldrin	<0.8	<1.2	< 1.2
Endosulfan I	<0.9	<1.2	< 1.2
Endosulfan II	<3.9	<4.4	< 4.4
Endrin	<1.2	<1.6	< 1.6
Heptachlor	<0.3	<0.4	< 0.4
Lindane	0.4	3.4	14.3
PCBs	33	171	261
Other Organic Compounds			
Oil and Grease	437 mg/kg	NT	NT
Total Organic Carbon	0.9%	NT	NT
Total Inorganic Carbon	0.3%	NT	NT

NT = not tested.

less. The pipeline discharge sediment contained PCBs at a concentration of 86 μg/kg, while the Galveston Channel sediment PCB value was 33 μg/kg.

Galveston Entrance Channel water contained lindane and aldrin at concentrations of 3.4 and 6.9 ng/l, respectively. These two compounds were released in the elutriate; concentrations were 14.3 and 35.1 ng/l, respectively. The pipeline discharge supernatant contained lindane and aldrin at concentrations of 8.7 and 20 ng/l. Though the elutriate showed more release than the pipeline discharge supernatant, it should be remembered that the elutriate test was run at 1:19 sediment-to-water ratio. None of the DDT compounds detected in either sediment was released.

The elutriate test showed a 53 percent release of PCBs. The concentration of 171 ng/l in the water increased to 261 ng/l in the elutriate. In the pipeline discharge supernatant a concentration of 78 ng/l was found; this represents 54 percent sorption.

Houston Ship Channel

Characteristics of Sampling Site

The Houston Ship Channel (HSC) is one of the major shipping and industrial areas on the Gulf of Mexico. Figure 110 depicts the channel, as well as the three HSC sampling sites. On April 21, 1976, UTD staff took sediment and water samples for elutriate tests from these sites. The sampling boat used was the Erin Leddy Jones, a 53-foot research vessel belonging to the University of Texas Biomedical Institute. A Ponar grab sampler was used to take the sediment samples, which were sealed in five-gallon plastic buckets. Surface water samples were taken at each sediment site with a rope and bucket. These were stored in 13.5-gallon or five-gallon plastic carboys. Hydrolab profiles of D.O., temperature, pH, and specific conductance were run at two-meter intervals at Sites 1 and 3.

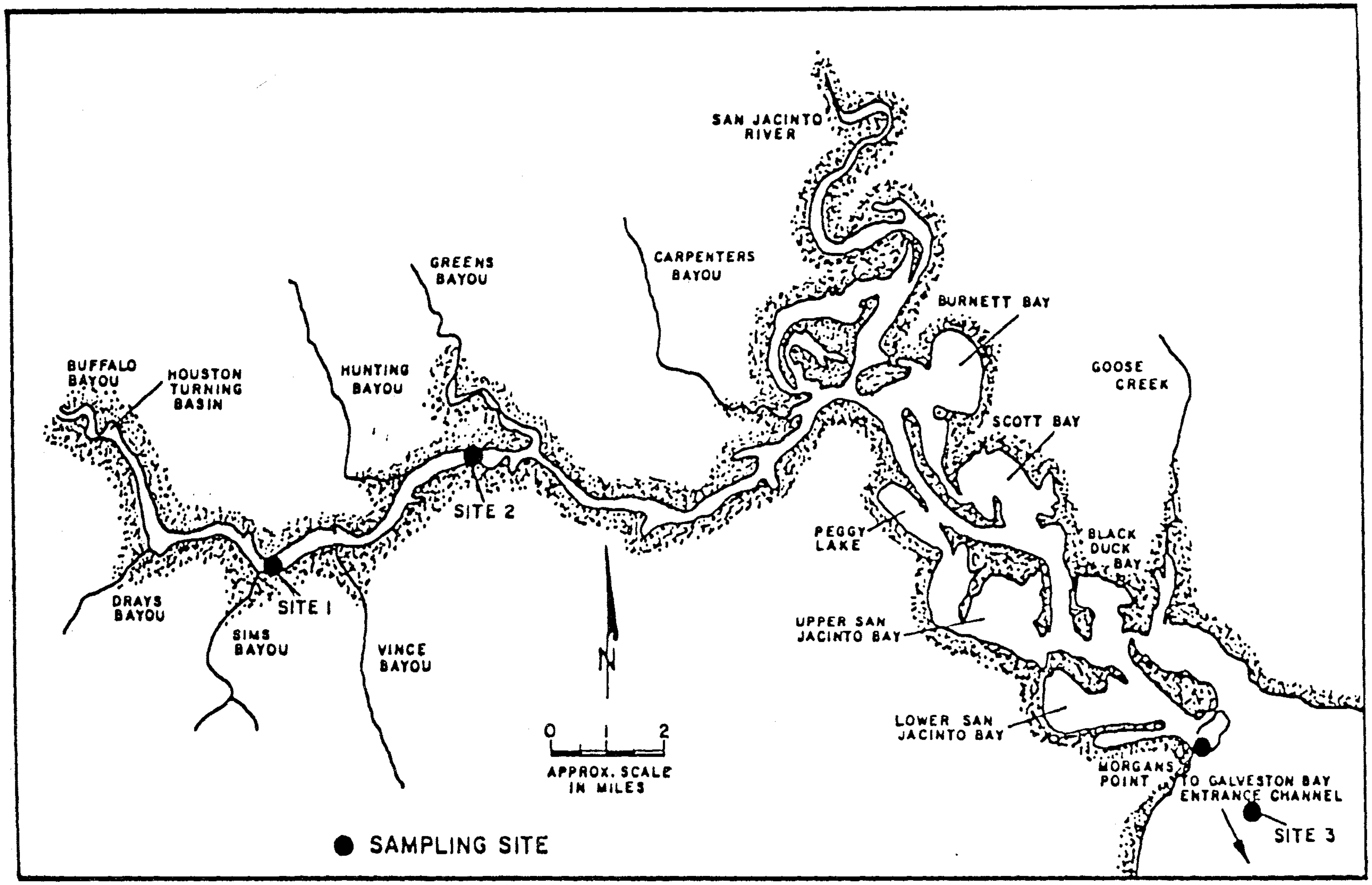

Figure 110

Houston Ship Channel and Morgan's Point Sampling Locations

At HSC Site 1 (furthest up the channel and near the US Gypsum Plant), two five-gallon buckets of sediment and one 13.5-gallon surface water sample were collected. HSC Site 2 was on the south side of the channel between Olin-Matheson and Phillips 66. Three five-gallon sediment samples and one 13.5-gallon and one five-gallon surface water sample were collected at this site. HSC Site 3 was located near Buoy 87 in the channel in Galveston Bay. This area was relatively unpolluted compared to Sites 1 and 2. Two five-gallon sediment samples and one 13.5-gallon water sample were collected at this site. All sediment and water samples were iced down and sent to UTD by van, where they were stored at 4°C until elutriation.

General Sediment Characteristics and Oxygen Demand

The sediment samples taken from these sites in the HSC were analyzed for Eh, sulfide concentration, percent dry weight, and particle size distribution. The data presented in Table 345 show the Eh of the samples was found to be -96 mv for HSC Site 1, -137 mv for HSC-2,and -104 mv for HSC-3. The redox conditions of the sediments were similar. The mean sulfide concentrations were found to be very high at HSC-1 and 2, 2962 mg/kg with a standard deviation of 78 and 3483 mg/kg with a standard deviation of 291, respectively. The sulfide concentrations of these two sites cannot be considered significantly different. HSC Site 3 had a much lower mean sulfide concentration, 633 with a standard deviation of 35. Percent dry weights were 34 percent for HSC-1, 28 percent for HSC-2, and 44 percent for HSC-3. Particle size analysis was performed only on HSC-1 and HSC-3 sediment. It was determined that Site 1 sediment was 35 percent clay, 22 percent silt, and 42 percent sand, while Site 3 sediment was 35 percent clay, 39 percent silt, and 26 percent sand.

The oxygen demand data for the Site 1 sediment sample is presented in Table A30 of Appendix A. The standard

Table 345

General Sediment Characteristics: Houston Ship Channel Sediments

Sample Designation	Eh (mv)	Sulfide (mg/kg)		Percent Dry Weight		Oxygen Uptake First Hour	
		$\bar{X}$	SD	$\bar{X}$	SD	Per Cubic Meter ($g\ O_2$)	Per Gram Dry Wt ($mg\ O_2$)
HSC-1	-96	2962	78	34	0.1	$5.8\text{x}10^2$	1.42
HSC-2	-137	3483	291	28	0.2	$6.0\text{x}10^2$	1.80
HSC-3	-104	633	35	44	0.0	$5.2\text{x}10^2$	0.88

Mean and standard deviation calculated from triplicate analyses.

deviation between the four runs ranged from 0.1 to 0.3, indicating good reproducibility. The sediment was found to have an oxygen demand of 5.8 x 10^2 g O_2 per cubic meter, and 1.42 mg O_2 per gram dry weight for the first hour (Table 345).

There were three runs of the oxygen demand tests on HSC-2 sediment. The range of standard deviation, 0 to 0.3 (Table A31 of Appendix A) indicated good reproducibility. HSC-2 sediment oxygen demand was 6.0 x 10^2 g O_2 per cubic meter and 1.80 mg O_2 per gram dry weight (Table 345). These values are higher than those seen for Site 1 sediment. The plots of the data from these two sites are presented in Figures 111 and 112. They both showed two-component slopes. The fast components were -0.012 mg/l min^{-1} and -0.020 mg/l min^{-1} for Sites 1 and 2, respectively. The greater slope seen in the plot of HSC-1 demand was expected due to the higher oxygen demand.

Table A32 of Appendix A presents the sediment oxygen demand of Site 3 sediment. The data for the HSC-3 sediment exhibited a marked difference from those of sediments from HSC-1 and 2. The range of the standard deviations between runs for Site 3, 0 to 0.2, indicated good reproducibility. The first hour oxygen uptakes (Table 345) were lower: 5.2 x 10^2 g O_2 per cubic meter and 0.88 mg O_2 per gram dry weight. The plot of the data, Figure 113 had a fast component slope of -0.031 mg/l min^{-1} and slow component slope of -0.007 mg/l min^{-1}. The greater slopes for HSC-3 sediments may be attributed to the use of a 3 cc sample.

Elutriate Test General Parameters

On April 21, 1976, sediment and water samples were collected at two locations in the HSC (HSC-1 and 2). A third set of samples (HSC-3) were also collected in Galveston Bay near the mouth of the HSC. On April 29-30, duplicate 5 percent oxic and 20 percent oxic and 20 percent anoxic elutriate tests were run on HSC-1 samples. Duplicate 5 percent oxic,

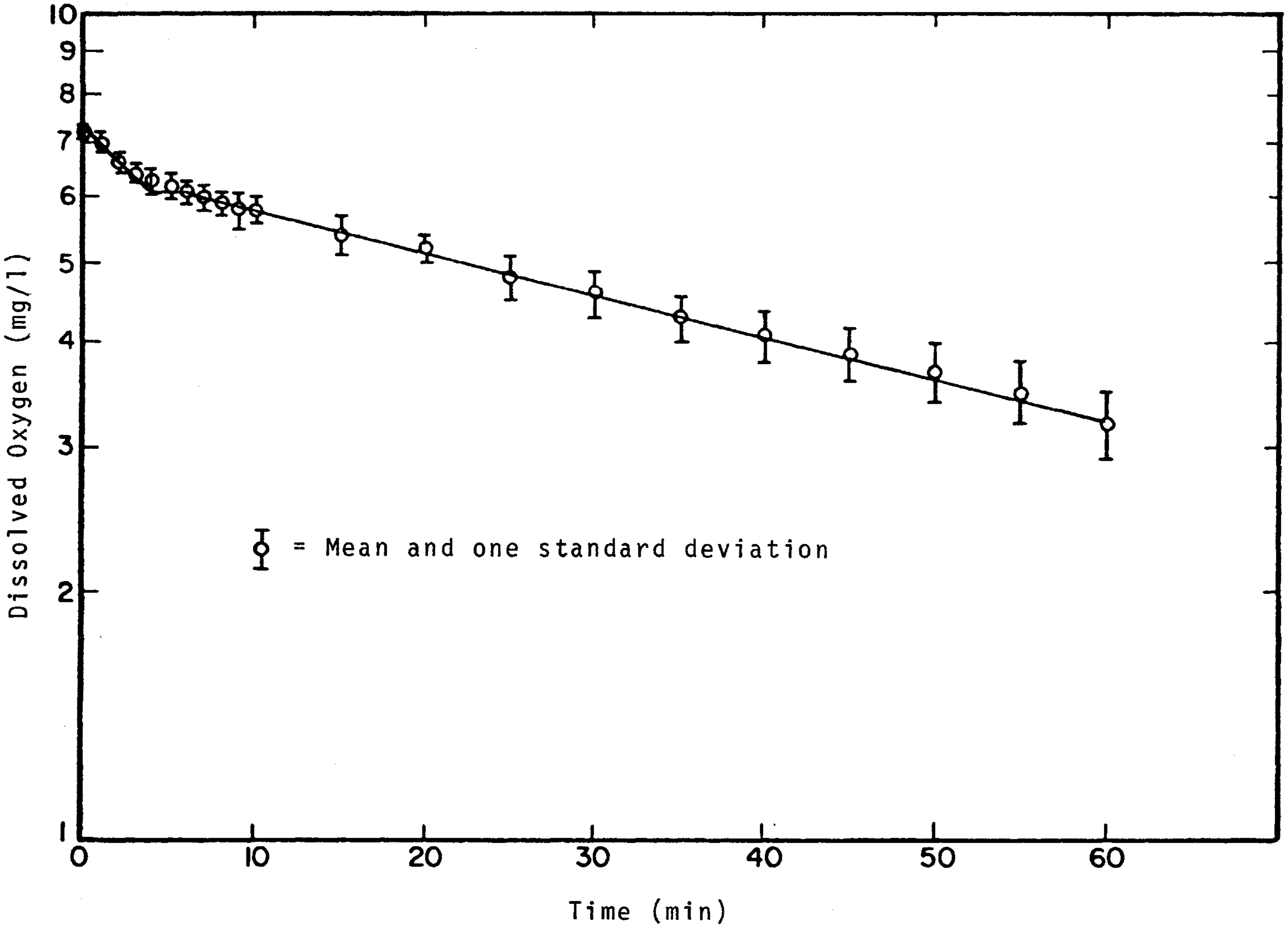

Figure 111
Oxygen Demand Test: Houston Ship Channel Site 1 Sediment
(Sample size - 3 cc)

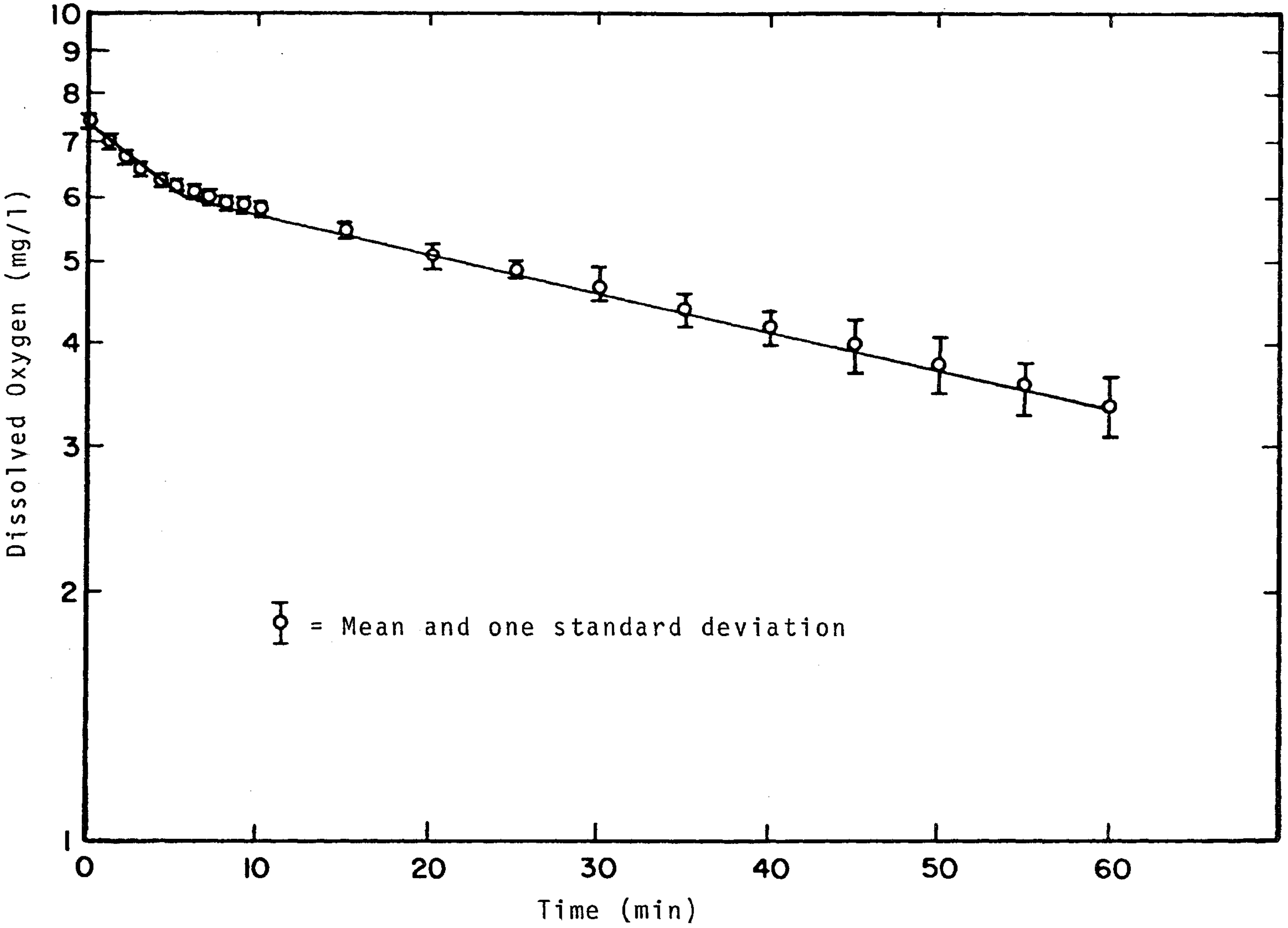

Figure 112

Oxygen Demand Test: Houston Ship Channel Site 2 Sediment

(Sample size - 3 cc)

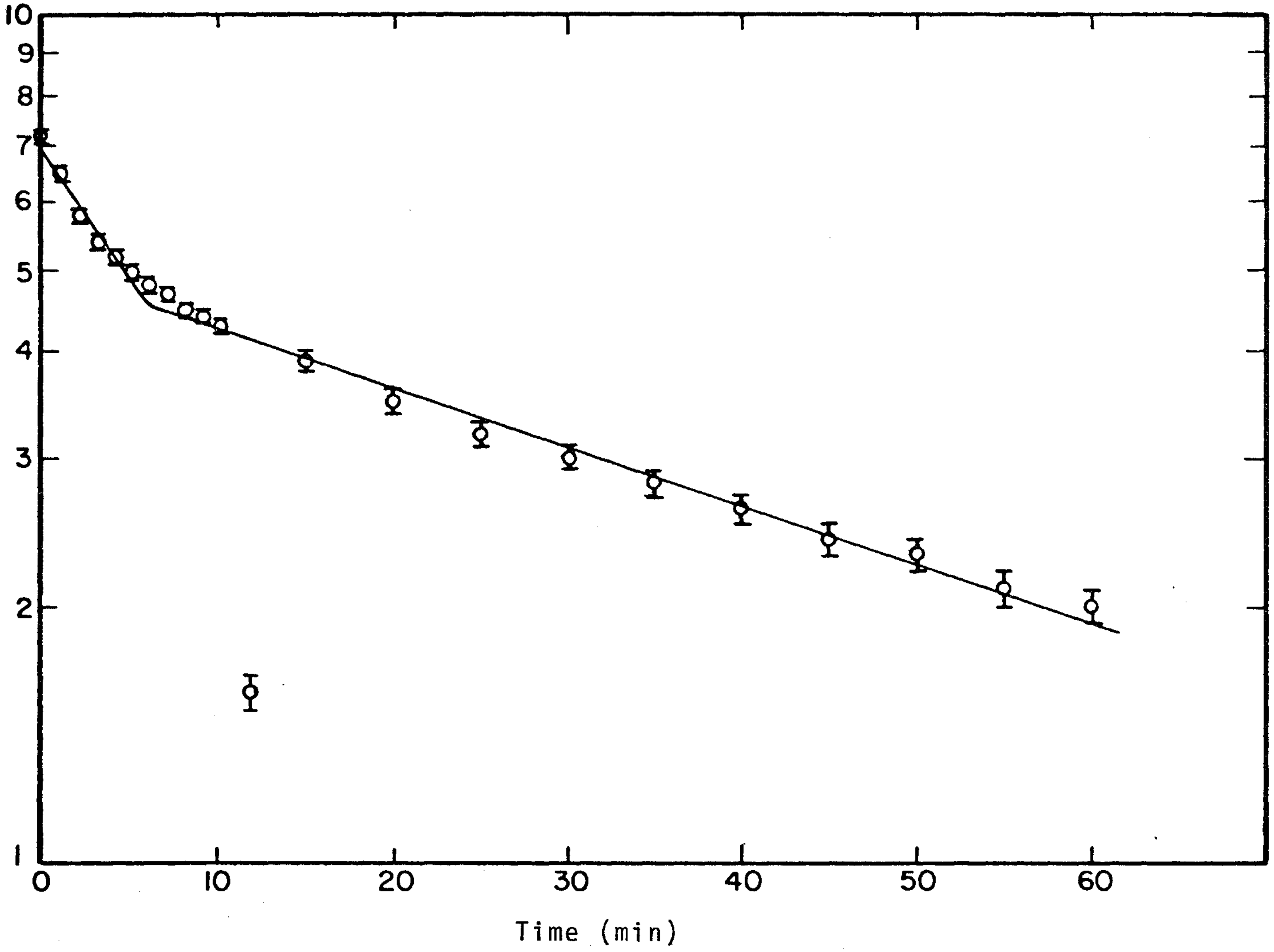

Figure 113

Oxygen Demand Test: Houston Ship Channel Site 3 Sediment
(Sample size-3cc)

20 percent oxic, and 20 percent anoxic elutriate tests were run on HSC-3 sediment and water.

In addition to the duplicate 5 percent oxic and 20 percent anoxic elutriate tests run on Site 2 sediment and water, five 20 percent oxic tests were also run. The purpose of running the five tests on one set of samples was to better assess the reproducibility of the elutriate test procedure and possibly determine why some of the replicate tests previously run did not yield reproducible data. To assess the reproducibility of the plop test with regard to varying total elutriate volumes (2, 4, and 8 liter), three plot tests (20 percent sediment by volume) were run on the HSC-2 sediment. Since the plop test was designed to be a more appropriate method for assessing chemical contaminant release during open-water barge disposal operations, Elliott Bay water, which more closely approximated the Gulf of Mexico waters than did the Galveston Bay waters, was used for these plop tests.

The values for the general physical and chemical parameters measured during elutriate tests on HSC Site 1 sediment and water are presented in Table 346. The D.O. concentrations during mixing of the 20 percent oxic tests were low, less than 3 mg/l. These concentrations decreased to 0.6 and 0.5 mg/l during the settling period, which indicated that the sediment had a fairly high oxygen demand. The D.O. levels were higher during mixing of the 5 percent oxic tests as there was less sediment exerting a demand. The D.O. concentration decreased about 1.5 mg/l (to 4.5 and 5.2 mg/l) during settling. The D.O. in the anoxic tests remained below 0.5 mg/l during the settling period.

The pH remained essentially unchanged after all six elutriate tests. The turbidity increased to about the same level in all elutriates; values ranged from 76 to 150 NTU. The specific conductance increased slightly (to 3750 µmhos/cm @ 25°C) as a result of 5 percent oxic elutriation. The 20 percent elutriate values were greater, ranging from 4420 to 5080 µmhos/cm.

Table 346

General Physical and Chemical Parameters: Houston Ship Channel Site 1 Elutriate Tests

Sample Designation	D.O. (mg/l @ 25°C) Initial	After Mixing	After Settling	pH	Turbidity (NTU)	Specific Conductance (µmhos/cm @ 25°C)
Site Water	4.9	-	-	7.6	22	3310
5% Oxic A	5.1	6.1	4.5	7.7	120	3750
B	5.5	6.5	5.2	7.7	120	3750
20% Oxic A	2.1	2.9	0.6	7.7	76	5080
B	2.2	1.5	0.5	7.7	120	4640
20% Anoxic A	1.9	< 0.5	< 0.5	7.7	130	4420
B	3.3	< 0.5	< 0.5	7.7	150	4640

Dash (-) indicates not applicable.

Table 347 presents the values of the general physical and chemical parameters measured during the elutriate tests on HSC Site 2 sediment and water. The initial D.O. of this site water was lower than the HSC Site 1 concentration as well as those typically found at other sites studied for this report. The pH of this water was slightly lower and the specific conductance higher than those values found in the HSC Site 1 water.

Judging from D.O. concentrations during the 5 and 20 percent oxic tests, the oxygen demand of this sediment appears to have been about the same or slightly greater than that of the HSC Site 1 sediment. The initial D.O. concentration (which was measured immediately after combining the sediment and water) in each 20 percent test was less than 0.5 mg/l. After mixing, 20 percent test D.O. levels increased from 2 to 2.5 mg/l, but they decreased to less than 1 mg/l after settling. The anoxic tests remained anoxic throughout the settling period.

The turbidity increased to about the same level in both the 5 percent oxic and 20 percent anoxic elutriates, which had values ranging from 55 to 85 NTU. In the oxic elutriates, however, values were all above 1000 NTU. The pH (7.4 in the site water) rose to about 8 as a result of elutriation under all conditions.

The specific conductance decreased as a result of 5 percent oxic elutriation; it increased slightly after anoxic elutriation. The greatest change in specific conductance was found in the five 20 percent oxic tests, where the values increased to between 7150 and 7360 μmhos/cm @ 25°C. In general, the physical and chemical parameters measured were well replicated in the replicate elutriate tests.

Table 347

General Physical and Chemical Parameters: Houston Ship Channel Site 2 Elutriate and Plop Tests

Sample Designation	D.O. (mg/l @ 25°C) Initial	After Mixing	After Settling	pH	Turbidity (NTU)	Specific Conductance (µmhos/cm @ 25°C)	Salinity (o/oo)
Elutriate Tests:							
Site Water	2.4	-	-	7.4	17	5410	-
5% Oxic A	4.0	5.9	3.6	7.9	85	4030	-
B	4.4	5.3	3.6	8.0	70	4350	-
20% Oxic A	< 0.5	2.0	0.7	7.9	> 1000	7280	-
B	< 0.5	2.5	0.9	8.0	> 1000	7150	-
C	< 0.5	2.3	0.8	7.8	> 1000	7280	-
D	< 0.5	2.0	< 0.5	7.9	> 1000	7360	-
E	< 0.5	1.8	< 0.5	7.9	> 1000	7180	-
20% Anoxic A	< 0.5	< 0.5	0.6	7.9	65	5840	-
B	2.3	< 0.5	< 0.5	7.9	55	5840	-
Plop Tests:*							
Site Water	11.0	-	-	7.6	0.5	37,340	23.5
2 liters	-	10.8	8.8	7.7	53	36,880	22.5
4 liters	-	10.2	8.5	7.7	67	37,340	23.5
8 liters	-	10.4	8.0	7.7	68	38,210	23.5

Dash (-) indicates not applicable or not measured.

*Elliott Bay site water was used. The 20% sediment solution was mixed for 1 hour in a 7 mm glass aeration tube. Solution was settled for 30 minutes. Liters indicated represent total elutriate volume.

The values of the general physical and chemical parameters measured during the HSC Site 2 plop tests are also reported in Table 347. In general, these values were well replicated in the three tests. The D.O. content after settling appeared to decrease slightly with increasing total elutriate volume; the range was 8.0 to 8.8 mg/l. The pH remained virtually unchanged in all three tests as a result of elutriation. Turbidity increased from 0.5 NTU in the site water to 53 to 68 NTU in the three elutriates. The specific conductance and salinity showed a slight decrease after elutriation with a 2 liter total volume, no change with the 4 liter volume, and a slight increase with the 8 liter volume. The range of elutriate specific conductance values was less than 1500 μmhos/cm, which corresponded to a 1 ^{o}/oo salinity spread. These plop test results are not directly comparable to the standard elutriate test results since different site waters were used.

Presented in Table 348 are the values of the general physical and chemical parameters measured during elutriate tests on HSC Site 3 sediment and water. This site water had the highest D.O. content, pH, and specific conductance of the three HSC water samples. This is to be expected because the sampling site was near the mouth of the channel but actually in Galveston Bay.

The D.O. levels present during the HSC-3 five percent oxic elutriate tests were generally slightly higher than those found in the HSC Site 1 tests. Although the D.O. concentration after mixing of the HSC-3 20 percent oxic tests were higher than the corresponding levels in HSC-1 and 2 tests, the levels present after settling were less than 1 mg/l.

The pH increased slightly (from 7.8 to 8.1) as a result of elutriation under all conditions. Turbidity also increased to about the same level in the elutriates; elutriate turbidity values ranged from 32 to 92 NTU. The specific conductance and salinity values appear to have increased slightly

Table 348

General Physical and Chemical Parameters: Houston Ship Channel Site 3 Elutriate Tests

Sample Designation	D.O. (mg/l @ 25°C)			pH	Turbidity (NTU)	Specific Conductance (µmhos/cm @ 25°C)	Salinity (°/oo)
	Initial	After Mixing	After Settling				
Site Water	6.4	-	-	7.8	10	21,600	13.0
5% Oxic A	5.4	6.7	5.6	8.1	79	21,900	13.2
B	4.2	6.3	5.5	8.1	92	22,000	13.2
20% Oxic A	1.7	4.7	0.8	8.1	32	22,700	13.8
B	1.9	4.7	0.6	8.1	53	22,700	13.8
20% Anoxic A	1.1	< 0.5	< 0.5	8.1	60	22,500	13.6
B	1.8	< 0.5	< 0.5	8.1	45	22,600	13.6

Dash (-) indicates not applicable.

as a result of elutriation. Specific conductance values in the elutriates ranged from 21,900 to 22,700 µmhos/cm compared to the site water value of 21,600 µmhos/cm.

Heavy Metals

The concentrations of selected heavy metals in sediment samples at the three sites in the HSC are shown in Table 349. Two sample buckets taken in Site 2 were analyzed because each was used in a different set of elutriate tests. The data show that for most metals, the sediment from Site 3 is relatively uncontaminated compared to those from Sites 1 and 2. Concentrations of iron and arsenic were equivalent in all samples. The Site 3 sediment contained two to four times more manganese than the Sites 1 and 2 sediments. The sediments from Sites 1 and 2 were generally comparable in concentrations of all metals.

Zinc and mercury concentrations in the Sites 1 and 2 sediments ranged from 15.5 to 29.8 g/kg and from 0.313 to 0.740 mg/kg, respectively. HSC-3 sediment contained 0.1 g/kg zinc and 0.090 mg/kg mercury. Sites 1 and 2 sediment cadmium, chromium, copper, and lead concentrations were similar. Copper concentrations were three to eight times higher than those at Site 3. Nickel concentrations in the Sites 1 and 2 sediments, 25.7 and 23.6 mg/kg, were only slightly higher than in the Site 3 sediment, 19.6 mg/kg. Concentrations of iron and arsenic were comparable in sediments from all three sites and ranged from 19.0 to 20.0 g/kg and 0.9 to 1.1 mg/kg, respectively. For every metal except manganese, Sites 1 and 2 levels were higher than the Site 3 concentration.

Site 1 elutriate tests (Table 350) produced no change in lead, chromium, or mercury concentrations. There were losses of cadmium, zinc, nickel, copper, iron, and arsenic, but the degree of loss did not seem to be related to percent of sediment used or to the type of test (i.e., oxic or anoxic). Cadmium decreased from 1.1 µg/l to <0.5 µg/l (detection limit)

Table 349

Total Heavy Metal Composition: Houston Ship Channel Sediments

(mg/kg)

Sampling Site		Mn		Cd		Cr		Zn*		Ni		Pb		Cu		Fe*		Hg		As	
		$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
HSC-1		142	3	4.7	0.5	83.8	5.2	29.8	0.5	25.7	0	114.2	6.5	70.0	4.2	19.0	<0.1	0.740	0.035	0.9	0.1
HSC-2	A	259	17	3.9	0	86.0	7.1	21.1	0.7	23.6	0	132.7	4.7	68.9	5.3	20.0	0	0.383	0.018	0.9	0
	B	190	21	3.9	0.6	87.5	10.9	15.5	0.3	26.0	1.8	96.4	3.8	62.0	7.9	19.8	0.1	0.313	0.011	1.1	0.1
HSC-3		525	41	0.6	0.5	28.1	4.9	0.1	<0.1	19.6	1.1	10.6	1.9	12.3	2.2	19.3	0.2	0.090	0.007	1.0	0.2

A and B are replicates.

Mean and standard deviation calculated from triplicate analyses.

*Zinc and iron concentrations in g/kg.

Table 350

Soluble Heavy Metal Concentrations: Houston Ship Channel

Site 1 Elutriate Tests

(ug/l)

Sample	Mn		Cd		Cr		Zn		Ni		Pb		Cu		Fe		Hg		As	
Designation	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Site Water	76	0	1.1	0.1	<2	-	35.2	0	13.6	1.6	4.8	0.4	5.0	0.1	339	4	0.047	0	3.6	-
5% Oxic A	130	12	0.7	0.1	<2	-	20.1	3.2	10.2	-	4.8	0.4	1.4	0	29	3	0.047	0	2.1	-
B	121	24	0.7	0	<2	-	19.3	1.1	10.3	0.5	4.8	0.5	1.6	0.2	23	1	0.047	0	<2	-
20% Oxic A	57	4	<0.5	-	<2	-	14.5	1.3	12.0	0.8	4.3	1.2	3.3	0.2	274	0	0.047	0	2.3	-
B	43	8	<0.5	-	<2	-	48.2	4.6	12.7	0.8	5.1	0.7	1.6	0	210	4	0.047	0	3.0	-
20% Anoxic A	179	20	<0.5	-	<2	-	14.6	0	12.0	1.1	4.3	0.4	1.4	0.1	64	1	0.047	0	2.8	-
B	195	7	<0.5	-	<2	-	17.1	2.0	12.5	0.5	4.8	1.2	1.5	0.1	52	0	0.047	0	2.8	-

A and B are replicates.

Mean and standard deviation calculated from duplicate analyses.

Dash (-) indicates no data.

in all 20 percent tests. Zinc in the site water was 35.2 μg/l and in all but one elutriate ranged from 14.5 to 20.1 μg/l. In the 20 percent oxic elutriate B, zinc was 48.2 μg/l. Nickel decreased slightly in all tests, from 13.6 μg/l in the site water to a range of 10.2 to 12.7 μg/l in the elutriates. Copper decreased from 5.0 μg/l in the site water to 1.4 to 3.3 μg/l in the elutriates. Iron showed the greatest decrease in the 5 percent oxic and 20 percent anoxic elutriates. The site water contained 339 μg/l, and these elutriates contained 210 and 274 μg/l iron. Arsenic decreased to below detection limit (2 μg/l) in one of the 5 percent oxic elutriates (from 3.6 μg/l in the site water). The other elutriates showed from 2.1 to 3.0 μg/l arsenic. Manganese increased from 76 μg/l in the site water to 121 and 130 μg/l in the 5 percent oxic and to 179 and 195 μg/l in the 20 percent anoxic tests. The 20 percent tests, however, contained 43 and 57 μg/l manganese.

Metal analysis results for the HSC-2 elutriate and plop tests are presented in Table 351. There was a loss from solution of zinc in all tests. Site water 2A used for the elutriate tests contained 182 μg/l zinc and the elutriates contained 16.4 to 143.9 μg/l zinc. The range in the five replicate 20 percent oxic tests was 28.2 to 143.9 μg/l zinc.

The pattern with the rest of the metals was not distinct. Chromium concentrations did not change. Some of the tests showed slight or large release and others showed uptake from solution. Replicates of the 5 percent and 20 percent oxic tests did not agree well. The plop tests showed the same general variation as the standard elutriate tests.

The most significant changes in metals concentrations resulting from these tests were in manganese and mercury. The site water for the elutriate tests contained 352 μg/l manganese. The 20 percent oxic elutriates and one of the

Table 351

Soluble Heavy Metal Concentrations: Houston Ship Channel

Site 2 Elutriate and Plop Tests

(μg/1)

Sample Designation	Mn		Cd		Cr		Zn		Ni		Pb		Cu		Fe		Hg		As	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Elutriate Tests:																				
Site Water	352	52	0.6	0	<2	-	182.0	76.8	8.6	3.5	4.3	0.4	4.4	1.2	39	2	0.047	0	2.3	-
5% Oxic A	646	37	0.6	0.1	<2	-	27.5	1.6	11.3	0.2	3.1	0	4.0	0	26	0	0.047	0	2.3	-
B	92	11	0.6	0.1	<2	-	16.4	2.7	8.6	0.4	5.4	0.7	2.5	0.3	786	15	0.057	0.014	2.3	-
20% Anoxic A	218	10	0.7	0.1	<2	-	17.5	1.2	7.5	0.6	4.3	0.4	2.4	0	181	0	0.047	0	3.9	-
B	345	11	1.0	0	<2	-	16.6	2.9	8.3	0	4.9	0	2.2	0.1	144	0	0.047	0	3.8	-
20% Oxic A	1340	57	0.7	0	<2	-	143.9	54.9	8.4	0.6	3.6	0	2.3	0.3	42	0	0.248	0	2.5	-
B	929	57	0.6	0	<2	-	28.2	1.4	13.8	0	3.8	0.3	4.6	0	68	8	0.248	0	2.7	-
C	943	132	0.9	0	<2	-	45.5	1.0	12.9	0	4.0	0	7.2	0	48	0	0.191	0	2.5	-
D	1301	258	0.8	0.1	<2	-	44.8	3.0	7.4	0	3.8	0.3	5.5	0.2	37	1	0.048	0	2.6	-
E	1260	326	1.0	0	<2	-	38.1	1.6	6.8	0.4	4.3	0.4	5.0	0.1	31	1	0.048	0	2.0	-
Plop Tests:*																				
Site Water	78	0	1.2	0.1	<2	-	52.6	10.4	8.0	0	12.2	0.3	4.0	0.1	22	0	0.047	0	<2	-
Plot Test																				
(2 1)	346	18	1.0	0.1	<2	-	20.9	2.1	12.3	0	14.5	0.8	3.0	0.2	43	0	0.047	0	<2	-
(4 1)	188	25	1.3	0.3	<2	-	23.9	2.8	11.6	0	10.7	0	2.2	0	29	1	0.154	0	<2	-
(8 1)	362	90	1.2	0.3	<2	-	21.6	6.2	13.6	0.8	12.2	0.3	2.5	0.1	33	1	0.047	0	<2	-

A,B,C,D and E are replicates.

Mean and standard deviation calculated from duplicate analyses.

Dash (-) indicates no data.

*Plop tests used Elliott Bay site water. For explanation and description, see General Parameters section.

5 percent oxic elutriates showed release of manganese. They ranged in concentration from 646 (the 5 percent oxic replicate A elutriate) to 1340 µg/l manganese (the 20 percent oxic A elutriate). The 20 percent anoxic elutriates (218 and 345 µg/l) and 5 percent oxic replicate A (92 µg/l manganese) contained less manganese than did the site water. There was apparent release of mercury in three 20 percent oxic replicates, one 5 percent oxic A replicate, and the 4 liter plop test. The elutriate test site water contained 0.047 µg/l mercury and the 20 percent oxic A,B, and C replicates ranged from 0.191 to 0.248 µg/l mercury. The 5 percent oxic A elutriate and 4 liter plop test solution contained 0.057 and 0.154 µg/l mercury, respectively.

The Site 3 elutriates showed less variation in metal concentrations. Table 352 shows little change if any in concentrations of chromium, cadmium, lead, mercury, and arsenic. Released in all tests, manganese ranged from 33 µg/l in the site water to a range of 1654 (5 percent oxic B) to 4951 µg/l (20 percent anoxic B) in the elutriates. This was expected because this sediment had the highest manganese content of the three. Copper decreased in all elutriates (from 3.1 µg/l in the site water) and ranged from 1.7 to 2.9 in the elutriates. There was some zinc and nickel release in most of the oxic elutriates and uptake or loss from solution seen in the anoxic elutriates. Iron was reduced from 6 µg/l in the site water to below the detection limit (5 µg/l) in the 5 percent oxic elutriates. It was released to varying degrees in the 20 percent oxic and anoxic elutriates. These concentrations ranged from 15 to 429 µg/l iron.

It should be noted that while the total metal concentration of the Site 3 sediment was quite different from those of the Sites 1 and 2 sediments, the results of the elutriate tests were not markedly different with respect to heavy metals uptake or release. Only in the case of manganese did the behavior of the metal in the elutriate tests seem to correspond to the concentration in the sediment.

Table 352

Soluble Heavy Metals Concentrations: Houston Ship Channel

Site 3 Elutriate Tests

(ug/l)

Sample	Mn		Cd		Cr		Zn		Ni		Pb		Cu		Fe		Hg		As	
Designation	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Site Water	33	-	1.0	0	<2	-	14.8	0.3	10.5	0.1	3.0	0	3.1	0.1	6	0	0.047	0	2.0	-
5% Oxic A	1857	-	1.0	0.1	<2	-	27.6	2.1	10.8	0.1	2.7	0.4	2.6	0.1	<5	-	0.047	0	2.0	-
B	1654	-	0.9	0	<2	-	11.1	0.7	11.0	0.1	2.4	0	2.2	0	<5	-	0.154	0	2.2	-
20% Oxic A	3914	-	1.0	0.1	<2	-	14.9	-	12.6	1.0	3.4	0.7	2.9	0.8	33	2	0.047	0	<2	-
B	4284	-	0.9	0.1	<2	-	17.8	1.6	10.0	0	4.6	0.5	1.9	0	50	2	0.047	0	2.2	-
20% Anoxic A	4432	-	0.8	0	<2	-	10.7	0.2	6.9	0.3	4.0	0.5	1.8	0	15	0	0.047	0	2.6	-
B	4951	-	0.6	0.2	<2	-	10.7	1.0	7.6	0	4.0	0.5	1.7	0.1	429	0	0.154	0	2.3	-

A and B are replicates.

Mean and standard deviation calculated from duplicate analyses.

Dash (-) indicates no data.

Nitrogen Compounds

Sediment samples collected from HSC were analyzed to determine the nitrogen compound concentrations. The data are listed in Table 353. HSC-3 sediment had much lower ammonium and organic N contents than the other two sediments. HSC-2 sediment had the highest concentration for both parameters.

The nitrogen compound concentrations for HSC Site 1 elutriate tests are listed in Table 354. The site water showed a much higher ammonium concentration than that seen in any other site water studied thus far. In the 20 percent tests, ammonium release was higher under oxic conditions than under anoxic conditions. Ammonium release was also a function of the percent sediment volume in the total elutriate volume. Organic N concentrations also increased in all the elutriates; however, the increase was greater under oxic conditions. Nitrate decreased as a result of elutriation. The decreases were greater in the higher sediment percentage tests.

Ammonium and nitrate data for the HSC-2 elutriate tests and plop test are presented in Table 355. The elutriate site water ammonium concentration was higher than that of the HSC-1 site water. The ammonium and nitrate data from the five replicate 20 percent oxic elutriate tests indicate satisfactory reproducibility. Nitrate concentrations in all the plop test elutriates (Table 355) increased over that of the site water used (from Elliott Bay). It appears that the higher ammonium concentration in the site water might be a reason for greater release observed in the larger volume tests.

The nitrogen compound concentrations for the HSC-3 elutriate tests are presented in Table 356. The site water had a lower ammonium concentration than the Sites 1 and 2 water samples. The ammonium release was also less than that observed from the other two sediments. However, the ammonium release pattern resembled that seen in the HSC-2 tests; release was greater under oxic conditions and in higher percent

Table 353

Nitrogen Compound Concentration: Houston Ship Channel Sediment Samples

(mg N/kg)

Sample Location	Organic N		Ammonium	
	$\bar{X}$	SD	$\bar{X}$	SD
HSC-1	975	36	182	9
HSC-2	1113	51	218	22
HSC-3	221	34	83	17

Mean and standard deviation calculated from duplicate analyses.

Table 354

Nitrogen Compound Concentrations: Houston Ship Channel Site 1 Elutriate Tests

Sample Designation		Organic N		Ammonium		Nitrate	
		$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Site Water		0.60	0.03	3.60	0.04	0.32	0.01
5% Oxic	A	-	-	6.78	0.04	0.26	0.01
	B	1.73	0.14	6.85	0	0.28	0.02
20% Oxic	A	-	-	13.65	0.07	0.16	0.01
	B	1.40	0.34	14.72	0.11	0.10	0.01
20% Anoxic	A	1.26	0.60	11.22	0.04	0.12	0.01

A and B are replicates.

Mean and standard deviation calculated from duplicate analyses.

Dash (-) indicates data not available.

Table 355

Ammonium and Nitrate Concentrations: Houston Ship Channel Site 2 Elutriate and Plop Tests

(mg N/l)

Sample Designation		Ammonium		Nitrate	
		$\bar{X}$	SD	$\bar{X}$	SD
Elutriate Tests:					
Site Water		3.99	0	0.21	0.01
5% Oxic	A	8.02	0.04	0.16	0.02
2	B	8.31	0.04	0.16	0
20% Oxic	A	17.70	0.42	0.07	0
	B	17.00	0.14	0.17	0.10*
	C	16.30	0.07	0.07	0
	D	16.08	0.17	0.08	0
	E	15.95	0.07	0.08	0.02
20% Anoxic	A	13.10	0.14	0.08	0.01
	B	12.30	0	0.10	0.01
Plop Tests:					
Site Water		< 0.05	∿0	0.39	0.01
(2 1)		-	-	0.46	0.02
(4 1)		2.76	0	0.43	0.01
(8 1)		6.28	0.13	0.38	0

A, B, C, D, and E are replicates.

Mean and standard deviation calculated from duplicate analyses.

Dash (-) indicates no analysis due to insufficient sample volume.

*Standard deviation possibly due to analytical error.

Table 356

Nitrogen Compound Concentration: Houston Ship Channel Site 3 Elutriate Tests

(mg N/1)

Sample Designation	Organic N		Ammonium		Nitrate	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Site Water	0.54	0.14	1.08	0	0.28	0.01
5% Oxic A	-	-	2.95	0.10	0.32	0.01
B	0.38	0.07	3.04	0.04	0.24	0.02
20% Oxic A	<0.05	∿0	8.11	0	0.11	0
B	-	-	8.62	0.05	0.06	0.01
20% Anoxic A	0.12	0.26	6.50	0.06	0.10	0
B	-	-	7.16	0.13	0.09	0.03

A and B are replicates

Mean and standard deviation calculated from duplicate analyses.

Dash (-) indicates no data available.

sediment elutriates. Organic N was highest in the 5 percent elutriate. Nitrate decreased in all elutriates except the 5 percent replicate A.

Phosphorus Compounds

Total phosphorus concentrations in the sediments used in the HSC elutriate tests are presented in Table 357. Site 2 sediment appears to be the most highly contaminated with phosphorus, Site 3 the least. This would be expected considering the relative locations of the sampling sites.

Table 358 presents the soluble orthophosphate concentrations in the HSC elutriates. As with the sediment total phosphorus concentrations, the highest HSC site water soluble orthophosphate concentration (2.1 mg P/1) was found at Site 2, the lowest (1.2 mg P/1) in the Site 3 (Galveston Bay) water. As previously discussed, the site water used for the plot tests was from Elliott Bay. The soluble ortho P concentration in that water was 0.079 mg P/1.

Table 357

Total Phosphorus Concentrations: Houston Ship Channel Sediments

(mg P/kg dry weight)

Sample Designation	Total P	
	$\bar{X}$	SD
Site 1	1968	-
Site 2	2936	-
Site 3	546	3

Mean and standard deviation calculated from duplicate analyses of one digested sample.

Dash (-) indicates a single analysis performed.

The HSC-Site 1 elutriate tests showed uptake of soluble orthophosphate during 5 percent oxic elutriation. The approximately 50 percent decrease was from 1.7 mg P/l to 0.97 and 0.76 mg P/l in duplicate elutriates. Both the oxic and anoxic 20 percent tests showed release of soluble ortho P upon elutriation. In the oxic elutriates, the increase was about two-fold; in the anoxic elutriates, it was greater than five-fold.

There was a substantial decrease in the soluble orthophosphate concentrations resulting from 5 percent oxic elutriation with HSC-Site 2 samples. Elutriates contained about 0.3 mg P/l whereas the site water concentration was 2.1 mg P/l. The Site 2 20 percent oxic tests, in general, showed little change in the soluble ortho P concentration. Four of the five replicates had between 1.9 and 2.9 mg P.1, the fifth was 0.63 mg P/l. Substantial release was found under anoxic conditions; elutriate concentrations were 9 and 11 mg P/l.

The HSC-Site 3 sediment showed little soluble orthophosphate release during elutriate tests. Both the 5 and 20

Table 358

Soluble Orthophosphate Concentrations: Houston Ship Channel Elutriate and Plop Tests

(mg P/l)

Sample Designation	Soluble Ortho P $\bar{X}$	SD
Site 1:		
Site Water	1.7	0.015
5% Oxic A	0.97	0.006
B	0.76	0.006
20% Oxic A	2.7	0
B	3.8	0.006
20% Anoxic A	9.8	0.07
B	9.0	0.035
Site 2 Elutriate Tests:		
Site Water	2.1	0.015
5% Oxic A	0.32	0.002
B	0.28	0.001
20% Oxic A	0.63	0.007
B	1.9	0.006
C	2.0	0.006
D	2.9	0.006
E	2.7	0
20% Anoxic A	11.0	0
B	9.0	0.058
Plop Tests*		
Site Water	0.079	0.001
(2 l)	0.39	0.009
(4 l)	0.32	0
(8 l)	0.26	0.001

(Continued)

Table 358 (Concluded)

Sample Designation	Soluble Ortho P	
	$\bar{X}$	SD
Site 3		
Site Water	1.2	0.006
5% Oxic A	0.21	0.001
B	0.32	0.001
20% Oxic A	0.91	0.023
B	0.36	0.001
20% Anoxic A	1.2	0.006
B	1.4	0

A and B are replicates.

Mean and standard deviation calculated from triplicate analyses of one sample.

*Plop tests used Elliott Bay site water.

percent oxic tests showed decreases in concentration as a result of elutriation. The duplicate anoxic tests showed no change and a slight increase in concentration above that of the site water.

Organic Compounds

Duplicate 20 percent elutriate tests were run on sediment and water samples from HSC Sites 1 and 2. Usually, in the analyses for chlorinated hydrocarbon pesticides and PCBs, there is only enough sample to run one elutriate test per site. The samples from these sites were collected with the specific objective of obtaining enough sample for duplicate tests to be run for organic analyses.

Results of organic analyses of the elutriate tests are presented in Tables 359 and 360. In Site 1 sediment, aldrin, pp'DDT, op'DDE, pp'DDE, dieldrin, lindane, and PCBs were detected. PCB contamination was high; values of 5208

Table 359

Data for Organic Compounds: Houston Ship Channel

Site 1 Elutriate Tests

Parameter	Sediment		Water		Elutriate	
	A	B	A	B	A	B
	(μg/kg)		(ng/l)		(ng/l)	
Chlorinated Hydrocarbons:						
Aldrin	54.7	46.0	<0.6	<0.6	31.8	39.1
op'DDT	<3.0	<3.0	<3.0	<3.0	<3.0	< 3.0
pp'DDT	96.8	73.5	<3.0	<3.0	49.0	46.8
op'DDD	<2.0	<2.0	<2.0	<2.0	<2.0	< 2.0
pp'DDD	<2.0	<2.0	<2.0	<2.0	<2.0	< 2.0
op'DDE	238.1	215.5	<2.0	<2.0	92.0	119.7
pp'DDE	107.7	95.1	<2.0	<2.0	58.7	54.5
Dieldrin	88.8	74.8	<1.2*	<1.2*	44.6	40.6
Endosulfan I	< 0.9	<0.9	<1.2	<1.2	<1.2	< 1.2
Endosulfan II	< 1.7	<1.7	<2.2	<2.2	<2.2	< 2.2
Endrin	< 1.2	<1.2	<1.6	<1.6	<1.6	< 1.6
Heptachlor	0.3	<0.3	<0.4	<0.4	<0.4	< 0.4
Lindane	32.4	33.4	35.7	29.6	22.3	23.7
PCBs	5208	5442	<6	<6	12,322	11,188
Other Organic Compounds	(mg/kg)		(mg/l)			
Oil and Grease	6517	5218	<0.5	<0.5	73.3	36.1
Total Organic Carbon	0.6 %	0.6%	13	14	374	155
Total Inorganic Carbon	0.3 %	0.2%	23	21	422	120

A and B are replicates.

*Compound detected on two columns.

Table 360

Data for Organic Compounds: Houston Ship Channel Site 2 Duplicate 20 Percent Oxic Elutriate Tests

Parameter	Sediment		Water		Elutriate	
	A	B	A	B	A	B
	(μg/kg)		(ng/l)		(ng/l)	
Chlorinated Hydrocarbons:						
Aldrin	40.7	54.7	9.9	5.8	10.7	14.5
op'DDT	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
pp'DDT	53.5	80.2	<3.0	<3.0	7.5	13.4
op'DDD	78.8	98.8	<2.0	<2.0	23.2	34.7
pp'DDD	96.8	143.5	<2.0	<2.0	10.5	20.1
op'DDE	142.5	183.8	<2.0	<2.0	49.6	45.0
pp'DDE	63.4	90.1	<2.0	<2.0	12.3	17.8
Dieldrin	52.8	73.1	<1.2	<1.2	21.6	16.6
Endosulfan I	<0.9	<0.9	<1.2	<1.2	<1.2	<1.2
Endosulfan II	<3.4	<3.4	<4.4	<4.4	<4.4	<4.4
Endrin	<1.2	<1.2	<1.6	<1.6	<1.6	<1.6
Heptachlor	43.2	58.3	6.2	5.5	11.5	14.8
Lindane	21.8	15.4	22.2	16.7	7.5	8.6
PCBs	7762	8074	57	70	965	779
Other Organic Compounds	(mg/kg)		(mg/l)			
Oil and Grease	3881	3386	<0.5	<0.5	44.0	49.9
Total Organic Carbon	0.5%	0.5%	15	18	207	173
Total Inorganic Carbon	0.3%	0.2%	23	21	127	130

A and B are replicates.

and 5442 µg/kg were found in the duplicates. The oil and grease content was 6517 and 5218 mg/kg, and the percent total organic carbon was 0.6 percent for both samples. In Site 1 water dieldrin, lindane, and PCBs were detected, but only lindane was measurable above the detection limit.

In spite of the high oil and grease content of the sediment, in the elutriates there was release of every compound identified in the sediment except lindane. In fact, the Site 1 elutriate PCB release was the highest found in this study. PCB values measured in the duplicate elutriates were 12,322 and 11,188 ng/l.

The Site 2 sediment contained the same pesticides as the Site 1 sediment: op'DDD, pp'DDD, and heptachlor were also detected in measurable amounts. The PCB values (7762 and 8074 µg/kg) again were among the highest concentrations found throughout this study. The oil and grease content was high (3881 and 3386 mg/kg), though not as high as in the Site 1 sediment. The total organic carbon was 0.5 percent. In the Site 2 water, aldrin, heptachlor, lindane, and PCBs were detected in measurable amounts. All compounds (except lindane) which were detected in the sediment were released during the elutriate test. The PCB concentrations in the elutriates were high (965 and 779 ng/l) but not of the order of magnitude of those found in Site 1 elutriate tests.

Bioassays

General physical and chemical characteristics of elutriates of HSC Site 2 sediment and US EPA Reconstituted Sea Water[22] are presented in Table 361. The data show that the total ammonium nitrogen content for the 20 percent sediment tests was 13 to 14 mg/l, with approximately 0.15 mg/l present as unionized ammonia. The total ammonium nitrogen content for the 5 percent sediment tests was 5 mg/l, with 0.11 mg/l present as unionized ammonia. The data in Table 362 show that no significant changes in the concentration

Table 361
Chemical and Physical Characteristics: Houston Ship Channel Site 2 Bioassay Elutriates*

Sample Designation		pH	D.O. (mg/l @21°C)	Spec. Cond. (umhos/cm)	Total Ammonium as N (mg/l)	Unionized Ammonia as NH_3 (mg/l)**	Turbidity (NTU)	Salinity (°/oo)
Control	A	8.0	7.0	41,500	0.06	<0.01	<1	30
	B	8.0	7.0	41,000	0.06	<0.01	<1	30
5%	A	7.9	3.8	39,500	4.93	0.11	42	29
	B	7.8	3.9	39,400	5.04	0.11	48	29
20%	A	7.6	1.3	37,600	13.30	0.15	22	27
	B	7.6	1.2	37,300	14.30	0.16	22	27
Aerated	A	-	5.8	-	-	-	-	-
	B	-	5.6	-	-	-	-	-

A and B are replicates.

Dash (-) indicates no data collected.

*Measurements taken after one-hour settling period.

**For all bioassay elutriates, unionized ammonia calculated from Skarheim's[9] tables for fractions of ammonia in the undissociated form.

Table 362

Ammonium Concentrations After the 96-Hour Test Period: Houston Ship Channel Site 2 Bioassay Elutriate*

Sample Designation		pH	Total Ammonium as N (mg/l)	Unionized Ammonia as NH_3 (mg/l)
Control	A	8.0	0.13	< 0.01
	B	8.0	0.20	< 0.01
5%	A	7.9	5.42	0.12
	B	7.9	4.71	0.10
20%	A	7.7	12.20	0.17
	B	7.6	12.80	0.14

A and B are replicates.

*Temperature 21°C.

of ammonium took place over the 96-hour test period. In addition, there were initial decreases in the D.O. concentrations and increased levels of turbidity.

The D.O. decreases in the 20 percent sediment tests after the one-hour settling period necessitated using an additional 30-minute aeration period to raise the D.O. concentration to a level where additional oxygen demand would not lower the D.O. concentration below 2 mg/l. Table 363 shows that the D.O. concentrations of the bioassay elutriate waters never decreased to below 2 mg/l over the 96-hour test period.

The results of the heavy metal analyses of these bioassay elutriates are presented in Table 364. The data show releases of both iron and manganese. The release of manganese was relatively small: increases were 40 μg/l in the 5 percent test and 80 μg/l in the 20 percent tests. The data show that large amounts of iron were released to the elutriate waters with concentrations of approximately 1 mg/l and 2 mg/l

Table 363

Dissolved Oxygen Concentrations Over Bioassay Period: Houston Ship Channel Site 2

Time (hrs)	Dissolved Oxygen (mg/l @ 21°C)					
	Control		5%		20%	
	A	B	A	B	A	B
0	7.0	7.0	3.8	3.9	1.3	1.2
0.5 hr aeration	-	-	-	-	5.8	5.6
24	6.2	6.0	3.6	3.4	3.8	3.4
48	5.6	5.5	3.6	3.2	3.5	3.2
72	5.5	5.4	3.4	3.0	3.2	3.2
96	5.5	5.2	3.2	3.0	3.2	3.0

A and B are replicates.

Dash (-) indicates no data.

Table 364

Release of Heavy Metals: Houston Ship Channel

Site 2 Bioassay Elutriate

(μg/l)

Sample Designation		Mn	Cd	Cr	Zn	Ni	Pb	Cu	Fe	Hg
Control	A	132	2.7	< 2.0	158	23.3	24.5	32.3	39	0.004
	B	152	2.8	< 2.0	178	25.0	24.5	40.3	41	0.004
5%	A	192	1.8	< 2.0	112	16.8	17.3	13.0	899	0.004
	B	192	2.0	< 2.0	160	21.8	18.0	14.2	1105	0.004
20%	A	233	3.1	< 2.0	142	18.8	16.6	13.7	1825	0.004
	B	213	1.6	< 2.0	124	15.3	12.2	10.3	2504	0.004

A and B are replicates.

in the 5 and 20 percent sediment tests, respectively. Copper, lead, and nickel were removed from the elutriate waters. No significant changes from the test water concentrations were observed for chromium, cadmium, zinc, and mercury.

Table 365 presents the results of the bioassays using P. pugio for Houston Ship Channel Site 2. Examination of the table shows no toxicity of HSC-2 sediments to P. pugio over the 96-hour test period for the 5 percent sediment tests. There was a 10 percent toxicity observed in the 20 percent sediment tests.

The chemical characteristics of the HSC-3 bioassay test waters are presented in Table 366. The data presented in the table show that the total ammonium nitrogen content for the 20 percent sediment tests was approximately 7 to 8 mg/l, with 0.08 to 0.14 mg/l present as unionized ammonia. In addition, there were initial decreases in the D.O. concentrations and increased levels of turbidity. Again, the initial decreases in D.O. concentration in both of the 20 percent tests were severe enough to warrant a ten-minute aeration of the elutriate water. This additional aeration period after settling did not significantly change the level of ammonium present in the 20 percent elutriate waters.

Table 367 presents the 96-hour concentrations of D.O. in the HSC-3 bioassay elutriates. The data indicate the minimal aeration period assured an adequate concentration of D.O. even after an initial decrease below 2.0 mg/l.

The results of the heavy metal analysis for these bioassay elutriate waters are presented in Table 368. The data show large releases of both iron and manganese. Concentrations of the latter ranged from 9.6 mg/l in the 20 percent tests to over 11 mg/l in the 5 percent tests. Copper was removed from solution in both the 5 and 20 percent sediment tests as was nickel. No significant changes from the test water concentrations were observed for cadmium, chromium, lead,

Table 365

Response of P. pugio to Varying Sediment Percent of Total Elutriate Volume as a Function of Time: Houston Ship Channel Site 2 Bioassay Elutriates

Time (hrs)	Number of *P. pugio* Living at Varying Sediment Percentages					
	Controls		5%		20%	
	A	B	A	B	A	B
0	10	10	10	10	10	10
2	10	10	10	10	9	9
12	10	10	10	10	9	9
24	10	10	10	10	9	9
36	10	10	10	10	9	9
48	10	10	10	10	9	9
60	10	10	10	10	9	9
72	10	10	10	10	9	9
84	10	10	10	10	9	9
96	10	10	10	10	9	9

A and B are replicates.

zinc, or mercury. In addition, the data indicate that the 10-minute aeration period caused no significant differences in heavy metal concentrations.

Table 369 presents the results of the bioassays using *P. pugio* and HSC Site 3 sediments. Examination of the table shows no toxicity of HSC-3 sediments to *P. pugio* over the 96-hour test period.

Houston Ship Channel-Morgan's Point

Water and sediment samples for elutriate tests were collected at Morgan's Point in the HSC. Figure 114 shows the sampling site as well as the locations of other HSC sampling sites. A water sample was collected from the surface with a

Table 366
Chemical and Physical Characteristics: Houston Ship Channel Site 3 Bioassay Elutriates*

Sample Designation		pH	D.O. (mg/l @ 21°C)	Spec. Cond. (umhos/cm)	Turbidity (NTU)	Total Ammonium as N (mg/l)	Unionized Ammonia as NH_3 (mg/l)	Salinity (°/oo)
Control	A	8.0	7.6	41,300	< 1	0.05	< 0.01	30.5
	B	8.0	7.6	41,300	< 1	0.03	< 0.01	30.5
5%	A	7.8	4.2	40,900	68	2.60	0.04	30.1
	B	7.8	4.1	40,800	72	2.68	0.04	30.0
20%	A	7.8	1.6	39,300	21	8.11	0.14	28.9
	B	7.6	1.5	39,800	37	6.89	0.08	29.2
After aeration:		-	6.2	-	-	7.39	0.13	-
		-	5.8	-	-	6.98	0.08	-

A and B are replicates.

Dash (-) indicates no data collected.

*Measurements taken after one-hour settling period.

Table 367

Dissolved Oxygen Concentrations Over Bioassay Period: Houston Ship Channel Site 3 Bioassay Elutriates

Time (hrs)	Dissolved Oxygen (mg/l @ 21°C)					
	Control		5%		20%	
	A	B	A	B	A	B
0	7.6	7.6	4.2	4.1	1.6	1.5
10 min. aeration	-	-	-	-	5.8	6.2
24	7.2	7.5	4.3	4.3	4.8	5.0
48	7.0	7.3	4.2	4.2	4.6	4.7
72	6.7	6.8	4.1	4.0	4.3	4.1
96	6.6	6.6	4.0	3.9	4.3	4.0

A and B are replicates.

Dash (-) indicates no data.

Table 368

Release of Heavy Metals: Houston Ship Channel

Site 3 Bioassay Elutriates

(µg/l)

Sample Designation		Mn	Cd	Cr	Zn	Ni	Pb	Cn	Fe	Hg
Control	A	111	2.4	< 2.0	141	32.5	12.2	22.1	38	0.004
	B	132	2.5	< 2.0	90	34.2	14.4	22.6	39	0.004
5%	A	11,366	1.8	< 2.0	73	19.5	7.2	8.4	1023	0.004
	B	11,342	2.1	< 2.0	150	20.8	10.1	9.9	1064	0.004
20%	A	9,563	3.1	< 2.0	169	14.3	5.8	9.5	406	0.004
	B	9,684	2.4	< 2.0	137	16.0	7.2	8.8	961	0.004

A and B are replicates.

Table 369

Response of P. pugio to Varying Sediment Percent of Total Elutriate Volume as a Function of Time: Houston Ship Channel Site 3 Bioassay Elutriate

Time (hrs)	Number of *P. pugio* Living at Varying Sediment Percentages					
	Controls		5%		20%	
	A	B	A	B	A	B
0	10	10	10	10	10	10
1	10	10	10	10	10	10
2	10	10	10	10	10	10
12	10	10	10	10	10	10
24	10	10	10	10	10	10
36	10	10	10	10	10	10
48	10	10	10	10	10	10
36	10	10	10	10	10	10
48	10	10	10	10	10	10
60	10	10	10	10	10	10
72	10	10	10	10	10	10
84	10	10	10	10	10	10
96	10	10	10	10	10	10

A and B are replicates.

rope and plastic bucket on April 11, 1975. Unfavorable weather conditions delayed sediment sampling until April 18, 1976. A Ponar grab sampler was used. The samples were cooled in ice in insulated boxes and transported directly to the UTD laboratory where they were stored in the dark at 4°C.

Elutriate Test General Parameters

Single 5 percent and 20 percent oxic tests were run; the total test volume was 3 liters. The 20 percent oxic elutriate was centrifuged prior to measuring general parameters and analyses of the unfiltered water. The quantity of Morgan's

Point sediment available was insufficient for determination of general sediment characteristics or sediment oxygen demand.

Table 370 shows that the D.O. decreased during settling to a lesser extent in the 5 percent than in the 20 percent elutriate. The final D.O. values were within the range found for the TCC elutriates. The site water had a slightly lower pH than did the TCC site waters; pH increased to 8.0 upon both 5 and 20 percent elutriation. The Morgan's Point site water had a fairly high turbidity (28 NTU) which increased to 120 NTU in the 5 percent oxic elutriate. The 7 NTU turbidity value for the 20 percent elutriate does not accurately represent the actual elutriate turbidity because the elutriate was centrifuged prior to analysis. Specific conductance in the 20 percent elutriate was greater than in the 5 percent. The site water (7,127 μmhos/cm @ 25°C) had a much lower specific conductance than did the TCC site waters.

Heavy Metals

Table 371 contains the results of analyses of site water and elutriates for soluble heavy metals. There was no significant difference in the concentrations of zinc, cadmium, copper, or nickel in the site water and the elutriates. The concentration of iron in the Morgan's Point site water was 11.6 μg/l. This dropped to 3.4 and 1.5 μg/l iron in the 5 and 20 percent elutriates, respectively. There was release of manganese, chromium, and lead from these sediments. The concentration of manganese in the test water was 4.1 μg/l. The 5 percent oxic test showed greater manganese release than was seen in the 20 percent oxic tests; the concentrations were 1920 and 507 μg/l, respectively. Releases of lead and chromium were slight. In the case of mercury, slight uptake was seen in the 5 percent test and slight release was seen in the 20 percent test.

Table 370

General Physical and Chemical Parameters: Morgan's Point Elutriate Tests

Sample Designation	Dissolved Oxygen (mg/l @ °C)			pH	Turbidity (NTU)	Specific Conductance (μmhos/cm @ 25°C)	Salinity (°/oo)
	Initial	After Mixing	After Settling				
Site Water	11.6@7.5°	-	-	7.5	28	7,125	4
5% Oxic	-	9.9@15.0°	9.6@16.0°	8.0	120	7,300	4
20% Oxic*	-	9.0@14.5°	5.3@17.0°	8.0	7	8,960	5

Dash (-) indicates not applicable.

*Sample centrifuged to reduce turbidity.

Table 371

Soluble Heavy Metal Concentrations: Morgan's Point

Elutriate Tests
(μg/l)

Sample Designation	Mn		Cd		Cr		Zn		Ni		Pb		Cu		Fe		Hg	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Site Water	4.1	-	0.3	-	< 2.0	-	14.9	-	2.6	-	< 1.0	-	1.3	-	11.6	-	0.041	-
5% Oxic	1920	103	< 0.3	∿0	5.0	4.2	15.6	2.4	4.0	0.8	< 1.0	∿0	< 1.0	∿0	3.4	2.1	0.028	-
20% Oxic	507	7	< 0.3	∿0	6.0	2.8	14.8	1.3	1.6	-	1.3	0.3	< 1.0	∿0	1.5	0.6	0.086	-

Mean and standard deviation calculated from duplicate determinations.

Dash (-) indicates that standard deviation could not be computed.

Nitrogen Compounds

Morgan's Point sediment had a total Kjeldahl nitrogen concentration of 1500 mg N/kg. The elutriate test results in Table 372 show that nitrate concentrations decreased slightly in both elutriates. Ammonium release was again found to be a function of the percent sediment in the total elutriate volume. Due to the centrifugation step, the organic N data do not represent the total concentrations.

Phosphorus Compounds

The soluble orthophosphate and total phosphorus concentrations found in the Morgan's Point elutriates are presented in Table 373. The sediment total P concentration was 706 mg/kg dry weight. The site water contained the highest concentrations of soluble orthophosphate and total phosphorus of all Galveston Bay area sampling locations. Elutriate tests showed decreases in soluble orthophosphate concentrations in both the 5 and 20 percent elutriates. Total phosphorus concentrations in both elutriates were also lower than that in the site water.

Bioassays

Table 374 presents the physical and chemical characteristics of the Morgan's Point bioassay elutriates following the one-hour settling period. Examination of the table reveals that the D.O. concentrations decreased and total ammonium and turbidity levels increased. Total ammonium increased with increasing sediment percentages (increases of 1.3, 2.9, and 3.6 mg N/l in the 5, 10, and 20 percent sediment tests, respectively). Increases in turbidity ranged from 20 to 70 NTU with the highest turbidities observed in the 5 percent sediment tests. Dissolved oxygen decreases corresponded to increased sediment percentages with a decrease of over 5 mg/l in the 20 percent sediment tests. Table 374 also presents release data for manganese. The results show release of manganese (the only heavy metal for which release was monitored) to each bioassay elutriate with over 1 mg/l of manganese

Table 372

Nitrogen Compound Concentrations: Morgan's Point Elutriate Test* with One-Hour Settling

(mg N/1)

Sample Designation	Organic N		Ammonium		Nitrate	
	$\bar{X}$	SD**	$\bar{X}$	SD**	$\bar{X}$	SD†
Site Water	0.84	0.81	1.2	0.01	0.38	0.01
5%	0.98	0.66	1.86	0.06	0.27	0.01
20%	<0.05	0.91	4.23	0.11	0.26	0.01

*Samples centrifuged prior to analysis. Consequently, values do not represent totals.

**Standard deviation calculated from duplicate analyses.

†Standard deviation calculated from triplicate analyses.

Table 373

Soluble Orthophosphate and Total Phosphorus Concentrations: Morgan's Point Elutriate Tests

(mg P/1)

Sample Designation	Soluble Ortho P		Total Phosphorus	
	$\bar{X}$	SD	$\bar{X}$	SD
Site Water	0.57	0.004	0.86	0.01
5% Oxic	0.13	0.01	0.20	0.005
20% Oxic*	0.095	0.001	0.21	0.01

Mean and standard deviation calculated from duplicate or triplicate analyses of one sample.

*Elutriates were centrifuged @ 5000 rpm for 5 minutes prior to analysis.

Table 374

Chemical and Physical Characteristics: Morgan's Point Bioassay Elutriates

Sample Designation	pH	D.O. (mg/@ 20.5°C)	Spec.Cond. (µmhos/cm @ 20.5°C)	Total Ammonium (mg N/l)	Unionized Ammonia* (mg N/l)	Turbidity (NTU)	Mn** (µg/l)
Control A	8.1	7.2	35,000	0.04	< 0.01	2	5
B	8.1	7.2	35,000	0.04	< 0.01	2	5
5% A	7.9	5.5	38,200	1.33	0.04	60	747
B	7.9	5.5	38,300	1.33	0.04	70	300
10% A	7.7	2.3	38,000	2.97	0.06	42	470
B	7.7	2.4	37,900	2.97	0.06	42	731
20% A	7.7	1.9	37,000	3.64	0.07	21	1059
B	7.7	2.0	36,900	3.64	0.07	20	959

A and B are replicates.

Measurements taken after the one hour settling period.

*For all bioassay elutriates, unionized ammonia calculated from Skarheim's[9] tables for fractions of ammonia in undissociated form.

**The only heavy metal for which release was monitored was manganese.

released in 20 percent sediment elutriates.

The results of the acute toxicity 96-hour Morgan's Point elutriate bioassays using P. pugio are presented in Table 375. The data show increased toxicity to P. pugio with increasing sediment percentages for the 96-hour test period. The percentages of grass shrimp dead after 96 hours in the 5, 10, and 20 percent sediment elutriates were 10, 20, and 35 percent, respectively. The toxicity associated with sediments from Morgan's Point were some of the highest observed for sediments sampled within the HSC.

Table 375

Response of P. pugio to Varying Sediment Percent of Total Elutriate Volume as a Function of Time: Morgan's Point Bioassay Elutriates

Time (hr)	Number of P. pugio Living at Varying Sediment Percentages							
	Control		5%		10%		20%	
	A	B	A	B	A	B	A	B
0	10	10	10	10	10	10	10	10
12	10	10	10	10	9	9	8	8
24	10	10	9	9	8	9	8	8
36	10	10	9	9	8	8	7	8
48	10	10	9	9	8	8	7	8
60	10	10	9	9	8	8	7	8
72	10	10	9	9	8	8	7	8
84	10	10	9	9	8	8	7	7
96	10	10	9	9	8	8	7	6

A and B are replicates.

Port Lavaca

A sediment sample collected in Cox Bay near Port Lavaca was taken for elutriate test studies. The primary purpose for sampling sediments in this area was a reported high concentration of mercury in this region. The water and sediment samples were collected in Cox Bay, Texas. The sampling site, illustrated in Figure 114, was near the junction of two ship channels and approximately 50 yards from an island formed by disposal of dredged material. Sediment samples collected with an Ekman dredge were placed and sealed in polyethylene containers. A 13-gallon sample of surface water was obtained at the same site using a plastic bucket. A sample of water was obtained six inches off the bottom (1.5 m depth) using a horizontal, metal-free Van Dorn sampler. All samples were kept on ice, transported to the UTD laboratory, and stored at 4°C. They were subjected to elutriate tests.

General Sediment Characteristics and Oxygen Demand

The sediment from Port Lavaca was found to be 36.6 percent clay, 23.9 percent silt, and 39.5 percent sand. It was analyzed in triplicate for sulfide concentration and percent dry weight. The oxidation reduction potential (Eh) was found to be -40 mv. The mean sulfide content was found to be 116 mg/kg, with a standard deviation of 7. The mean percent dry weight was found to be 44.6 percent with a standard deviation of 1.3.

The oxygen demand of a 5 cc sample of Port Lavaca sediment was determined. Table A33 , Appendix A , shows that the standard deviations between runs indicated good reproducibility. The uptake during the first hour for a cubic meter of sediment was calculated to be 2.5×10^2 g O_2, while the uptake per gram dry weight was 0.42 mg O_2 for the same time period. The plot of the log of the D.O. versus time is seen in Figure 115. The slope of the fast component was calculated to be -0.027 mg/l min^{-1}; the slow component slope was -0.004 mg/l min^{-1}.

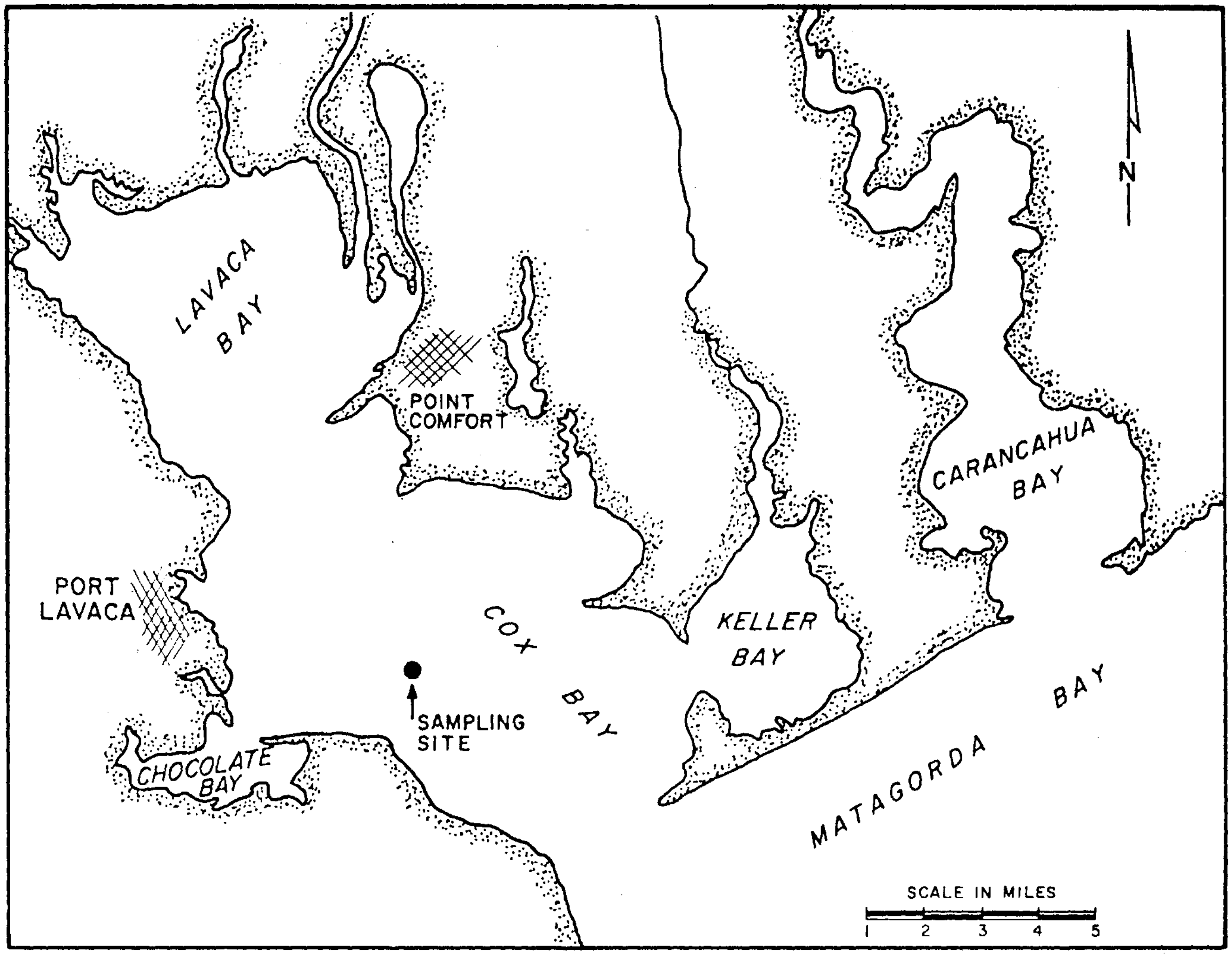

Figure 114
Port Lavaca Sampling Location

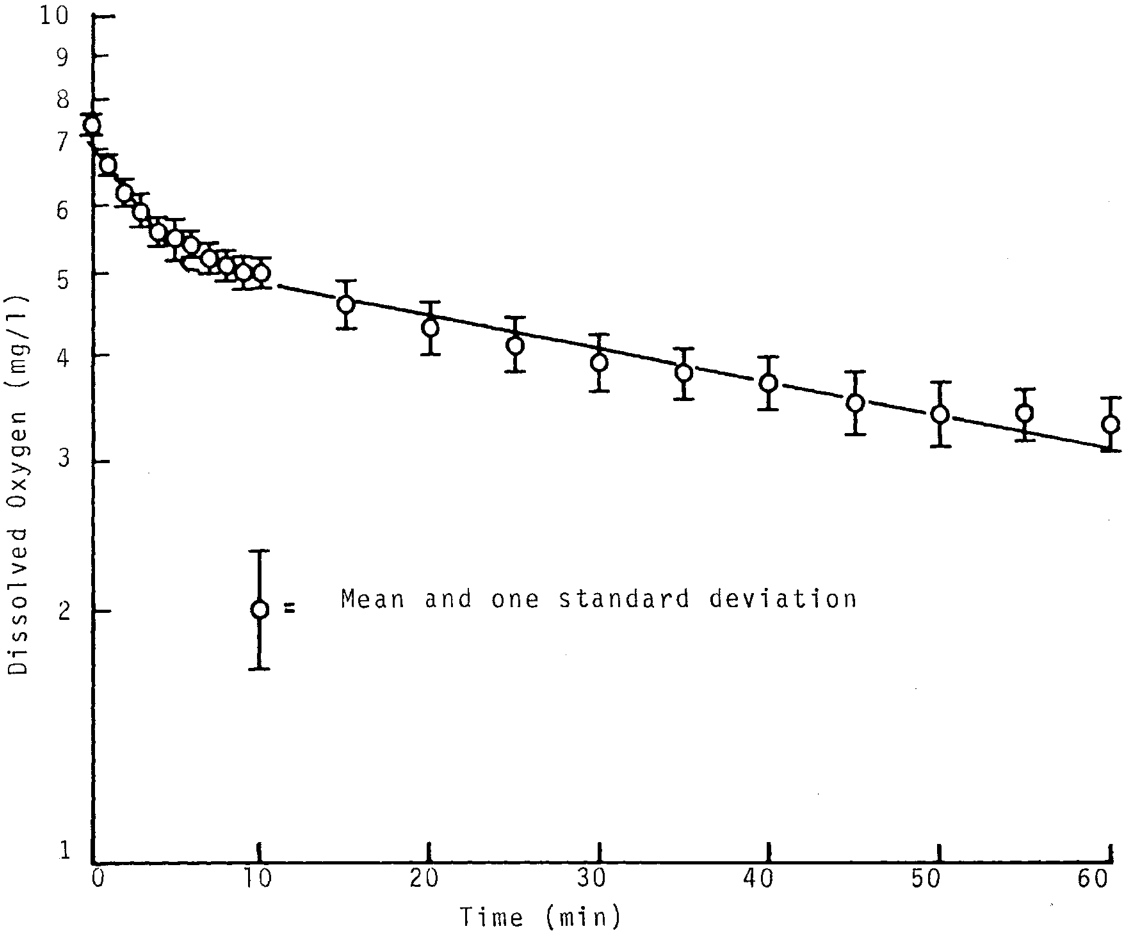

Figure 115
Oxygen Demand Test: Port Lavaca Sediment

Elutriate Test General Parameters

Single 5 percent and 20 percent oxic elutriate tests were run in addition to duplicate 5 percent anoxic/oxic and duplicate 20 percent anoxic/oxic tests. These anoxic/oxic tests all were subjected to 20 minutes of oxygen-free nitrogen gas mixing followed by 10 minutes of compressed air mixing. To determine effects of sediment and water sample storage on elutriate test results, a single 20 percent oxic elutriate test on the sediment and water samples was run 54 days after collection. During the storage period sediment and water samples were kept in the dark at 4°C.

The general physical and chemical parameters data from the Port Lavaca elutriate tests are presented in Table 376. The patterns of D.O. concentrations during the elutriate tests indicated that the oxygen demand of this sediment was not high. The 20 percent elutriate had only a slightly lower D.O. than the 5 percent. Both the 5 percent and 20 percent anoxic/oxic elutriates generally had high D.O. concentrations (after settling) even though they had been aerated only 10 minutes. The D.O. of the 20 percent anoxic/oxic replicate B elutriate was lower than the others after air mixing and decreased to 1.5 mg/l after settling. This inconsistency may have been related to differences in intensities of air mixing or in homogeneity of sediments used in replicate tests. The pH values in the elutriates were generally within 0.1 units of the site water pH. The turbidity values of the elutriates were all greater than that of the site water and ranged from 42 to 110 NTU. Reproducibility of this parameter in duplicate (generally a function of decantation technique) tests was moderately good.

The specific conductance increased as a result of elutriation under all conditions tested and showed, in general, good replication in all duplicate tests. The increase was less in the 5 percent oxic elutriate than in the others.

Table 376

General Physical and Chemical Parameters: Port Lavaca Elutriate Tests

Sample Designation and Date Performed (1975)	Dissolved Oxygen (mg/l @ °C)				pH	Turbidity (NTU)	Specific Conductance (μmhos/cm @ 25°C)	Salinity (°/oo)
	Initial	After Mixing		After Settling				
		N_2	Air					
July 25:								
Site water	8.1@ 6.0°	-	-	-	8.4	17	14,340	8.3
5% Oxic	9.5@ 9.0°	-	11.4@11.0°	9.9@14.0°	8.1	89	15,000	8.5
20% Oxic	7.3@ 8.5°	-	9.7@11.0°	7.3@14.5°	8.3	42	17,110	10
5% Anoxic/Oxic								
A	9.8@10.0°	1.3@11.5°	9.5@12.0°	8.8@15.0°	8.3	110	17,170	10
B	7.5@12.5°	0.7@14.5°	8.6@14.0°	8.1@16.0°	8.5	44	17,020	10
20% Anoxic/Oxic								
A	7.9@ 9.0°	<0.5@11.5°	8.7@12.0°	7.5@14.0°	8.4	68	17,220	10
B	2.1@12.0°	1.0@13.5°	5.0@14.0°	1.5@15.5°	8.5	47	16,830	9.5
September 8:								
Site water	9.9@20.0°	-	-	-	8.1	2	16,700	9.5
20% Oxic	4.8@20.3°	-	9.2@20.5°	5.0@21.0°	8.4	62	16,800	9.5

A and B are replicates.

Dash (-) indicates not applicable.

Salinity, being derived from the specific conductance values, followed the same pattern.

After the 54-day storage period, the site water showed a slightly lower pH and turbidity but a higher specific conductance value. The difference in site water specific conductance values before and after storage may have been related to the different temperatures at which the sample had been measured. Although both values were corrected to 25°C, the error involved in such a correction was probably greater in the pre-storage site water samples (measured at 6°C) than in the water measured (at 20°C) after storage. In the 20 percent oxic elutriate test run after storage, the D.O. after settling was about 2 mg/l less than in the corresponding pre-storage tests. In general, for the other parameters, values found for the later tests were comparable to those found for the earlier tests.

Heavy Metals

Table 377 contains the results of trace heavy metal analysis of the Port Lavaca sediment and water samples. The sediments of this area had been reported to contain relatively high mercury levels, possibly stemming from leakage from chloroalkali cells in a nearby aluminum plant. The mercury concentration found in this sediment was 0.075 mg/kg, which was lower than the concentrations found in Texas City Channel (0.5 mg/kg Hg) and much lower than those seen in the San Francisco sediments analyzed in this study (∿1.4 mg/kg). The zinc content of the Port Lavaca sediment (75 mg/kg) was equivalent to the proposed criterion for determining acceptability of dredged sediments, but concentrations of all other metals were below the criteria.[10]

Dissolved and total available trace heavy metal concentrations were determined for the Port Lavaca Bay water sample taken immediately overlying the sediment. These levels

Table 377

Soluble Heavy Metal Concentrations: Port Lavaca Sediment and Water Samples

Metal	Sediment (mg/kg)		Bottom Water (mg/l)				Surface Water (mg/l)	
			Soluble		Total		Soluble	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Manganese	417	22	50	-	120	-	90	-
Cadmium	< 1	0	1.7	0.1	1.9	0.4	1.0	-
Chromium	20	12	< 2	-	< 2	-	< 2	-
Zinc	75	33	30.1	4.2	56.4	12.7	17.7	-
Nickel	13	5	7.2	0	7.1	1.6	2.6	-
Lead	12	2	3.0	0.2	7.7	0.8	2.4	-
Copper	9.5	2.0	4.8	0.3	8.5	0.6	4.0	-
Iron*	21.0	1.0	19.4	0.9	424	9	21.1	-
Mercury	0.075	0.010	0.062	0.002	0.091	0.006	0.016	0.002

Mean and standard deviation calculated from duplicate analyses.

Dash (-) indicates SD cannot be computed.

*Iron sediment concentration in g/kg.

are compared to corresponding dissolved metal concentrations in surface water in Table 377. Dissolved available metals occurred in greater concentration near the bottom than near the surface. Notably, nickel, zinc, and mercury concentrations were several times higher near the bottom than in the surface water. The increased concentrations at the sediment-water interface could be the result of mobility of metal components between these two areas.

Relatively high mercury concentrations were found in the bottom water. Total mercury was 0.091 μg/l and dissolved mercury 0.062 μg/l. It has been established that mercury concentrations equal to or exceeding 0.10 μg/l constitute a hazard in the marine environment. Total available manganese and iron in the bottom water also exceeded established potentially harmful levels. Zinc concentrations were below the hazardous level (100 μg/l) but substantially higher than the level presenting minimal deleterious effects (20 μg/l) according to NAS-NAE.[33]

Trace heavy metal concentrations for Port Lavaca elutriate tests are presented in Table 378. Significant increases in manganese concentrations were observed in all elutriates. Manganese release was greater, on the average, in tests with 20 percent sediment content than in those with five percent sediment content. In addition, the average release of manganese was greater in the systems partially treated with nitrogen gas than in those that were aerated only. The highest manganese concentration occurred in 20 percent anoxic/oxic replicate B, coinciding with the lowest D.O. concentration found during these elutriate tests.

Very small, statistically significant increases in lead and nickel appear to have occurred. Iron concentrations in the elutriates showed considerable scatter around the site water value (25 μg/l). Iron release (159 μg/l) was

Table 378

Soluble Heavy Metal Concentrations: Port Lavaca Elutriate Tests

Sample Designation	Mn		Cd		Cr		Zn		Ni		Pb		Cu		Fe		Hg	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Site Water	90	~ 0	1.0	-	< 2	-	17.7	-	2.6	-	2.4	-	4.0	-	25.1	-	0.016	0.002
5% Oxic	450	~ 0	1.0	0.2	< 2	-	19.4	1.9	4.7	0.4	5.9	0.6	3.7	0.2	74.4	23	0.019	0.009
20% Oxic	550	~ 0	0.8	0.1	< 2	-	18.0	2.0	4.5	0.3	6.6	0	3.2	0.2	22.3	1.3	0.037	0.013
5% Anoxic/Oxic																		
A	450	~ 0	1.2	0.1	< 2	-	20.4	4.1	4.7	0	5.0	0.6	3.7	0.7	159.3	3.9	0.033	0.011
B	600	~ 0	1.0	0.1	< 2	-	17.3	0.6	3.7	0.1	5.6	0.2	2.6	0.1	40.1	7.5	0.007	0.006
20% Anoxic/Oxic																		
A	610	~ 0	1.0	0.2	< 2	-	16.2	0.4	5.6	1.0	5.7	0.4	3.6	0.1	38.2	0.7	0.017	0.002
B	980	~ 0	0.8	0	< 2	-	18.5	1.8	2.6	0	3.9	0.9	1.9	0.4	20.8	2.1	0.015	0.000

A and B are replicates.

Mean and standard deviation calculated from duplicate analyses.

Dash (-) indicates SD cannot be computed.

apparently significant only in 5 percent anoxic/oxic replicate A. No statistically significant differences occurred between the concentrations of mercury, zinc, chromium, and copper in the various elutriates and corresponding concentrations in the site water.

Nitrogen Compounds

Port Lavaca samples and elutriates were analyzed to determine the relative release of nitrogen compounds under oxic and anoxic/oxic conditions. The ammonium and organic N concentrations for this sediment were 19 and 243 mg N/kg, respectively. This Port Lavaca sediment nitrogen content was low compared to that of other sediments studied.

Table 379 presents the results of nitrogen analyses of Port Lavaca elutriate tests. Duplicate analyses showed a tendency for higher release of ammonium and organic N in higher sediment volume tests, although reproducibility was not good. Nitrate was released in the 5 percent elutriates with higher release under oxic conditions. However, no clear patterns of release could be ascribed to these variations in the aeration procedure.

The nitrogen data for the later tests (also presented in Table 379) show that ammonium and organic N concentrations increased from site water levels, though nitrate did not show any change. Ammonium release was comparable to that observed in the earlier test, but nitrate release was much higher in the later test. Organic N concentrations, which were highest in the 20 percent oxic elutriate in the earlier test, showed removal in the later test.

Phosphorus Compounds

Soluble orthophosphate and total phosphorus concentrations in Port Lavaca elutriates from tests run both before and after sample storage are presented in Table 380 . The Port Lavaca sediment had a total phosphorus concentration

Table 379

Nitrogen Compound Concentrations: Port Lavaca Elutriate Tests

(mg N/l)

Sample Designation and Date Performed (1975)	Organic N		Ammonium		Nitrate	
	$\bar{X}$	SD*	$\bar{X}$	SD*	$\bar{X}$	SD**
July 25:						
Site Water	0.46	0.02	<0.05	∿0	<0.04	∿0
5% Oxic	0.23	0.06	0.81	0.02	0.38	0.01
5% Anoxic/Oxic						
A	0.34	0.09	0.78	0.01	0.28	0.01
B	0.67	0.07	1.53	0.07	0.07	0.01
20% Oxic	0.98	0.13	1.98	0.05	<0.04	0.01
20% Anoxic/Oxic						
A	0.66	0	1.54	0	0.05	0.01
B	0.80	0.03	3.28	0.01	<0.04	∿0
September 8:						
Site Water	0.86	0.15	0.10	-	<0.04	0.01
20% Oxic	0.05	∿0	1.95	-	0.12	0.01

A and B are replicates.

*Mean and standard deviation calculated from duplicate analyses.

**Mean and standard deviation calculated from triplicate analyses.

Dash (-) indicates single analysis with no standard deviation.

Table 380

Soluble Orthophosphate and Total Phosphorus Concentrations: Port Lavaca Elutriate Tests

(mg P/l)

Sample Designation	Soluble Ortho P		Total P	
	$\bar{X}$	SD	$\bar{X}$	SD
July 25:				
Site Water	0.023	0.001	0.06	0.01
5% Oxic	0.082	0.001	0.20	0.016
20% Oxic	0.058	0	0.38	0.028
5% Anoxic/Oxic				
A	0.26	0.005	0.24	0.017
B	0.10	0.002	0.15	0.03
20% Anoxic/Oxic				
A	0.086	0.003	0.20	0
B	0.12	0	0.27	0.007
September 8:				
Site Water	0.080	0	0.09	0.009
20% Oxic	0.095	0.002	-	-

A and B are replicates.

Mean and standard deviation calculated from triplicate analyses of one sample.

Dash (-) indicates no analysis made.

comparable to those found in the GBEC. It contained 263 mg P/kg dry weight (standard deviation of 6 mg P/kg).

Table 380 shows that soluble orthophosphate concentrations increased as a result of elutriation under the conditions tested. In the tests run prior to storage, the increase was greater in the 5 percent oxic than in the 20 percent oxic test. This may have been related to the differences in settling as seen in the turbidity values, the 5 percent elutriate having a greater turbidity than the 20 percent elutriate (See Table 370).

The tests run under anoxic/oxic conditions tended to show somewhat greater release than those run under oxic conditions. The soluble ortho P concentration in one 5 percent anoxic/oxic elutriate was almost three times greater than that in the others, but reproducibility was better in the 20 percent anoxic/oxic tests.

During the 54-day storage period the site water soluble orthophosphate concentrations appear to have risen nearly four-fold. The concentration in the 20 percent oxic elutriate run after storage was more than 1.5 times that of the corresponding test run earlier.

Total phosphorus concentrations in the Port Lavaca elutriates are also presented in Table 380. Total P concentrations increased to about the same level (generally to between 0.15 and 0.27 mg P/l) under the elutriate test conditions employed. The 20 percent oxic elutriate had a slightly higher concentration (0.38 mg P.l) than the rest. In general, the elutriate total P concentration did not appear to be closely related to the turbidity value of the elutriates, although the elutriate turbidities all fell within a fairly narrow range. The soluble orthophosphate fraction of the total phosphorus concentrations was not a constant factor in these elutriates. As expected, the storage of the site water did not appear to affect its total P content.

Bioassays

Port Lavaca bioassays were started July 28, 1975. Table 381 shows the chemical characteristics of the Port Lavaca bioassay elutriates following the one-hour settling period. Examination of the table reveals that the D.O. concentrations decreased and total ammonium and turbidity levels increased. Total ammonium increased with increasing sediment percentages (increases of 0.7, 0.9, and 1.5 mg N/l in the 5, 10, and 20 percent sediment tests, respectively). Increases in turbidity ranged from 20 to 36 NTU in the elutriate. Dissolved oxygen decreases corresponded to increased sediment percentages, with a decrease of over 5 mg/l in the 20 percent sediment tests.

Table 382 shows the concentrations of D.O. in these elutriates over the 96-hour test period. The data show that the daily one-hour aeration period was sufficient to keep D.O. above 4 mg/l throughout the 24-hour aeration period.

The results of the metal analyses for the bioassay elutriates are presented in Table 383. Manganese, iron, cadmium, lead, zinc, and mercury were released to the elutriates. Manganese levels were 10, 20, and 30 times greater than the control concentrations in the 5, 10, and 20 percent sediment tests, respectively. Iron release was from 20 to 50 times that of the controls. Small amounts of cadmium, lead, zinc, and mercury were also released to the bioassay elutriate waters. Copper was removed from solution, and chromium and nickel did not change.

The results of the acute toxicity 96-hour Port Lavaca elutriate bioassays using P. pugio are presented in Table 384. The data show no acute lethal effects for the Port Lavaca bioassay elutriates.

Table 381

Chemical and Physical Characteristics : Port Lavaca Bioassay Elutriates *

Sample Designation	pH	D.O. (mg/l @ 16.0-17.1°C)	Spec. Cond. (μmhos/cm @ 16.0-17.1°C)	Total Ammonium (mg N/l)	Unionized** Ammonia (mg N/l)	Turbidity (NTU)
Control A	8.2	7.4	37,000	0.05	< 0.01	1.2
B	8.2	7.4	36,500	0.005	< 0.01	0.4
5% A	8.2	5.2	36,100	0.74	0.04	33
B	8.2	5.5	35,900	0.79	0.04	36
10% A	8.2	2.9	37,000	0.95	0.04	34
B	8.2	2.5	35,400	1.00	0.05	26
20% A	8.2	2.5	36,000	1.62	0.07	27
B	8.2	2.2	36,000	1.58	0.07	26

A and B are replicates.

*Measurements taken after the one-hour settling period.

**For all bioassay elutriates, unionized ammonia calculated from Skarheim's[9] tables for fractions of ammonia in the undissociated form.

Table 382

Dissolved Oxygen Concentrations Over Test Period: Port Lavaca Bioassay Elutriate

(mg/l @ 16.1 - 18.5°C)

Time	Control		Percent of Sediment of Total Elutriate Volume					
			5%		10%		20%	
(hr)	A	B	A	B	A	B	A	B
0	7.5	7.5	5.2	5.5	2.9	2.5	2.5	2.2
1*	7.4	7.4	6.6	6.9	6.9	7.0	6.7	6.7
24	7.1	7.1	6.4	6.8	6.5	6.5	6.6	6.4
48	6.9	6.9	5.4	5.9	5.5	5.5	5.3	5.4
72	6.0	5.7	6.3	6.8	6.9	6.9	6.7	6.7
96	6.7	6.6	6.2	6.5	6.7	6.3	6.4	6.1

A and B are replicates.

*Measurements taken after first hour of aeration.

Table 383

Release of Heavy Metals: Port Lavaca Bioassay Elutriates

(μg/l)

Sample Designation	Mn	Cd	Cr	Zn	Ni	Pb	Cu	Fe	Hg
Control A	50	<0.3	<2.0	18.0	12.2	1.2	6.2	3.5	<0.001
B	50	<0.3	<2.0	18.0	12.2	1.2	6.2	3.5	<0.001
5 percent A	580	0.7	<2.0	29.0	8.1	4.6	4.7	102	0.011
B	600	1.2	<2.0	17.0	11.4	3.7	4.8	93	0.004
10 percent A	1030	1.1	<2.0	27.0	20.7	7.3	4.9	81	0.005
B	1090	0.8	<2.0	25.0	7.2	5.7	6.1	93	0.021
20 percent A	1770	1.3	<2.0	28.0	14.0	4.8	4.9	178	0.015
B	1550	1.2	<2.0	28.0	9.3	3.8	3.9	107	0.007

A and B are replicates.

Table 384

Response of P.pugio to Varying Sediment Percent of Total Elutriate Volume as a Function of Time: Port Lavaca Elutriates

Time (hr)	Number of P. pugio Living at Varying Sediment Percentages							
	Control		5%		10%		20%	
	A	B	A	B	A	B	A	B
0	10	10	10	10	10	10	10	10
12	10	10	10	10	10	10	10	10
24	10	10	10	10	10	10	10	10
36	10	10	10	10	10	10	10	10
48	10	10	10	10	10	10	10	10
60	10	10	10	10	10	10	10	10
72	10	10	10	10	10	10	10	10
84	10	10	10	10	10	10	10	10
96	10	10	10	10	10	10	10	10

A and B are replicates.

Chlorinated Hydrocarbons in Aquatic Organisms

In order to investigate whether or not aquatic organisms inhabiting an area that has been extensively used for dredged material disposal accumulate excessive amounts of chlorinated hydrocarbon pesticides and PCBs, a series of biological samples was collected in late November, 1975, by trawling within the GBEC Disposal Site. These samples included nine species of fish, a group of mixed fish (considered to be predators) and a group of miscellaneous invertebrates including squid, crabs and polychaetes. The names, number and ranges of total lengths of each group of organisms are listed in Table 385. All nine species of fish were identified, and the white shrimp were tentatively identified as Penaeus setiferous. The rest of the invertebrates were not identified. All samples were wrapped in aluminum foil and frozen at -10°C shortly after sampling.

Due to shortage of funds, only three samples have been analyzed thus far for the chlorinated hydrocarbon pesticides and PCBs under investigation in the sediment and water collected from the area. The rest of the samples are under investigation by A. Jung, a graduate student in the Environmental Sciences Program. The three samples analyzed include a single spotfish, identified as Leiostomus xanthurus, with a total length of 15.2 cm, three small fish (unidentified predators) with total lengths of 2.5, 3.6 and 7.6 cm and two white shrimp with total lengths of 5.1 and 7.6 cm. The spot fish weighed 57.3 g (whole organism). The three small fish all weighed 9.3 g and the two white shrimp weighed 23.9 g (without the exoskeleton). A single analysis was performed on the spot, a composite of the small fish, and composite of the two white shrimp. Each sample was thoroughly ground and mixed with anhydrous sodium sulfate to dehydrate the sample. The dehydrated samples

Table 385

List of the Biological Samples* Collected from the Galveston Bay Entrance Channel Disposal Site , November, 1975

Organism*	Number	Range of Total Length (cm)
Atlantic croaker (*Micropogon undulatus*)	28	2.5-15
Anchovy (*Anchoa mitchilli*)	300+	5 - 6
Bumper (*Chloroscombrus chrysurus*)	100+	5 - 6
Pompano (*Trachinotus carolinus*)	100+	5 - 6
Fringed flounder (*Etropus crossotus*)	4	5 -10
Spotfish (*Leiostomus xanthurus*)	5	15 -16
Atlantic spadefish (*Chaetodipterus faber*)	8	8 -10
Silver seatrout (*Cynoscion nothus*)	12	5 -20
Tonguefish (*Symphurus civitatus*)	12	8 -10
Crab (unidentified)	20	2.5- 5
White shrimp (*Leiostomus xanthurus*)**	60	5 -15
Pink shrimp (unidentified)	20	2.5- 5
Squid (unidentified)	100	5 -10
Annelids (polychaetes)	10	5 -10
Mixed fish (predators)	100	2 - 7

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*Identified by Dr. T. Waller and A. Jung.

**Tentative identification.

were extracted for four hours with a 50 percent ethyl ether-hexane mixture in a Soxhlet extractor. The chlorinated hydrocarbon pesticides and PCBs were quantified according to procedures previously described in this report.

Electron capture gas chromatograms of the sample extracts indicated the presence of 22 to 26 characteristic peaks of relative retention times (R_r) ranging from 0.3 to 7.9. Fourteen of these peaks were of the same R_r values as those detected in sediment and water from the area. Generally the magnitudes of the peaks were higher in the spotfish extract than in the small fish extract. Peaks of the shrimp extract were the least in magnitude and number. Based on two chromatographic columns detection, lindane, aldrin, dieldrin, DDT and its analogs, 2,4-D esters and mirex were found in all the extracts. Total PCBs determined by chemical derivatization as decachlorobiphenyl were detected in all the samples. Table 386 presents the quantitative results as well as the lower detection limits and the US FDA[34] guidelines for edible portions of fish and shellfish. The table shows that the spot contained aldrin, pp'DDD, pp'DDE and total PCBs at concentration levels of 1.3, 2.7, 1.9 and 95.1 ppb, respectively. The same compounds were present in the small fish at concentration levels of 1.1, 1.9, 3.0, and 35.3 ppb, respectively. In addition, 0.4 ppb lindane was present in the small fish. The sum of the concentrations of pp'DDD and pp'DDE in the spotfish was 4.6 ppb which was comparable to the 4.9 ppb found in the small fish. It was noted that the concentration of the parent pp'DDT compound was below the lower detection limits in both fish. The shrimp did not contain measurable concentrations of any of the chlorinated hydrocarbon pesticides. Total PCBs detected in the shrimp was 6.3 ppb, which was much lower than the levels detected in either of the fish samples. Concentrations of the compounds found in all the samples were well below the US FDA[34] guideline levels for edible portions of fish and shellfish. It

Table 386

Concentrations of Chlorinated Hydrocarbon Pesticides and PCBs in Biological Samples Collected November, 1975, GBEC Disposal Site

(ppb)

Compound	Spot (57.3 g)	Small Fish (Composite of 3) (9.3 g)	White Shrimp (Composite of 2) (23.9 g)*	Lower Detection Limits	US FDA[34] Guideline Levels for Edible Portions
Aldrin	1.3	1.1	< 0.4	0.4	300
Dieldrin	< 0.8	< 0.8	< 0.8	0.8	
op'DDT	< 1.6	< 1.6	< 1.6	1.6	5000
op'DDD	< 2.0	< 2.0	< 2.0	2.0	
op'DDE	< 2.0	< 2.0	< 2.0	2.0	
pp'DDT	< 2.2	< 2.2	< 2.2	2.2	
pp'DDD	2.7	1.9	< 1.5	1.5	
pp'DDE	1.9	3.0	< 1.4	1.4	
Endosulfan I	< 0.9	< 0.9	< 0.9	0.9	NL
Endosulfan II	< 2.0	< 2.0	< 2.0	2.0	NL
Endrin	< 1.2	< 1.2	< 1.2	1.2	300
Heptachlor	< 0.3	< 0.3	< 0.3	0.3	300**
Lindane	< 0.2	0.4	< 0.2	0.2	NL
Methoxychlor	< 3.0	< 3.0	< 3.0	3.0	NL
Total PCBs	95.1	35.3	6.3	6	5000

*Weight after removal of the exoskeleton.
**Including heptachlor epoxide.
NL = No limits.

should be noted that analyses of the spot and small fish were performed on the whole organism.

In summary, these preliminary results indicate the presence of some chlorinated hydrocarbon pesticides and PCBs in three of the biological samples collected from the disposal area shortly after major disposal operations from August to October, 1975. However, the concentrations were below the levels that are considered adverse to the use of these organisms as a human food. The studies being conducted by A. Jung on the remaining samples (collected in November, 1975) will provide additional data to help determine whether or not disposal of dredged GBEC sediments at the GBEC site has a significant adverse effect on the water quality of this region. If the results of the subsequent analyses support those reported here, it can be concluded that there appears to be neither short-term nor long-term significant adverse effect on water quality from these dredging and disposal operations.

Seattle

Characteristics of Sampling Site

A study of the factors influencing the results of the elutriate tests and the relationships between these test results and the actual release during an open water disposal operation was conducted on sediments from the Duwamish River with disposal at Elliott Bay, Puget Sound. The Duwamish River is a highly industrialized waterway which flows through Seattle, Washington, into Elliott Bay (Puget Sound). The situation provided an opportunity to examine in detail elutriate test results for sediments from a highly industrialized area in the Pacific Northwest. Further, since mechanical dredging and barge disposal were employed, there was an opportunity to examine the relationships between the conventional elutriate test and the plop test for open water disposal of estuarine sediments from a barge dumping operation. Another unique characteristic of this study is that the water depth at the disposal site was approximately 60 meters, which was deeper than the depth of any other site investigated in this study.

In addition, one of the most important reasons for studying this area was the PCB spill that occurred when a large electrical transformer fell during an unloading operation in a boat slip adjacent to the Duwamish River water. The transformer broke open, and large amounts of PCBs were released to the water and sediment in the slip. Initially, most of the spilled material was hydraulically removed with a diver-operated dredge. However, some of the PCB materials were incorporated into the surrounding sediments. Due to the tidal currents these PCBs were likely spread both upriver and downriver into Elliott Bay. Both federal and state water pollution and other agencies had expressed concern about the potential effect of dredging the sediments in the waterway on the release of PCBs and water quality.

The Corps of Engineers maintains a navigation channel 17 feet deep in the waterway. Figure 116 contains a general map of the area as well as sampling locations. On February 16, 1976, samples of sediments scheduled to be dredged the next day were obtained from three sites in a portion of the waterway near the Boeing Aircraft airport. Duwamish River Site 1 was at the Corps of Engineers mark 206 + 00, just upstream from the 16th Street bridge. Site 2 was at mark 209 + 00, 300 meters further upstream, and Site 3 was at mark 212 + 00, another 300 meters further upstream but just downstream from the pier of the South Park Marina. The samples were taken with a pipe dredge. Temperature, D.O., and salinity profiles of water samples were also taken at these sites.

A fourth sediment sample was taken with a pipe dredge from Duwamish River Slip No. 1, which is several miles downstream from the 16th Street bridge. This was the site of the major PCB spill the previous year. One sample of surface water and one of water collected with the sediment were taken to study the release of PCBs in the elutriate test.

All samples were placed in 5-gallon polyethylene buckets and iced down. They were air shipped to UTD and placed under refrigeration at 4°C until elutriation. Disposal site water for the elutriate tests came from the bottom waters of Puget Sound and from nearshore surface waters. These waters were found to have identical salinities and were treated as the same water.

Sediment from Duwamish River mark 206 + 00 to 212 + 00 was dredged on February 17 and disposed of at Buoy D in Elliott Bay (see Figure 116). The dredge was a clam shell dredge with a bucket of 11 cubic yards. The dredged material was placed in barges with capacities of 400 to 600 cubic yards. Two of these barges were filled during each run and taken to the dump site. On February 16, two water sample profiles

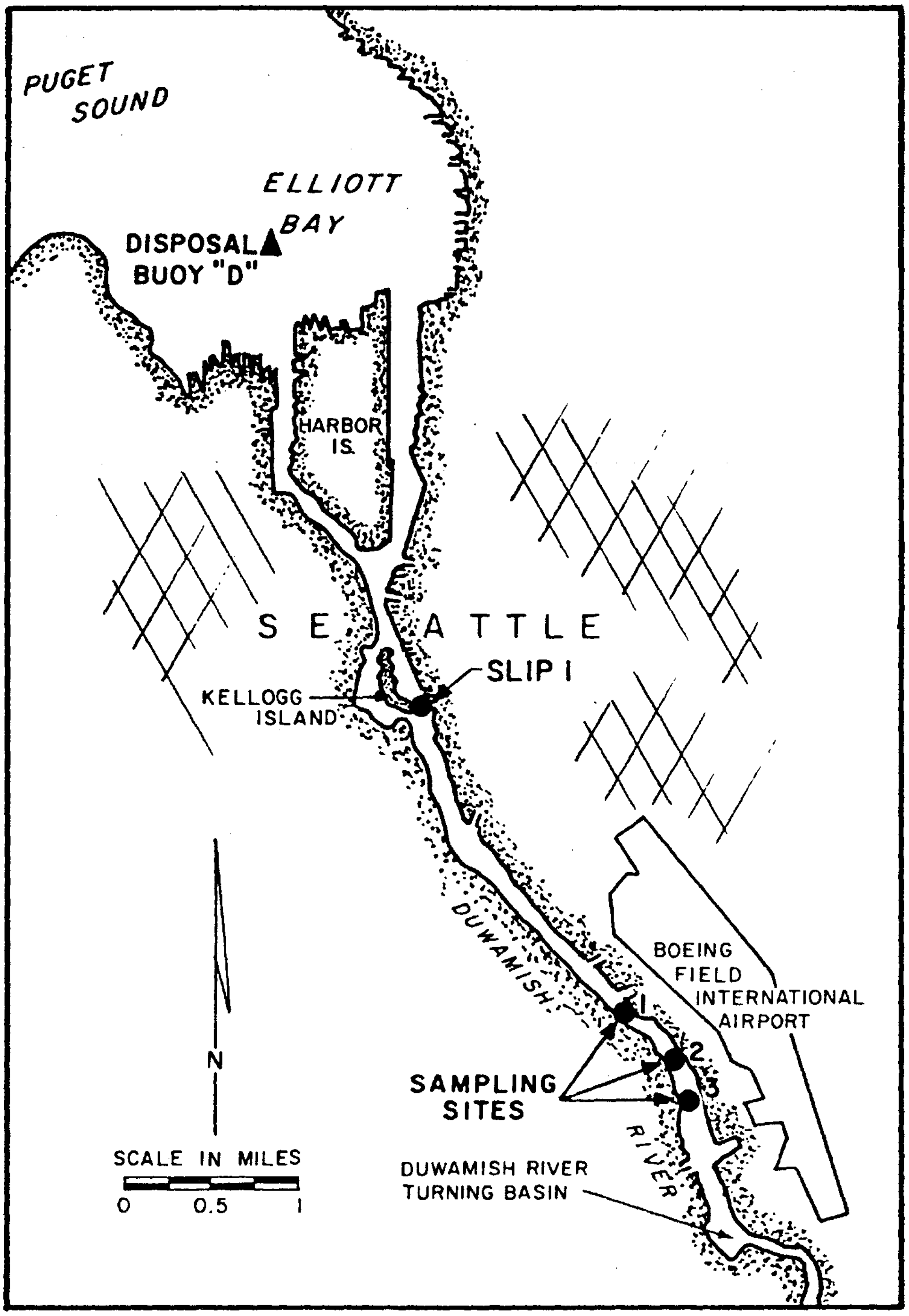


Figure 116
Seattle Sampling Locations

(seven individual samples) and D.O. and temperature profiles were taken above and below the dredge operating in the Duwamish River Turning Basin.

On February 17, there were three disposal operations involving release of material contained in two barges at Buoy D. The first was not monitored except for D.O. data. The other two disposals were labeled Elliott Bay Dumps Nos. 1A, 1B and 2A, 2B in accord with the time sequence in which the barges emptied their holds.

A total of 142 water samples was collected. Sampling lasted from about 30 minutes before the first dump (1A) until 41 minutes after the last dump (2B); the total monitoring time was approximately 4.5 hours. Samples were collected from depths of 1, 30, and 60 meters with Little Giant submersible pumps on plastic hose line. The sampling vessel was a Corps of Engineers 130 foot snag barge named The Puget.

Elutriate and Plop Tests

General Sediment Characteristics and Oxygen Demand

The sediments were analyzed for oxidation-reduction potential (Eh), sulfide concentrations, and percent dry weight. The sample from Site 1 (-54 mv) differed greatly from Sites 2 (-91 mv) and 3 (-111 mv) samples. There was a marked difference noted between Site 1 mean sulfide (13 mg/kg) and Sites 2 and 3 mean sulfide (254 and 247 mg/kg, respectively). The mean percent dry weights also showed a similar trend, 80 percent for Site 1, 57 percent for Site 2, and 60 percent for Site 3 sediments with standard deviations of 0.8, 0.3 and 0.5, respectively. Site 2 sediment contained 9.5 percent clay, 49 percent silt, and 41.5 percent sand. Particle size analyses for Sites 1 and 3 were not done but should have a similar composition as they were taken fairly near Site 2.

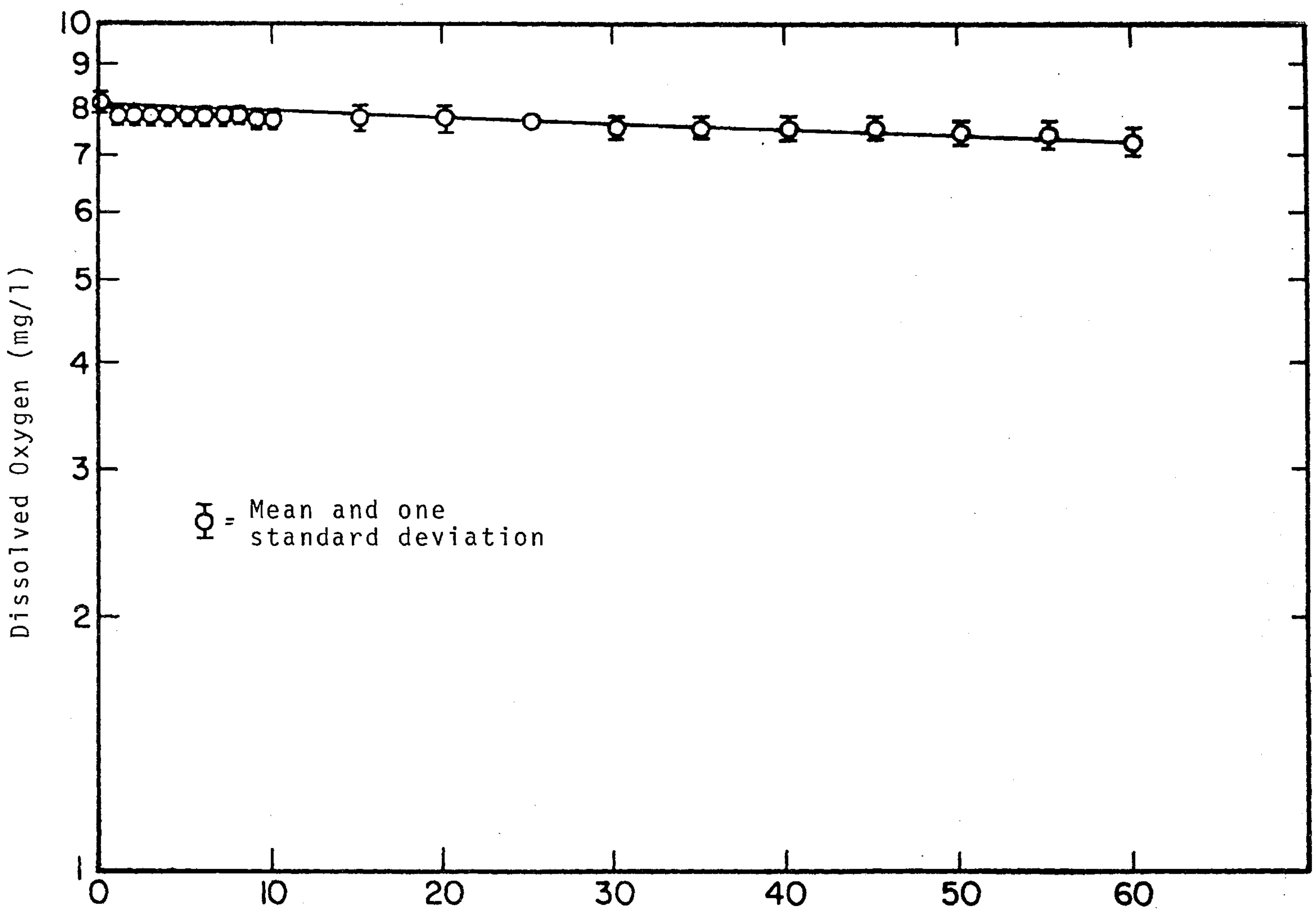
The oxygen demand test was performed on all three Duwamish sediment samples. Table A34, Appendix A shows the results of the Site 1 sediment triplicate runs. The standard deviation ranged between 0.1 and 0.3, indicating good reproducibility. Figure 117 presents the plot of the data. The slope of the line formed was -0.001 mg/l min^{-1} for the first hour. The sample from Site 1 showed a low uptake over a one-hour period. The uptake for the first hour per cubic meter was calculated to be 42 g O_2 m^3 and 0.03 mg O_2/dry weight.

The samples from Duwamish Sites 2 and 3 showed similarities, as can be seen in Tables A35 and A36. The uptake for a cubic meter in the first hour was 5.2 x 10^2 g O^2 for Site 2 sediment and 5.7 x 10^2 g O_2 for Site 3 sediment. The uptake for the same time period per dry weight was 0.64 mg O_2 for Site 2 and 0.62 mg O_2 for Site 3 sediment. The slopes of the fast and slow components from the plots of the samples from Sites 2 and 3 were also similar, as can be seen in Figures 118 and 119. The slope of the fast components for one hour were -0.030 mg/l min^{-1} for Site 2 and -0.033 mg/l min^{-1} for Site 3. In the first hour, the slopes for the slow components were -0.006 mg/l min^{-1} for Site 2 and -0.007 mg/l min^{-1} for Site 3.

Elutriate Test General Parameters

Duplicate 5 percent oxic, 20 percent oxic, and 20 percent anoxic elutriate tests were run on Sites 1 and 2 sediments and disposal site water. Site 1 elutriate tests used site water 1 and Site 2 tests used site waters 1 and 2 (taken at the same place at the same time). In addition to the single 5 percent oxic, 20 percent oxic, and 20 percent anoxic elutriate tests run on Site 3 sediment, a 20 percent plop test (12 liter total volume) was also run. All Site 3 elutriate tests used site water 2.

Duplicate elutriate tests run on Duwamish River Site 1 sediment showed good reproducibility for the general physical and chemical parameters measured (Table 387). The



Time (min)

Figure 117

Oxygen Demand Test: Duwamish River Site 1

(Sample Size - 3 cc)

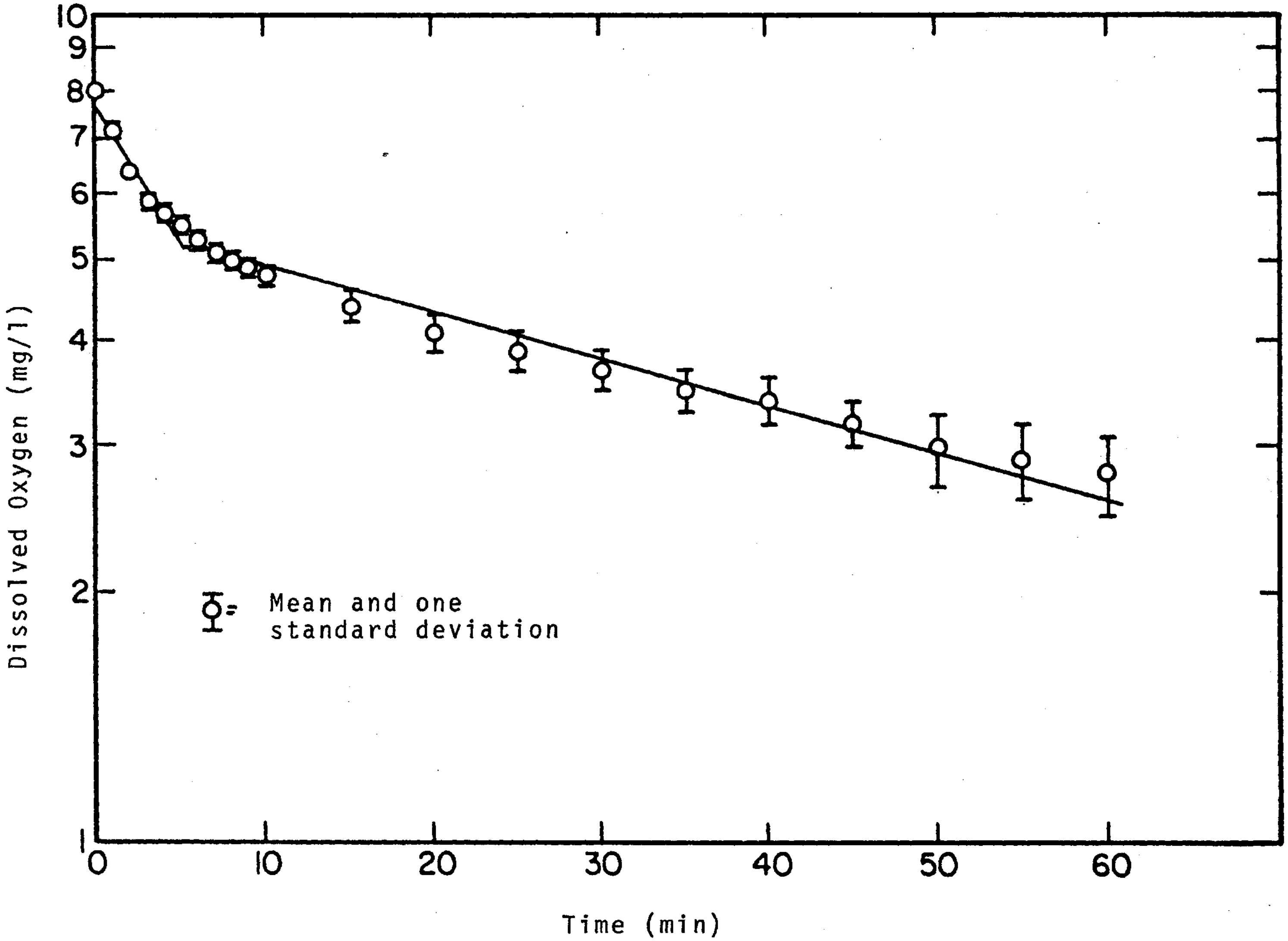


Figure 118

Oxygen Demand Test: Duwamish River Site 2

(Sample Size - 3 cc)

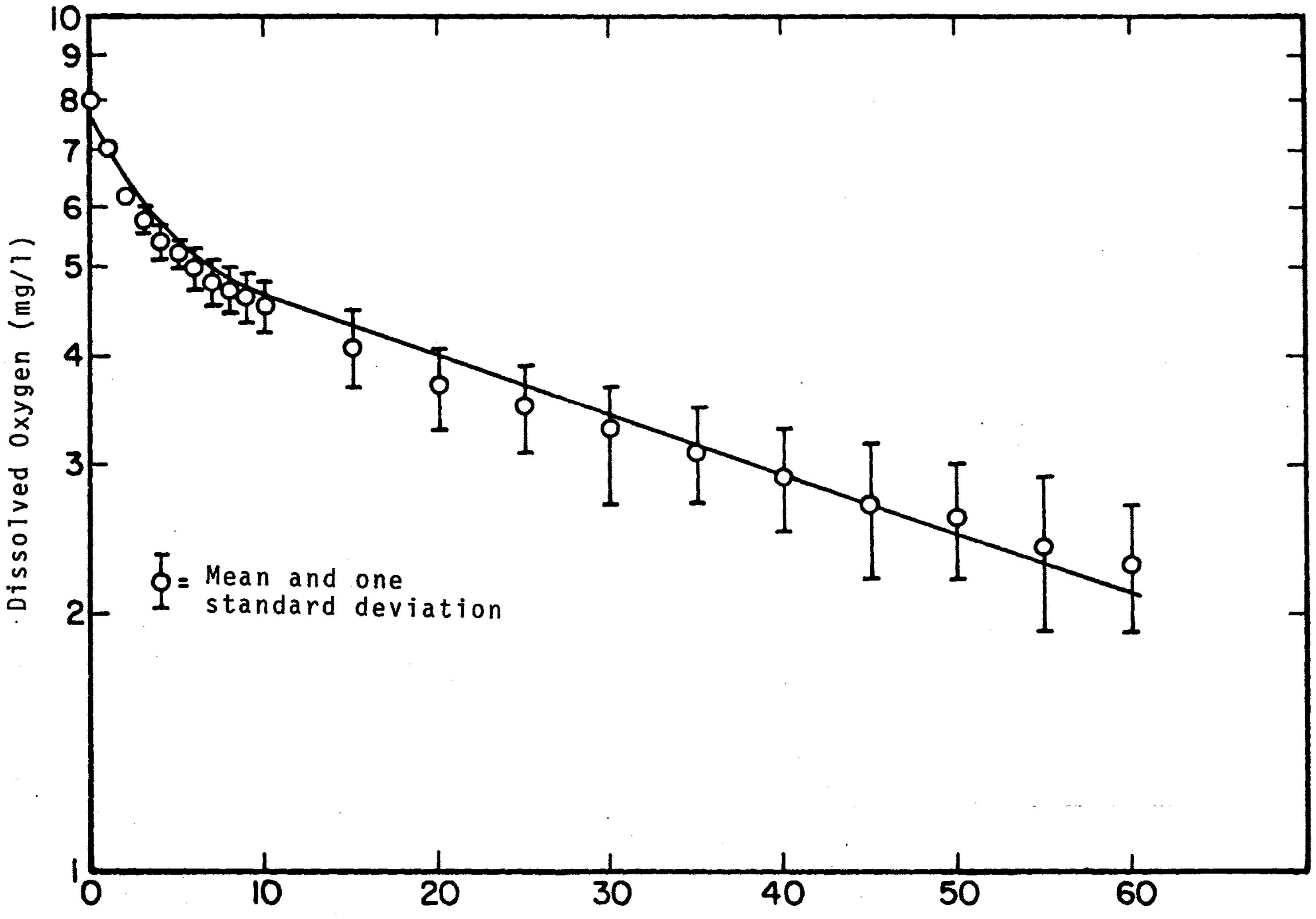


Figure 119

Oxygen Demand Test: Duwamish River Site 3

(Sample Size - 3 cc)

Table 387

General Physical and Chemical Parameters: Duwamish River Site 1

Oxic and Anoxic Elutriate Tests

Sample Designation		Dissolved Oxygen (mg/l @ 22.2-23.5°C) Initial	After Mixing	After Settling	pH	Turbidity (NTU)	Specific Conductance (µmhos/cm @ 25°C)	Salinity (°/oo)
Site Water 1		13.1	-	-	7.8	1	33,600	26
5% Oxic	A	7.3	7.6	7.3	7.6	140	33,700	26
	B	7.0	7.6	7.1	7.7	160	33,400	25.5
20% Oxic	A	1.0	12.2	9.4	7.2	200	30,000	22.8
	B	4.0	11.6	10.2	7.4	220	29,800	22.8
20% Anoxic	A	5.0	< 0.5	1.4	6.8	230	29,800	22.8
	B	3.8	< 0.5	0.6	7.0	170	30,000	22.8

A and B are replicates.

Dash (-) indicates not applicable.

D.O. concentrations did not appear to change more than 0.6 mg/l during the 5 percent tests. A greater D.O. concentration was found in the 20 percent elutriate after mixing than in the 5 percent tests. After settling, the 20 percent oxic elutriates still had higher D.O. levels than the two 5 percent elutriates. Dissolved oxygen, during settling of the anoxic duplicate tests, rose from below 0.5 to 1.4 and 0.6 mg/l.

The pH decreased during all six Site 1 tests but decreased to a lesser extent in the 5 percent tests. The greatest pH decrease was found in the 20 percent anoxic tests. Specific conductance decreased to the same level in the 20 percent oxic and anoxic tests. Virtually no change in specific conductance was found after 5 percent elutriation. Turbidity values were about the same in all elutriates with an indication that the turbidity in the 5 percent elutriate may have been slightly less than in the 20 percent elutriates.

Table 388 shows good reproducibility among general physical and chemical parameters measured during elutriate tests on Duwamish River Site 2 sediment. This sediment was collected upriver from Site 1 and appeared to have a greater oxygen demand than Site 1 sediment. This is consistent with the D.O. uptake results in this study. Dissolved oxygen concentrations after settling were greater in the 5 percent than in the 20 percent oxic tests. They remained below the detection limit during settling of the two anoxic tests. The fact that Site 2 D.O. concentrations after settling were lower than those for Site 1 may be related to the relatively lower D.O. in the site water used. The pH decreased to varying degrees as a result of elutriation, with the 5 percent test showing the least change, the anoxic showing the greatest decrease (1.1 units). The specific conductance decreased to the same level in both oxic and anoxic 20 percent elutriates. It decreased by a greater amount

Table 388

General Physical and Chemical Parameters: Duwamish River Site 2

Elutriate Tests

Sample Designation	Dissolved Oxygen (mg/l @ 21.5-23.8°C)			pH	Turbidity (NTU)	Specific Conductance (µmhos/cm @ 25°C)	Salinity (°/oo)
	Initial	After Mixing	After Settling				
Site Water 1	8.5	-	-	7.8	1	33,600	26
20% Oxic A	< 0.5	6.4	4.0	7.0	130	29,600	22.5
B	< 0.5	6.8	3.1	7.0	140	30,600	23
20% Anoxic A	< 0.5	< 0.5	< 0.5	6.7	180	29,600	22.5
B	< 0.5	< 0.5	< 0.5	6.7	200	30,600	23
Site Water 2	9.4	-	-	7.8	1	38,100	29.2
5% Oxic A	4.8	7.6	6.7	7.6	170	32,600	25
B	4.7	7.5	6.6	7.6	130	32,600	25

A and B are replicates.

Dash (-) indicates not applicable.

during 5 percent elutriation; but, because the specific conductance of the site water for 5 percent tests was greater than that of the water used for 20 percent tests, the specific conductance values in the 5 percent elutriates were greater than those in the other elutriates. Salinity decreased to about the same level in all elutriates. The exception was in the 5 percent elutriates, where there was a 1.7 °/oo difference between elutriate values. Although not much difference in turbidity was found in the elutriates, it appeared that generally values were lowest in the 20 percent oxic elutriate and highest in the anoxic elutriate.

Values for the general physical and chemical parameters measured during elutriate tests on Site 3 sediment are presented in Table 389. The oxygen demand of this sediment appears to have been the same or slightly greater than that of Site 2 sediment. The D.O. after settling of the 5 percent oxic test was the lowest of the three Duwamish River sediments, 4.8 mg/l. The 20 percent oxic elutriate D.O. was about the same as that of Duwamish River Site 2. The patterns and values of pH were comparable to those found in the corresponding elutriates for the other Duwamish River sites.

A decrease in specific conductance was found after 5 percent elutriation. The 20 percent oxic and anoxic elutriates showed an increase, which was not seen in the other area elutriates. As was generally found in the Site 2 elutriates, the highest turbidity was seen in the anoxic elutriates. Turbidity values in the 5 and 20 percent oxic elutriates were comparable.

The D.O. found during the plop test was low, with values falling midway between those in the 20 percent oxic and

Table 389

General Physical and Chemical Parameters: Duwamish River Site 3

Elutriate Tests and Plop Test

Sample Designation	Dissolved Oxygen (mg/l @ 18-24°C)			pH	Turbidity (NTU)	Specific Conductance (μmhos/cm @ 25°C)	Salinity (°/oo)
	Initial	After Mixing	After Settling				
Elutriate Tests:							
Site Water 2	8.0	-	-	7.8	1	38,100	29.5
20% Oxic	1.9	5.4	3.6	7.0	170	39,500	31
20% Anoxic	1.4	< 0.5	< 0.5	6.8	230	39,500	31
5% Oxic	4.5	6.4	4.8	7.4	150	36,400	28
Plop Test:							
Site Water 2	8.1	-	-	-	-	-	-
20% (12 1)*	6.0	1.9	1.7	7.1	41	32,700	25.5

Dash (-) indicates not applicable.

*Total elutriate volume.

anoxic tests. The concentration after mixing was 1.9 mg/l and after settling was 1.7 mg/l. The specific conductance and salinity decreased to a greater extent than it had in the standard elutriate tests. Turbidity was also much lower than it had been in the other tests.

Several patterns were apparent from the general parameter data for these elutriate tests. The D.O. concentrations measured after settling indicate that sediments collected farther upriver had greater oxygen demand. The decreases in pH upon elutriation were more pronounced the farther upriver the sediments were collected. The anoxic tests tended to cause greatest depressions in pH, and 5 percent oxic tests, the least. Turbidity was generally highest in the 20 percent anoxic elutriate. This can be explained by the fact that iron under oxic conditions would tend to flocculate, which would tend to reduce turbidity. Under anoxic conditions, the iron would remain soluble.

Heavy Metals

Total metal compositions of three sediment samples collected from the dredging sites in the Duwamish River are presented in Table 390. The results were typical of those found for relatively uncontaminated sediments. Manganese and iron ranged from 493 to 572 mg/kg and 15,581 to 16,079 mg/kg, respectively. The nickel (15.0 to 17.5 mg/kg) and zinc (68.6 to 73.6 mg/kg) concentrations varied only slightly between samples. More variation was noted with lead (13.0 to 27.1 mg/kg) and copper, 22.5 to 42.8 mg/kg. Mercury concentrations in all three samples were below 0.1 mg/kg.

The metal composition of these Duwamish River samples was comparable to that of Puget Sound sediments reported by Crecelius *et al.*[35] However, the metal concentrations,

Table 390

Total Heavy Metal Composition: Duwamish River Sediment Samples

(mg/kg)

Sampling Location	Mn		Cd		Cr		Zn		Ni		Pb		Cu		Fe		Hg		As	
	X̄	SD	X̄	SD	X̄	SD	X̄	SD	X̄	SD	X̄	SD	X̄	SD	X	SD	X	SD	X	SD
Site 1	493	57	<0.5	-	11.2	1.8	68.6	1.6	15.0	0	13.0	1.7	22.5	2.8	15,581	44	0.058	0.004	1.8	0
Site 2	572	10	<0.5	-	18.4	0.7	73.6	1.9	15.0	3.5	17.7	8.3	42.0	2.1	16,079	88	0.085	0.007	1.7	0
Site 3	558	54	<0.5	-	15.3	2.0	71.9	6.2	17.5	0	27.1	1.7	42.8	6.0	15,892	220	0.050	0.007	1.3	0

Mean and standard deviation calculated from duplicate analyses.

Dash (-) indicates not determined.

particularly the mercury levels, in these Duwamish River sediments were significantly lower than those found at the mouth of the Duwamish River, indicating that the sediments in the Duwamish River appear to be less contaminated with mercury than those in Puget Sound.

The results of soluble heavy metal analysis of standard elutriate tests and plop tests run on these sediments are presented in Tables 391 through 393. Table 391 shows that iron was released from Duwamish River Site 1 sediment in both the oxic and anoxic 20 percent elutriate tests. As indicated by the data in the three tables, anoxic conditions favored the release of iron, which increased from 12 µg/l in the initial site water to 5,770 µg/l in anoxic elutriate A, and 10,400 µg/l in anoxic elutriate B. The release of manganese from this sediment was not significant; only one of six elutriates (5 percent sediment-oxic) showed any readily discernible manganese increase. Sorption of zinc was observed in five of six tests.

The elutriate tests using Duwamish River Site 2 sediment (Table 392) also showed iron release. Reducing conditions in the two 20 percent sediment anoxic flasks caused an increase in soluble iron from an initial 12 µg/l to 13,910 and 14,050 µg/l. No manganese release was detected in the 5 percent oxic tests, but some was observed in the 20 percent oxic tests, indicating the influence of the sediment-to-water ratio on release seen in the elutriate. Zinc, and to a lesser degree, manganese were apparently sorbed in the anoxic elutriate tests.

Elutriate tests on Duwamish River Site 3 sediment yielded similar results. Table 393 shows that soluble iron increased in the anoxic test from 12 to 22,660 µg/l. Only slight release of manganese was observed under oxic conditions. Reducing conditions showed sorption of zinc. The table also shows that for this sediment, results of the

Table 391

Soluble Heavy Metal Concentrations: Duwamish River Site 1 Elutriate Tests

(μg/l)

Sampling Location		Mn		Cd		Cr		Zn		Ni		Pb		Cu		Fe		Hg		As	
		$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Site Water		143	16	1.8	0.1	<2	-	20.9	1.0	6.6	0.3	1.5	0	4.5	0.6	12	2	0.055	0.028	<2	-
5% Oxic	A	244	18	1.0	0	<2	-	21.3	0.5	3.6	0	1.0	0	2.4	0	14	3	0.020	0	<2	-
	B	141	18	1.1	0.1	<2	-	9.2	0.7	3.7	0.1	1.2	0.2	2.0	0.3	17	6	0.060	0	<2	-
20% Oxic	A	52	36	1.1	0	<2	-	14.3	0	6.5	0.5	0.7	0.2	1.8	0	97	0	0.020	0	<2	-
	B	116	54	1.1	0.1	<2	-	11.5	0.4	7.5	2.7	0.9	0.1	2.7	0	54	0	0.060	0	<2	-
20% Anoxic	A	77	0	0.9	0.1	<2	-	4.0	-	5.5	0.4	0.8	0	2.1	0.6	10,400	-	0.020	0	<2	-
	B	26	0	0.9	0	<2	-	3.8	1.0	5.8	0.1	1.0	0	3.2	0.4	5,770	-	0.020	0	<2	-

A and B are replicates.

Mean and standard deviation calculated from duplicate analyses.

Dash (-) indicates not determined.

Table 392

Soluble Heavy Metal Concentrations: Duwamish River Site 2 Elutriate Tests

(μg/l)

Sample Designation	Mn		Cd		Cr		Zn		Ni		Pb		Cu		Fe		Hg		As	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Site Water	143	16	1.8	0.1	<2	-	20.9	1.0	6.6	0.3	1.5	0	4.5	0.6	12	2	0.055	0.028	<2	-
5% Oxic A	131	0	0.9	0	<2	-	15.4	4.5	5.1	0.5	0.9	0.2	1.8	0.3	52	2	0.090	0	<2	-
B	131	0	0.9	0	<2	-	13.9	0.5	5.4	0	2.3	0	1.8	0.1	18	2	0.055	0.028	<2	-
20% Oxic A	251	28	1.8	0	<2	-	18.4	0.4	8.1	0.2	2.9	0	1.9	0.1	489	4	0.095	0.007	<2	-
B	211	28	1.1	0	<2	-	15.0	1.3	7.9	0	2.2	0.2	2.1	0	606	13	0.055	0.020	<2	-
20% Anoxic A	100	14	0.9	0.1	<2	-	1.7	0.4	7.3	0	1.5	0.2	2.2	0	13,910	-	0.055	0.020	<2	-
B	111	29	1.0	0.1	<2	-	1.5	0.2	7.3	0	1.5	0.2	2.5	0	14,050	-	0.068	0.011	2	-

A and B are replicates.

Mean and standard deviation calculated from duplicate analyses.

Dash (-) indicates not determined.

Table 393

Soluble Heavy Metal Concentrations: Duwamish River Site 3

Elutriate Tests and Plop Test

(µg/l)

Sample Designation	Mn		Cd		Cr		Zn		Ni		Pb		Cu		Fe		Hg		As	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Site Water	143	16	1.8	0.1	< 2	-	20.9	1.0	6.6	0.3	1.5	0	4.5	0.6	12	2	0.055	0.028	<2	-
5% Oxic	151	28	0.9	0	< 2	-	11.4	3.7	5.4	0.4	2.0	0.5	2.3	0.1	55	3	0.015	-	<2	-
20% Oxic	191	0	0.9	0	< 2	-	13.3	2.6	7.3	0	2.2	0.2	2.0	0.1	1165	21	0.020	0	<2	-
20% Anoxic	90	0	< 0.5	-	< 2	-	1.6	0	5.6	0.2	1.3	0	1.9	0.2	22,660	-	0.068	0.011	<2	-
Plop Test	205	0	1.6	0.2	< 2	-	9.0	3.0	8.3	0.2	2.2	0.1	3.7	2.0	1300	-	0.028	0.004	<2	-

Mean and standard deviation calculated from duplicate analyses.

Dash (-) indicates not determined.

elutriate and plop tests were fairly comparable. The release of iron and manganese was detected along with sorption of zinc. Manganese release was greater in the plop test (205 μg/l) than in the two oxic elutriate tests (151 and 191 μg/l). The results for the metals other than iron, manganese, and zinc were similar to those found in the elutriates using Duwamish River Site 3 sediment.

Nitrogen Compounds

The results of the nitrogen compound analysis of the Duwamish sediments are presented in Table 394. In Duwamish River Sites 2 and 3 sediment samples, total Kjeldahl nitrogen concentrations (organic N plus ammonium) exceeded the US EPA proposed bulk sediment criteria of November, 1971 for open water disposal of dredged material[36]. However, Duwamish River Site 1 sediment had a lower concentration of organic nitrogen than samples from the other two sites, and its ammonium levels were also lower.

Results of nitrogen compound analyses for Duwamish River Site 1 elutriate tests are presented in Table 395. Relatively moderate amounts of ammonium were released in both oxic and anoxic tests. Higher ammonium and organic N release was observed in the 20 percent elutriates. Organic N release in the 20 percent anoxic elutriates was twice that in the 20 percent oxic elutriates. There was no apparent change in nitrate as a result of elutriation. However, a slight nitrate decrease was observed under anoxic conditions. The lack of analytical reproducibility in the 5 percent oxic tests hindered formulation of a conclusive assessment of the relationship between nitrate release and the sediment volume in the elutriate.

Nitrogen data for Site 2 elutriate tests appear in Table 396. Examination of the table reveals that ammonium

Table 394

Organic Nitrogen and Ammonium Concentrations: Duwamish River Sediment Samples

(mg N/kg)

Sampling Location	Total Kjeldahl Nitrogen		Organic N		Ammonium	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Site 1	301	45	268	54	33	9
Site 2	1162	57	1031	72	131	15
Site 3	1493	5	1403	35	90	30

Mean and standard deviation calculated from duplicate analyses.

Table 395

Nitrogen Compound Concentrations: Duwamish River Site 1 Elutriate Tests

(mg N/l)

Sample Designation		Organic N		Ammonium		Nitrate	
		$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Site Water		0.17	0.03	< 0.05	∿0	0.39	0.01
5% Oxic	A	0.53	0.09	0.50	0.01	0.46	0.01
	B	0.18	0.15	0.68	0.01	0.37	0.02
20% Oxic	A	1.58	0.14	2.70	0.03	0.37	0.01
	B	1.22	0.23	1.90	0.06	0.41	0.01
20% Anoxic	A	2.40	0.14	2.38	0.06	0.36	0.01
	B	2.56	0.22	2.26	0.06	0.33	0.01

A and B are replicates.

Mean and standard deviation calculated from duplicate analyses.

Table 396

Nitrogen Compound Concentrations: Duwamish River Site 2 Elutriate Tests

(mg N/l)

Sample Designation		Organic N		Ammonium		Nitrate	
		X	SD	X	SD	X	SD
Site Water		0.17	0.03	< 0.05	∿0	0.39	0.01
5% Oxic	A	1.86	0.06	1.54	0	0.33	0.01
	B	0.20	0.13	1.54	0.01	0.37	0.01
20% Oxic	A	1.26	0.32	5.74	0.15	0.33	0.01
	B	2.92	0.56	5.82	0.08	0.31	0.01
20% Anoxic	A	3.71	0.25	4.15	0.11	0.32	0.01
	B	1.02	0.19	3.92	0.11	0.34	0.01

A and B are replicates.
Mean and standard deviation calculated from duplicate analyses except for nitrate (calculated from triplicate analyses).

release was higher with the higher percentage elutriates and under oxic conditions. It was higher than that observed with the Duwamish River Site 1 elutriates. Nitrate was essentially unaffected by experimental manipulations of the aeration procedures and the percent sediment volume in the elutriate. Organic N analyses showed somewhat poor reproducibility, which may be related to sampling of the suspension.

Nitrogen compound data from Duwamish River Site 3 elutriate tests and the plop test are listed in Table 397. Ammonium release was similar under oxic and anoxic conditions, with concentrations falling between those released in elutriates using Duwamish River Sites 1 and 2 sediments. Both ammonium and organic N release decreased in the lower sediment volume elutriate, and organic N release was apparently enhanced by anoxic conditions. The nitrate increase in the anoxic elutriate was unexpected. Nitrate concentrations

Table 397

Nitrogen Compound Concentrations: Duwamish River Site 3 Elutriate Tests and Plop Test

(mg N/l)

Sample Designation	Organic N		Ammonium		Nitrate	
	X	SD	X	SD	X	SD
Site Water	0.17	0.03	< 0.05	∼ 0	0.39	0.01
Elutriate Tests:						
5% Oxic	0.36	0.15	1.38	0.01	0.42	0.01
20% Oxic	1.96	0.16	3.80	0.05	0.36	0.01
20% Anoxic	3.19	0.33	3.77	0.10	0.48	0.03
Plop Test	0.38	0.01	0.86	0.01	0.45	0.02

Mean and standard deviations calculated from duplicate analyses, except for nitrate (calculated from triplicate analyses).

customarily decrease in anoxic elutriate tests. This may be due to the problems of release of interferences in the nitrate analyses.

The plop test was devised to simulate as closely as possible the conditions in the water column during disposal operations at Puget Sound. Results of nitrogen compound analysis (found in Table 397) showed that organic N release was comparable to that found in the 5 percent oxic elutriate tests using the same sediment. Ammonium concentrations were lower, and nitrate concentrations were essentially the same as those observed in the corresponding 5 percent oxic elutriate tests.

Some generalizations can be derived from the series of tests on Duwamish River sediments. There was no consistent pattern for either release or removal of nitrate. Ammonium release was generally moderate and was higher for Duwamish River Site 2 sediments, even though Duwamish River Site 3 sediments had originally shown a higher nitrogen content.

Organic N release was apparently higher under anoxic conditions and, like ammonium, increased with the higher sediment percentage elutriate.

Phosphorus Compounds

The total phosphorus concentrations in the Duwamish River sediment used in elutriate tests are presented in Table 398. The concentrations at Duwamish Sites 2 and 3 were not statistically different at the 95 percent confidence level. Those total P concentrations were greater than the concentration found at Site 1, the most seaward sampling site.

An apparent iron precipitate formed in the samples between the time the anoxic elutriates were filtered and the soluble ortho P analyses were made. Each of these elutriates was, therefore, refiltered. To estimate the quantity of phosphorus removed with the precipitate, an attempt was made to calculate the total phosphorus concentrations of the original filtrate. However, the large quantity of iron interfered in the analysis and total P could not be determined. Therefore, the reported soluble ortho P concentrations for these anoxic elutriates are probably low.

Three sets of duplicate elutriate tests were run on sediment from Duwamish Site 1. In each case, one replicate showed an increase in soluble orthophosphate and the other showed a decrease (Table 399). Differences in the ortho P concentrations between replicate elutriates ranged from 2.5 to 7-fold and did not seem to be related to any of the physical and general parameters monitored.

Table 400 presents soluble orthophosphate data for Duwamish Site 2 elutriate tests. Although the replicate elutriates showed 1.8 to 3.6-fold differences in soluble ortho P concentrations, the direction of concentration changes relative to the site water was the same in the replicates. Both the 20 percent oxic and 20 percent anoxic elutriates

Table 398

Total Phosphorus Concentrations: Duwamish River Sediment Samples

(mg P/kg dry weight)

Sampling Site	Total Phosphorus	
	$\bar{X}$	SD
1	508	76
2	828	29
3	925	21

Mean and standard deviation calculated from duplicate digestions of one sample.

Table 399

Soluble Orthophosphate Concentrations: Duwamish River Site 1 Oxic and Anoxic Elutriate Tests

(mg P/l)

Sample Designation		Soluble Ortho P		Total Phosphorus	
		$\bar{X}$	SD	$\bar{X}$	SD
Site Water		0.079	0.001	0.11	0.005
5% Oxic	A	0.054	0	-	-
	B	0.13	0	-	-
20% Oxic	A	0.19	0	-	-
	B	0.050	0.001	-	-
20% Anoxic	A*	0.29	0.001	-	-
	B*	0.042	0.001	-	-

A and B are replicates.
Dash (-) indicates not applicable.

Mean and standard deviation calculated from triplicate analyses of one sample.

*Samples refiltered prior to analysis to remove material in suspension.

Table 400

Soluble Orthophosphate Concentrations: Duwamish River Site 2 Oxic and Anoxic Elutriate Tests

(mg P/l)

Sample Designation		Soluble Ortho P		Total Phosphorus	
		$\bar{X}$	SD	$\bar{X}$	SD
Site Water		0.079	0.001	0.11	0.005
5% Oxic	A	0.072	0.001	-	-
	B	0.039	0	-	-
20% Oxic	A	0.11	0.002	-	-
	B	0.40	0	-	-
20% Anoxic	A*	0.23	0.001	-	-
	B*	0.42	0.003	-	-

A and B are replicates.
Mean and standard deviation calculated from triplicate analyses of one sample.

Dash (-) indicates not applicable.

*Samples refiltered prior to analysis to remove suspended material.

showed the increases in soluble ortho P concentration. Although there was no statistical difference in concentration (at the 95 percent confidence level) between the 20 percent oxic and anoxic elutriates, some soluble ortho P was probably removed with the precipitate during the refiltration of the anoxic elutriates. Only in the 5 percent oxic elutriates, which had the highest final D.O. concentrations (approximately 6.6 mg/l), did the soluble ortho P concentration appear to decrease as a result of elutriation.

Soluble orthophosphate concentrations in Duwamish River Site 3 elutriates are presented in Table 401. Only the anoxic tests (which had been refiltered) showed an increase in soluble ortho P resulting from elutriation. The reported concentration is likely lower than that present

Table 401

Soluble Orthophosphate Concentrations: Duwamish River Site 3 Elutriate Tests and Plop Test

(mg P/l)

Sample Designation	Soluble Ortho P	
	$\bar{X}$	SD
Site Water	0.079	0.001
Elutriate Tests:		
5% Oxic	0.032	0.002
20% Oxic	0.020	0.001
20% Anoxic *	0.41	0.003
Plop Test (12	0.030	0.001

Mean and standard deviation calculated from triplicate analyses.

*Sample refiltered prior to analysis to remove a precipitate.

immediately following the elutriate test. Soluble ortho P concentrations in the oxic elutriates and in the plop test elutriate were lower than those in the site water.

These soluble ortho P concentrations can be related to the D.O. content of the elutriate after settling. The 5 and 20 percent elutriates had D.O. concentrations of 4.8 and 3.6 mg/l, respectively, whereas the anoxic elutriates had less than 0.5 mg/l D.O. Although the plop test solution contained only 1.7 mg/l D.O., its soluble ortho P concentration was about the same as that of the 5 percent oxic elutriate.

From these tests it would appear that when dealing with the water and/or sediment with a high iron content, if the oxygen conditions resulting from dredged material disposal could be estimated, the direction of change in soluble orthophosphate concentration might be predicted. If oxic conditions are likely, then water column soluble ortho P levels might be expected to decrease. Conversely, if anoxic conditions are expected, increases in ortho P would seem likely.

Organic Compounds

A 20 percent elutriate test was run on sediment and water samples from Duwamish River Site 2. The samples were analyzed for selected chlorinated hydrocarbons, total organic carbon, and oil and grease. Figure 120A shows the profile of organic residues for the sediment, water and elutriate samples. Table 402 lists the peaks and relative retention times for these samples and is derived from Figure 120B. It can be seen that only a small amount of release of chlorinated hydrocarbons occurred.

Table 403 lists the concentrations of chlorinated hycrocarbons and related parameters found in these samples. In the sediment pp'DDT (25.9 μg/kg), pp'DDE (4.5 μg/kg), PCBs (406 μg/kg), and heptachlor (1.8 μg/kg) were detected. The oil and grease content was 702 mg/kg and total organic carbon was 3.6 percent. Heptachlor (2.8 ng/l) and PCBs (11.5 ng/l) were detected in the site water. Release of pp'DDE (2.8 ng/l), heptachlor (4.0 ng/l), and PCBs (33.4 ng/l) could be seen in the elutriate,

The fine silt sediment was collected at Duwamish River Slip 1(site of the PCB spill described earlier) with a pipe dredge. Water which was collected with the sediment was poured off into a separate container and the sediment was placed in a bucket. A surface water sample was also collected at the site. Before analysis for PCBs, water remaining in

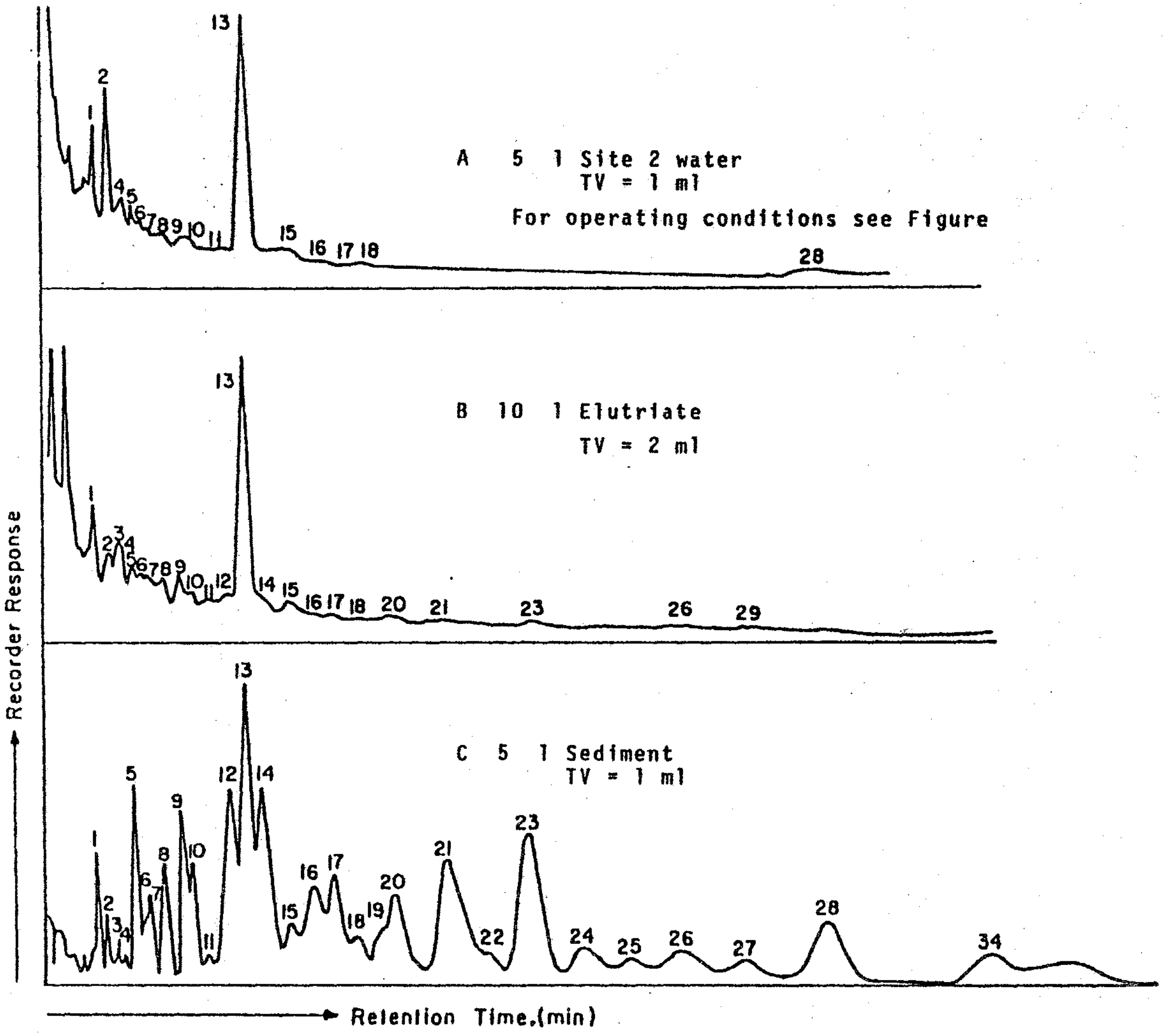


Figure 120

GC Chromatograms: Profile of Organic Residues of Duwamish River Site 2 Sediment, Water and Elutriate

Table 402

Relative Retention Correlation Data: Duwamish River Site 2 Elutriate Test

Peak Number	Organic Compound	X_{mm}	R_r	Sediment	Water	Elutriate
1		29	0.46	✓	✓	✓
2		33	0.52	✓	✓	✓
3		37	0.57	✓	✓	✓
4		40	0.63	✓	✓	✓
5		45	0.71	✓	✓	✓
6		48	0.76	✓	✓	✓
7	Heptachlor	51	0.81	✓✓	✓✓	✓✓
8		57	0.90	✓	✓	✓
9		64	1.02	✓	✓	✓
10		69	1.10	✓	✓	✓
11		75	1.19	✓	✓	✓
12		85	1.35	✓		✓
13	Heptachlor Epoxide	91	1.44	✓	✓	✓
14		98	1.56	✓		✓
15		110	1.75	✓	✓	✓
16	pp'DDE	121	1.92	✓✓	✓✓	✓✓
17		128	2.03	✓	✓	✓
18	Dieldrin	138	2.19	✓	✓	✓
19		148	2.35	✓		
20		154	2.44	✓		✓
21		176	2.79	✓		✓
22		192	3.05	✓		
23	pp'DDT	213	3.38	✓✓		✓
24		236	3.75	✓		
25		256	4.06	✓		

(Continued)

Table 402 (Concluded)

Peak Number	Organic Compound	X_{mm}	R_r	Sediment	Water	Elutriate
26		278	4.41	✓		
27		298	4.73	✓	✓	✓
28		332	5.27		✓	
29		335	5.32	✓		
30		404	6.41	✓		
31		440	6.98	✓		
32		544	8.63	✓		

✓ = Compound was indicated on one column.

✓✓ = Compound was indicated on two columns.

the sediment bucket was poured off and mixed with the other water taken with the pipe dredge. These waters are referred to as sediment-associated water.

Table 404 presents the results for PCB, oil and grease, and carbon analyses of these samples. The sediment contained 3,222 µg/kg PCBs and 1.7 percent TOC. In the sediment-associated water, the PCB concentration was 175 ng/l and TOC was 90 mg/l. The concentrations of PCBs and TOC in the surface water were 70 ng/l and 60.3 mg/l, respectively. The sediment was compared to several Aroclor standards and most closely resembled Aroclor 1248.

Table 403

Data for Organic Compounds and Related Parameters: Duwamish River Site 2 Elutriate Test

Parameter	Sediment	Water	Elutriate
Chlorinated Hydrocarbons:	(μg/kg)	(ng/l)	(ng/l)
Aldrin	< 0.4	< 0.6	< 0.6
op'DDT	< 1.6	< 3.0	< 3.0
pp'DDT	25.9	< 3.0	< 3.0
op'DDD	< 2.0	< 2.0	< 2.0
pp'DDD	< 2.0	< 2.0	< 2.0
op'DDE	< 1.4	< 2.0	< 2.0
pp'DDE	4.5	< 2.0	2.8
Dieldrin	< 0.8	< 1.2	< 1.2
Endosulfan I	< 0.9	< 1.2	< 1.2
Endosulfan II	< 3.4	< 4.4	< 4.4
Endrin	< 1.2	< 1.6	< 1.6
Heptachlor	1.8	2.8	4.0
Lindane	< 0.2	< 0.3	< 0.3
PCBs	406	11.5	33.4
Other Organic Compounds		(mg/l)	(mg/l)
Oil and Grease	702 mg/kg	< 0.5	< 0.5
TOC	3.6%	NT	25.7
Total Inorganic Carbon	0.2%	NT	10.5

Table 404

Data for Selected Organic Compounds: Duwamish River Slip 1

Parameter	Sediment	Sediment-Associated Water (mg/l)*	Surface Water (mg/l)*
PCBs	3222 µg/kg	175	70
Oil and Grease	NT	< 0.5	< 0.5
Total Organic Carbon	1.7%	90	60.3
Total Inorganic Carbon	0.1%	54.0	22.5

*PCB concentrations in ng/l.
NT = Not tested.

Bioassays

The Duwamish River sediment toxicity data were collected for bioassays with *P. pugio* in elutriates using Site 3 sediment. The chemical characteristics data for the bioassays are presented in Table 405. The total ammonium nitrogen in the 20 percent sediment tests increased 4 to 5 mg/l, with approximately 0.02 mg/l present as unionized ammonia. In addition, the elutriates showed decreased D.O. concentrations and increased levels of turbidity.

Total ammonium and D.O. concentrations were measured at the end of the 96-hour test period. The data presented in Table 406 show that the ammonium concentration increased slightly in each bioassay elutriate. Table 407 indicates that the one-hour aeration period following the one-hour settling period was sufficient to raise the D.O. to above 4 mg/l. No further aeration was used.

Table 405

Chemical and Physical Characteristics: Duwamish River Site 3

Elutriate Bioassays*

Sample Designation		pH	D.O. (mg/l @ 21°C)	Spec. Cond. (umhos/cm @ 21°C)	Total Ammonium (mg N/l)	Unionized Ammonia** (mg N/l)	Turbidity (NTU)	Salinity (°/oo)
Control	A	8.1	7.0	40,210	0.14	< 0.01	0.4	29.0
	B	8.1	7.0	40,210	0.12	< 0.01	0.5	29.0
5%	A	7.3	4.3	39,510	1.65	< 0.01	74	28.5
	B	7.0	3.8	39,910	1.42	< 0.01	68	28.7
20%	A	7.0	2.0	39.210	5.29	0.02	78	28.2
	B	7.2	1.1	39,310	4.41	0.02	84	28.3

A and B are replicates.

*Measurements taken at the end of the one-hour settling period.

**For all bioassay elutriates, unionized ammonia calculated from Skarheim's[9] tables for fractions of ammonia in undissociated form.

Table 406

Total Ammonium Content: Duwamish River Site 3 Elutriate Bioassays at Completion of 96-Hour Test Period

Sample Designation		pH	Total Ammonium (mg N/1)	Unionized Ammonia (mg N/1)
Control	A	8.1	0.10	< 0.01
	B	8.1	0.10	< 0.01
5%	A	7.3	2.14	< 0.01
	B	7.0	2.17	< 0.01
20%	A	7.0	5.84	0.02
	B	7.2	5.23	0.02

A and B are replicates.

Table 407

Dissolved Oxygen Concentrations: Duwamish River Site 3 Sediment Elutriate Bioassays over Test Period

(mg/1 @ 20-21°C)

Time	Control		5%		20%	
(hr)	A	B	A	B	A	B
0	7.0	7.0	4.3	3.8	2.0	1.1
1*	7.1	7.2	6.3	6.0	6.0	5.9
24	6.2	6.5	3.9	3.9	3.5	3.4
48	5.8	6.1	3.9	3.8	3.2	3.2
72	5.7	6.0	3.7	3.7	3.2	2.8
96	5.4	5.6	3.6	3.7	3.0	2.7

A and B are replicates.

*Measurements taken after first hour of aeration.

The results of the metal analyses of the bioassay elutriates are presented in Table 408. The data show large releases of both iron and manganese. Manganese concentrations ranged from 29 μg/l in the 5 percent tests to over 6900 μg/l in the 20 percent sediment tests. Copper release in the 20 percent elutriates was approximately two to five times that of the controls. Mercury was removed in the 5 percent sediment tests and released in the 20 percent tests. A ten-fold increase in cadmium was observed in one 5 percent replicate; the other showed no significant change. Lead was removed in both the 5 and 20 percent sediment tests. No significant changes from the test water concentrations were observed for chromium, nickel, and zinc.

Table 409 presents the results of the bioassays using Site 3 sediments. Only one organism died over the entire 96-hour test period.

Field Studies

Characteristics of Study Site

The mechanically dredged Duwamish River sediments were loaded onto a barge and disposed of in Elliott Bay (Puget Sound). The water column at Buoy D, the disposal site, was monitored for approximately 4.5 hours, a period which included pre-disposal conditions and two disposal operations.

The disposal operations were monitored while the sampling ship was anchored at Buoy D in Elliott Bay. Two split-bottom barges at a time, hooked up in sequence, were brought out to Buoy D from the dredging. Each barge dumped its material when adjacent to the sampling ship. When the first barge was empty, the second one was moved into place and the procedure repeated. The barges were either upcurrent from the sampling vessel or parallel to it in the current.

Table 408

Release of Heavy Metals: Duwamish River Site 3

Sediment Elutriate Bioassays

(μg/l)

Sample Designation		Mn	Cd	Cr	Zn	Ni	Pb	Cu	Fe	Hg
Control	A	49	3.1	<2.0	76	11.9	47.8	13.3	11	0.060
	B	29	3.3	<2.0	141	13.9	49.3	14.8	13	0.060
5 percent	A	2430	33.8	<2.0	94	15.1	12.9	21.3	8506	<0.001
	B	2177	2.6	<2.0	82	14.7	12.9	19.8	9772	<0.001
20 percent	A	6962	6.1	<2.0	188	21.5	33.6	71.6	22177	0.096
	B	6354	6.1	<2.0	106	13.9	14.0	34.3	23038	0.128

A and B are replicates.

Table 409

Response of *P. pugio* to Varying Sediment Percent of Total Elutriate Volume as a Function of Time: Duwamish River Site 3 Sediment Elutriates

Time (hr)	Number of P. pugio Living at Varying Sediment Percentages					
	Controls		5%		20%	
	A	B	A	B	A	B
0	10	10	10	10	10	10
12	10	10	9	10	10	10
24	10	10	9	10	10	10
36	10	10	9	10	10	10
48	10	10	9	10	10	10
60	10	10	9	10	10	10
72	10	10	9	10	10	10
84	10	10	9	10	10	10
96	10	10	9	10	10	10

A and B are replicates

The time between the two dumps varied from 5 to 10 minutes. Each barge dump took 1 to 2 minutes. The barge was very close and sometimes touching the sampling vessel during the dumps. The distance between the barge and the pumps used to take water samples during the dumps and between the barge and the other monitoring equipment varied between 15 and 100 feet.

Current measurements were made at varying depths in the water column. Table 410 shows a profile of the currents at Buoy D several hours before the first disposal operation. From surface to one meter off of the bottom the current speed varied from 0.05 to 0.175 cm/sec. The faster currents were found at mid-depth, between 23 and 43 meters, and the slower currents were found in the upper and lower thirds of the water column. The measured direction of the current was quite variable. Throughout the water column it ranged from 50° to 245°. In the upper half of the water column, the range was 50° to 325°. In the lower half it was 85° to 280°. Table 411 shows current direction readings over time at a constant 30 m depth. The direction was quite variable, ranging from 55° to 360°.

During the disposal operations the current meter was maintained at 60 meters. The direction of the current during this period generally ranged from 285 to 290° and was considerably steadier than the current at 30 meters. The current speed ranged from 0.1 to 0.5 cm/sec.

The climatic conditions during the Elliott Bay disposal operation varied. Initially the sky was overcast with light rain and very light winds. During the day the winds grew quite heavy, gusting to 30 mph. The seas became heavy with white caps. There were intermittent heavy showers during the day. The temperature was approximately 45°C.

Table 410

Pre-Disposal Current Profile at Buoy D in Elliott Bay

February 17, 1976

Time (hr:min:sec)	Depth (m)	Direction (° magnetic)	Speed (cm/sec)
9:51:00	3	270	0.05-0.075
9:53:30	8	50-270	0.1
9:56:00	13	310-325	0.12
9:57:30	13	80	0.10
9:58:00	18	245-260	0.10
10:00:00	23	275-280	0.175
10:02:00	28	10-25	0.15
10:03:00	33	350-25	0.10
10:05:00	38	360-35	0.15
10:06:00	43	80-90	0.11
10:07:30	48	360-10	0.10
10:08:15	53	325-360	0.10
10:09:15	53	40-65	0.075
10:10:00	58	310-315	0.05
10:11:30	61 (1 m off bottom)	280-320	0.08-0.10

Optical Properties

Changes in turbidity at the Elliott Bay disposal site were monitored with a transmissometer. The data were collected using a 10 cm light path. Figure 121 presents the pre-disposal data collected at the Elliott Bay disposal site at 9:30 on the day of the disposal operations. The percent transmission steadily decreased with depth through the water column. The surface waters had a 47 percent transmission while the bottom waters showed a 24 percent transmission. These values were much lower than those found during disposal.

The data collected at 12:23:20 and 12:27:15 (during disposal) are presented in Figure 122. They show a much higher percent transmission than noted earlier in the surface waters. Readings were taken at depths of 1, 3, and 5

Table 411

Current Direction at 30 Meters at Buoy D in Elliott Bay

Time (hr:min:sec)	Direction* (° magnetic)
10:20:30	55-75
10:21:00	80-95
10:22:00	300-315
10:22:15	90-95
10:23:45	310-315
10:24:15	315
10:24:45	270-315
10:27:45	5-315
10:28:45	80
10:29:15	315
10:29:30	60
10:30:30	360

*Speed was 0.075-0.1 cm/sec.

meters. The data showed little fluctuation at 3 meters five minutes after the dump.

Data were collected with two transmissometers during Elliott Bay Dumps Nos 1 and 2. During the first operation, transmission at depths of 5 and 60 meters (bottom) was monitored. The data collected at 5 meters are presented in Figure 123. The general trend was for a decrease in transmission to come just after disposal, followed by a return to ambient conditions. This generally occurred except that between 15:10 and 15:20, the transmission was apparently much lower. This is likely due to a turbid surface water cloud arising from sediments which washed out of the barge after it left the disposal area.

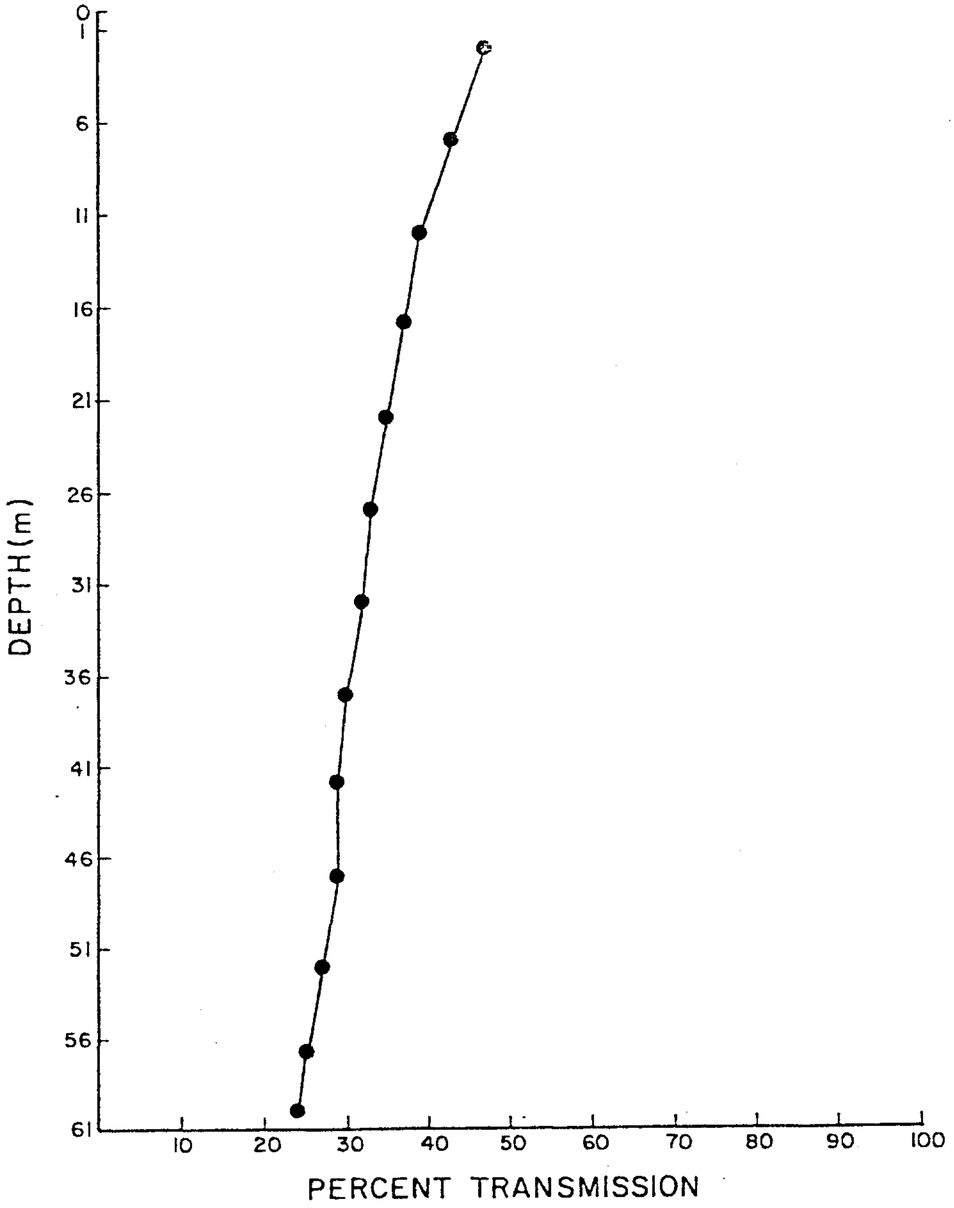


Figure 121

Percent Transmission Profile: Pre-Disposal
Elliott Bay - 9:30

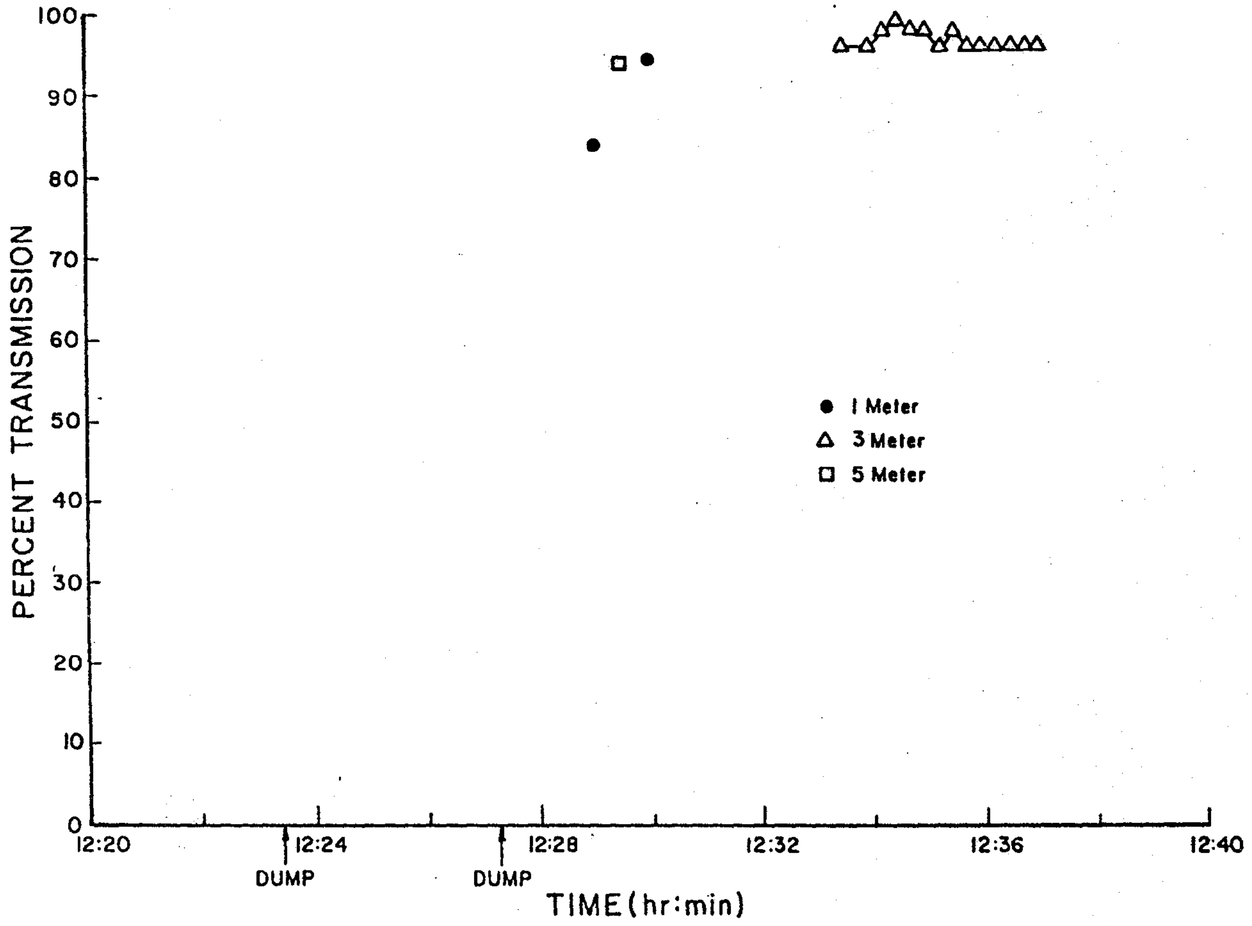


Figure 122
Percent Transmission: Elliott Bay Unmonitored Dump

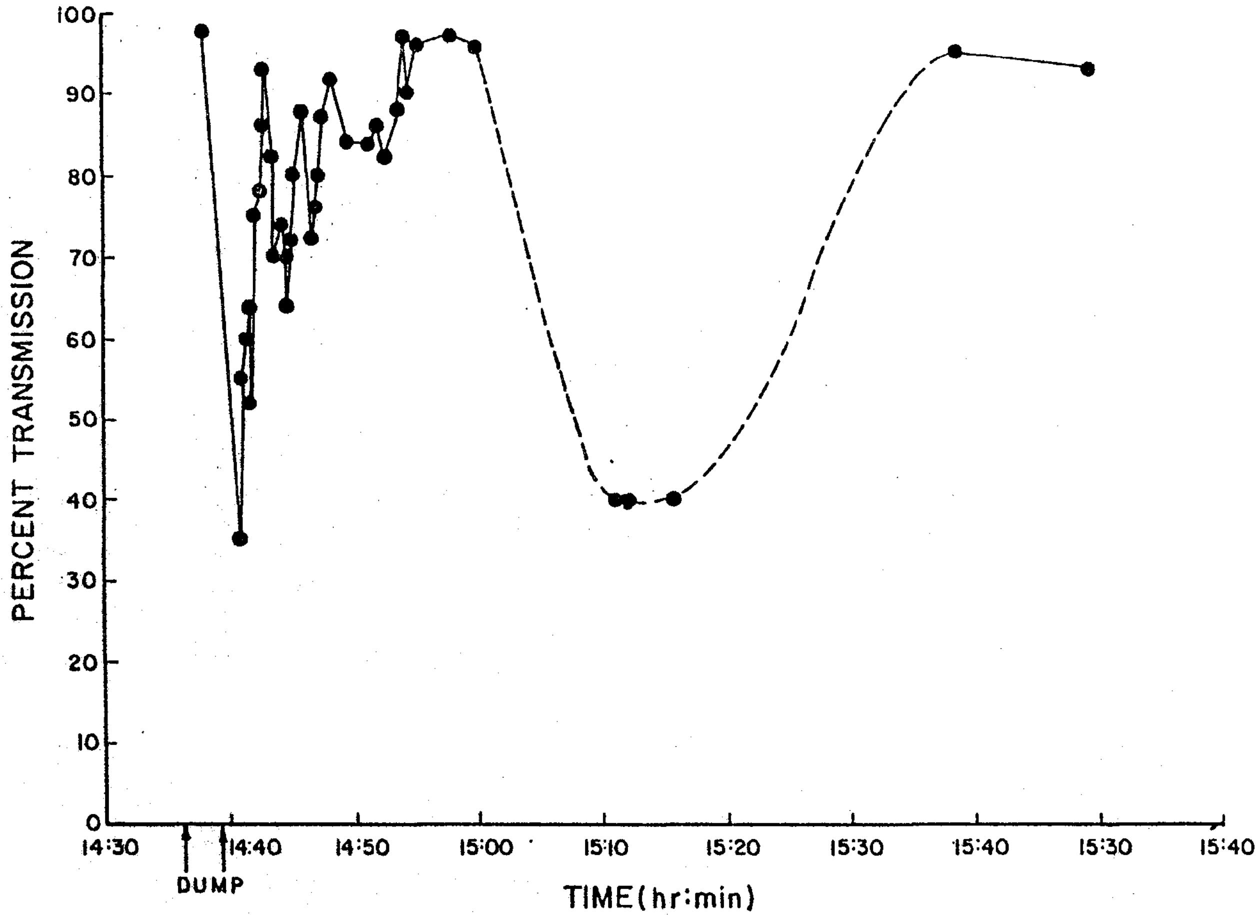


Figure 123

Percent Transmission: Elliott Bay Dump No. 1
Depth: 5 meters

The data collected during the first disposal operation at a depth of 60 meters are presented in Figure 124. The readings decreased sharply just after disposal. Within a ten-minute period, the percent transmission returned to the pre-disposal levels. During that ten-minute period, however, the percent transmission decreased to zero upon three separate observations. Transmission at 60 meters did not show the decrease 30 minutes after disposal that was seen at 5 meters. This difference indicates that the cause for decreased percent transmission was localized in the upper waters.

Data were collected during the second disposal operation at depths of 30 and 60 meters. Figures 125 and 126 present these data. At 30 meters a smaller decrease than that seen earlier was noted approximately 10 minutes after disposal. The readings returned to the pre-disposal levels within 20 minutes of disposal. The plot of the data collected from a depth of 60 meters shows extreme variability after disposal. The effects of the disposal were seen more quickly at this depth than at 30 meters. There was not the quick return to pre-disposal condition seen at 30 meters; instead the system exhibited large fluctuations in values. The condition at the bottom appeared to stabilize by 50 minutes after disposal.

The disposal operations caused detectable changes in the turbidity of the water column. In most cases, within 60 minutes or less (a relatively short period of time) the turbidity conditions adjacent to the disposal site returned to the pre-disposal levels.

In Situ Measurements

The water column was measured for D.O. and temperature at 5 meter intervals to a depth of 60 meters, which was 1 to 2 meters off the bottom. The first disposal operation took place at 11:44 on February 17. Circumstances (loss of anchorage) prevented the taking of samples during

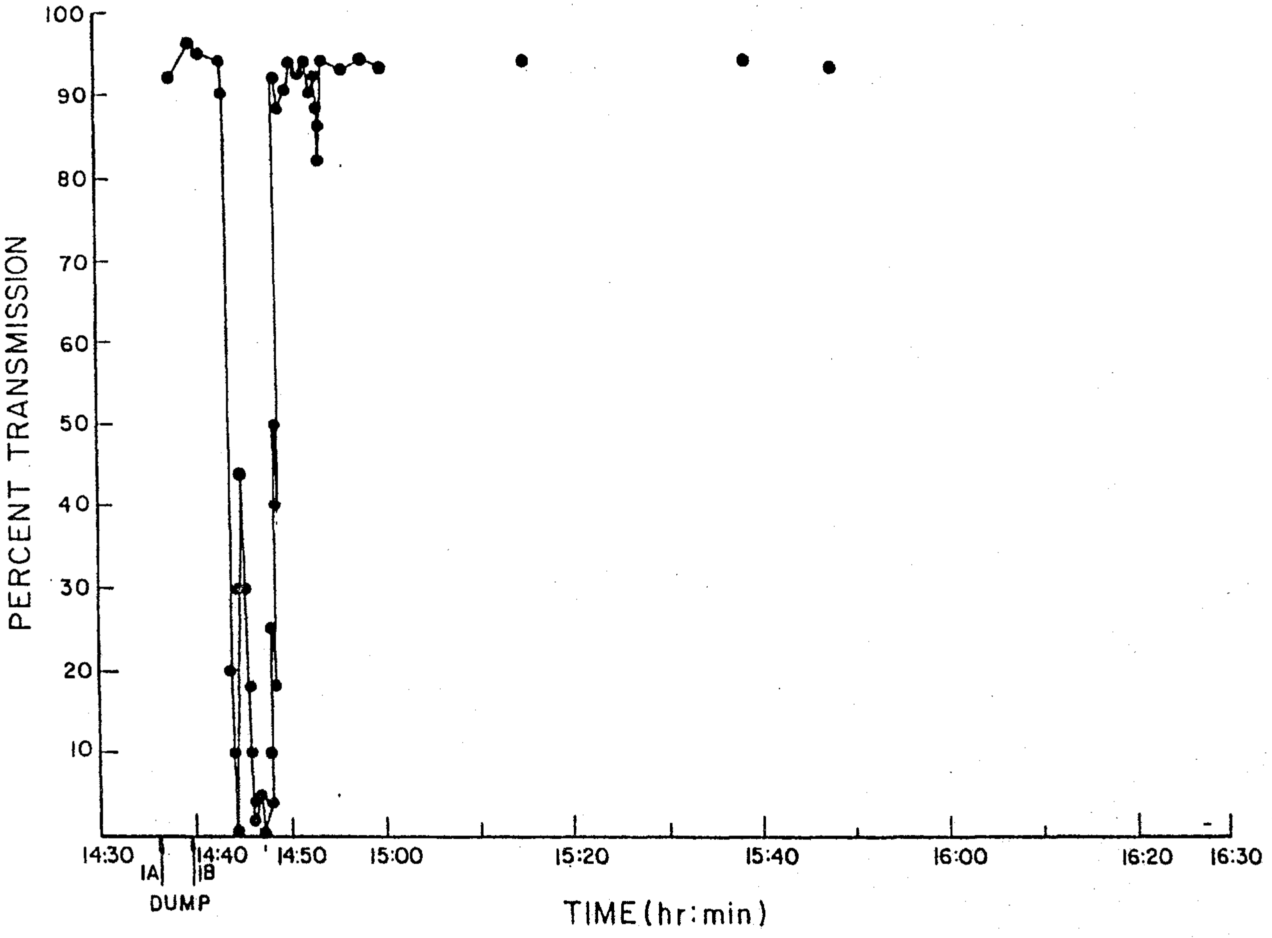


Figure 124

Percent Transmission: Elliott Bay Dump No. 1
Depth: 60 meters

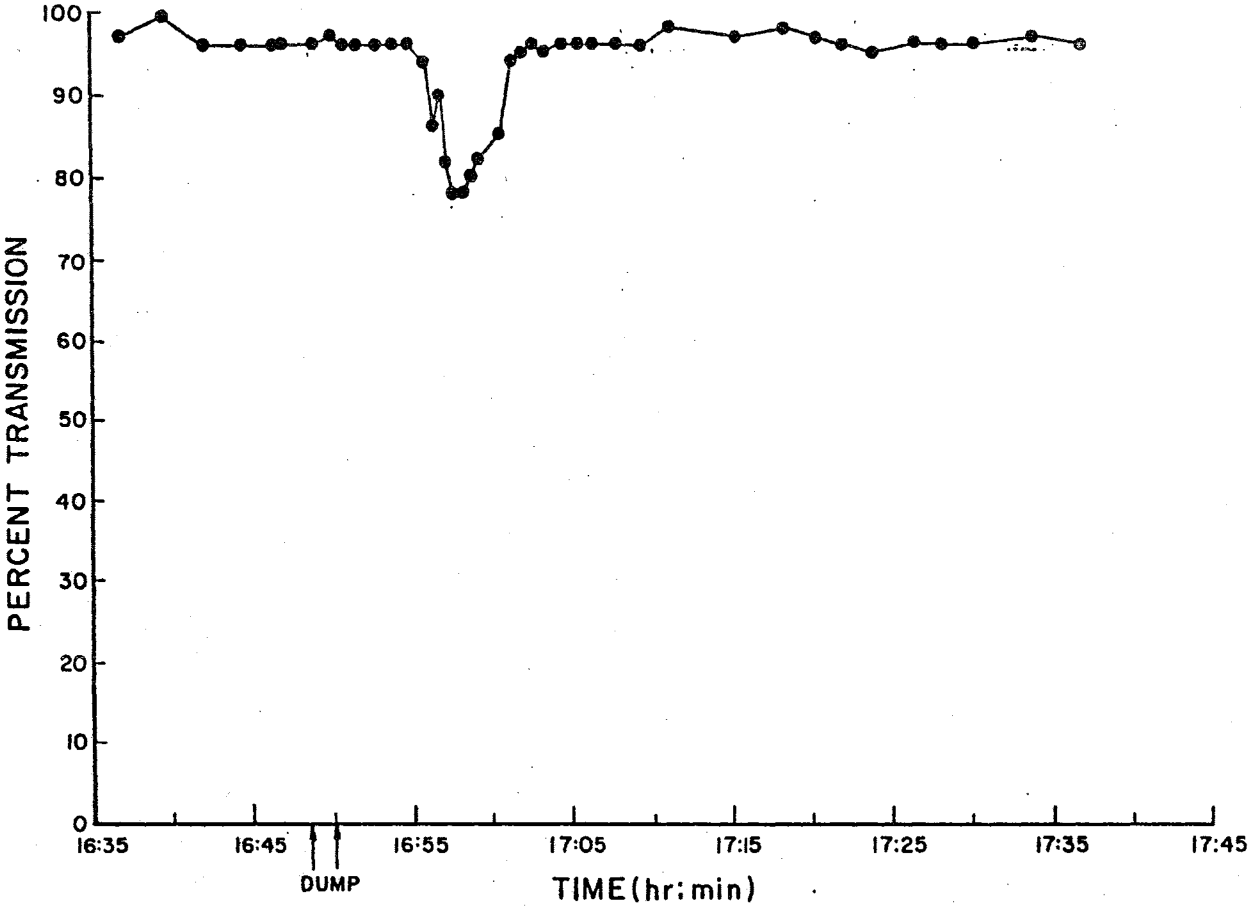


Figure 125
Percent Transmission: Elliott Bay Dump No. 2
Depth: 30 meters

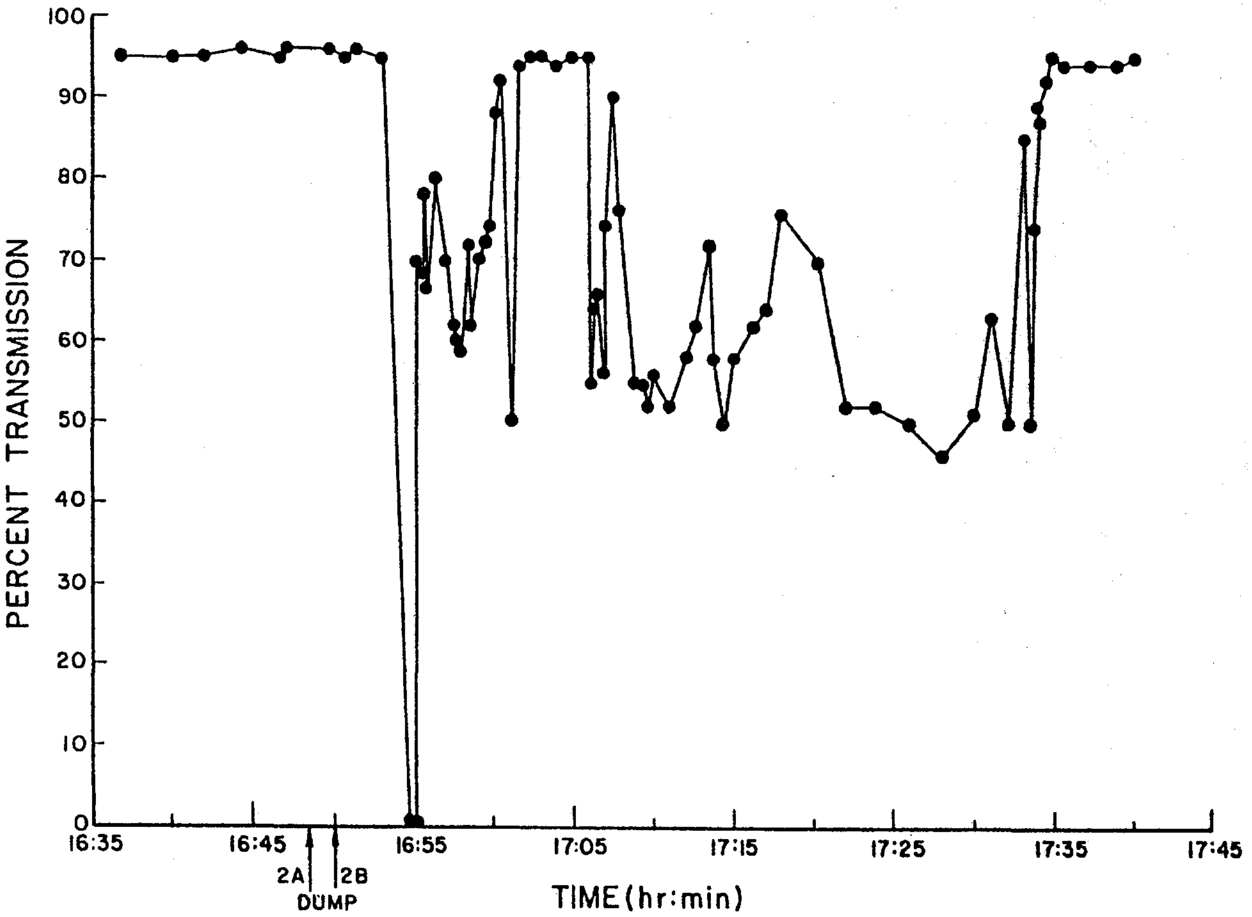


Figure 126

Percent Transmission: Elliott Bay Dump No. 2
Depth: 60 meters

the actual disposal, so only pre- and post-disposal data are available. The pre-disposal data (Table 412) were taken from 11:25 to 11:43. The temperature ranged from 7.0°C near the surface to 8.5°C at 60 meters. Dissolved oxygen concentrations ranged from 14.4 mg/l near the surface to 9.8 mg/l at 60 meters. Figure 127 shows the D.O. profiles of the water column before and after disposal. There was a small increase in temperature and decrease in D.O. The temperature ranged from 8.0 to 8.5°C, and the D.O. ranged from 10.4 to 9.7 mg/l. The decrease in D.O.was less than 1.0 mg/l throughout the water column, except for the top 5 meters. The reason for the marked difference in D.O. in the surface waters is uncertain because D.O. was not monitored during disposal.

Pre- and post-disposal water column profile data for the first disposal operation (Elliott Bay Dump No. 1) are presented in Table 413. Pre-disposal measurement was commenced at 14:06. The temperature ranged from 8.0 to 8.5°C, while D.O. ranged from 10.7 mg/l at the surface to 9.2 mg/l at 60 meters. The post-disposal profile (15:20) showed the same temperature range. Dissolved oxygen, however, ranged from 9.3 to 8.7 mg/l, decreases of 1.4 and 0.5 mg/l from corresponding pre-disposal values. Figure 128 is a plot of the pre- and post-disposal D.O. reading. The D.O. was relatively uniformly decreased by 0.5 mg/l, except at the surface where the decrease was 1.4 mg/l.

Temperature and D.O. were continuously monitored at a depth of 60 meters. Table 414 shows that the temperature remained at 8.0°C. However, there were fluctuations in D.O. concentrations (more clearly seen in Figure 129). Nevertheless, these changes were very small, 0.1 and 0.2 mg/l O_2. Post-disposal D.O. changes were so slight that one cannot attribute them to the disposal.

Table 412

Pre- and Post-Disposal Water Column Measurements: Elliott Bay Unmonitored* Disposal Operation

Time (hr:min)	Depth (m)	Temp (^{o}C)	D.O. (mg/l)
11:25:00	5	7.0	14.4
11:30:00	10	8.0	11.4
11:32:00	15	8.0	11.1
11:34:00	20	8.0	10.8
11:35:00	25	8.0	10.5
11:36:00	30	8.0	10.4
11:37:00	35	8.0	10.4
11:37:00	40	8.0	10.3
11:39:00	45	8.0	10.1
11:41:00	50	8.5	10.2
11:42:00	55	8.5	10.0
11:43:00	60	8.5	9.8
Unmonitored Dump Occurred			
13:15:00	1	8.0	10.4
13:17:00	5	8.5	10.2
13:18:00	10	8.0	10.4
13:19:00	15	8.0	10.4
13:19:30	20	8.0	10.2
13:20:00	25	8.0	10.2
13:21:00	30	8.0	10.1
13:21:30	35	8.0	10.0
13:22:00	40	8.0	9.9
13:22:00	45	8.0	9.9
13:23:00	50	8.5	9.8
13:24:00	55	8.5	9.8
13:24:00	60	8.5	9.7

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*Circumstance prevented sampling boat from being present during actual disposal operation.

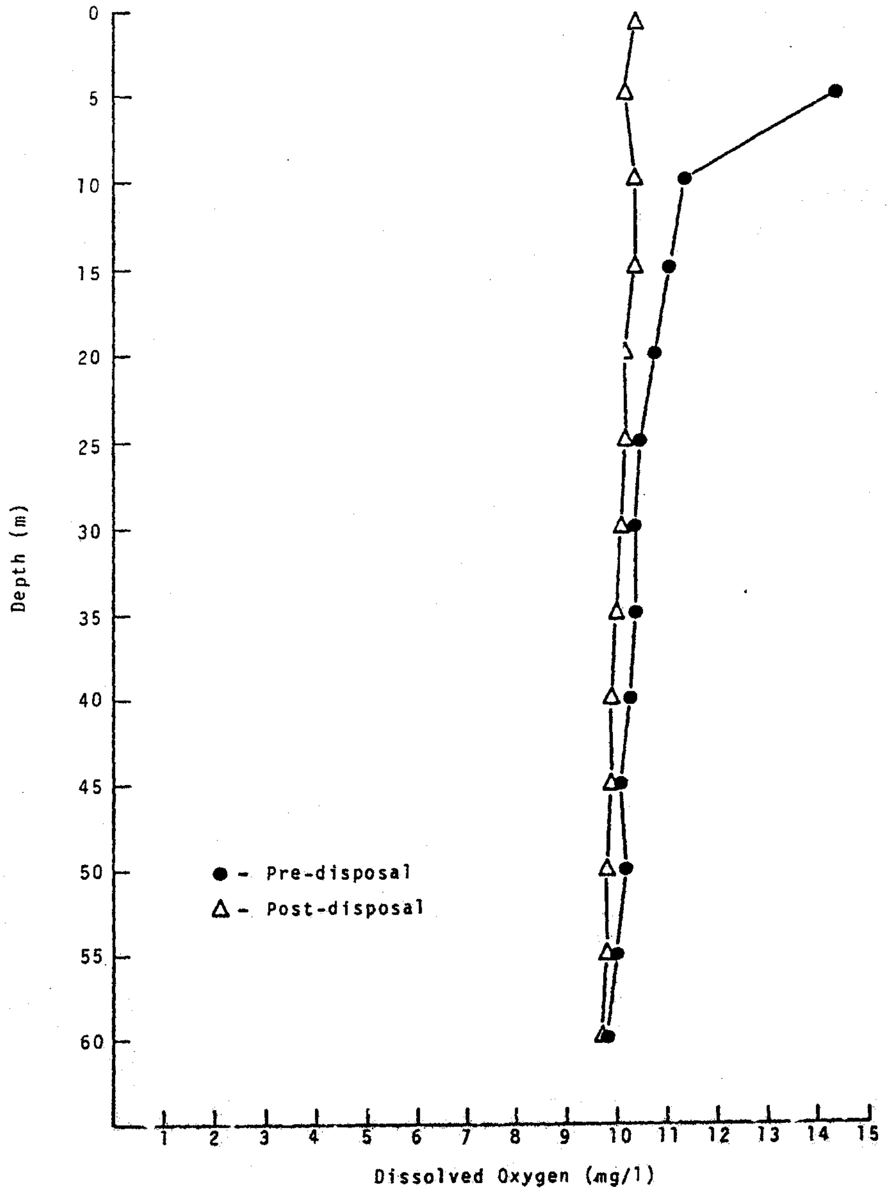

Figure 127
Changes in Dissolved Oxygen: Elliott Bay
Unmonitored Disposal Operation
(February 17, 1976)

Table 413

Pre- and Post-Disposal Water Column Measurements: Elliott Bay Dump No. 1

Time (hr.min)	Depth (m)	Temp (°C)	D.O. (mg/l)	Salinity (°/00)
14:06	1	8.0	10.7	23.0
	5	8.0	10.0	25.5
	10	8.0	10.0	25.5
	15	8.0	9.8	25.5
	20	8.0	9.8	25.5
	25	8.0	9.7	25.7
	30	8.0	9.6	25.8
	35	8.0	9.6	25.9
	40	8.0	9.4	26.0
	43	8.0	9.3	26.0
	45	8.0	9.5	-
	50	8.5	9.4	-
	55	8.5	9.3	-
	60	8.0	9.2	-
		14:36 - Dump Occurred		
15:20	1	8.5	9.3	-
	5	8.5	9.2	-
	10	8.5	9.2	-
	15	8.5	9.2	-
	20	8.5	9.3	-
	25	8.5	9.2	-
	30	8.5	9.2	-
	35	8.5	9.1	-
	40	8.5	9.0	-
	45	8.5	8.9	-
	50	8.0	8.8	-
	55	8.0	8.7	-
	60	8.0	8.7	-

Dash (-) indicates data not available.

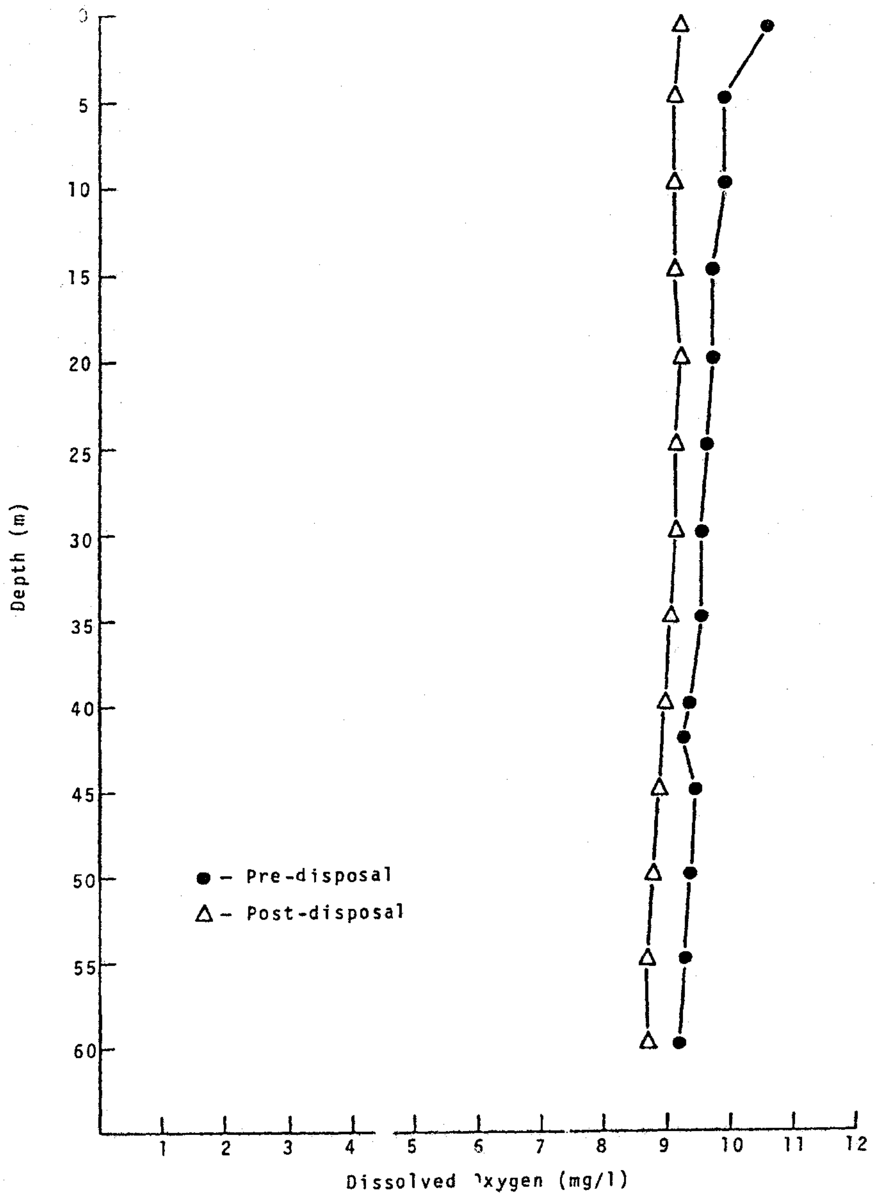

Figure 128

Pre- and Post-Disposal Dissolved Oxygen: Elliott Bay Dump No. 1
(February 17, 1976)

Table 414

Changes in Dissolved Oxygen and Temperature at 60 Meters: Elliott Bay Dump No. 1

Time (hr:min: sec)	Temp (°C)	D.O. (mg/l)	Time (hr:min: sec)	Temp (°C)	D.O. (mg/l)
14:28:00	8.0	9.2	14:42:00	8.0	8.9
14:29:00	8.0	9.0	14:42:30	8.0	8.9
14:31:00	8.0	9.1	14:43:00	8.0	8.9
14:32:00	8.0	9.1	14:43:30	8.0	8.9
14:33:00	8.0	9.1	14:44:00	8.0	8.9
14:34:00	8.0	9.1	14:44:30	8.0	8.9
14:35:00	8.0	9.1	14:45:00	8.0	8.9
14:36:00	8.0	9.1	14:46:00	8.0	8.9
14:36:30 - Dump No. 1A					
14:37:00	8.0	9.1	14:47:00	8.0	8.9
14:37:30	8.0	8.9	14:48:00	8.0	8.9
14:38:00	8.0	8.9	14:49:00	8.0	8.9
14:38:30	8.0	9.0	14:50:00	8.0	8.9
14:39:00	8.0	9.0	14:51:00	8.0	8.9
14:39:30 - Dump No. 1B					
14:39:30	8.0	8.9	14:55:00	8.0	8.7
14:40:00	8.0	9.0	15:00:00	8.0	8.8
14:40:30	8.0	8.9	15:10:00	8.0	8.7
14:41:30	8.0	9.0			

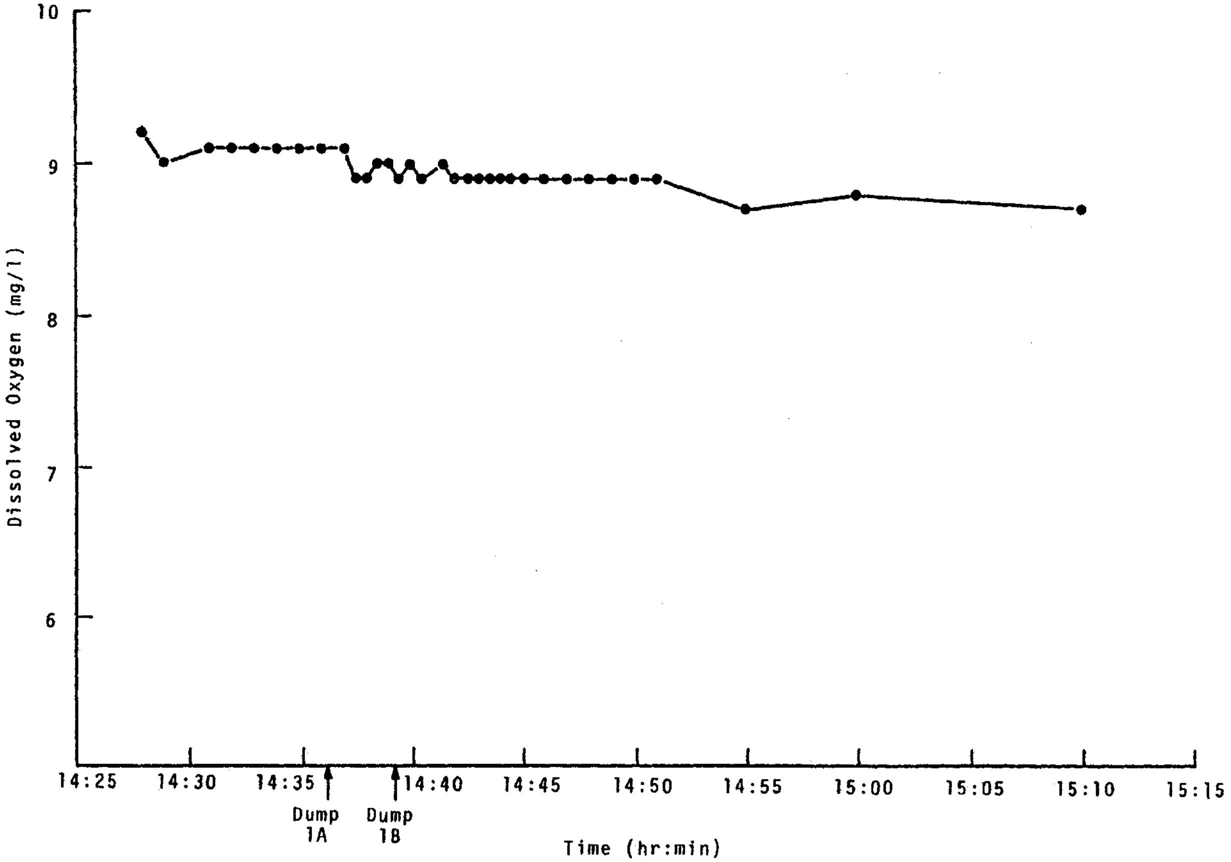

Figure 129

Changes in Dissolved Oxygen: Elliott Bay Dump No. 1
Depth: 60 meters

Pre- and post-disposal data for Elliott Bay Dump No. 2 are presented in Table 415. At 16:50, a pre-dump profile showed a temperature of 8.0°C from top to bottom. Dissolved oxygen ranged from 10.2 mg/l at the surface to 9.0 mg/l at the bottom. The post-disposal profile (17:30) showed a temperature range from 8.0 to 8.5°C. The D.O. range (9.2 to 8.8 mg/l) was definitely lower than the pre-disposal range. Figure 130 presents the profiles of D.O. data. The post-disposal plot shows a slight (approximately 1.0 to 0.2 mg/l) decrease in oxygen concentration. Considering the high initial D.O. levels, the decrease is not signigicant to water quality. Figure 131 presents changes in D.O. at 60 meters during Elliott Bay Dump No. 2. From the data presented, no lasting effect of disposal operations can be detected.

Heavy Metals

Results of heavy metal analyses for samples taken throughout the disposal operation sampling period are listed in Table 416. Background data taken just prior to disposal showed no obvious trends in soluble metal concentrations with respect to depth. Iron levels were usually higher at 60 m than at 1 and 30 m. Pre-disposal manganese concentrations were consistently below 100 μg/l. The cadmium and copper concentrations, which varied little, were never above 4 μg/l; nickel and lead concentrations were consistently below 7 μg/l. Zinc levels fluctuated somewhat, ranging from 2.9 to 12.9 μg/l. Mercury levels were below detection limits (0.005 μg/l) for most samples, although concentrations as high as 0.04 μg/l were found.

The first dump (1A) occurred at 14:36:30 and the second dump (1B) occurred at 14:39:30. Samples collected during this disposal operation (Elliott Bay Dumps 1A and 1B) showed no changes in the concentrations of chromium, cadmium, nickel, lead, copper, and arsenic. Soluble iron increased

Table 415

Pre- and Post-Disposal Water Column Measurements: Elliott Bay Dump No. 2

Depth (m)	Pre-Disposal (16:50)		Post-Disposal (17:30)	
	Temp (°C)	D.O. (mg/l)	Temp (°C)	D.O. (mg/l)
1	8.0	10.2	8.0	9.1
5	8.0	9.9	8.5	9.0
10	8.0	9.8	8.5	9.2
15	8.0	9.6	8.5	9.2
20	8.0	9.6	8.5	9.1
25	8.0	9.5	8.5	9.0
30	8.0	9.5	8.5	8.9
35	8.0	9.4	8.0	8.9
40	8.0	9.3	8.5	8.9
45	8.0	9.3	8.0	8.8
50	8.0	9.2	8.0	8.8
55	8.0	9.2	8.5	8.8
60	8.0	9.0	8.0	8.8

as a result of disposal; concentrations as high as 328 µg/l were observed at 1 meter and as high as 438 and 911 µg/l at 30 and 60 meters, respectively. The release of manganese was also indicated, with concentrations in the water column increasing 20 to 40 µg/l (to near 100 µg/l). As with iron, the manganese release was more pronounced at the lower depths.

Concentrations of soluble iron and manganese returned to pre-disposal levels within minutes of Dumps 1A and 1B. Higher levels did not persist in the sampling area for

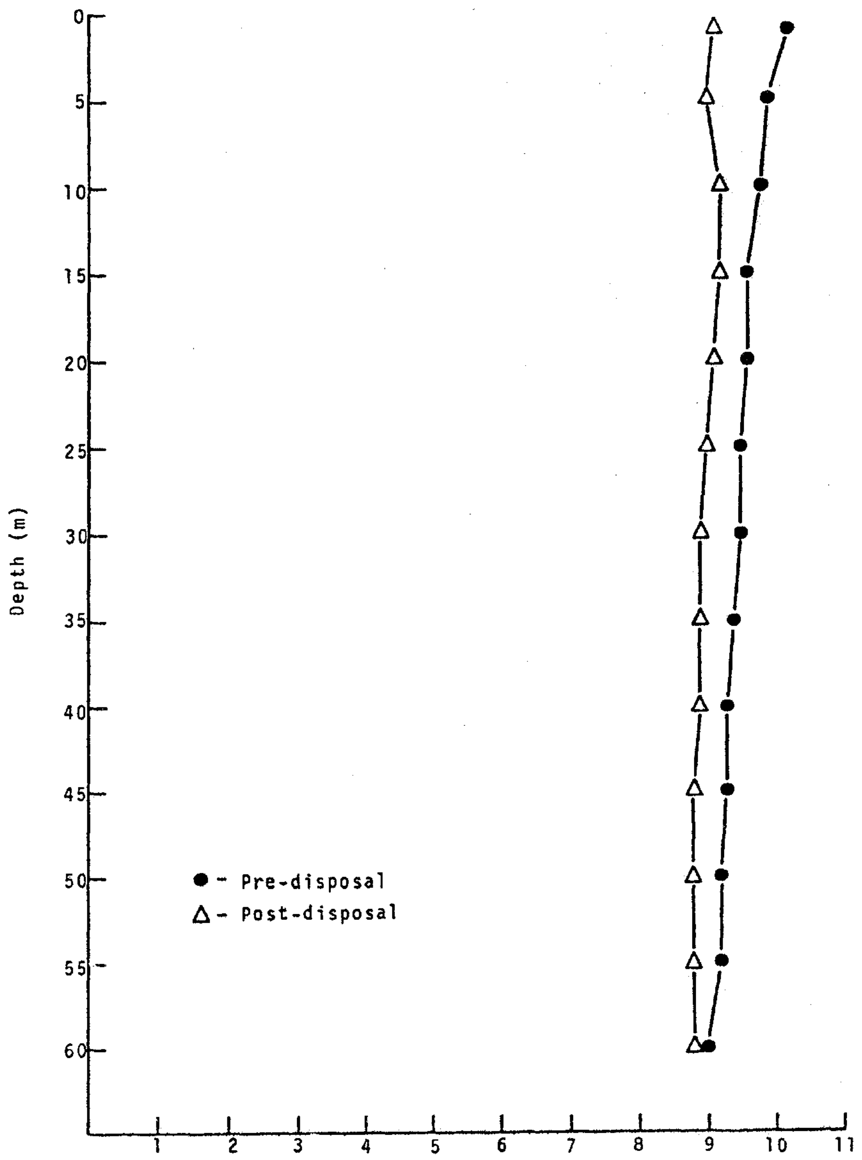

Figure 130

Pre- and Post-Disposal Dissolved Oxygen: Elliott Bay Dump No. 2
(February 17, 1976)

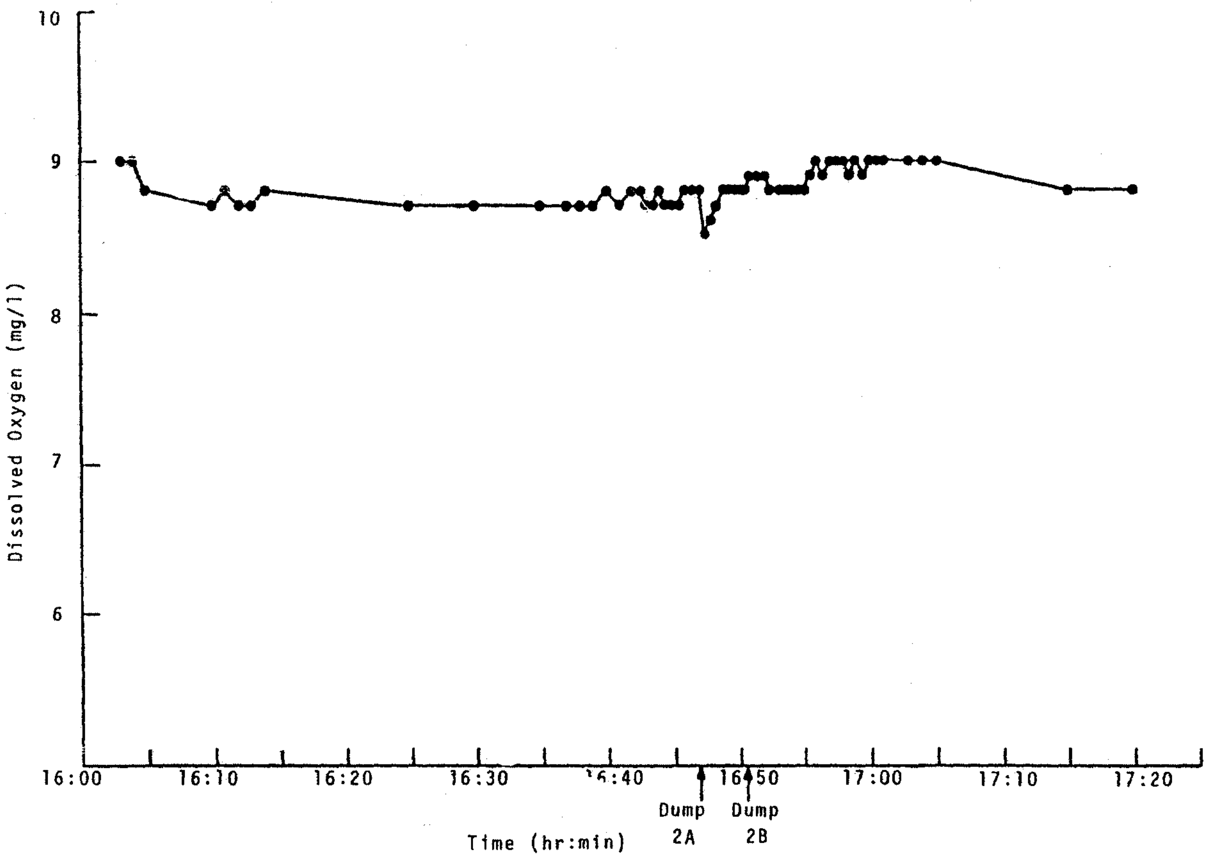

Figure 131

Changes in Dissolved Oxygen: Elliott Bay Dump No. 2

Depth: 60 meters

Table 416

Soluble Heavy Metal Concentrations: Elliott Bay Disposal Operations, Material Dredged from Duwamish River

(μg/l)

Time (hr:min:sec)	Depth (m)	Mn	Cd	Cr	Zn	Ni	Pb	Cu	Fe	Hg	As
13:07:30	1	53	1.8	< 2	12.4	5.9	3.8	2.1	22	< 0.005	< 2
13:08:00	30	46	1.9	< 2	7.8	6.2	4.5	2.4	31	< 0.005	< 2
13:08:30	60	61	1.4	< 2	6.9	5.9	3.8	1.5	136	< 0.005	< 2
13:54:00	1	68	1.6	< 2	12.9	5.6	2.6	2.1	13	< 0.005	< 2
13:55:00	30	61	1.8	< 2	7.3	6.2	3.8	2.0	40	< 0.005	< 2
13:55:50	60	53	1.8	< 2	7.3	6.5	3.3	1.7	24	< 0.005	< 2
14:06:00	1	53	1.9	< 2	10.7	5.6	3.3	2.0	131	< 0.005	< 2
14:07:00	30	46	1.5	< 2	10.2	5.6	3.0	1.6	20	< 0.005	< 2
14:07:45	60	53	1.7	< 2	8.0	5.9	2.8	2.0	133	< 0.005	< 2
14:20:30	1	53	1.7	< 2	8.4	5.6	2.8	2.1	13	< 0.005	< 2
14:21:00	30	61	1.9	< 2	6.9	5.9	3.8	1.7	62	< 0.005	< 2
14:21:30	60	61	1.8	< 2	5.6	5.0	2.8	1.2	18	< 0.005	< 2
14:25:00	1	53	1.8	< 2	9.1	5.9	3.5	2.2	22	< 0.005	< 2
14:25:30	30	84	1.3	< 2	5.2	3.8	1.4	1.9	13	0.040	< 2
14:25:50	60	36	1.0	< 2	6.6	4.1	1.5	2.6	237	0.020	< 2
14:30:00	1	84	0.9	< 2	7.5	2.4	1.4	3.3	18	0.020	< 2
14:30:30	30	36	1.0	< 2	5.6	3.8	1.2	2.0	14	0.020	< 2
14:31:00	60	36	0.8	< 2	6.8	3.4	2.0	2.2	25	0.020	< 2

(Continued)

Table 416 (Continued)

Time (hr:min:sec)	Depth (m)	Mn	Cd	Cr	Zn	Ni	Pb	Cu	Fe	Hg	As
14:34:30	1	84	1.0	< 2	7.0	2.8	1.2	3.2	14	0.020	< 2
14:35:00	30	36	0.5	< 2	5.6	2.6	1.5	3.0	16	0.020	< 2
14:35:15	60	52	0.9	< 2	4.9	3.8	2.3	2.1	22	0.020	< 2
14:36:00	1	52	0.9	< 2	2.9	4.3	2.0	3.4	13	0.020	< 2
14:36:30	30	36	0.8	< 2	5.2	3.2	1.5	2.4	14	0.165	< 2
14:36:30 - Dump 1A occurred											
14:36:45	60	68	0.9	< 2	6.9	4.1	1.8	2.1	131	0.020	< 2
14:37:15	1	68	1.1	< 2	7.6	3.4	1.2	2.5	21	0.020	< 2
14:37:30	30	36	1.0	< 2	6.0	2.8	< 1	2.9	12	0.165	< 2
14:37:45	60	68	0.7	< 2	6.6	3.0	1.8	2.8	30	0.165	< 2
14:38:15	1	36	0.9	< 2	5.4	4.1	2.4	2.2	214	0.020	< 2
14:38:30	30	68	0.9	< 2	5.7	3.8	1.4	1.9	107	0.090	< 2
14:38:45	60	52	1.0	< 2	6.6	3.9	1.5	2.5	228	0.020	< 2
14:39:30	1	52	0.9	< 2	8.0	3.9	1.7	2.5	328	0.020	< 2
14:39:30 - Dump 1B occurred											
14:39:45	30	84	0.9	< 2	7.0	4.1	1.8	2.6	202	0.020	< 2

(Continued)

Table 416 (Continued)

Time (hr:min:sec)	Depth (m)	Mn	Cd	Cr	Zn	Ni	Pb	Cu	Fe	Hg	As
14:40:00	60	19	0.7	< 2	5.9	3.8	1.4	2.0	488	< 0.005	< 2
14:40:15	1	63	1.4	< 2	8.8	5.0	2.0	2.5	170	< 0.005	< 2
14:40:40	30	75	1.3	< 2	8.3	3.8	1.5	1.9	97	< 0.005	< 2
14:41:00	60	38	1.5	< 2	8.5	4.3	1.8	2.2	551	< 0.005	< 2
14:41:15	1	63	1.8	< 2	13.0	4.0	1.8	2.2	72	< 0.005	< 2
14:41:30	30	75	1.7	< 2	6.8	4.5	1.5	2.0	338	< 0.005	< 2
14:41:45	60	75	1.7	< 2	9.5	3.8	2.0	2.3	443	< 0.005	< 2
14:42:30	1	63	1.7	< 2	8.3	4.8	1.5	2.2	44	< 0.005	< 2
14:42:45	60	50	1.4	< 2	8.5	6.1	1.5	1.9	172	< 0.005	< 2
14:43:00	30	38	1.5	< 2	6.8	5.0	1.3	2.0	17	< 0.005	< 2
14:43:45	30	100	2.4	< 2	7.0	5.3	1.8	2.5	67	< 0.005	< 2
14:44:00	60	38	2.0	< 2	10.9	6.3	2.0	5.7	911	< 0.005	< 2
14:44:15	30	88	1.4	< 2	8.2	3.0	1.5	1.9	76	< 0.005	< 2
14:44:45	60	88	1.3	< 2	7.5	5.0	1.5	2.2	681	< 0.005	< 2
14:45:05	30	50	1.4	< 2	13.7	5.6	1.3	2.3	72	< 0.005	< 2
14:45:20	60	88	1.4	< 2	6.3	5.3	2.0	1.6	76	< 0.005	< 2
14:45:40	30	88	1.4	< 2	7.8	4.3	2.3	2.0	322	< 0.005	< 2
14:46:00	60	100	1.7	< 2	8.2	5.0	1.8	1.9	90	< 0.005	< 2

(Continued)

Table 416 (Continued)

Time (hr:min:sec)	Depth (m)	Mn	Cd	Cr	Zn	Ni	Pb	Cu	Fe	Hg	As
14:46:20	30	75	1.5	< 2	20.9	5.3	1.8	2.7	438	< 0.005	< 2
14:46:30	60	75	1.3	< 2	7.8	3.8	1.3	1.5	51	< 0.005	< 2
14:47:00	30	63	1.4	< 2	7.2	5.0	1.8	2.5	360	< 0.005	< 2
14:47:15	60	52	1.6	< 2	8.0	5.0	2.1	2.1	140	0.065	< 2
14:47:30	30	52	1.7	< 2	5.6	5.0	2.6	3.8	53	0.055	< 2
14:48:00	60	52	1.7	< 2	4.2	5.0	2.1	2.6	45	0.085	< 2
14:48:30	1	68	1.7	< 2	7.1	5.3	2.6	2.1	37	0.075	< 2
14:48:50	30	68	1.5	< 2	6.7	4.5	2.4	1.8	29	0.065	< 2
14:49:05	60	36	1.5	< 2	17.8	4.8	2.1	2.0	71	0.065	< 2
14:50:00	1	19	1.7	< 2	6.6	4.8	2.4	1.8	10	0.075	< 2
14:50:30	30	68	1.5	< 2	5.0	4.5	2.3	2.2	25	0.030	< 2
14:50:45	60	52	1.4	< 2	10.3	5.6	2.4	2.2	42	0.055	< 2
14:55:00	1	68	1.6	< 2	11.4	4.5	2.1	1.9	36	0.055	< 2
14:55:20	30	19	1.5	< 2	6.0	4.5	1.7	2.3	7	0.030	< 2
14:55:45	60	52	1.4	< 2	4.1	5.0	1.5	1.7	42	0.030	< 2
15:00:00	1	68	1.8	< 2	11.8	5.0	2.1	2.2	26	0.055	< 2
15:00:20	30	36	1.7	< 2	6.4	4.8	1.7	2.5	24	0.030	< 2
15:00:40	60	36	1.4	< 2	5.7	4.3	2.4	2.4	51	0.030	< 2

(Continued)

Table 416 (Continued)

Time (hr:min:sec)	Depth (m)	Mn	Cd	Cr	Zn	Ni	Pb	Cu	Fe	Hg	As
15:14:45	1	19	1.7	< 2	6.0	5.0	1.9	2.0	79	0.020	< 2
15:51:15	30	52	1.6	< 2	14.9	5.0	2.6	2.3	11	0.005	< 2
15:15:30	60	52	1.5	< 2	9.1	5.6	2.4	2.8	89	0.110	< 2
15:30:00	1	38	1.7	< 2	10.0	5.9	2.8	2.2	42	< 0.005	< 2
15:30:15	30	68	1.6	< 2	7.1	5.9	3.0	1.6	16	< 0.005	< 2
15:30:50	60	68	1.7	< 2	7.6	5.0	2.8	1.3	20	< 0.005	< 2
15:50:20	60	61	1.5	< 2	6.2	5.3	3.0	1.3	29	< 0.005	< 2
16:02:00	1	53	1.6	< 2	7.4	6.5	3.8	1.9	16	< 0.005	< 2
16:02:45	30	46	1.6	< 2	7.1	5.3	3.3	1.9	40	< 0.005	< 2
16:03:15	60	61	1.8	< 2	6.0	6.5	3.5	1.6	58	< 0.005	< 2
16:15:30	1	36	1.7	< 2	7.1	5.3	1.9	2.7	26	0.055	< 2
16:16:45	30	27	1.8	< 2	5.2	4.8	1.7	2.2	9	< 0.005	< 2
16:18:30	60	27	1.8	< 2	4.9	5.3	1.7	2.2	11	0.040	< 2
16:30:00	60	37	2.0	< 2	5.3	5.5	2.0	2.6	25	< 0.005	< 2
16:35:45	1	27	1.8	< 2	9.4	5.3	1.7	3.4	94	< 0.005	< 2
16:36:15	30	48	1.7	< 2	6.3	5.8	2.0	1.4	7	< 0.005	< 2
16:36:40	60	48	1.9	< 2	5.7	5.1	2.0	2.2	15	< 0.005	< 2
16:40:00	1	48	1.7	< 2	11.5	5.1	2.0	1.7	11	< 0.005	< 2

(Continued)

Table 416 (Continued)

Time (hr:min:sec)	Depth (m)	Mn	Cd	Cr	Zn	Ni	Pb	Cu	Fe	Hg	As
16:40:15	30	37	1.9	< 2	6.3	6.3	2.6	2.1	47	< 0.005	< 2
16:40:30	60	37	1.7	< 2	7.9	6.0	2.0	1.9	11	< 0.005	< 2
16:44:45	1	27	1.7	< 2	7.0	5.1	1.4	1.9	71	< 0.005	< 2
16:45:00	30	37	2.0	< 2	5.5	5.5	2.0	2.9	9	< 0.005	< 2
16:45:15	60	58	1.9	< 2	5.5	6.3	2.0	1.9	11	< 0.005	< 2
16:45:45	1	27	1.8	< 2	5.8	4.8	2.9	2.6	17	< 0.005	< 2
16:46:00	30	41	1.4	< 2	4.0	4.1	1.4	1.9	11	< 0.005	< 2
16:46:20	60	29	1.5	< 2	12.8	4.4	2.1	2.8	20	< 0.005	< 2
16:46:45	1	29	1.5	< 2	4.4	5.0	1.4	1.6	61	< 0.005	< 2
16:47:00	30	17	1.4	< 2	5.1	4.4	2.1	2.2	39	< 0.005	< 2
16:47:10	60	29	1.3	< 2	3.3	4.4	2.1	2.1	13	< 0.005	< 2
16:47:40	1	17	1.4	< 2	8.1	6.9	2.1	2.7	16	< 0.005	< 2
16:47:55	30	17	1.7	< 2	4.7	3.9	1.1	2.7	17	< 0.005	< 2
16:47:55 - Dump 2A occurred											
16:48:15	60	29	1.5	< 2	3.8	4.6	1.8	2.4	12	< 0.005	< 2
16:48:30	30	17	1.4	< 2	4.6	4.6	1.4	2.1	59	< 0.005	< 2
16:48:45	30	41	1.5	< 2	4.8	4.6	1.1	2.2	12	< 0.005	< 2

(Continued)

Table 416 (Continued)

Time (hr:min:sec)	Depth (m)	Mn	Cd	Cr	Zn	Ni	Pb	Cu	Fe	Hg	As
16:49:00	60	41	1.4	< 2	3.7	5.0	1.4	2.2	59	< 0.005	< 2
16:49:45	1	29	1.3	< 2	5.1	3.9	1.8	2.2	18	< 0.005	< 2
16:50:15	60	29	1.3	< 2	27.7	5.5	1.4	2.9	44	< 0.005	< 2
16:50:20 - Dump 2B occurred											
16:50:30	1	53	1.6	< 2	5.6	5.9	1.8	3.0	801	< 0.005	< 2
16:50:45	60	29	1.3	< 2	8.2	6.0	2.1	2.4	38	< 0.005	< 2
16:51:30	1	29	1.8	< 2	5.1	4.6	2.1	4.1	23	< 0.005	< 2
16:51:45	30	17	1.8	< 2	5.1	4.6	1.1	2.8	11	< 0.005	< 2
16:52:05	60	41	1.5	< 2	4.6	4.8	1.8	2.2	29	< 0.005	< 2
16:52:20	1	23	1.2	< 2	10.5	6.0	1.8	4.1	45	< 0.005	< 2
16:52:50	30	38	1.5	< 2	6.1	5.1	1.5	1.9	24	0.120	< 2
16:53:10	60	38	1.7	< 2	5.8	5.1	1.3	1.7	57	< 0.005	< 2
16:53:30	1	23	1.6	< 2	7.1	4.2	< 1	2.0	32	< 0.005	< 2
16:53:45	30	23	2.0	< 2	11.4	6.0	1.0	2.4	34	< 0.005	< 2
16:54:00	60	68	1.2	< 2	7.2	4.8	1.0	1.6	16	< 0.005	< 2
16:54:25	1	23	1.5	< 2	7.0	4.2	< 1	2.0	40	< 0.005	< 2
16:54:40	30	53	1.4	< 2	11.0	5.1	1.5	1.8	32	< 0.005	< 2

(Continued)

Table 416 (Continued)

Time (hr:min:sec)	Depth (m)	Mn	Cd	Cr	Zn	Ni	Pb	Cu	Fe	Hg	As
16:55:00	60	38	1.2	< 2	5.7	6.0	1.8	1.6	85	< 0.005	< 2
16:55:20	1	23	1.3	< 2	10.2	4.8	2.0	2.4	35	0.120	< 2
16:55:40	30	53	1.9	< 2	8.1	6.0	1.5	2.1	23	< 0.005	< 2
16:56:00	60	53	1.5	< 2	9.3	5.7	1.3	1.8	213	< 0.005	< 2
16:56:15	1	68	1.4	< 2	8.0	5.1	1.5	1.9	38	< 0.005	< 2
16:56:36	30	38	1.7	< 2	8.8	5.4	1.5	3.3	218	0.065	< 2
16:57:00	60	53	1.5	< 2	8.8	6.3	1.0	1.9	35	< 0.005	< 2
16:57:20	1	23	2.0	< 2	13.1	4.8	1.0	2.3	31	0.120	< 2
16:57:35	30	23	2.3	< 2	8.1	5.4	1.3	2.3	21	0.120	< 2
16:58:10	60	68	1.8	< 2	6.7	5.4	1.3	1.9	33	0.170	< 2
16:58:15	1	38	1.8	< 2	7.7	6.0	1.3	2.1	29	< 0.005	< 2
16:58:30	30	54	1.8	< 2	6.7	6.1	3.2	1.8	32	0.100	< 2
17:00:30	60	139	1.5	< 2	9.6	6.1	2.6	1.6	33	0.235	< 2
17:00:30	1	103	1.6	< 2	14.7	5.4	2.9	1.6	34	0.235	< 2
17:00:30	30	139	2.0	< 2	13.4	6.1	2.3	1.9	25	0.100	< 2
17:00:30	60	78	1.3	< 2	8.3	5.7	2.6	1.2	74	0.045	< 2
17:10:00	1	91	1.5	< 2	11.9	5.4	2.9	2.7	10	0.045	< 2
17:10:00	30	115	1.8	< 2	5.6	5.4	2.6	1.6	22	0.075	< 2
17:10:00	60	91	1.6	< 2	8.5	6.8	2.9	1.3	34	0.175	< 2

(Continued)

Table 416 (Concluded)

Time (hr:min:sec)	Depth (m)	Mn	Cd	Cr	Zn	Ni	Pb	Cu	Fe	Hg	As
17:20:00	1	91	1.8	< 2	8.3	6.4	3.2	2.1	84	0.090	< 2
17:20:00	60	139	1.5	< 2	13.9	5.7	2.3	2.4	10	0.220	< 2
17:21:00	30	127	1.9	< 2	17.0	6.4	3.2	3.1	208	0.100	< 2
17:31:30	1	91	1.5	< 2	7.6	6.1	2.6	1.8	16	0.235	< 2
17:31:30	30	91	4.3	< 2	23.5	6.8	2.6	2.8	22	0.100	< 2

over seven minutes, although about eight minutes after the dumps there was a slight increase (to 0.055 μg/l) in soluble mercury at 30 and 60 meters. Elevated mercury concentrations dissipated after about 30 minutes.

Elliott Bay Dumps Nos. 2A and 2B occurred at 16:47:55 and 16:50:20, respectively. No changes in the concentrations of cadmium, chromium, nickel, lead, copper, mercury, and arsenic were observed for the samples collected during these disposal operations. Only five samples at various depths showed concentrations of these metals that were above the pre-disposal levels. Manganese release was more pronounced in these dumps than in Dumps 1A and 1B; concentrations increased at all three depths, with the maximum 139 μg/l. Both manganese and iron levels returned to predisposal concentrations by seven minutes after disposal ceased.

The delayed release of mercury observed in the samples from the first disposal operation was also detected for the second disposal. Concentrations as high as 0.235 μg/l were observed in the 60 m samples collected about 8 minutes after Dump No. 2B. The elevated mercury levels persisted for only three minutes.

The 4.5 hours of continuous monitoring in connection with the two Elliott Bay disposal operations allowed a thorough examination of the resultant changes in heavy metal concentrations in the water column. Increases in soluble manganese, iron and mercury (delayed) were observed in both disposal operations. Increases in iron and mercury are readily apparent from the data in Table 416. The manganese increases, not quite as dramatic, are more clearly discerned in Figures 132 through 134.

As has been seen, elutriate tests on dredged Duwamish River sediments and water predicted the observed release of manganese and iron, as well as the observed sorption

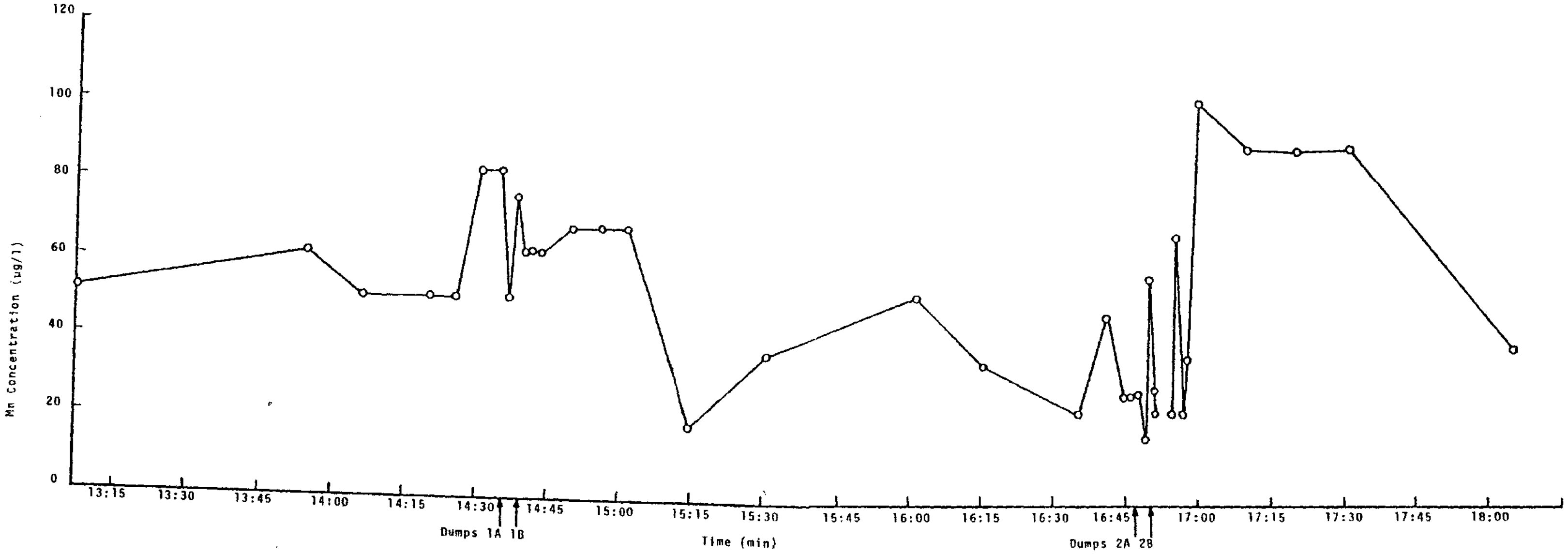

Figure 132
Soluble Manganese Concentrations at 1 Meter Depth,
Elliott Bay Disposal Operations: Sediment from Duwamish River

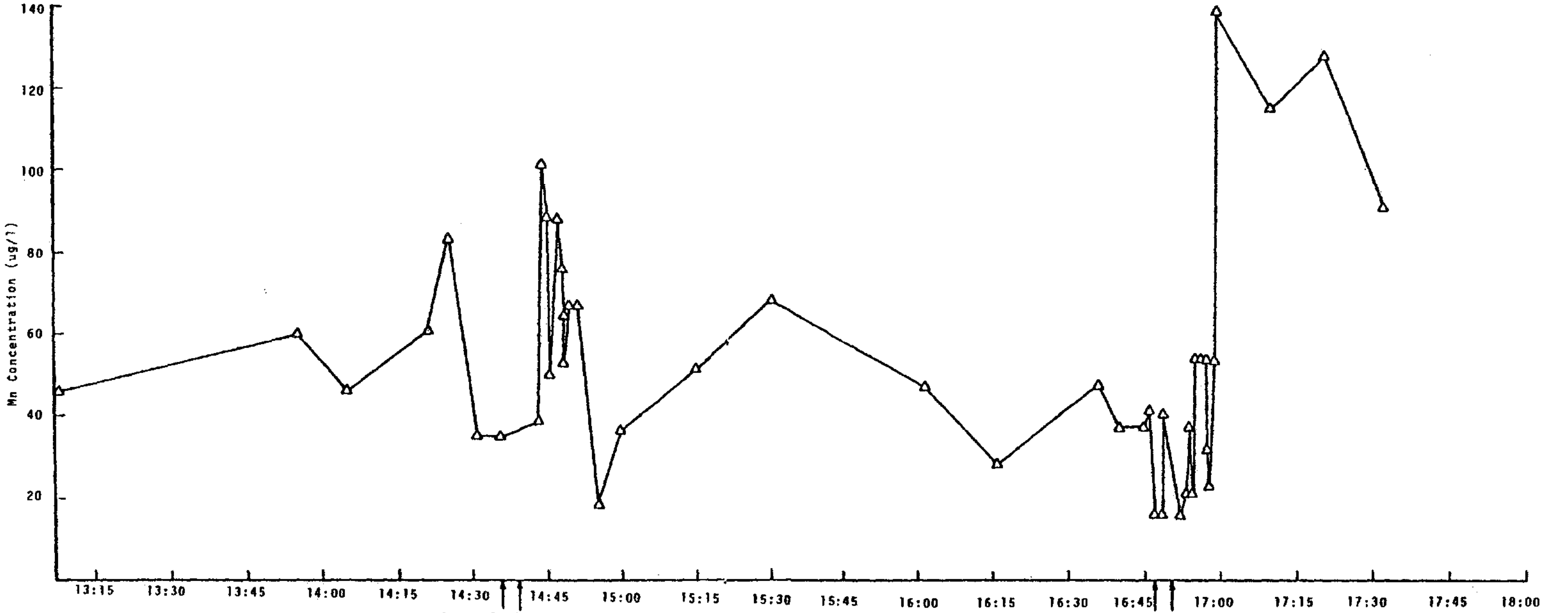

Figure 133

Soluble Manganese Concentrations at 30 meters Depth,
Elliott Bay Disposal Operations, Sediment Dredged from Duwamish River

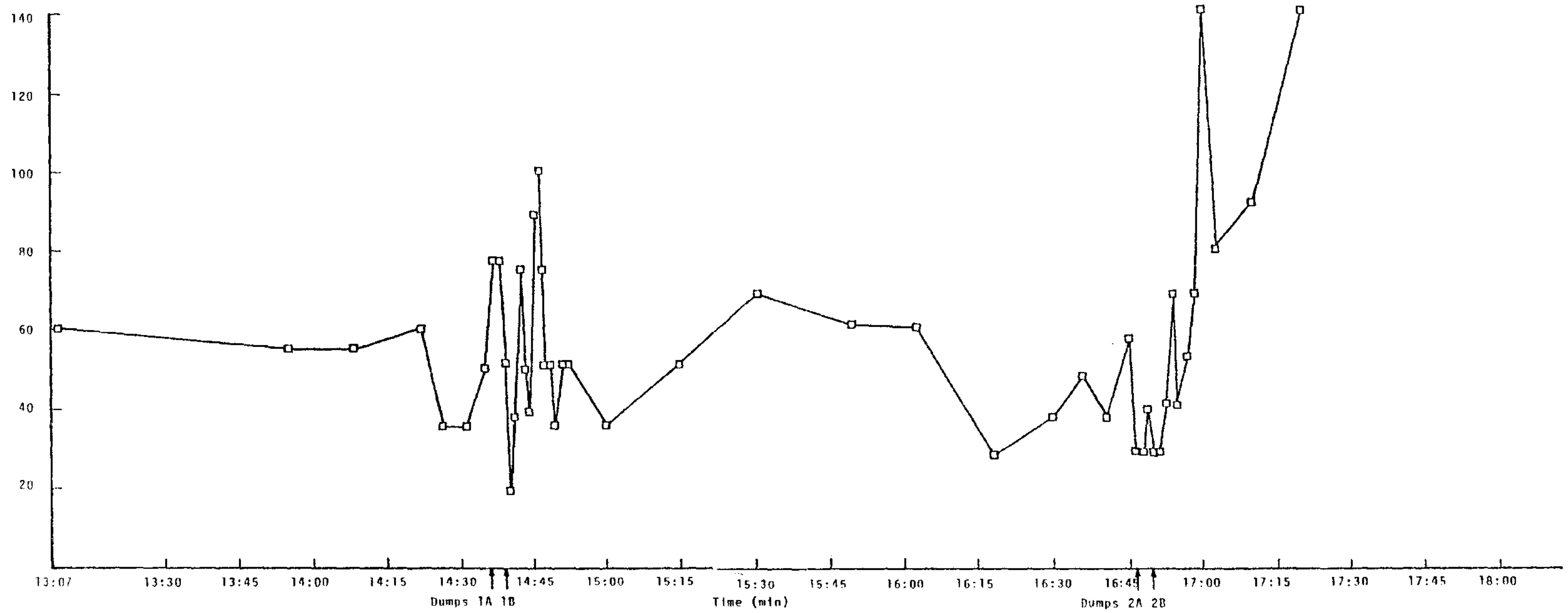

Figure 134
Soluble Manganese Concentrations at 60 meters Depth,
Elliott Bay Disposal Operations: Sediment Dredged from Duwamish River

of zinc. They did not, however, show the mercury release seen from the samples collected during actual disposal of Duwamish River sediment.

Nitrogen Compounds

Results of ammonium and nitrate analyses of the water samples collected before, during and after disposal, appear in Table 417. Prior to disposal, ammonium concentrations were below 0.05 mg N/l at all times and depths. Nitrate concentrations, however, were extremely variable, ranging from 0.31 to 0.49 mg N/l at the three depths monitored. No discernible pattern with respect to depth could be observed.

Elliott Bay Dump No. 1A did not affect ammonium concentrations, although nitrate concentrations increased in the bottom water for 15 seconds after the dump. Following Elliott Bay Dump No. 1B, ammonium was released in the bottom water, but nitrate decreased. However, the concentrations of both returned to pre-disposal levels within one minute of the increase.

During the nearly two-hour period between the first and second dumps, ammonium concentrations in the bottom water occasionally rose above 0.05 mg N/l. Nitrate concentrations during this period ranged between 0.33 and 0.49 mg N/l.

Within one minute of Elliott Bay Dump No. 2A ammonium increased and nitrate decreased in the bottom water. From Table 417 it appears that the bottom turbid plume took more than 30 seconds to reach the sampling point. A significantly high ammonium concentration was observed in the surface water immediately following Dump No. 2B, and nitrate was again found to decrease. However, concentrations of both shortly returned to ambient levels.

The only ammonium concentrations higher than 0.05 mg N/l in the post-disposal water samples were in two bottom water samples. Nitrate concentrations during this period ranged between 0.23 and 0.44 mg N/l; there was no observable pattern with respect to depth.

Table 417

Ammonium and Nitrate Concentrations: Elliott Bay Disposal Operations, Material Dredged from Duwamish River

Time (hr:min:sec)	Depth (m)	Ammonium (mg N/l)	Nitrate (mg N/l)
13:07:30	1	< 0.05	0.36
13:08:00	30	< 0.05	0.34
13:08:30	60	< 0.05	0.41
13:54:00	1	< 0.05	0.49
13:55:00	30	< 0.05	0.37
13:55:50	60	< 0.05	0.31
14:06:00	1	< 0.05	0.36
14:07:00	30	< 0.05	0.39
14:07:45	60	< 0.05	0.37
14:20:30	1	< 0.05	0.37
14:21:00	30	< 0.05	0.37
14:21:30	60	< 0.05	0.34
14:25:00	1	< 0.05	0.35
14:25:30	30	< 0.05	0.40
14:25:50	60	< 0.05	0.48
14:30:00	1	< 0.05	0.38
15:30:30	30	< 0.05	0.39
14:31:00	60	< 0.05	0.35
14:34:30	1	< 0.05	0.40
14:35:00	30	< 0.05	0.35
14:35:15	60	< 0.05	0.34
14:36:00	1	< 0.05	0.49
14:36:30	30	< 0.05	0.41
14:36:30 - Dump No. 1A occurred.			
14:36:45	60	< 0.05	0.64
14:37:15	1	< 0.05	0.48

(Continued)

Table 417 (Continued)

Time (hr:min:sec)	Depth (m)	Ammonium (mg N/l)	Nitrate (mg N/l)
14:37:30	30	< 0.05	0.38
14:37:45	60	< 0.05	0.40
14:38:15	1	< 0.05	0.38
14:38:30	30	< 0.05	0.34
14:38:45	60	0.05	0.37
14:39:30	1	< 0.05	0.35
14:39:30 - Dump No. 1B occurred.			
14:39:45	30	< 0.05	0.38
14:40:00	60	0.17	0.26
14:40:15	1	< 0.05	0.38
14:40:40	30	< 0.05	0.35
14:41:00	60	< 0.05	0.35
14:41:15	1	< 0.05	0.37
14:41:30	30	< 0.05	0.40
14:41:45	60	< 0.05	0.35
14:42:30	1	< 0.05	0.35
14:42:45	60	0.08	0.43
14:43:00	30	< 0.05	0.40
14:43:45	30	< 0.05	0.37
14:44:00	60	0.05	0.35
14:44:15	30	< 0.05	0.35
14:44:45	60	0.06	0.44
14:45:05	30	< 0.05	0.40
14:45:20	60	0.09	0.44
14:45:40	30	< 0.05	0.38
14:46:00	60	< 0.05	0.35
14:46:20	30	< 0.05	0.43
14:46:30	60	< 0.05	0.42
14:47:00	30	< 0.05	0.40
14:47:15	60	< 0.05	0.37
14:47:30	30	< 0.05	0.43
14:48:00	60	< 0.05	0.40

Table 417 (Continued)

Time (hr:min:sec)	Depth (m)	Ammonium (mg N/l)	Nitrate (mg N/l)
14:48:00	60	< 0.05	0.40
14:48:30	110	< 0.05	0.39
14:48:50	30	< 0.05	0.36
14:49:05	60	< 0.05	0.40
14:50:00	1	< 0.05	0.49
14:50:30	30	< 0.05	0.42
14:50:45	60	< 0.05	0.36
14:55:00	1	< 0.05	0.38
14:55:20	30	< 0.05	0.38
14:55:45	60	0.07	0.35
15:00:00	1	< 0.05	0.35
15:00:20	30	< 0.05	0.33
15:00:40	60	< 0.05	0.38
15:14:45	1	< 0.05	0.40
15:15:15	30	< 0.05	0.42
15:15:30	60	< 0.05	0.34
15:30:00	1	< 0.05	0.39
15:30:15	30	< 0.05	0.36
15:30:50	60	< 0.05	0.34
15:50:20	60	< 0.05	0.34
16:02:00	1	< 0.05	0.36
16:02:45	30	< 0.05	0.37
16:03:15	60	< 0.05	0.36
16:15:30	1	< 0.05	0.36
16:16:45	30	< 0.05	0.40
16:18:30	60	< 0.05	0.39
16:30:00	60	< 0.05	0.41
16:35:45	1	< 0.05	0.49
16:36:15	30	< 0.05	0.46
16:36:40	60	< 0.05	0.40
16:40:00	1	< 0.05	0.44
16:40:15	30	< 0.05	0.41

(Continued)

Table 417 (Continued)

Time (hr:min:sec)	Depth (m)	Ammonium (mg N/l)	Nitrate (mg N/l)
16:40:40	60	< 0.05	0.41
16:44:45	1	< 0.05	0.39
16:45:00	30	< 0.05	0.43
16:45:15	60	< 0.05	0.42
16:45:45	1	< 0.05	0.42
16:46:00	30	< 0.05	0.35
16:46:20	60	< 0.05	0.34
16:46:45	1	< 0.05	0.37
16:47:00	30	< 0.05	0.34
16:47:10	60	< 0.05	0.34
16:47:40	1	< 0.05	0.36
16:47:55	30	< 0.05	0.35
16:47:55 - Dump No. 2A occurred.			
16:48:15	60	< 0.05	0.34
16:48:30	30	< 0.05	0.40
16:48:45	30	< 0.05	0.36
16:49:00	60	0.20	0.28
16:49:45	1	< 0.05	0.36
16:50:15	60	0.08	0.30
16:50:20 - Dump No. 2B occurred.			
16:50:30	1	2.64	0.23
16:50:45	60	< 0.05	0.36
16:51:30	1	< 0.05	0.36
16:51:45	30	< 0.05	0.33
16:52:05	60	< 0.05	0.36
16:52:20	1	< 0.05	0.40
16:52:50	30	< 0.05	0.33
16:53:10	60	< 0.05	0.42
16:53:30	1	< 0.05	0.43
16:53:45	30	< 0.05	0.44
16:54:00	60	< 0.05	0.39
16:54:25	1	< 0.05	0.41
16:54:40	30	< 0.05	0.43

(Continued)

Table 417 (Concluded)

Time (hr:min:sec)	Depth (m)	Ammonium (mg N/l)	Nitrate (mg N/l)
16:55:00	60	< 0.05	0.23
16:55:20	1	< 0.05	0.34
16:55:40	30	< 0.05	0.44
16:56:00	60	0.09	0.42
16:56:15	1	< 0.05	0.31
16:56:30	30	< 0.05	0.34
16:57:00	60	0.06	0.38
16:57:20	1	< 0.05	0.35
16:57:35	30	< 0.05	0.43
16:58:10	60	< 0.05	0.41
16:58:15	1	< 0.05	0.33
16:58:30	1	< 0.05	0.43
16:58:30	30	< 0.05	0.31
17:00:30	60	< 0.05	0.31
17:00:30	1	< 0.05	0.29
17:00:30	30	< 0.05	0.33
17:03:00	60	< 0.05	0.33
17:10:00	1	< 0.05	0.31
17:10:00	30	< 0.05	0.35
17:10:00	60	< 0.05	0.31
17:20:00	1	< 0.05	0.32
17:20:00	60	< 0.05	0.33
17:21:00	30	< 0.05	0.31
17:31:30	1	< 0.05	0.41
17:31:30	30	< 0.05	0.32

In order to minimize sample processing time for organic N analysis composite disposal operation samples were prepared by mixing equal volumes from two different water samples. Every sampling depth and every sampling period (i.e., before, during and after disposal) was represented by at least one composite sample. To calculate organic N concentrations of the composite samples, individual sample ammonium concentrations below 0.05 mg N/l were considered. In the two samples with the ammonium concentration higher than 0.05 mg N/l, ammonium was determined separately in the composite samples.

Organic N data are presented in Table 418, from which it can be observed that organic N concentrations were much higher in the water samples collected prior to disposal than in those collected during and after disposal. Concentrations in the bottom water were a little higher than those in the overlying water. It appears that overall, organic nitrogen decreased as a result of disposal operations.

Phosphorus Compounds

The mean soluble orthophosphate concentrations during the 4.5-hour monitoring of the Elliott Bay disposal operations can be found in Table 419. In general, it appeared that the ambient water had similar soluble orthophosphate concentrations at all three depths monitored. Pre-disposal concentrations were generally between 0.085 and 0.097 mg P/l. There appeared to be an increase in concentration near the bottom immediately following Elliott Bay Dump No. 1A, after which the concentration there began to decrease. This decline appears to have continued until the second barge dumped its load (Dump No. 1B), at which time the concentration rose and fluctuated between 0.040 and 0.066 mg P/l. Within 55 minutes of Dump No. 1A, soluble ortho P near the bottom appears to have returned to, and stabilized at, predisposal levels.

Table 418

Organic Nitrogen Concentrations: Composite Water Samples Collected During Elliott Bay Disposal Operations

Composites Times (hr:min:sec)	Depth (m)	Organic N (mg N/1) $\bar{X}$	SD
Pre-Disposal:			
13:08:00 13:55:00	30	0.25	0.08
13:08:30 13:55:50	60	0.29	0.08
Dump No. 1:			
14:42:30 14:48:30	1	< 0.05	0.06
14:44:15 14:45:40	30	0.13	0.03
14:44:00 14:45:20	60	0.20	0.06
16:15:30 16:44:45	1	0.07	0
16:30:00 16:40:40	60	0.07	0
Dump No. 2:			
16:57:20 16:58:15	1	0.05	0.03
16:55:40 16:57:35	30	< 0.05	∿0
16:55:00 16:56:00	60	0.09	0.03
Post-Disposal:			
17:10:00	30	0.05	0.03
17:00:00 17:03:30	60	0.17	0.03

Mean and standard deviation calculated from duplicate analyses.
*Water samples collected at designated times were combined 1:1 by volume and analyzed for organic N.

Table 419

Soluble Orthophosphate Concentrations: Elliott Bay Disposal Operations Dredged Material from Duwamish River

Time (hr:min:sec)	Depth (m)	Soluble Ortho P (mg P/l)	
		$\overline{X}$	SD
13:07:30	1	0.094	0
13:08:00	30	0.088	0.001
13:08:30	60	0.062	0.005
13:54:00	1	0.092	0.001
13:55:00	30	0.088	0
13:55:50	60	0.086	0
14:06:00	1	0.097	0.001
14:07:00	30	0.097	0.001
14:07:45	60	0.090	0.001
14:20:30	1	0.090	0.002
14:21:00	30	0.104	0.001
14:21:30	60	0.092	0
14:25:00	1	0.096	0
14:25:30	30	0.090	0.002
14:25:50	60	0.090	0
14:30:00	1	0.088	0.001
14:30:30	30	0.096	0
14:31:00	60	0.094	0.001
14:34:30	1	0.088	0
14:35:00	30	0.096	0.001
14:35:15	60	0.091	0
14:36:00	1	0.090	0
14:36:30	30	0.096	0

(Continued)

Table 419 (Continued)

Time (hr:min:sec)	Depth (m)	Soluble Ortho P (mg P/l) $\bar{X}$	SD
	14:36:30 - Dump No. 1A occurred.		
14:36:45	60	0.12	0
14:37:15	1	0.091	0
14:37:30	30	0.091	0
14:37:45	60	0.092	0
14:38:15	1	0.080	0
14:38:30	30	0.088	0.001
14:38:45	60	0.080	0
14:39:30	1	0.082	0
	14:39:30 - Dump No. 1B occurred.		
14:39:45	30	0.076	0
14:40:00	60	0.028	0
14:40:15	1	0.084	0
14:40:40	30	0.088	0
14:41:00	60	0.059	0
14:41:15	1	0.10	0
14:41:30	30	0.080	0.001
14:41:45	60	0.066	0
14:42:30	1	0.10	0
14:42:45	60	0.059	0
14:43:00	30	0.094	0
14:43:45	30	0.090	0
14:44:00	60	0.055	0.002
14:44:15	30	0.094	0.001
14:44:45	60	0.042	0.001
14:45:05	30	0.078	0.001
14:45:20	60	0.039	0

(Continued)

Table 419 (Continued)

Time (hr:min:sec)	Depth (m)	Soluble Ortho P (mg P/l) $\overline{X}$	SD
14:45:40	30	0.078	0.001
14:46:00	60	0.042	0
14:46:20	30	0.098	0
14:46:30	60	0.063	0
14:47:00	30	0.069	0
14:47:15	60	0.047	0.001
14:47:30	30	0.075	0
14:48:00	60	0.053	0.001
14:48:30	1	0.078	0.001
14:48:50	30	0.076	0
14:49:05	60	0.042	0
14:50:00	1	0.072	0.001
14:50:30	30	0.078	0.001
14:50:45	60	0.044	0.001
14:55:00	1	0.098	0.002
14:55:20	30	0.079	0
14:55:45	60	0.042	0
15:00:00	1	0.076	0.001
15:00:20	30	0.078	0.001
15:00:40	60	0.051	0
15:14:45	1	0.082	0
15:15:15	30	0.085	0
15:15:30	60	0.064	0.001
15:30:00	1	0.096	0.001
15:30:15	30	0.093	0.001
15:30:50	60	0.088	0

(Continued)

Table 419 (Continued)

Time (hr:min:sec)	Depth (m)	Soluble Ortho P (mg P/l) $\bar{X}$	SD
15:50:20	60	0.094	0.001
16:02:00	1	0.098	0
16:02:45	30	0.099	0
16:03:15	60	0.095	0
16:15:30	1	0.080	0.001
16:16:45	30	0.080	0
16:18:30	60	0.080	0
16:30:00	60	0.080	0.001
16:35:45	1	0.080	0.001
16:36:15	30	0.084	0.001
16:36:40	60	0.081	0.001
16:40:00	1	0.083	0
16:40:15	30	0.080	0.001
16:40:40	60	0.089	0.003
16:44:45	1	0.083	0
16:45:00	30	0.082	0.001
16:45:15	60	0.10	0
16:45:45	1	0.084	0.001
16:46:00	30	0.087	0
16:46:20	60	0.083	0
16:46:45	1	0.091	0
16:47:00	30	0.043	0
16:47:10	60	0.082	0.001
16:47:40	1	0.072	0.001
16:47:55	30	0.087	0.001

16:47:55 - Dump No. 2A occurred.

(Continued)

Table 419 (Continued)

Time (hr:min:sec)	Depth (m)	Soluble Ortho P (mg P/l)	
		$\bar{X}$	SD
16:48:15	60	0.086	0.001
16:48:30	30	0.087	0.001
16:48:45	30	0.074	0.002
16:49:00	60	0.028	0
16:49:45	1	0.075	0
16:50:15	60	0.030	0
16:50:20 - Dump No. 2B occurred.			
16:50:30	1	0.020	0
16:50:45	60	0.041	0
16:51:30	1	0.071	0
16:51:45	30	0.084	0.001
16:52:05	60	0.064	0.001
16:52:20	1	0.057	0.001
16:52:50	30	0.088	0.001
16:53:10	60	0.074	0.001
16:53:30	1	0.073	0
16:53:45	30	0.096	0.001
16:54:00	60	0.093	0
16:54:25	1	0.084	0
16:54:40	30	0.095	0.001
16:55:00	60	0.028	0.001
16:55:20	1	0.096	0.001
16:55:40	30	0.10	0.001
16:56:00	60	0.040	0
16:56:15	1	0.095	0
16:56:36	30	0.092	0.001
16:57:00	60	0.040	0

(Continued)

Table 419 (Concluded)

Time (hr:min:sec)	Depth (m)	Soluble Ortho P (mg P/1)	
		$\bar{X}$	SD
16:57:20	1	0.092	0.001
16:57:35	30	0.094	0.001
16:58:10	60	0.083	0
16:58:15	1	0.094	0
16:58:30	1	0.084	0.001
16:58:30	30	0.086	0
17:00:30	60	0.040	0.001
17:00:30	1	0.081	0
17:00:30	30	0.081	0
17:00:30	60	0.064	0.001
17:10:00	1	0.081	0.001
17:10:00	30	0.094	0.001
17:10:00	60	0.076	0.001
17:20:00	1	0.10	0.001
17:20:00	60	0.061	0
17:21:00	30	0.089	0
17:31:30	1	0.085	0.001
17:31:30	30	0.081	0

Mean and standard deviation calculated from duplicate analyses of one sample.

Both surface and mid-depth soluble orthophosphate concentrations showed no regular pattern following Elliott Bay Dump No. 1A. They fluctuated between 0.10 and 0.072 mg P/l at the surface, and between 0.097 and 0.069 mg P/l at mid-depth. Concentrations at the surface and mid-depth also appeared to have stabilized at ambient levels within about 55 minutes of the first set of dumps.

In the bottom waters, decreased orthophosphate concentrations were found following Dumps Nos. 1A and 1B. About 25 minutes after disposal concentrations at all three depths appear to have returned to ambient levels (0.094 to 0.096 mg P/l). The concentrations at all depths measured decreased to approximately 0.08 mg P/l and remained at about that level until the second series of dumps began.

Soluble orthophosphate concentrations appeared to fluctuate somewhat (most noticeably at mid-depth) just prior to the second set of dumps. This decrease may have been caused by leakage of dredged material from the barges as they were preparing to dump their load. The surface concentrations of soluble ortho P decreased to 0.072 mg P/l at about the time of Elliott Bay Dump No. 2A and decreased to 0.02 mg P/l immediately following Dump 2B. They then rose steadily to ambient (0.096 mg P/l) and fluctuated between 0.08 and 0.10 mg P/l for the duration of the monitoring period.

Concentrations at mid-depth fluctuated generally between 0.08 mg P/l and 0.10 mg P/l during the second set of dumps. Following Dump 2A, until the end of monitoring, the soluble ortho P near the bottom showed three pulses of decreased concentration, the first two to 0.028 mg P/l, the third to 0.040 mg P/l, rising to ambient levels in between. Only the soluble ortho P concentrations near the bottom had not returned to ambient levels by the time monitoring ceased.

There appear to have been some correlations between soluble orthophosphate concentration and percent light transmission (Figures 122 through 126), during the first set of Elliott Bay dumps. As the percent light transmission at the surface decreased following Dump No. 1B, the concentration of soluble ortho P increased. As the percent light transmission decreased near the bottom during this set of dumps, soluble ortho P concentrations also decreased. Although the percent light transmission near the bottom had returned to ambient levels within 10 minutes of Dump No. 1B, the soluble ortho P concentrations remained below ambient levels until nearly one hour after the dump. During Dumps 2A and 2B, the concentrations of soluble ortho P increased at mid-depth as the percent light transmission decreased. In the near bottom waters, there was a decrease in soluble ortho P before any decrease in percent light transmission, but the second and third pulses of decreased concentrations coincided with decreases in percent light transmission.

Data from Elliott Bay disposal operations show that the two sets of dumps had some different effects on soluble orthophosphate concentrations in the water column. After Dumps No. 1A and 1B, surface soluble ortho P fluctuated and decreased to 0.072 mg P/l, although it generally stayed within 0.01 mg P/l of the ambient concentrations. By contrast, after the second set of dumps, the concentration decrease was more immediate and more pronounced (to 0.02 mg P/l). Moreover, the soluble ortho P in the bottom water following Dumps 1A and 1B appears to have remained at a depressed level for nearly 50 minutes before returning to ambient concentrations. The decreases in concentration in bottom waters following the last two dumps were more erratic; decreases to 0.03 mg P/l were followed by increases to ambient levels.

A number of unfiltered water samples collected during different phases of the Elliott Bay disposal operation were composited and analyzed for total phosphorus. Mean concentrations found are presented in Table 420. Surface water total phosphorus appeared to have increased between the two sets of dumps. The composite samples for Elliott Bay Dump No. 1 were from a period of greatly fluctuating turbidity and variable contaminant concentrations. In some cases, during such periods, the duplicate samples collected (one to be filtered, the other not) contained different amounts of sediment. This fact helps explain why the total P concentration during Dump No. 1 sometimes appeared lower than the soluble ortho P taken during the same period.

There was not much change in total phosphorus levels at mid-depth; the total P content during the disposal operations appear to have decreased from ambient (0.11 mg P/l) to a low of 0.061 mg P/l during Dump No. 2. The concentration was somewhat higher in the post-disposal samples.

The total phosphorus found in the near bottom waters best demonstrates the relationship between the high turbidity and total P content. Maxima of 0.47 and 0.32 mg P/l were found concurrent with low percent light transmission in the bottom water found during the dumps. Between dumps, the total P was below pre-disposal concentrations. In the post-disposal composite sample collected about 15 minutes after the last dump, the total P concentration had not returned to ambient levels.

Organic Compounds

Six water samples collected during Elliott Bay disposal operations were analyzed for selected chlorinated hydrocarbon pesticides and PCBs. These samples represent the water conditions before, during and after disposal. Data for these samples are presented in Table 421.

The EC chromatograms of the six sample extracts are illustrated in Figures 135 and 136. Table 422 shows

Table 420

Total Phosphorus Concentrations: Composites* of Water Samples Collected During Elliott Bay Disposal Operations

Composites Times (hr:min:sec)	Depth (m)	Total Phosphorus (mg P/l) $\bar{X}$	SD
Pre-Disposal:			
13:08:00 13:55:00	50	0.11	0.007
13:08:30 13:55:50	60	0.12	0.005
Dump No. 1:			
14:42:30 14:48:30	1	0.062	0.001
14:44:15 14:45:40	30	0.08	0.012
14:44:00 14:45:20	60	0.47	0.01
16:15:30 16:44:45	1	0.08	0.017
16:30:00 16:40:40	60	0.077	0.001
Dump No. 2:			
16:57:20 16:55:15	1	0.097	0.001
16:55:40 16:57:35	30	0.061	0.004
16:55:00 16:56:00	60	0.32	0.015

(Continued)

Table 420 (Concluded)

Composites Times (hr:min:sec)	Depth (m)	Total Phosphorus (mg P/l)	
		$\bar{X}$	SD
Post-Disposal:			
17:10:00	30	0.08	0.008
17:00:00 17:03:00	60	0.20	0.009

Mean and standard deviation calculated from triplicate analyses of one sample.

*Water samples collected at designated times were combined 1:1 by volume and analyzed for total P.

Table 421

Water Samples Analyzed for Organic Concentrations: Elliott Bay Disposal Operations

Time (hr:min:sec)	Sample Designation*	Figure No.	
Dump No. 1 (14:36 - 14:39)			
14:06:00 - 14:07:45	Pre-Disposal	A	
14:46:20 - 14:47:15	Turbid Plume	B	(135)
15:50:20 - 16:03:15	Post-Disposal	C	
Dump No. 2 (16:47 - 16:50)			
17:00:30	Turbid Plume (60 m)	A	
17:20:00	Post-Disposal (60 m)	B	(136)
17:31:30	Post-Disposal (1 m)	C	

*The first three samples were composites of several subsamples. The others were collected in 2.5 gallon cubitainers.

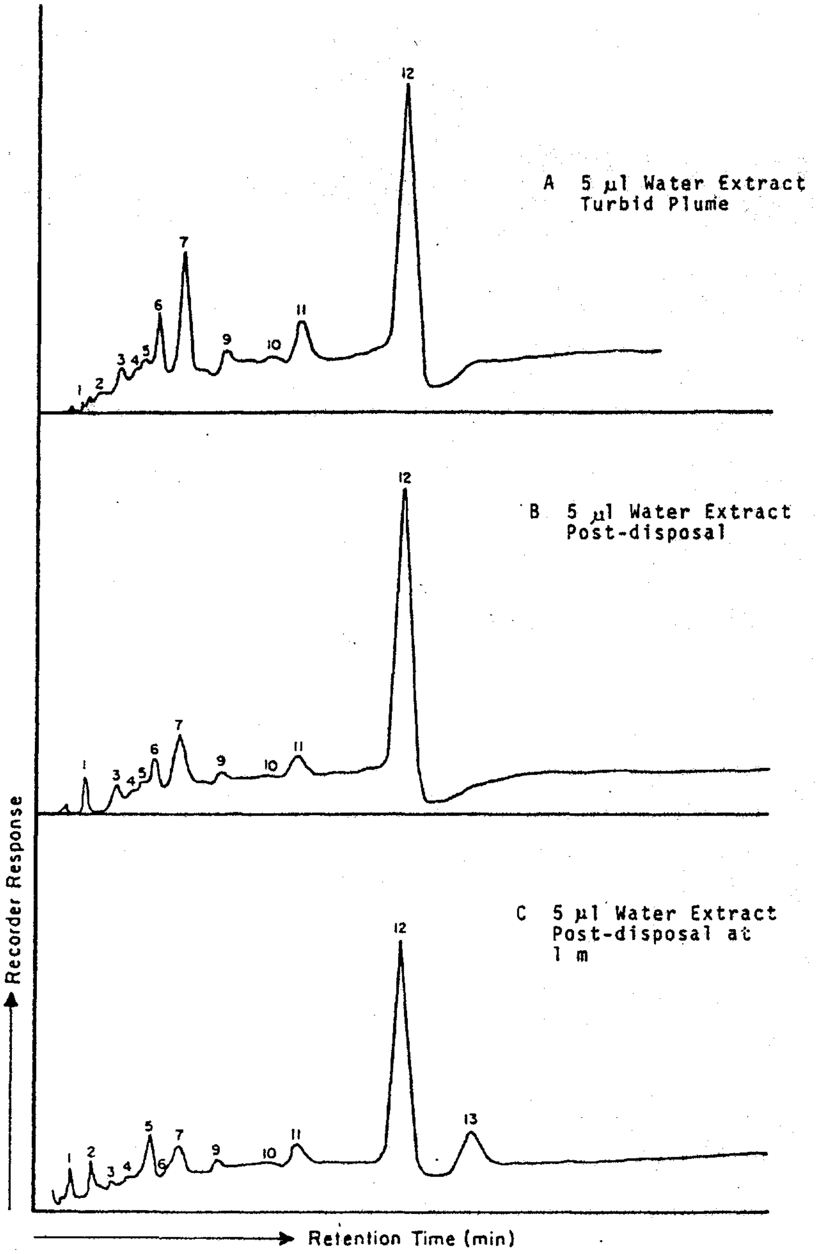

Figure 135

Profile of Organic Residues on EC Chromatograms Elliott Bay Dump No. 2

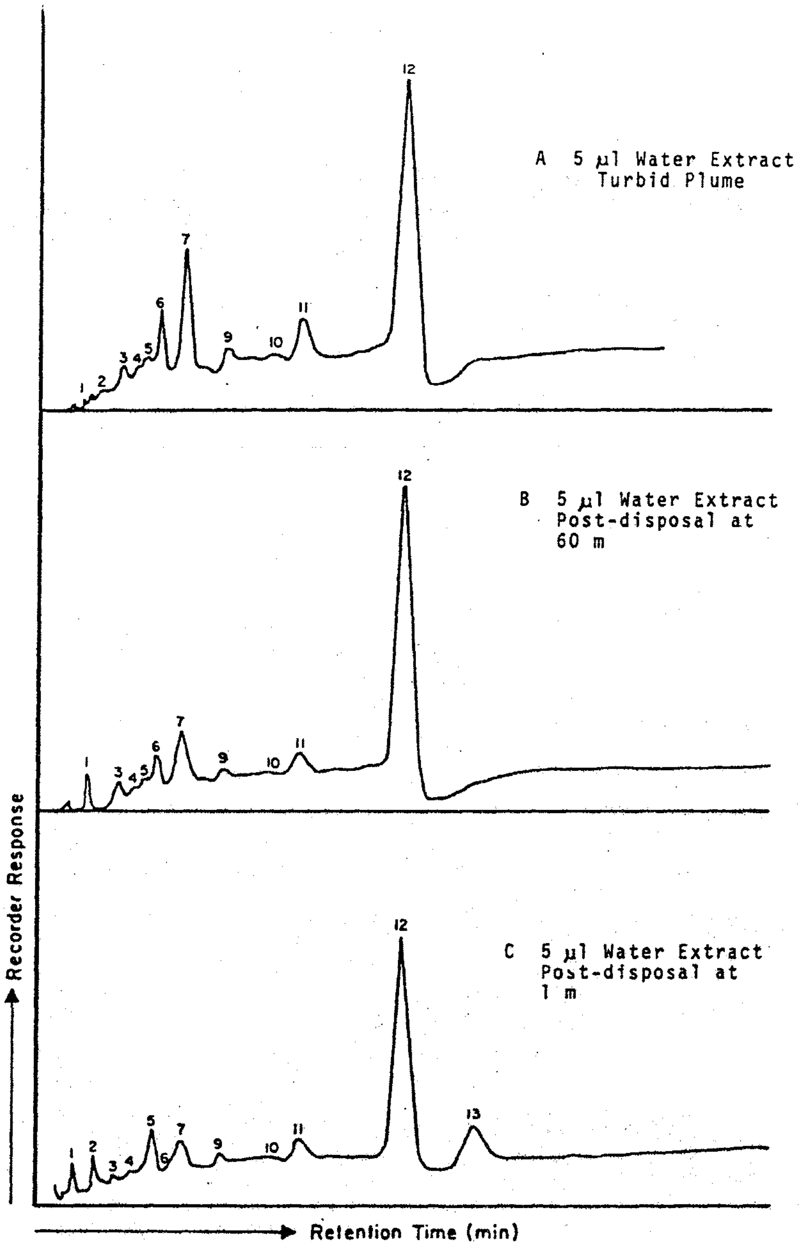

Figure 136

Profile of Organic Residues on EC Chromatograms
Elliott Bay Dump No. 2

Table 422

Relative Retention Correlation Data:** Elliott Bay Dump No. 2 Water Samples, February 17, 1976

Peak Number	Organic Compound	X_{mm}	R_r
1		13	0.20
2		16	0.24
3		21	0.32
4		26	0.39
5		28	0.41
6		31	0.47
7	Lindane*	37	0.56
8		42	0.64
9		50	0.76
10		60	0.91
11		66	1.00
12	Internal Standard Heptachlor Epoxide	95	1.44
13		115	1.74

*Compound identified on two columns.

the relative retention times of the resolved peaks. Examination of the two figures shows that almost all the characteristic peaks were present in all the samples and that the difference is only in the magnitude of peaks.

Table 423 lists the results of the organic analysis for these samples. It can be seen from this table that lindane was the only pesticide under investigation that was detected on two columns. PCBs were also present in all samples tested. The concentration of lindane decreased to 0.3 ng/l in the turbid plume from the first disposal operation but increased to 3.5 ng/l during the second turbid plume. At other times, the concentrations ranged between 1.3 and 1.7 ng/l. The PCB concentrations of all samples were between 18.0 and 24.0 ng/l, except during passage of the turbid plume from Dump No. 1, when PCBs increased to 36.0 ng/l. This

Table 423

Data for Organic Compounds: Elliott Bay Disposal Operations

Parameter	Dump No. 1*			Dump No. 2*		
	Pre-Disposal	Turbid Plume	Between Disposals	Second Turbid Plume	Post Disposal (60 m)	Post Disposal (1 m)
Chlorinated Hydrocarbons:	(ng/l)	(ng/l)	(ng/l)	(ng/l)	(ng/l)	(ng/l)
Aldrin	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6
op' DDT	< 3.0	< 3.0	< 3.0	< 3.0	< 3.0	< 3.0
pp' DDT	< 3.0	< 3.0	< 3.0	< 3.0	< 3.0	< 3.0
op' DDD	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0
pp' DDD	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0
op' DDE	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0
pp' DDE	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0
Dieldrin	< 1.2	< 1.2	< 1.2	< 1.2	< 1.2	< 1.2
Endosulfan I	< 1.2	< 1.2	< 1.2	< 1.2	< 1.2	< 1.2
Endosulfan II	< 4.4	< 4.4	< 4.4	< 4.4	< 4.4	< 4.4
Endrin	< 1.6	< 1.6	< 1.6	< 1.6	< 1.6	< 1.6
Heptachlor	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4
Lindane	1.3	0.3	1.5	3.5	1.7	1.5
PCBs	20.0	36.0	24.0	22.0	20.0	18.0
Other Organic Compounds:						
	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)
Oil and Grease	< 0.5	7.6	< 0.5	< 0.5	< 0.5	< 0.5
Total Organic Carbon	NT	11.4	24.3	16.9	22.8	6.9
Total Inorganic Carbon	NT	11.6	20.8	12.9	7.3	17.9

NT = not listed.

*See Table 421 for explanation of column designations.

corresponds to the oil and grease data pattern for these samples: oil and grease were below the detection limit of 0.5 mg/l for all samples except the one taken during the first turbid plume (7.6 mg/l).

Both elutriate test and field study results showed only a slight release. The low retention times for unknown compounds were reduced during passage of the turbid plume and in the elutriate. Comparisons of the PCB concentrations show that in the pre-disposal extract, they were 20.0 ng/l and in the water extract, 11.5 ng/l. During the turbid plume the concentration increased to 36.0 ng/l and in the elutriate to 33.4 ng/l. The elutriate test gave the same G.C. profile and also the same trend towards release or sorption.

Water Quality at the Dredging Site

Percent Transmission

Profiles of the water column above and below the dredging site were taken to determine if mechanical dredging operations had an effect on the turbidity of the Duwamish River. The data for the two sites are presented in Figure 137 and show similar profiles. The surface waters were more turbid at both sites than the bottom waters, with approximately 40 percent transmission for surface water compared to 70 percent for the bottom waters. No effects of dredging can be discerned from these data.

Heavy Metals

Soluble heavy metal concentrations in water samples collected above and below the mechanical dredge in the Duwamish River Turning Basin are shown in Table 424. There was no difference in metal concentrations between the samples taken above the dredge and those taken below. Manganese and zinc concentrations ranged from 37 to 58 and from 10.5 to 44.9 µg/l, respectively. Cadmium and lead concentrations ranged from 1.8 to 4.0 µg/l and from 2.0 to 2.9 µg/l, respectively. Nickel and copper concentrations ranged from 4.6 to 6.7 µg/l and

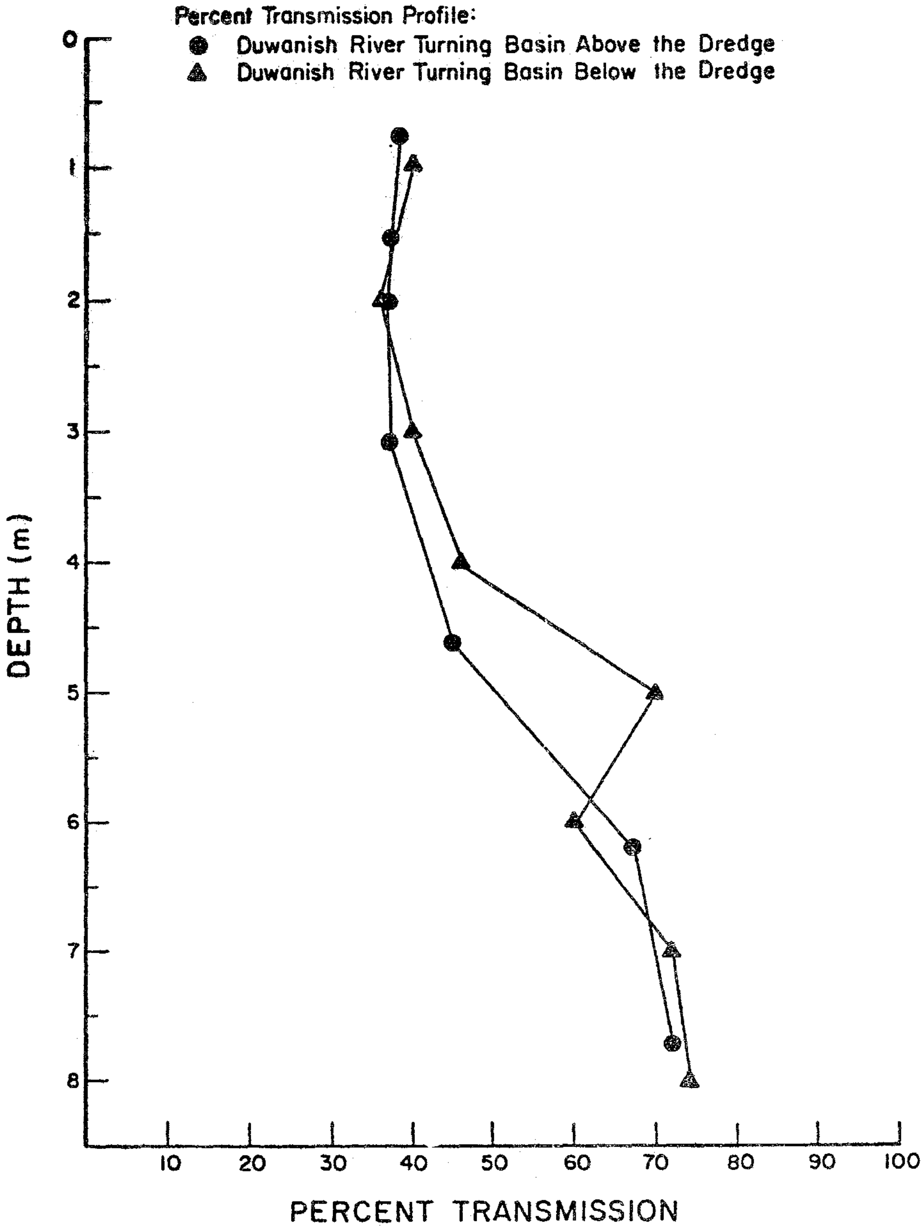

Figure 137

Percent Transmission Profile: Duwamish River Above and Below Dredge

Table 424

Soluble Heavy Metal Concentrations: Samples Collected Above and Below the Dredge in Duwamish River Turning Basin

(μg/l)

Depth (m)	Mn	Cd	Cr	Zn	Ni	Pb	Cu	Fe	Hg	As
Above Dredge - 16:30										
0.5	58	2.0	< 2	11.8	5.5	2.9	3.1	473	< 0.005	< 2
2.0	37	4.0	< 2	44.9	6.7	2.3	10.0	181	< 0.005	< 2
4.0	48	1.9	< 2	13.1	5.8	2.0	2.7	55	< 0.005	< 2
Below Dredge - 16:40										
0.5	27	1.8	< 2	12.8	4.6	2.6	3.9	318	< 0.005	< 2
2.0	37	2.3	< 2	18.4	5.8	2.0	3.4	98	< 0.005	< 2
4.0	48	2.0	< 2	11.8	6.0	2.0	3.4	63	< 0.005	< 2
6.0	48	2.1	< 2	10.5	4.8	2.3	2.7	37	< 0.005	< 2

3.1 to 10.0 μg/l, respectively. Iron concentrations decreased with depth. They were 318 to 473 μg/l at the surface and from 37 to 55 μg/l at 4 to 6 meters below the surface. Chromium, arsenic, and mercury concentrations were all below detection limits of <2, <2, and <0.005 μg/l, respectively.

Nitrogen Compounds

For comparison, water samples were also collected from the Duwamish River Turning Basin. Results of ammonium and nitrate analyses are presented in Table 425. Ammonium concentrations were much higher than those observed in the disposal site water samples. Concentrations in the upper two meters of the dredging site water column were apparently as much as twice those in the underlying water. Specific conductance data (Table 388) had indicated that at the dredging site, the more contaminated river water overlies the bay water. Nitrate concentrations ranged between 0.34 and 0.48 mg N/l, with higher concentrations in the surface waters.

It is apparent from the data in Tables 418 and 425 that the water column at the Elliott Bay disposal area was less contaminated with nitrogen compounds than the dredging site water column. Monitoring of disposal operations generally indicated release of ammonium and removal of nitrate and organic N. The only exception to this trend was observed with Elliott Bay Dump No. 1A. The ammonium release following Dump No. 2B, although significantly high (2.64 mg N/l), should not harm aquatic organisms because of the brevity of the expected period of exposure.

Phosphorus Compounds

Soluble orthophosphate concentrations of samples collected in the Duwamish River Turning Basin both above and below the mechanical dredge, are presented in Table 426. Above the dredge, concentrations appeared to be fairly constant with depth, ranging from 0.079 to 0.094 mg P/l. Below the dredge, the concentration at 0.5 and 2 m (0.14 and 0.22

mg P/l) appeared to be somewhat higher than those found above the dredge at corresponding depths. The concentrations at 4 and 6 m, however, were lower than near-bottom water concentrations above the dredge.

Table 425

Ammonium and Nitrate Concentrations: Water Samples Collected Above and Below the Dredge in Duwamish River Turning Basin*

(mg N/l)

Depth (m)	Ammonium	Nitrate
Above:		
0.5	0.23	0.48
1.0	0.33	0.42
2.0	0.28	0.43
Below:		
2.0	0.28	0.44
4.0	0.13	0.43
4.0	0.12	0.42
6.0	0.12	0.34

*All samples collected between 16:30 and 16:45.

Table 426

Soluble Orthophosphate Concentrations: Samples Collected Above and Below Dredge in Duwamish River Turning Basin

Depth (m)	Soluble Ortho p (mg P/l)	
	$\overline{X}$	SD
Above Dredge - 16:30		
0.5	0.079	0
2	0.094	0
4	0.084	0.001
Below Dredge - 16:40		
0.5	0.14	0
2	0.22	0
4	0.072	0.001
6	0.071	0

Mean and standard deviation calculated from duplicate analyses of one sample.

New York-New Jersey Waterways - New York Bight

The New York Bight area off the coast of Sandy Hook, New Jersey has recently been the focus of considerable controversy over the disposal of sewage sludge and dredged material. In the summer of 1976, the bottom waters in a band about eight miles wide and extending about 100 miles down the New York-New Jersey coast, generally a few miles offshore, became anoxic. The anoxic conditions led to large scale-die offs of clams, crab, lobster, and bottom-dwelling fish such as flounder.

The New York District of the Corps of Engineers dredges approximately 10 million cubic yards of sediment from New York-New Jersey harbors and waterways annually. These dredged sediments are all dumped at one site (mud dump site) in the New York Bight. The surrounding shoreline contains some of the most intensely urbanized and industrialized areas in the world. Large amounts of untreated or only partially treated wastewaters are discharged to the waterways. Further, rivers such as the Hudson that discharge to this area carry persistent contaminants from the municipal and industrial wastewaters and agricultural drainage from several states. This results in the potential for large-scale contamination of the waters and sediments in the New York-New Jersey area. Computations of the total contaminant load to the New York Bight such as those made by Mueller *et al.*,[37] which are based on the bulk sediment content, show that for many contaminants of potential concern, the total load to the New York Bight arising from the disposal of dredged sediment is a significant part of the total load from all sources including sewage sludge dumping and the discharge of municipal and industrial waste. However, as pointed out by Lee and Jones,[38] in their discussion of the Mueller *et al.*[39] paper, in order to judge the true significance of the contaminants associated with the dredged sediment, it is necessary to determine the amounts of these contaminants that become available to affect water quality in the New York Bight. In order to provide information on this topic and to evaluate the reliability of the elutriate test in predicting the potential for contaminant release from dredged sediment upon openwater disposal, a study was conducted in this region in late August-early September 1976. This study involved collecting sediments from the area scheduled to be dredged and subjecting them to the elutriate test under a variety of conditions. Also, the disposal operations involving the dredged material from these areas were monitored to determine the release of contaminants during disposal. Further, samples of dredged material accumulating in the hoppers were collected during dredging. Also, samples were collected from the hoppers periodically during transport from the dredging site to the mud dump site. Thsee samples were collected so that measurements of the release of contaminants at the time of dredging and during transport to the disposal site could be made. In addition, a set of water samples was taken from the mouth of Raritan Bay to compare the concentration of contaminants present at the mouth of the bay (which receives municipal and industrial wastewater discharges from New York and New Jersey) to that found at the dredged material disposal site.

Elutriate and Plop Tests

Characteristics of Sampling Site

On August 30, 1976 sediment and water samples were collected using a Ponar grab and pump, respectively, from areas in the Bay Ridge Channel and the Perth Amboy Anchorage and Channel that were scheduled to be dredged on the following two days. The locations of these sampling sites are presented in Figures 138 and 139

The Secchi depth at the Bay Ridge Channel sediment sampling site (Figure 138) was 0.75 m; depth of the water column was approximately 13 m. The sediment collected in that

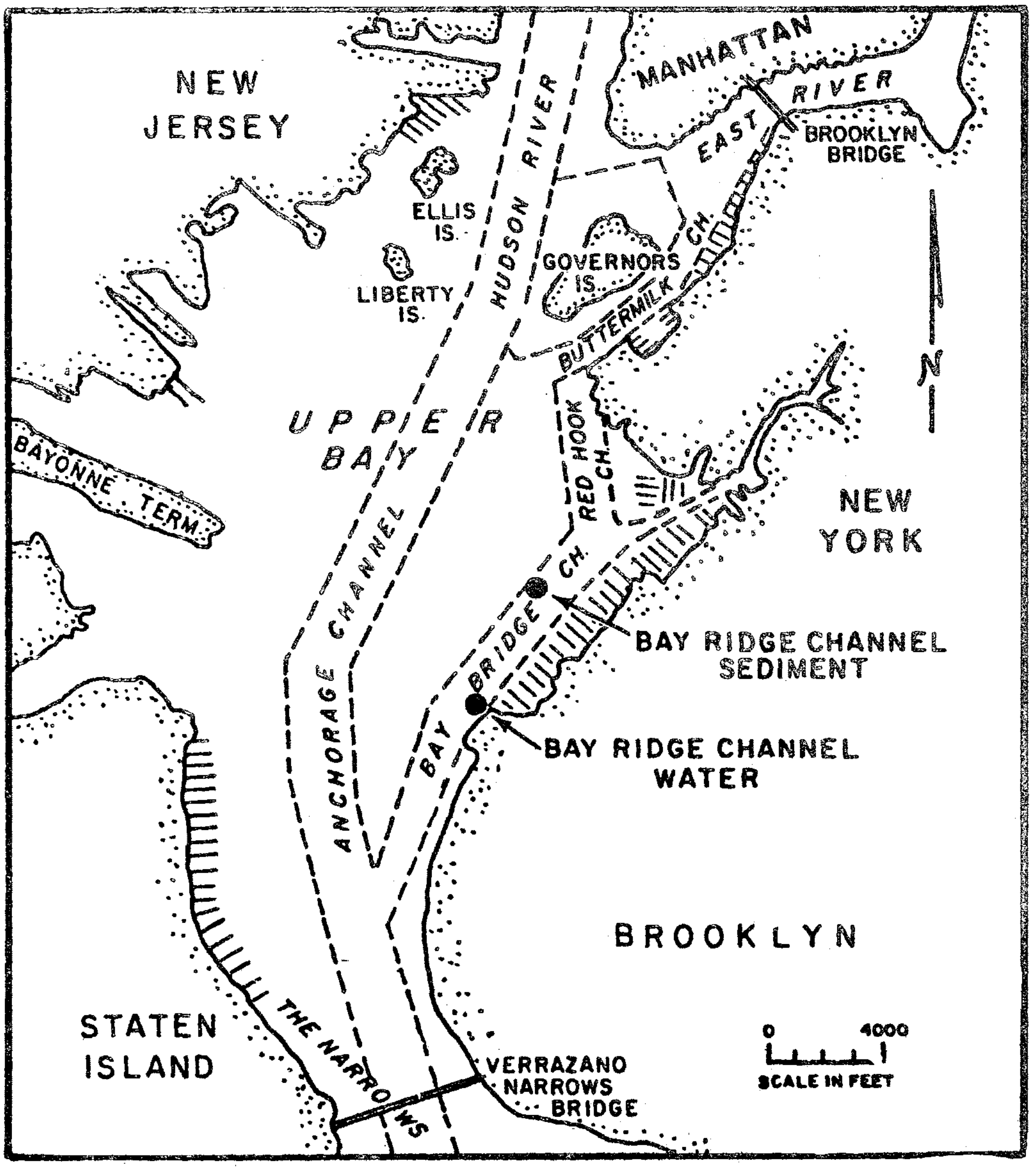

Figure 138
Bay Ridge Channel Sampling Locations

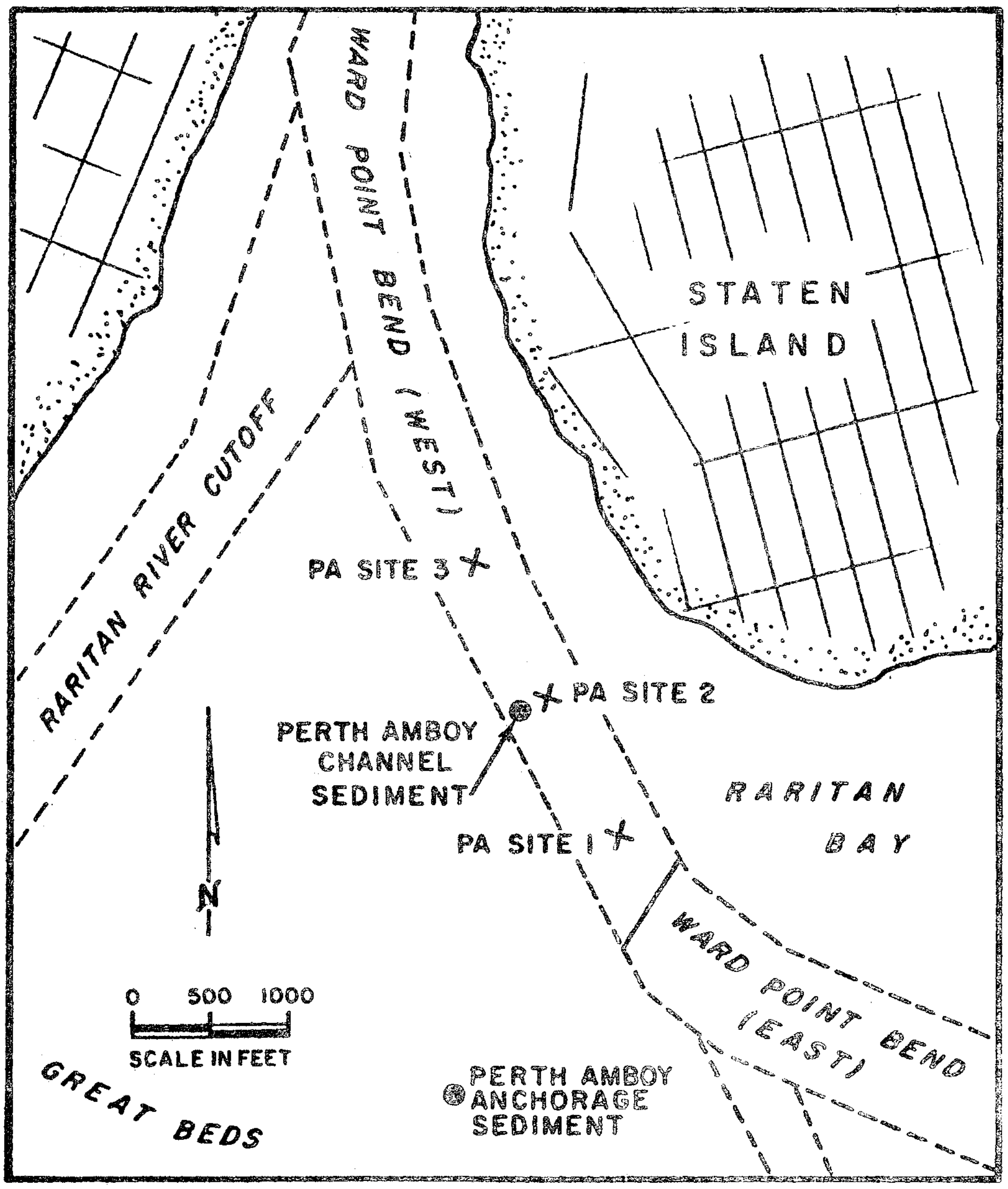

Figure 139
Perth Amboy Channel and Anchorage
Sampling Locations

area was pasty, black, and oily in appearance. Since the water at that location was turbid, it was decided to collect the water from a nearby, less turbid area (Figure 138). At the site chosen, the water column was about 12 m deep; the Secchi depth was 1.25 m. The water sample was pumped from a depth of about 10 m.

The Perth Amboy Anchorage (Figure 139) is a barge anchorage area. Two sets of sediment and water samples were collected in the anchorage area. At the first location, the water depth was 8 m, and the Secchi depth was 1 m. The sediment was black and pasty with a strong sulfide odor. A water sample was collected at that location from a depth of 6 m.

A second set of Perth Amboy Anchorage samples was taken about 100 m east-northeast of the previously sampled anchorage site. The water depth was about 9 m, and the Secchi depth was 1 m. The appearance of this sediment generally resembled the other sediment, except that the sulfide odor was not as strong in this sediment. A water sample was collected from 6 m. The two sediment samples were later pooled and processed as the Perth Amboy Anchorage sample.

The depth of the Perth Amboy Channel sampling site (Figure 139) was about 13 m, and the Secchi depth was 1.3 m. The Perth Amboy Channel sediment sample had a thin layer of brownish, oxidized material on its surface and a strong sulfide odor. Its consistency resembled that of the anchorage sample. There were also some roots and twigs in the sample. A water sample was also collected from a depth of 10 m.

The sealed sediment buckets and water bottles were placed in insulated shipping boxes and immediately air-freighted to Dallas. Upon arrival, they were stored in the dark at 4°C and were not opened until used for the elutriate tests.

General Sediment Characteristics and Oxygen Demand

The sediments collected for elutriate tests were analyzed for Eh, sulfide concentration, percent dry weight, and particle size distribution. The results of these measurements are presented in Table 427.

Perth Amboy Channel and Anchorage sediments were analyzed in triplicate. They had Eh values of -353 mv and -381 mv, respectively. The Perth Amboy Channel sediment's mean sulfide concentration was 1502 mg/kg; that of the Anchorage sediment was 2373 mg/kg. Their mean percent dry weights were 34 percent and 40 percent, respectively. The particle size distribution of the Channel sediment sample was 4 percent clay, 63 percent silt, and 33 percent sand. Anchorage sediment was zero percent clay, 69 percent silt, and 31 percent sand. The Bay Ridge Channel sediment had an Eh of -379 mv. The mean sulfide concentration was found to be 1190 mg/kg. The mean percent dry weight value was determined to be 48 percent. These sediments were found to be 6 percent clay, 54 percent silt, and 40 percent sand.

The oxygen demand test was performed on the three sediment samples. The oxygen uptake data for the multiple runs for all three sediments are presented in Tables A 37, A 38, and A 39 of Appendix A. For the samples from the Perth Amboy Channel, the standard deviation ranged from 0 to 0.3, indicating good reproducibility. As can be seen in Table 427, the Anchorge area sediment showed a slightly higher oxygen demand per cubic meter for the first hour (9.3×10^2 g O_2 compared to 8.4×10^2 g O_2 for the Channel sediment). The same was true for the uptake per gram dry weight for the first hour: 1.43 mg O_2 for the Anchorage sediment compared to 1.29 mg O^2 for the Channel sediment.

The plot of the data from the Perth Amboy oxygen demand tests are presented in Figures 140 and 141. The Channel sediment showed a two-stage uptake. The slope of the fast component was -0.16 mg/l min^{-1}, and that of the slow component was 0.009 mg/l min^{-1}. The Anchorage sediment had a single-component slope of -0.012 mg/l min^{-1}. The initial fast component found for most sediments tested in this study was very short lived.

Table 427

Characteristics of Perth Amboy Channel, Anchorage, and Bay Ridge Channel Sediments

Sample Designation	Eh (mv)	Sulfide mg S/kg		Percent Dry Wt		Particle Size Distribution Percent			Oxygen Uptake First Hour	
		$\bar{X}$	SD	$\bar{X}$	SD	Clay	Silt	Sand	Per Cubic Meter (g O_2)	Per Gram Dry Wt (mg O_2)
Perby Amboy Channel	-353	1502	25	34	0.1	4	63	33	8.4×10^2	1.29
Perth Amboy Anchorage	-381	2373	121	40	0.1	0	69	31	9.3×10^2	1.43
Bay Ridge Channel	-379	1190	27	48	0.2	6	54	40	6.6×10^2	0.90

Mean and standard deviations based on triplicate analyses of one sample.

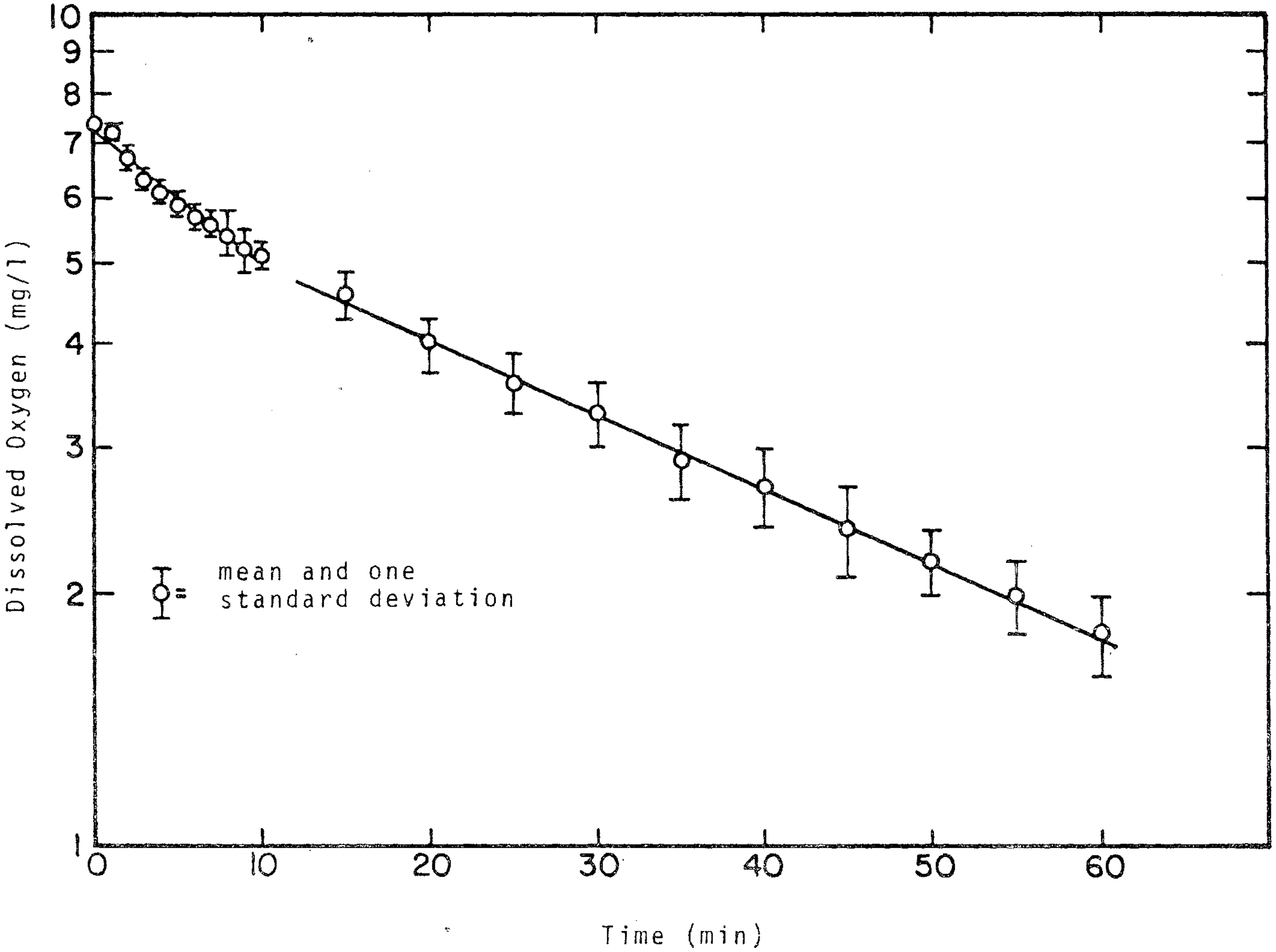

Figure 140
Oxygen Demand Test:
Perth Amboy Channel Sediment
(Sample Size - 2 cc)

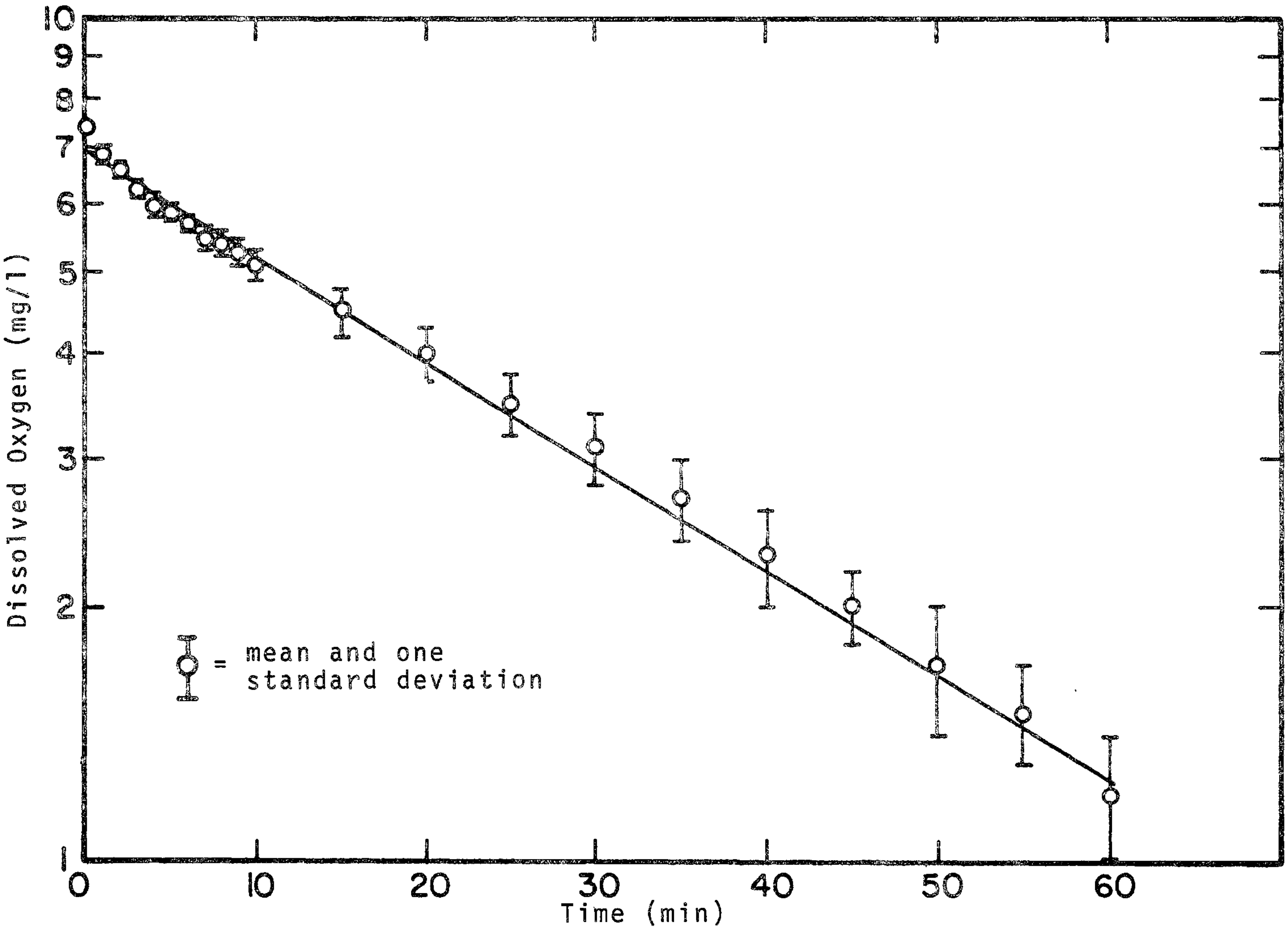

Figure 141
Oxygen Demand Test:
Perth Amboy Anchorage Sediment
(Sample Size - 2 cc)

Table 427 shows that the Bay Ridge Channel sediment had a lower uptake in the first hour than the Perth Amboy samples. The oxygen demand in the first hour for a cubic meter was 6.6 x 10^2 g O_2; it was 0.90 mg O_2 per gram dry weight. The plot of the results, Figure 142, shows a two-component slope. The fast component was calculated to be -0.015 mg/l min^{-1}; the slow component was -0.006 mg/l min^{-1}.

Elutriate Test General Parameters

Duplicate 5 percent oxic, 20 percent oxic, and 20 percent anoxic tests were run on Perth Amboy Channel, Perth Amboy Anchorage, and Bay Ridge Channel sediments on September 3-8, 1976. In addition, a set of duplicate plop tests were run on September 15 on sediment and water from the Perth Amboy Anchorage.

Table 428 presents the values of the general physical and chemical parameters measured during elutriate tests run on Perth Amboy Channel sediment and water. Judging from the D.O. values during the replicate 20 percent oxic tests, the oxygen demand of this sediment was high compared to most test sediments elutriated during this study. This is based on the observation that during settling of the 20 percent oxic tests, D.O. concentrations in the elutriate decreased to 0.7 and 1.7 mg/l. Because of the smaller percent sediment used, the 5 percent oxic elutriates had consistently higher D.O. levels than the 20 percent oxic elutriates and showed higher decrease during settling. During the anoxic tests, the D.O. remained below 0.5 mg/l (detection limit).

The pH values rose from 7.5 in the site water to about 8 in all elutriates. Turbidity levels were about the same in both 5 and 20 percent oxic elutriates but were somewhat higher in the anoxic elutriates. Specific conductance values increased slightly as a result of elutriation, but no discernible differences were found among the elutriates.

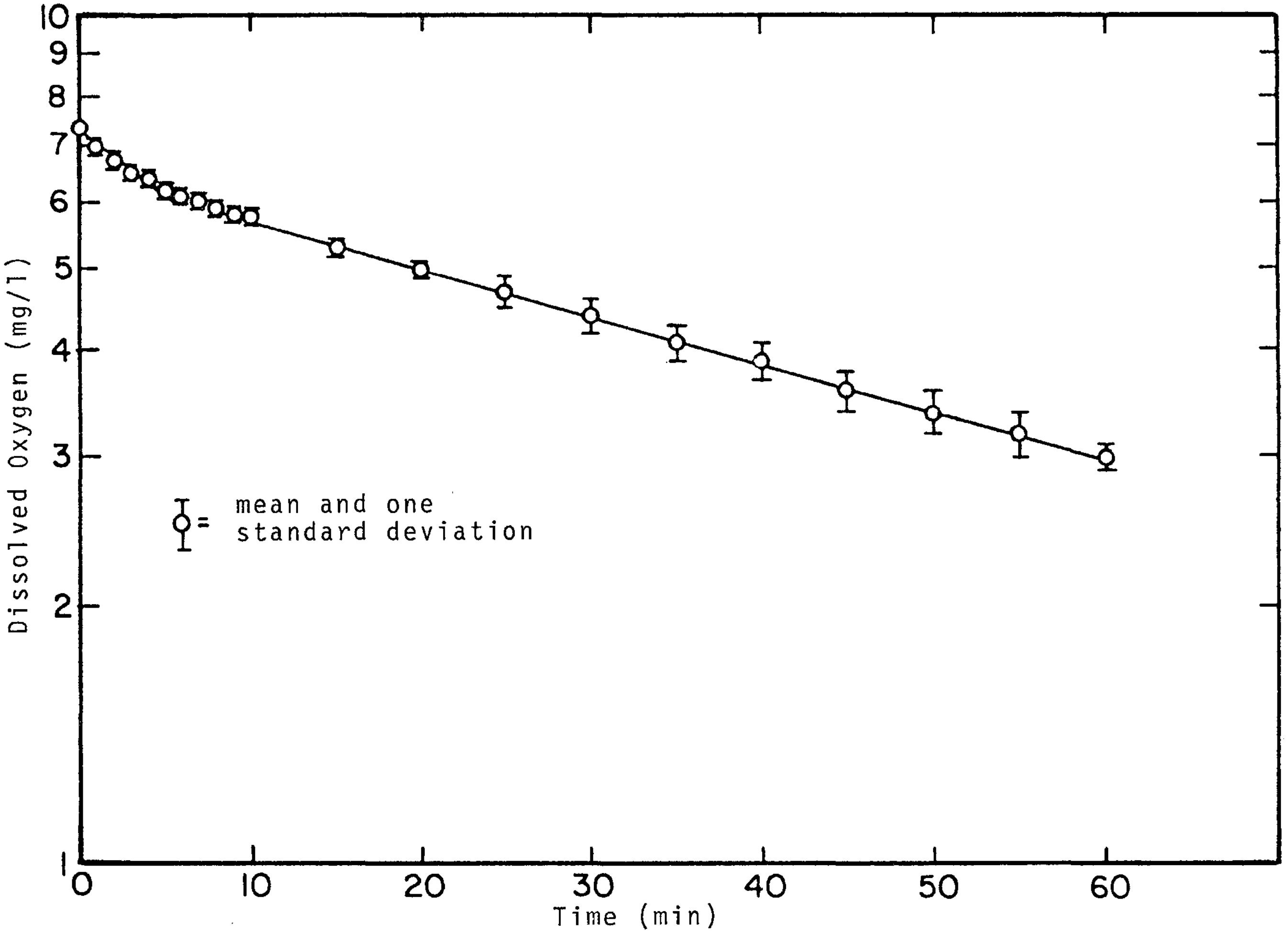

Figure 142

Oxygen Demand Test:

Bay Ridge Channel Sediment

(Sample Size - 2 cc)

Table 428

General Physical and Chemical Parameters:

Perth Amboy Channel Elutriate Tests

Sample Designation		Dissolved Oxygen (mg/l @ 21°C)			pH	Turbidity (NTU)	Specific Conductance (μmhos/cm @ 25°C)
		Initial	After Mixing	After Settling			
Site Water		4.2	-	-	7.5	2.5	29,400
5% Oxic	A	5.6	6.1	5.1	8.0	80	33,600
	B	5.5	5.8	4.8	8.0	100	31,500
20% Oxic	A	2.2 4.7	2.6	0.7	8.0	66	32,240
	B	4.0 4.8	4.9	1.7	8.0	90	32,240
20% Anoxic	A	<0.5	<0.5	<0.5	8.0	150	33,390
	B	<0.5	<0.5	<0.5	7.9	140	29,680

Dash (-) indicates not applicable.

A and B are replicates.

Table 429 shows that the general characteristics of the Perth Amboy Anchorage site water were about the same as those of the Perth Amboy Channel site water. Because the plop tests were run ten days after the oxic and anoxic tests on the Anchorage sediments, a second sample of site water was analyzed at that time for its general characteristics. The only difference between the two was in turbidity; whereas it was 2.5 NTU prior to the first tests, it was 6 NTU prior to the running of the plop tests.

From the D.O. concentrations during the Perth Amboy Anchorage elutriate tests, it would appear that the oxygen demand of these sediments was about the same as that of the Channel sediments. The D.O. values were higher in the 5 percent oxic elutriates than in the 20 percent oxic elutriates and below 0.5 mg/l during the anoxic tests.

The D.O. in the test column during the plop tests on Perth Amboy Anchorage sediment remained constant with depth. The initial and after-mixing values were about the same as those found during the 5 percent oxic tests. After settling, D.O. values were slightly higher than those found in the 5 percent elutriates.

The pH rose during elutriation of Perth Amboy Anchorage sediment. The turbidity found in the 20 percent oxic and 20 percent anoxic elutriates ranged from 76 to 105 NTU. The 5 percent oxic duplicates had somewhat lower turbidities (65 and 62 NTU); plop test elutriate turbidities were the lowest at 25 and 30 NTU.

The specific conductance of the Perth Amboy Anchorage site water was 29,640 μmhos/cm @ 25°C. Although 20 percent oxic A elutriate showed no change in specific conductance, the 20 percent oxic B elutriate showed a slight increase to 31,800 μmhos/cm @ 25°C. The values in the 5 percent oxic and 20 percent anoxic elutriates were below that of the site water. Plop test specific conductance values decreased to about the

Table 429

General Physical and Chemical Parameters: Perth Amboy Anchorage Elutriate Tests

Sample Designation		Dissolved Oxygen (mg/l @ 20.2-22.2°C)			pH	Turbidity (NTU)	Specific Conductance (μmhos/cm @ 25°C)
		Initial	After Mixing	After Settling			
Elutriate Tests:							
Site Water		3.8	-	-	7.4	2.5	29,640
5% Oxic	A	5.7	5.9	4.4	8.1	65	28,350
	B	6.0	6.6	4.7	8.1	62	28,080
20% Oxic	A	3.2	2.0	0.8	8.0	76	29,680
		2.6					
	B	3.2	2.8	1.0	8.0	105	31,800
		3.3					
20% Anxoic	A	<0.5	< 0.5	< 0.5	7.9	88	28,620
		<0.5	< 0.5	< 0.5	7.6	93	28,620
Plop Tests:							
Site Water		8.4	-	-	7.6	6	29,700
Surface	A	6.8	6.5	5.2	7.7	30	28,620
Bottom		6.8	6.5	5.0			
Surface	B	5.5	6.4	5.5	7.8	25	28,090
Bottom		5.4	6.4	5.4			

A and B are replicates.

Dash (-) indicates not applicable.

same level found in the anoxic and 5 percent oxic elutriates.

The general characteristics of Bay Ridge Channel site water were about the same as that of the two Perth Amboy waters, though specific conductance was slightly lower. From the D.O. data during the elutriate tests (Table 430), it appears that the oxygen demand of the Bay Ridge Channel sediment was about the same or slightly less than that of the Perth Amboy sediments.

The pH increased slightly as a result of the elutriations. The turbidity increased to slightly higher levels after 5 percent oxic elutriation than after 20 percent elutriation. The highest turbidity values (about 125 NTU) were found in the anoxic elutriates.

The specific conductance decreased as a result of 20 percent oxic elutriation but remained unchanged or increased slightly during 5 percent oxic and 20 percent anoxic tests.

Heavy Metals

Three sediment samples collected from dredging sites in the Perth Amboy Channel, Perth Amboy Anchorage and Bay Ridge Channel were analyzed for selected total heavy metal concentrations. The data are shown in Table 431.

The manganese concentration in the Bay Ridge Channel sediment was 183 mg/kg; in the Perth Amboy Channel and Anchorage sediments concentrations were 99 and 245 mg/kg, respectively. The iron concentrations in the three sediments ranged from 14 g/kg to 16 g/kg. The zinc ranged from 97 mg/kg to 140 mg/kg, and lead ranged from 8.9 mg/kg to 84 mg/kg. For the above elements, Bay Ridge Channel sediment concentrations generally fell between those of the two Perth Amboy sediments. There were other patterns. The Bay Ridge sediment had the lowest concentrations of the three sediments of chromium, nickel, copper, mercury and arsenic, and Perth Amboy Anchorage sediment had the highest concentrations. The ranges were 3.2 to 69 mg/kg,

Table 430

General Physical and Chemical Parameters:
Bay Ridge Elutriate Tests

Sample Designation	Dissolved Oxygen (mg/l @ 19.8-20.8°C)					Specific Conductance (μmhos/cm @ 25°C)
	Initial	After Mixing	After Settling	pH	Turbidity (NTU)	
Site Water	3.1	-	-	7.5	4.7	28,730
5 % Oxic A	6.0	6.3	5.4	7.9	82	28,190
B	5.8	6.4	5.4	7.9	81	31,300
20 % Oxic A	2.9	3.8	0.9	7.7	68	27,670
B	3.3	4.2	1.3	7.7	64	27,670
20% Anoxic A	<0.5	<0.5	<0.5	7.8	125	28,350
B	<0.5	<0.5	<0.5	7.8	115	31,390

A and B are replicates.

Dash indicates not applicable.

Table 431

Heavy Metal Concentrations: New York Bight Area Sediment Samples

(mg/kg)

Sample Designation	Mn		Cd		Cr		Zn		Ni		Pb		Cu		Fe*		Hg		As	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Perth Amboy Channel	99	72*	1.7	0.6	18	17	140	127	11.6	9.1	8.9	0.3	380	39	14	5	3.44	0	15.1	12.6
Perth Amboy Anchorage	245	111	3.3	2.5	69	33	97	94	30	20	84	67	487	102	15	7	4.77	0.18	57.5	17.9
Bay Ridge Channel	183	126	6.9	3.4	3.2	2.9*	103	95	2.5	0.7	48	67	257	128	16	10	2.21	0.07	<5	0

Mean and standard deviation calculated from triplicate analyses except for mercury and arsenic which were calculated from duplicate analyses.

*g/kg

2.5 to 30 mg/kg, 257 to 487 mg/kg, 2.21 to 4.77 mg/kg, and <5 to 57.5 mg/kg for chromium, nickel, copper, mercury, and arsenic. The highest cadmium concentration was found in the Bay Ridge Channel sediment (6.9 mg/kg), and the lowest was found in the Perth Amboy Channel sediment (1.7 mg/kg).

In summary, of the three sediments, the Perth Amboy Anchorage sediment was found to be the most heavily contaminated with heavy metals. It had the highest concentration of seven of the ten metals determined. The Bay Ridge Channel sediment had the lowest concentration of five of the ten metals and the highest concentration of two. The Perth Amboy Channel sediment had the lowest concentration of four metals and the highest concentration of one.

Table 432 presents the soluble heavy metal concentrations of the site and elutriate waters from the elutriate tests run on these three sediments. The largest release seen was of iron in one of the Bay Ridge Channel 20 percent oxic tests. Smaller releases of iron were also seen in the tests with the two Perth Amboy sediments. Manganese increased in some tests and decreased in others. Zinc and copper concentrations decreased.

Only two of the Perth Amboy Channel tests showed release of large concentrations of iron. The site water contained 8 μg/l iron, one of the 20 percent oxic elutriates contained 689 μg/l iron,and one 20 percent anoxic elutriate contained 248 μg/l iron. Their duplicates and the 5 percent oxic elutriates contained from less than 5 to 32 μg/l iron. The Perth Amboy Anchorage site water had the highest iron concentration of the three, 22 μg/l. The 20 percent oxic and anoxic elutriates ranged in concentration from 48 to 161 μg/l. The plop test waters contained 82 and 45 μg/l iron. The 5 percent elutriates contained 25 and 11 μg/l iron.

Table 432

Soluble Heavy Metal Concentrations: New York Bight Area Elutriate Tests

(μg/l)

Sample Designation		Mn		Cd		Cr		Zn		Ni		Pb		Cu		Fe		Hg		As	
		$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Perth Amboy Channel																					
Site Water		<10	-	<0.5	-	<2	-	6.1	-	<2	-	<1	-	3.6	0.6	8	6	0.03	0	2	-
5% Oxic	A	52	12	<0.5	-	<2	-	3.0	0.2	<2	-	<1	-	< 1	-	5	0	0.03	0	<2	-
	B	44	0	<0.5	-	<2	-	< 1	-	2.5	0.4	<1	-	< 1	-	31	-	0.03	0	3	-
20% Oxic	A	28	0	<0.5	-	<2	-	< 1	-	<2	-	<1	-	< 1	-	689	-	0.03	0	<2	-
	B	19	12	<0.5	-	<2	-	< 1	-	2.6	0.1	<1	-	≤ 1	-	31	0	0.03	0	<2	-
20% Anoxic	A	28	-	<0.5	-	<2	-	< 1	-	<2	-	<1	-	< 1	-	32	8	0.03	0	16	-
	B	44	-	<0.5	-	<2	-	< 1	-	<2	-	<1	-	1.3	-	248	-	0.03	0	13	-
Perth Amboy Anchorage																					
Elutriate Tests:																					
Site Water		28	11	<0.5	-	<2	-	< 1	-	<2	-	<1	-	3.9	0.1	22	3	0.03	0	4	-
5% Oxic	A	36	-	0.7	0	<2	-	< 1	-	<2	-	<1	-	< 1	-	25	1	0.03	0	12	-
	B	28	11	0.6	-	<2	-	< 1	-	<2	-	<1	-	< 1	-	11	4	0.05	0	< 2	-
20% Oxic	A	<10	-	0.6	-	7.0	-	< 1	-	<2	-	<1	-	1.0	-	161	10	0.03	0	19	-
	B	<10	-	<0.5	-	<2	-	< 1	-	4.1	1.6	<1	-	< 1	-	48	7	0.03	0	13	-
20% Anoxic	A	20	-	<0.5	-	<2	-	< 1	-	<2	-	<1	-	2.8	-	71	15	0.07	0	44	-
	B	84	-	<0.5	-	<2	-	< 1	-	<2	-	<1	-	< 1	-	65	4	0.03	0	44	-
Plop Tests:																					
	A	52	23	<0.5	-	7.7	2.9	< 1	-	<2	-	<1	-	< 1	-	82	2	0.03	0	14	-
	B	12	11	0.7	0	<2	-	< 1	-	<2	-	<1	-	1.2	-	45	6	0.07	0.028	6	-
Bay Ridge Channel																					
Site Water																					
5% Oxic	A	44	23	<0.5	-	2.6	-	7.4	2.0	<2	-	1.8	-	4.9	0.1	8	2	0.02	0.014	< 2	-
		<10	-	<0.5	-	2.8	0.2	1.8	-	3.2	-	2.3	-	< 1	-	11	3	0.02	0	< 2	-
		<10	-	<0.5	-	2.2	0.3	1.2	-	<2	0	4.5	1.0	< 1	-	23	2	0.02	0	< 2	-
		28	-	<0.5	-	2.6	0.1	< 1	-	2.8	0.6	< 1	-	< 1	-	1081	-	0.18	0.014	< 2	-
		<10	-	<0.5	-	2.7	0.6	< 1	-	3.9	1.5	1.6	0.6	< 1	-	679	-	0.02	0	< 2	-
		93	-	<0.5	-	2.6	0.6	< 1	-	3.2	-	6.0	3.1	< 1	-	1100	-	0.02	0	6	-
		76	23	<0.5	-	3.6	0.3	< 1	-	<2	-	3.1	0.4	< 1	-	1286	-	0.02	0	< 2	-

A and B are replicates.

Mean and standard deviation calculated from duplicate analyses of one sample.

Dash (-) indicates single analysis or not applicable.

The Bay Ridge Channel site water iron concentration was 8 µg/l. The 5 percent oxic elutriates showed some release, 11 to 23 µg/l, but the 20 percent oxic and anoxic tests showed the highest release, 679 and 1081 µg/l in the oxic elutriates and 1100 and 1286 µg/l in the anoxic elutriates.

Bay Ridge Channel oxic elutriate tests all resulted in a decrease in manganese from that present in the site water, but the 20 percent anoxic tests showed some release (93 and 76 µg/l, compared to the site water concentration of 44 µg/l). All of the Perth Amboy Channel tests showed small releases with no apparent pattern due to type of test or volume of sediment. The site water contained less than 10 µg/l manganese (detection limit), and the elutriates contained from 19 to 52 µg/l manganese. The behavior of manganese in the Perth Amboy Anchorage tests was quite erratic. The site water contained 28 µg/l, and the elutriates contained from less than 10 to 84 µg/l manganese. There was release in one of the 5 percent oxic tests, decreases in the 20 percent oxic tests, and release in one and decrease in the other duplicate of the 20 percent anoxic and plop tests.

Zinc and copper decreased or remained unchanged in all tests. Site water concentrations of zinc ranged from less than one µg/l (detection limit) to 7.4 µg/l, and elutriate levels ranged from less than one to 3.0 µg/l. Copper concentrations in the three site waters ranged from 3.6 to 4.9 µg/l, and elutriate concentrations ranged from less than 1 to 2.8 µg/l.

Cadmium concentrations were below the detection limit (0.5 µg/l) in all Bay Ridge Channel and Perth Amboy Channel elutriates and in Perth Amboy Anchorage site water. There was release of cadmium in the 5 percent oxic tests for Perth Amboy Anchorage sediments (0.7 and 0.6 µg/l, respectively). Lead concentrations were below the detection limit of 1 µg/l in the Perth Amboy Channel and Anchorage site and elutriate waters. In the Bay Ridge Channel site water the lead concentration was 1.8 µg/l. There was release in the 5 percent oxic tests (2.3 and 4.5 µg/l) and in the 20 percent anoxic tests (6.0 and 3.1 µg/l). There was uptake or loss of lead in the 20 percent oxic tests (less than 1 and 1.6 µg/l).

Chromium and nickel concentrations in these elutriate tests hovered around their detection limits of 2 µg/l. With the Perth Amboy Anchorage sediment, there was release of chromium in one 20 percent oxic (7.0 µg/l) and one plop duplicate (7.7 µg/l). Concentrations in the Bay Ridge Channel elutriates ranged from 2.2 to 3.6 µg/l chromium; the site water contained 2.6 µg/l chromium. All site waters had nickel concentrations below the detection limit. There was release in one 20 percent oxic Anchorage test (4.1 µg/l nickel), in two Perth Amboy Channel oxic tests (2.5 and 2.6 µg/l nickel),and in four Bay Ridge Channel oxic and anoxic tests (2.8 to 3.9 µg/l nickel).

A similar pattern was seen with mercury concentrations. The Perth Amboy site waters contained 0.03 µg/l mercury. There was no change in the mercury content as a result of elutriation with sediment. There was some release in three of the elutriates with the Perth Amboy Anchorage sediment. One of the 20 percent anoxic tests and one of the plop test duplicates contained 0.07 µg/l mercury. One of the 5 percent oxic elutriates contained 0.05 µg/l mercury. In the Bay Ridge Channel tests there were decreases in all but one test, from 0.02 µg/l mercury in the site water. One 20 percent oxic elutriate showed up to 0.18 µg/l mercury.

The arsenic concentrations were somewhat variable. The most significant release occurred in the Perth Amboy Anchorage anoxic tests. This site water contained 4 µg/l arsenic. The 20 percent anoxic tests resulted in release of up to 44 µg/l arsenic. The 20 percent oxic tests with this sediment resulted in releases of 19 and 13 µg/l arsenic. Perth Amboy Channel site water contained 2 µg/l arsenic and the two anoxic elutriates contained 16 and 13 µg/l arsenic. One of the heavy metals tested that showed substantial release was iron. Occasionally, there was some manganese and mercury release. All of the other heavy metals examined showed little or no change as a result of elutriation.

Nitrogen Compounds

The ammonium and organic N data for the Bay Ridge Channel and Perth Amboy sediments collected are presented in Table 433. Concentrations of both compounds in all three sediments were high compared to many other study sites with the Perth Amboy Channel sample showing the highest concentrations.

The nitrogen compound concentrations for the Perth Amboy Channel elutriate tests are presented in Table 434. The ammonium release from this sediment was considerably higher than that obtained from most other sediments studied for this report. However, it should be noted that the site water ammonium concentration was somewhat higher than that generally observed in water samples from other sites. Ammonium release was higher in the oxic elutriates than in the anoxic elutriates and in the higher percent sediment elutriates, the highest value found (33 mg N/l) was found in one of the replicates of a 20 percent oxic replicate. Concentrations were higher under oxic conditions and with the greater percent sediment volume. Nitrate concentrations decreased in all elutriates except in the 5 percent oxic A elutriate where it was unchanged from that in the site water.

Nitrogen compound concentrations for the Perth Amboy Anchorage tests are presented in Table 435. The site water ammonium concentration was about the same as that observed in the channel site water, yet ammonium release was about half that found in the Perth Amboy Channel tests. Here also, the highest release was obtained in the 20 percent oxic elutriates.

Table 433
Organic Nitrogen and Ammonium Data: New York Bight Area Sediment Samples
(mg N/kg)

Sampling Location	Organic N		Ammonium	
	$\overline{X}$	SD	$\overline{X}$	SD
Perth Amboy Channel	3267	83	628	4
Perth Amboy Anchorage	2490	230	274	40
Bay Ridge Channel	1952	300	235	126

Mean and standard deviation calculated from duplicate analyses.

Table 434
Nitrogen Compound Concentrations: Perth Amboy Channel Elutriate Tests
(mg N/l)

Sample Designation		Organic N		Ammonium		Nitrate	
		$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD
Site Water	A	0.3	0.13	0.60	0.08	0.1	0
	B	0.4	0.04	0.54	0.02	0.08	0
5% Oxic	A	2.4	0.72	10.3	0.44	0.1	0.01
	B	1.2	0.31	10.0	0.11	0.08	0.01
20% Oxic	A	5.6	1.74	33.0	1.20	0.08	0.01
	B	3.3	1.59	24.8	1.20	<0.04	-
20% Anoxic	A	2.8	0.53	15.6	0.21	<0.04	-
	B	2.8	0.86	18.8	0.64	<0.04	-

A and B are replicates.

Mean and standard deviation calculated using duplicate analyses.

Dash (-) indicates not applicable.

Table 435

Nitrogen Compound Concentrations: Perth Amboy Anchorage Elutriate and Plop Tests

(mg N/l)

Sample Designation		Organic N $\overline{X}$	Organic N SD	Ammonium $\overline{X}$	Ammonium SD	Nitrate $\overline{X}$	Nitrate SD
Elutriate Tests:							
Site Water	A	0.2	0.04	0.63	0.02	0.14	0.01
5% Oxic	A	0.8	0.14	4.66	0.07	0.12	0
	B	0.7	0.19	4.40	0.13	0.11	0
20% Oxic	A	1.5	0.41	13.8	0.21	0.06	0.01
	B	1.8	0.90	14.4	0.57	0.06	0.01
20% Anoxic	A	0.3	0.39	9.90	0.32	0.1	0
	B	0.6	0.18	8.78	0.09	0.1	0.01
Plop Tests:							
Site Water	B	0.2	0.03	0.68	0.01	0.2	0
Plop Test	A	0.7	0.07	3.04	0.04	0.2	0
	B	0.6	0.06	3.24	0.02	0.1	0.01

A and B are replicates.

Mean and standard deviation calculated using duplicate analyses.

The releases in the anoxic tests were less than those in the 20 percent oxic elutriates but higher than those in the 5 percent oxic elutriates. The ammonium releases from the plop tests were less than those found in the 5 percent elutriates.

Nitrate decreased as a result of elutriation for all the elutriate test samples. Plop test concentrations resembled that of the site water. The results from the 5 percent oxic samples closely approximated the results from the plop tests. Organic N concentrations in the plop test samples were somewhat lower than in the 5 percent elutriates. Concentrations were higher in oxic than in anoxic elutriates.

The nitrogen compound concentrations for the Bay Ridge Channel elutriate tests are presented in Table 436. Ammonium release was less than that obtained from the other two sediments, although all three site waters had comparable concentrations. The Bay Ridge Channel tests also showed the same general pattern of higher ammonium release under oxic conditions and with a higher sediment percentage. Nitrate concentrations decreased to a similar extent in 20 percent oxic and anoxic elutriates. Again, very little decrease in nitrate concentration was observed in the 5 percent tests. Organic N showed higher concentrations under anoxic conditions. It was not possible to determine the effect of the sediment volume on organic N concentration because of wide variation in the duplicate 5 percent tests.

Phosphorus Compounds

Presented in Table 437 are the total phosphorus concentrations of the three New York area dredging site sediment samples. The Perth Amboy Channel and Anchorage sediments contained about the same concentrations of phosphorus. The concentration in the Bay Ridge sample (1186 mg P/kg) was about half those in the Perth Amboy samples.

Soluble orthophosphate concentrations in Perth Amboy Channel elutriates are shown in Table 438. Duplicate

Table 436

Nitrogen Compound Concentrations: Bay Ridge Channel Elutriate Tests

(mg N/l)

Sample Designation		Organic N		Ammonium		Nitrate	
		$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Site Water		0.4	0.09	0.56	0	0.1	0
5% Oxic	A	0.2	0.10	2.43	0.08	0.1	0
	B	0.4	0.16	2.96	0.11	0.1	0.01
20% Oxic	A	0.2	0.08	8.40	0.08	0.05	0
	B	0.2	0.17	7.46	0.14	0.04	0
20% Anoxic	A	0.7	0.15	5.24	0.09	0.04	0.01
	B	0.6	0.36	5.50	0.09	0.06	0

A and B are replicates.

Mean and standard deviations calculated from duplicate analyses.

Table 437

Total Phosphorus Content: New York Bight Area Sediment Samples

Sampling Location	Total Phosphorus (mg P/kg dry weight)	
	$\bar{X}$	SD
Perth Amboy Channel	2136	-
Perth Amboy Anchorage	2384	-
Bay Ridge Channel	1186	3*

Dash (-) indicates not applicable.

*Mean and standard deviation calculated from duplicate analyses of one digested sample. Other sediments were subjected to only single analysis.

Table 438

Soluble Orthophosphate Concentrations:
Perth Amboy Channel Elutriate Tests

Sample Designation		Soluble Orthophosphate (mg P/l)	
		$\overline{X}$	SD
Site Water		0.25	0.001
5% Oxic	A	0.04	0
	B	0.04	0
20% Oxic	A	0.11	0
	B	0.05	0
20% Anoxic	A	0.32	0.001
	B	0.73	0

Mean and standard deviation were calculated from duplicate analyses of one sample.

5 percent oxic tests ortho P concentrations showed good reproducibility; the 20 percent sediment tests did not. In general, the oxic tests showed decreases of soluble ortho P as a result of elutriation. Concentrations decreased from 0.25 mg P/l in the site water to 0.04 mg P/l in the 5 percent elutriates and to 0.05 and 0.11 mg P/l in the 20 percent oxic elutriates. As shown in Table 428, D.O. concentration in the 20 percent oxic B test both after mixing and after settling, was greater than that in 20 percent oxic replicate A. Although the difference was small (1 to 2 mg/l), it might have influenced the amount of orthophosphate decrease realized. The anoxic tests showed release of soluble orthophosphate.

Table 439 presents the soluble orthophosphate concentrations found in Perth Amboy Anchorage site water and elutriates. The site water (0.14 mg P/l) had a lower concentration than did the Perbh Amboy Channel water. The 5 percent oxic elutriate test showed a decrease in soluble ortho P; the concentration in these elutriates was 0.055 mg P/l. The 20 percent oxic and the plop tests showed about the same release of soluble ortho P. Their concentrations ranged from 0.23 to 0.46 mg P/l, representing approximately 2 to 3-fold increases over that of the site water. The greatest release was found under anoxic conditions. Concentrations in the anoxic elutriates were about 4 mg P/l.

Of the three New York dredging site waters analyzed, the Bay Ridge Channel site water (Table 440) had the lowest concentration, 0.094 mg P/l. The effect of 5 percent oxic elutriation on soluble ortho P concentrations was unclear. Both replicates showed different patterns. The difference in elutriate concentrations did not appear to be related to oxygen conditions during the test. Since concentrations in the previous New York 5 percent oxic elutriates were typically lower than those in the 20 percent oxic tests, it is likely that the 5 percent oxic B value may be in error. There appeared to be a decrease in soluble orthophosphate as a result of 20 percent oxic elutriation. Anoxic elutriation showed release of soluble ortho P to about 1 mg P/l in the elutriate.

Organic Compounds

Table 441 presents the results of chlorinated hydrocarbon pesticides and PCB analyses on Perth Amboy Channel sediments, site waters, and elutriates. Aldrin, pp'DDT, pp'DDD, op'DDE, pp'DDE, dieldrin, heptachlor, lindane, and PCBs were detected in the sediment. The concentrations of

Table 439

Soluble Orthophosphate Concentrations: Perth Amboy Anchorage Elutriate and Plop Tests

Sample Designation		Soluble Orthophosphate (mg P/l)	
		$\bar{X}$	SD
Site Water		0.14	0.001
Elutriate Tests:			
5% Oxic	A	0.053	0.001
	B	0.055	0
20% Oxic	A	0.29	0.001
	B	0.23	0.001
20% Anoxic	A	4.2	0.01
	B	3.6	0.02
Plop Tests:			
	A	0.46	0.001
	B	0.31	0.006

A and B are replicates.

Mean and standard deviation calculated from duplicate analyses of one sample.

Table 440

Soluble Orthophosphate Concentrations: Bay Ridge Channel Elutriate Tests

Sample Designation		Soluble Orthophosphate (mg P/l)	
		$\bar{X}$	SD
Site Water		0.094	0.001
5% Oxic	A	0.042	0
	B	0.53	0.004
20% Oxic	A	0.061	0.001
	B	0.53	0.001
20% Anoxic	A	1.2	0
	B	0.92	0

A and B are replicates.

Mean and standard deviation calculated from duplicate analyses of one sample.

Table 441

Data for Organic Compounds and Related Parameters: Perth Amboy Channel Elutriate Tests

Parameter	Sediment	Site Water	Elutriate
	(μg/kg)	(ng/l)	(ng/l)
Chlorinated Hydrocarbons:			
Aldrin	13.3	<0.6	<0.6
op'DDT	<1.6	<3.0	<3.0
pp'DDT	2.0	<3.0	<3.0
op'DDD	<2.0	<2.0	<2.0
pp'DDD	38.2	<2.0	<2.0
op'DDE	9.6	<2.0	<2.0
pp'DDE	16.3	<2.0	<2.0
Dieldrin	13.1	<1.2	<1.2
Endosulfan I	<0.9	<1.2	<1.2
Endosulfan II	<3.4	<4.4	<4.4
Endrin	<1.2	<1.6	<1.6
Heptachlor	5.9	<0.4*	<0.4*
Lindane	5.8	<0.3*	<0.3*
PCBs	1078	<6	69
Other Organic Compounds		(mg/l)	(mg/l)
Oil and grease	4044 mg/kg	<0.5	<0.5
TOC	3.5%	19	48
Soluble TOC	-	15	39
Total Inorganic Carbon	0.3%	22	47
Soluble TIC	-	22	47

Dash (-) indicates not applicable.

*Compound detected on both columns but below detection limit.

pesticides ranged from 2.0 µg/kg pp'DDT to 38.2 µg/kg pp'DDD. The concentration of total PCBs was 1078 µg/kg. The oil and grease concentration was 4044 mg/kg and TOC was 3.5 percent.

In the site water, only heptachlor and lindane were detected, but they were below measurable quantities. The TOC was 19 mg/l and the soluble TOC was 15 mg/l. Oil and grease was <0.5 mg/l. There was no release of pesticides during the elutriate test but there was a release of PCBs. The concentration of PCBs was 69 ng/l, and there was a corresponding increase in soluble TOC to 39 mg/l. The TOC was 48 mg/l.

A 20 percent oxic elutriate test was run on Perth Amboy Anchorage samples; the results of the analyses are presented in Table 442. Aldrin, pp'DDT, pp'DDD, op'DDE, pp'DDE, dieldrin, heptachlor, lindane, and PCBs were detected in the sediment. Pesticide concentrations ranged from 1.0 µg/kg (dieldrin) to 19.3 µg/kg (aldrin). The PCB value (1760 µg/kg) was slightly higher than found in the Perth Amboy Channel sediments. The oil and grease level was 2091 mg/kg which was about half the value found in the Perth Amboy Channel sediments.

The water contained no detectable pesticides but PCBs were present at a concentration of 17 ng/l. During the elutriate test on this sample, pesticides released were pp'DDD (20.5 ng/l), pp'DDE (5.3 ng/l), heptachlor (4.5 ng/l), and lindane (4.6 ng/l). PCBs (81 ng/l) were also detected in the elutriate. The TOC was 8 mg/l in the site water and 27 mg/l in the elutriate. The soluble TOC showed a slight increase from 7 mg/l in the site water to 10 mg/l in the elutriate.

A 20 percent oxic elutriate test was run on Bay Ridge Channel samples. Table 443 shows that aldrin, pp'DDT, pp'DDD, op'DDE, pp'DDE, heptachlor, lindane, and PCBs were detected in the sediment. The concentrations of these compounds

Table 442

Data for Organic Compounds and Related Parameters: Perth Amboy Anchorage Elutriate Tests

Parameter	Sediment	Site Water	Elutriate
	(μg/kg)	(ng/l)	(ng/l)
Chlorinated Hydrocarbons:			
Aldrin	19.3	<0.6	<0.6
op'DDT	<1.6	<3.0	<3.0
pp'DDT	14.0	<3.0	<3.0*
op'DDD	<2.0	<2.0	<2.0
pp'DDD	17.5	<2.0	20.5
op'DDE	<2.0 *	<2.0	<2.0
pp'DDE	2.5	<2.0	5.3
Dieldrin	1.0	<1.2	<1.2
Endosulfan I	<0.9	<1.2	<1.2
Endosulfan II	<3.4	<4.4	<4.4
Endrin	<1.2	<1.6	<1.6
Heptachlor	9.9	<0.4	4.5
Lindane	7.3	<0.3	4.6
PCBs	1760	17	81
Other Organic Compounds		(mg/l)	(mg/l)
Oil and grease	2091 mg/kg	0.7	1
TOC	3.2%	8	27
Soluble TOC	-	7	10
Total Inorganic Carbon	0.2%	23	32
Soluble TIC	-	22	32

Dash (-) indicates not applicable.

*Compound detected on both columns, but below the detection limit.

Table 443

Data for Organic Compounds and Related Parameters

Bay Ridge Channel Elutriate Tests

Parameter	Sediment	Site Water	Elutriate
	(μg/kg)	(ng/l)	(ng/l)
Chlorinated Hydrocarbons:			
Aldrin	22.7	9.2	<0.4
op'DDT	<1.6	<3.0	<3.0
pp'DDT	66.0	<3.0	<3.0
op'DDD	<2.0	<2.0	<2.0
pp'DDD	47.0	<2.0	<2.0
op'DDE	4.4	<2.0	<2.0
pp'DDE	13.0	<2.0	5.2
Dieldrin	<0.8	<1.2	<1.2
Endosulfan I	<0.9	<1.2	<1.2
Endosulfan II	<3.4	<4.4	<1.2
Endrin	<1.2	<1.6	<4.4
Heptachlor	14.6	<0.4	5.3
Lindane	16.7	5.0	4.5
PCBs	1820	8	86
Other Organic Compounds		(mg/l)	(mg/l)
Oil and grease	826 mg/kg	<0.5	4
TOC	3.2%	15	79
Soluble TOC	-	9	62
Total Inorganic Carbon	0.4%	22	39
Soluble TIC	-	21	39

Dash (-) indicates not applicable.

were 22.7, 66.0, 47.0, 4.4, 13.0, 14.6, 16.7, and 1820 µg/kg, respectively. The oil and grease value (826 mg/kg) was considerably lower than that of the Perth Amboy samples, while the total organic carbon (3.2 percent) was about the same. The site water contained aldrin (9.2 ng/l), lindane (5.0 ng/l), and PCBs (8 ng/l). The oil and grease concentration was below the detection limit of 0.5 mg/l. The TOC was 15 mg/l and soluble TOC was 9 mg/l. In the elutriate, pp'DDE (5.2 ng/l), heptachlor (5.3 ng/l), and PCBs (86 ng/l) were released. The aldrin concentration was reduced to below the detection limit (0.4 ng/l), and the lindane concentration (4.5 ng/l)remained about the same as that in the site water. The oil and grease concentration was 4 mg/l,and TOC and soluble TOC increased to 79 mg/l and 62 mg/l, respectively.

Bioassays

Sediments collected form Bay Ridge Channel, Perth Amboy Anchorage, and Perth Amboy Channel were also used for elutriate test bioassays. Based on the results of the elutriate test bioassays conducted on these sediments, it was decided that a second set of sediment samples should be taken from Perth Amboy Channel to determine the effect of sediment sample variation on bioassay results.

The physical and chemical characteristics of the elutriate test bioassays on Bay Ridge Channel sediments are presented in Table 444. The data presented in this table reveal increases in turbidity and ammonium content and a reduction in D.O. and pH in both the 5 and 20 percent sediment tests. The release of ammonium to the bioassay elutriate waters ranged from approximately 5 mg/l in the 5 percent tests to over 7 mg/l in the 20 percent tests. Increases in turbidity were observed in both the 5 and 20 percent tests and ranged from 75-80 NTUs. The pH of the bioassay elutriate waters decreased as a function of the percent sediment used. Decreases in D.O. content ranged from 3.5 to 5.7 mg/l in the 5 and 20 percent sediment tests, respectively, indicating a high oxygen demand.

Table 444

Physical and Chemical Characteristics:

Bay Ridge Channel Bioassay Elutriates*

Sample Designation		pH	Dissolved Oxygen (mg/l@ 20-21°C)	Specific Conductance (µmhos/cm)	Total Ammonium (mg N/l)	Unionized** Ammonia (mg N/l)	Turbidity (NTU)	Salinity ($^{o}/oo$)
Control	A	8.2	7.0	42,100	0.03	<0.01	<1	30
	B	8.2	7.1	42,000	0.03	<0.01	<1	30
5%	A	7.8	3.7	42,200	4.82	0.09	75	31
	B	7.7	3.5	43,000	5.04	0.07	80	31
20%	A	7.5	1.5	41,300	7.18	0.06	80	30
	B	7.5	1.1	41,700	7.42	0.07	80	30

A and B are replicates.

*Reading taken at end of one-hour settling period.

**For all bioassay elutriates, concentrations of unionized ammonia calculated from Skarheim's [9] tables for ammonia in undissociated form.

The results of the bioassay using Bay Ridge Channel sediment elutriates are presented in Table 445. Examination of this table shows variable results for the 5 percent sediment tests with mortalities ranging from zero to 50 percent at the end of 96 hours in the replicate tests. Limited toxicity was observed in the 20 percent tests with a single organism dying in one of the replicates. Based on the highly variable results in the 5 percent sediment tests, these results should be considered invalid.

Table 446 shows the ammonium content of the bioassay waters at the completion of the 96-hour test period. Examination of the data presented in Table 446 shows that the ammonium content of the controls and those tests which utilized a 20 percent sediment of total elutriate volume increased while the 5 percent sediment tests showed a decrease in ammonium content during the 96-hour test period.

Table 447 presents the concentrations of D.O. in the bioassay elutriate waters from Bay Ridge Channel sediments. The data indicate that the one-hour aeration period following settling was not sufficient early in the test period to keep the level of D.O. above 4 mg/l in the 20 percent tests. Subsequent aeration periods were increased to two hours per day to maintain a D.O. concentration greater than 4 mg/l throughout the 24-hour aeration cycle.

The physical and chemical characteristics of the bioassay elutriate waters for Perth Amboy Anchorage sediments are presented in Table 448. The data show that the concentrations of ammonium and turbidity increased while the pH and D.O. content of the bioassay elutriate waters decreased. The increase in total ammonium ranged from approximately 5.5 mg/l in the 5 percent sediment tests to 7.4 mg/l in the 20 percent sediment tests. Increases in turbidity were observed in both the 5 and 20 percent sediment tests with the higher levels of turbidity being observed in the 5 percent tests. The D.O. data

Table 445

Response of P. pugio to Varying Sediment Percent of Total Elutriate Volume as a Function of Time: Bay Ridge Channel Elutriate Bioassays

Time (hr)	Number of *P. pugio* Living at Varying Sediment Percentages					
	Controls		5%		20%	
	A	B	A	B	A	B
0	10	10	10	10	10	10
12	10	10	10	9	10	10
24	10	10	10	9	10	9
36	10	10	10	9	10	9
48	10	10	10	8	10	9
60	10	10	10	8	10	9
72	10	10	10	8	10	9
84	10	10	10	7	10	9
96	10	10	10	5	10	9

A and B are replicates.

Table 446

Ammonium Content of the Bay Ridge Channel Sediment Elutriate Bioassay Waters at the Completion of the 96-Hour Test Period

(@ 20°C)

Sample Designation		pH	Total Ammonium (mg N/l)	Unionized Ammonia (mg N/l)
Control	A	8.2	0.06	<0.01
	B	8.2	0.07	<0.01
5%	A	7.8	3.45	0.06
	B	7.7	3.33	0.04
20%	A	7.5	9.10	0.08
	B	7.5	9.38	0.08

Table 447

Dissolved Oxygen Concentrations over Test Period: Bay Ridge Channel Elutriate Bioassays

(mg/l @ 20-21°C)

Time (hr)	Control		5%		20%	
	A	B	A	B	A	B
0	7.0	7.1	3.7	3.5	1.5	1.1
1*	7.3	7.2	6.2	6.3	6.1	6.1
24	6.2	6.8	3.1	2.7	2.8	2.4
48	6.0	6.5	4.2	4.5	4.0	4.3
72	5.9	6.4	4.4	4.4	4.2	4.5
96	6.1	6.6	4.7	4.6	4.1	4.5

A and B are replicates

*Measurements taken after first hour of aeration.

Table 448

Physical and Chemical Characteristics: Perth Amboy Anchorage Bioassay Elutriates*

Sample Designation		pH	Dissolved Oxygen (mg/l@ 20-21°C)	Specific Conductance (μmhos/cm)	Total Ammonium (mg N/l)	Unionized Ammonia (mg N/l)	Turbidity (NTU)	Salinity (^{o}/oo)
Control	A	8.2	7.0	42,100	0.03	<0.01	<1	30
	B	8.2	7.1	42,000	0.03	<0.01	<1	30
5%	A	8.0	3.2	42,200	5.29	0.15	57	30
	B	7.8	3.1	42,200	5.86	0.11	72	30
20%	A	7.8	1.5	42,000	6.96	0.12	38	30
	B	7.9	1.3	42,000	7.94	0.18	27	30

A and B are replicates.

*Readings taken at end of one-hour settling period.

presented in Table 448.show decreases in D.O. concentrations with corresponding increases in percent sediment of total elutriate volume. Decreases in D.O. ranged from 4.0 mg/l in the 5 percent sediment test to 5.5 mg/l in the 20 percent sediment tests.

The results of the bioassay using P. pugio with Perth Amboy Anchorage sediment elutriate are presented in Table 449. The data show limited toxicity to P. pugio with 30 percent of the organisms dying in both the 5 and 20 percent tests over the 96-hour test period. The response of P. pugio was slightly faster in the 20 percent sediment tests. No additional mortalities occurred after 60 hours of exposure.

Table 450 presents the D.O. concentrations of the bioassay elutriate waters throughout the 96-hour test period. The data show that the one-hour aeration period following the initial settling period was not sufficient to keep the level of D.O. above 4 mg/l throughout the 24-hour aeration cycle for the 5 and 20 percent tests. Subsequent aeration periods were increased to two hours. The additional one-hour aeration of the bioassay elutriate waters seems to have satisfied the high oxygen demand of the sediment enough to keep the D.O. concentration of the waters above 4 mg/l throughout the remaining 24-hour aeration cycles.

The ammonium content of the bioassay elutriate waters at the completion of the 96-hour test period are presented in Table 451. Examination of the data reveals that the total ammonium content of the controls and that of the 20 percent sediment tests increased while the concentration of total ammonium decreased in the 5 percent sediment tests.

Table 452 shows the physical and chemical parameters of the bioassay elutriate waters for Perth Amboy Channel sediments after the one-hour settling period. Examination of the data show increases in the total ammonium and turbidity levels and decreases in pH and D.O. content of the bioassay elutriate waters. The release of ammonium to the bioassay elutriate

Table 449

Response of *P. pugio* to Varying Sediment Percent of Total Elutriate Volume as a Function of Time: Perth Amboy Anchorage Elutriate Bioassays

Time (hr)	Number of *P. pugio* living at Varying Sediment Percentages					
	Controls		5%		20%	
	A	B	A	B	A	B
0	10	10	10	10	10	10
12	10	10	10	10	9	10
24	10	10	9	10	9	9
36	10	10	8	10	8	9
48	10	10	8	9	8	9
60	10	10	8	7	8	7
72	10	10	8	7	8	7
84	10	10	8	7	8	7
96	10	10	8	7	8	7

A and B are replicates.

Table 450

Dissolved Oxygen Concentrations over Test Period: Perth Amboy Anchorage Elutriate Bioassays

(mg/l @ 20-21°C)

Time (hr)	Control		5%		20%	
	A	B	A	B	A	B
0	7.0	7.1	3.2	3.1	1.5	1.3
1*	7.3	7.2	5.3	5.7	5.4	5.9
24	6.2	6.8	2.0	2.3	3.3	2.3
48	6.0	6.5	4.1	4.4	4.2	4.7
72	5.9	6.4	4.0	4.6	5.0	4.6
96	6.1	6.6	4.2	5.0	4.8	5.0

A and B are replicates.

*Measurements taken after first hour of aeration.

Table 451

Ammonium Content of the Perth Amboy Anchorage Sediment Elutriate Bioassay Waters at the Completion of the 96-Hour Test Period

(@ 20°C)

Sample Designation		pH	Total Ammonium (mg N/l)	Unionized Ammonia (mg N/l)
Control	A	8.2	0.06	<0.01
	B	8.2	0.07	<0.01
5%	A	8.0	4.35	0.11
	B	7.8	3.36	0.06
20%	A	7.8	8.22	0.14
	B	7.9	8.71	0.18

A and B are replicates.

Table 452

Physical and Chemical Characteristics:

Perth Amboy Channel Bioassay Elutriates*

Sample Designation		pH	Dissolved Oxygen (mg/l@ 20°C)	Specific Conductance (µmhos/cm)	Total Ammonium (mg N/l)	Unionized Ammonia (mg N/l)	Turbidity (NTU)	Salinity (°/oo)
Control	A	8.2	7.5	38,800	0.02	<0.01	<1	29
	B	8.2	7.4	38,800	0.03	<0.01	<1	29
5%	A	7.9	4.1	37,800	8.97	0.19	72	28
	B	7.9	4.7	37,700	7.67	0.16	67	28
20%	A	7.8	1.6	36,900	25.0	0.42	56	27
	B	7.6	1.4	37,100	18.8	0.20	72	27

A and B are replicates.

*Readings taken at end of one-hour settling period.

waters ranged from approximately 8 mg/l in the 5 percent sediment tests to 20 mg/l in the 20 percent sediment tests. Increases in turbidity levels were obtained in both the 5 and 20 percent sediment tests with increased levels ranging from 50 to 70 NTUs. The pH of the bioassay elutriate waters, after the one-hour settling period, appeared to decrease with increased sediment percent of total elutriate volume. Decreases in D.O. concentration ranged from 3 to 6 mg/l in the 5 and 20 percent sediment tests, respectively.

The results of the bioassay using Perth Amboy Channel sediment elutriates are presented in Table 453. The data show toxicity in each replicate bioassay with mortalities ranging from 20 to 40 percent in the 5 percent sediment tests to 60 percent in the 20 percent sediment tests for the 96-hour test period. No mortalities were observed until after _P. pugio_ had been exposed to the elutriate waters in the presence of the dredged sediments for 60 hours.

The D.O. concentrations of the bioassay elutriate waters over the 96-hour test period are shown in Table 454. Based on the results of bioassays on Bay Ridge Channel and Perth Amboy Anchorage elutriates, the daily aeration periods of the bioassay elutriate waters utilizing Perth Amboy Channel sediments were increased to two hours. The data show that the two-hour aeration periods were sufficient to keep the D.O. of the bioassay elutriate waters above 4 mg/l.

Table 455 shows the ammonium concentration of the bioassay elutriate waters at the end of the 96-hour test period. Examination of the data presented in this table shows increases in the control group from the concentrations measured immediately following the one-hour settling period. The ammonium concentrations present in the waters of the 5 and 20 percent tests did not differ from the concentrations measured after the one-hour settling period with the exception of the 20 percent A sample which showed a decrease of approximately 6 mg/l.

Table 453

Response of *P. pugio* to Varying Sediment Percent of Total Elutriate Volume as a Function of Time:

Perth Amboy Channel Elutriate Bioassays

Time (hr)	Number of *P. pugio* Living at Varying Sediment Percentages					
	Controls		5%		20%	
	A	B	A	B	A	B
0	10	10	10	10	10	10
12	10	10	10	10	10	10
24	10	10	10	10	10	10
36	10	10	10	10	10	10
48	10	10	10	10	10	10
60	10	10	9	10	6	8
72	10	10	7	9	6	4
84	10	10	6	8	5	4
96	10	10	6	8	4	4

A and B are replicates.

Table 454

Dissolved Oxygen Concentrations over Test Period: Perth Amboy Channel Elutriate Bioassays

(mg/1 @ 20°C)

Time (hr)	Control		5%		20%	
	A	B	A	B	A	B
0	7.5	7.4	4.1	4.7	1.6	1.4
1*	7.8	7.8	7.1	6.4	6.3	5.9
24	7.3	7.1	4.8	5.1	4.3	4.2
48	6.8	6.7	4.4	4.5	4.1	4.1
72	6.7	6.7	4.4	4.4	4.0	4.2
96	6.5	6.3	4.2	4.4	4.1	4.0

A and B are replicates.

Table 455

Ammonium Content of the Perth Amboy Channel Sediment Elutriate Bioassay Waters at the Completion of the 96-Hour Test Period

(@ 20°C)

Sample Designation		pH	Total Ammonium (mg N/1)	Unionized Ammonia (mg N/1)
Control	A	8.2	0.19	<0.01
	B	8.2	0.18	<0.01
5%	A	7.9	8.65	0.18
	B	7.9	7.77	0.16
20%	A	7.8	19.0	0.32
	B	7.6	20.4	0.22

A and B are replicates.

Additional sampling within the Perth Amboy Channel was conducted on November 23, 1976. The sediment samples used in these bioassays were taken approximately 1000 feet from one another in the middle of the Perth Amboy Channel. The Site 2 sediment was from the same location as the previously tested Perth Amboy sample. The locations of these sites are depicted in Figure 139 as PA 1, PA 2, and PA 3.

The bioassays, initiated on November 30, were run as described in the procedures section with one exception; the length of exposure was extended to 16 days. They extended exposure period was maintained without replacement of the water following the initial 96-hour exposure. Feeding was initiated after 96 hours. Day-old Artemia nauplii were fed to the grass shrimp on a daily basis prior to aeration. Following the initial 96-hour exposure, observations of mortality were made on a daily basis.

Table 456 presents the chemical and physical characteristics of the elutriates used in the static bioassays. The data show that the total ammonium nitrogen in the 20 percent sediment tests ranged from 2 to 30 mg/l. The largest release of total ammonium nitrogen occurred in the tests using sediment from Site 2. In addition, the data show that for each sediment tested, turbidity increased while D.O., pH, and salinity decreased.

The initial low D.O. concentrations were raised to between 6 and 7 μg/l by a one-hour aeration of the elutriate water before the addition of test organisms. Table 457 shows the D.O. content of these elutriates throughout the 16-day exposure period. The data indicate that the one-hour aeration periods were sufficient to keep the D.O. content of the elutriate waters above 4 mg/l.

The results of the heavy metal analyses of these elutriates are presented in Table 458. The data show that the only metal released in substantial amounts from each site's sediment was iron, while small amounts of lead were

Table 456

Physical and Chemical Characteristics: Perth Amboy Channel Bioassay Elutriates*

Sample Designation		pH	Dissolved Oxygen (mg/l@ 20°C)	Specific Conductance (µmhos/cm)	Total Ammonium (mg N/l)	Unionized Ammonia (mg N/l)	Turbidity (NTU)	Salinity (^{o}/oo)
Control	A	8.1	7.3	39,500	<0.01	<0.001	<1	29
	B	8.1	7.2	39,600	<0.01	<0.001	<1	29
	C	8.1	7.3	39,500	<0.01	<0.001	<1	29
Site 1	A	7.9	3.3	38,300	4.5	0.09	58	29
	B	7.9	2.8	38,200	4.8	0.10	40	29
	C	7.9	2.9	37,800	3.7	0.08	65	28
Site 2	A	7.5	1.6	37,900	18.0	0.15	72	28
	B	7.7	1.9	37,800	28.0	0.37	29	28
	C	7.5	1.7	38,100	30.6	0.26	52	29
Site 3	A	7.9	3.0	38,400	2.4	0.05	82	29
	B	7.9	3.8	38,600	2.3	0.05	76	29
	C	7.9	3.2	38,400	2.8	0.06	76	29

A, B and C are replicates.

*Readings taken at end of one-hour settling period.

Table 457

Dissolved Oxygen Concentrations over the 16-Day Test Period: Perth Amboy Channel Bioassay Elutriates

(mg/l @ 20°C)

Time* (hr)	Controls			Site 1			Site 3			Site 2		
	A	B	C	A	B	C	A	B	C	A	B	C
0	7.3	7.2	7.3	3.3	2.8	2.9	1.6	1.9	1.7	3.0	3.8	3.2
1**	7.4	7.3	7.5	6.3	6.6	6.9	7.1	6.8	6.4	6.9	6.6	6.1
24	6.3	6.3	6.4	4.2	4.1	4.1	4.1	4.2	3.9	4.1	3.9	3.7
48	6.6	6.5	6.6	4.8	4.8	4.7	4.7	4.6	4.7	4.5	4.3	4.1
72	6.3	6.2	6.2	4.5	4.8	4.6	4.4	4.4	4.2	4.6	4.5	4.7
96	6.4	6.5	6.4	4.7	4.8	4.6	4.6	4.8	4.6	4.7	4.5	4.5
120	6.3	6.3	6.3	4.5	4.8	4.7	4.5	4.6	4.6	4.8	4.6	4.4
144	6.6	6.3	6.5	4.7	4.5	4.9	4.7	4.8	4.7	4.9	5.0	4.5
168	6.4	6.4	6.3	4.8	4.7	4.9	4.5	4.7	4.7	4.9	4.7	4.9
192	6.7	6.4	6.5	5.1	5.5	5.6	5.5	5.4	5.5	5.4	5.0	4.8
216	6.2	6.0	6.0	4.7	4.7	4.6	4.6	4.5	4.4	4.9	4.3	4.7
240	6.1	6.1	5.8	4.8	4.7	4.9	4.6	4.4	4.5	5.1	4.8	4.8
264	6.3	6.2	6.1	5.1	4.8	5.0	4.9	4.9	4.8	5.2	5.1	5.3
288	6.3	6.3	6.0	5.1	4.9	4.8	5.0	4.8	5.0	5.0	4.9	5.3
312	6.4	6.1	6.2	5.3	4.9	5.1	5.3	5.1	5.1	5.0	5.0	5.2
336	6.2	6.4	6.3	5.2	5.2	5.0	5.0	5.4	5.1	5.2	5.0	5.2
360	6.3	6.2	6.4	5.4	5.2	5.3	5.2	5.0	5.4	5.2	5.4	5.3
384	6.4	6.5	6.2	5.3	5.2	5.0	5.4	5.3	5.4	5.4	5.4	5.2

A, B, and C are replicates.

*Measurements taken before daily one-hour aeration period.

**Measurements taken after one-hour aeration period.

Table 458

Release of Heavy Metals: Perth Amboy Channel Bioassay Elutriates

(μg/l)

Sample Designation		Mn	Cd	Cr	Zn	Ni	Pb	Cu	Fe
Control	A	<10.0	1.4	<2.0	62.0	40	6.6	270	33
	B	15.4	1.7	<2.0	51.9	41	8.4	261	46
	C	12.5	2.0	<2.0	41.0	39	9.6	252	71
Site 1	A	<10.0	0.7	<2.0	9.7	10.9	12.3	15.6	1537
	B	<10.0	0.6	<2.0	5.1	8.8	11.1	12.0	1170
	C	<10.0	0.6	<2.0	8.0	11.8	8.4	13.8	1974
Site 2	A	<10.0	0.6	<2.0	20.7	11.5	17.7	25.4	1536
	B	12.5	0.9	<2.0	18.6	16.3	14.7	21.1	1546
	C	<10.0	0.6	<2.0	14.3	17.8	12.0	20.8	1464
Site 3	A	12.5	0.6	<2.0	6.5	11.5	8.1	14.1	2637
	B	-	-	-	-	-	-	-	2568
	C	<10.0	0.5	<2.0	8.0	12.5	9.3	14.9	2838

A, B, and C are replicates.

Dash (-) indicates analysis not performed.

released from Site 2 sediments. A decrease in cadmium, zinc, nickel, and copper was observed in all three bioassay elutriates. No changes from the control concentrations were observed for manganese and chromium in any of the bioassay elutriates.

The results of the bioassays of P. pugio are presented in Table 459. Examination of the data shows limited toxicity to P. pugio over the first 96 hours of exposure to Sites 1 and 3 sediment elutriates. The bioassays using sediment from Site 2 showed a higher toxicity with 40 percent of the test animals dying in each replicate after 96 hours of exposure.

The additional 12-day exposure of P. pugio to Perth Amboy Channel sediment bioassay elutriates resulted in 10 to 13 percent increased mortality. The bioassay tests were terminated after 16 days due to the death of an organism in one of the control replicates.

Hopper Dredge Studies

Forty-four samples of the material in the hoppers of the Corps of Engineers hopper dredge Essayons were collected during dredging in the Perth Amboy and Bay Ridge Channels for the dumps monitored on August 31 and September 1, 1976, respectively. Each sample was taken with a bucket on a rope which was lowered into the surface of the slurry in the hopper. These samples were packed in insulated containers and air-freighted to Dallas. They were stored in the dark at 4°C until analysis. Half of each sample was centrifuged and the supernatant was filtered through a 0.45 micron pore size millipore filter. These portions were analyzed as water samples, and the unfiltered half was analyzed as sediment.

Percent Settleable Solids

Tables 460 and 461 present percent settleable solids and pH data for the hopper samples. The pH of these samples varied from 7.0 to 7.9 with no noticeable pattern. The percent settleable solids content of the Perth Amboy samples

Table 459

Response of P. pugio to Perth Amboy Channel Bioassay*

Elutriates as a Function of Time

Time (hr)	Number of P. pugio Living											
	Controls			Site 1			Site 2			Site 3		
	A	B	C	A	B	C	A	B	C	A	B	C
0	10	10	10	10	10	10	10	10	10	10	10	10
12	10	10	10	10	10	10	10	10	10	10	10	10
24	10	10	10	10	10	10	10	10	10	10	10	10
36	10	10	10	10	10	10	10	10	10	10	10	10
48	10	10	10	10	10	10	10	9	10	10	10	10
60	10	10	10	10	10	10	9	9	8	10	10	10
72	10	10	10	9	8	10	9	8	7	9	10	10
84	10	10	10	9	8	10	7	8	6	9	10	10
96	10	10	10	8	8	9	6	6	6	9	8	9
120	10	10	10	8	8	9	6	6	6	9	8	9
144	10	10	10	8	8	9	6	6	6	9	8	9
168	10	10	10	8	8	9	6	6	6	9	8	8
192	10	10	10	8	8	9	5	6	6	9	8	8
216	10	10	10	8	7	8	5	6	5	9	8	8
240	10	10	10	7	7	8	5	6	5	8	8	8
264	10	10	10	7	7	8	5	6	5	8	8	8
288	10	10	10	7	7	8	5	6	5	8	7	8
312	10	10	10	7	7	8	5	6	5	8	7	8
336	10	10	10	7	7	8	5	5	5	8	7	8
360	10	10	10	7	7	8	5	5	5	8	7	8
384	9	10	10	7	7	8	5	5	4	8	7	8

Organisms were fed after 96-hour exposure time with live *Artemia nauplii*.
*All bioassays used 20 percent sediment of total elutriate volume.
A,B, and C are replicates.

Table 460

Percent Settleable Solids Data: Perth Amboy Channel Hopper Dredge Samples**

Time (hr:min)		Percent Settleable Solids	pH
7:15	Dredging began. Run 1 began.		
7:25*		100	7.2
7:27	Run 1 ended.		
7:30		91	7.5
7:35		91	7.3
7:43		90	7.4
7:44*	Run 2 began.		
7:45*		-	7.4
7:50*		93	7.0
7:55*		94	7.2
7:55	Run 2 ended.		
8:00		74	7.3
8:05		97	7.1
8:10		90	7.2
8:13	Run 3 began.		
8:15*		98	7.1
8:30	Run 3 ended.	98	7.5
8:44	Run 4 began.		
8:45*		100	7.1
8:45	Run 4 ended.		
9:00		100	7.2
9:06	Run 5 began.		
9:15*		98	7.4
9:23	Run 5 ended.		
9:30		86	7.4
9:45		28	7.4
10:00		88	7.4
10:15	(All of these samples taken while dredge was traveling to dump site.)	40	7.4
10:30		34	7.5
10:45		94	7.2
11:03		94	7.5
11:17		90	7.3
11:30		41	7.5
11:50		30	7.5
12:02		92	7.4
12:15		96	7.4
12:30		8	7.9
12:45		100	7.3
13:05		16	7.7

*Surface of material in hopper was turbulent. Otherwise, it was calm.

**The data for percent settleable solids and pH, as well as descriptions for dredging operations are applicable to all New York hopper dredge samples and are not repeated in other tables in this section.

Dash (-) indicates no determination made.

Table 461

Percent Settleable Solids Data: Bay Ridge Channel

Hopper Dredge Samples

Time (hr:min)		Percent Settleable Solids	pH
6:24*	Run 1 began.	29	7.2
6:29*		62	7.2
6:33*		-	7.1
6:40*		-	7.2
6:45*		40	7.3
6:47	Run 1 ended.		
7:00	Run 2 began.		
7:07*		-	7.2
7:22*	Run 2 ended.	-	7.1
7:37*		100	7.7
7:38	Run 3 began.		
7:50*		89	7.4
8:00*		100	7.4
8:13	Run 3 ended.		
8:15		57	7.3
8:30		42	7.3
8:45		-	7.3
9:00		95	7.1
9:17		100	7.5

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*Surface of material in hopper was turbulent. Otherwise, it was calm.

Dash (-) indicates no determination made.

ranged from 74 to 100 percent during dredging. They were much more variable after dredging ceased, fluctuating from 8 to 100 percent. Not all Bay Ridge Channel samples were analyzed for percent settleable solids, but those collected during dredging showed a somewhat higher variability in settleable solids, 29 to 100 percent, than did samples collected during Perth Amboy Channel dredging operations.

Heavy Metals

Samples taken from the hoppers of the dredge Essayons were analyzed for soluble heavy metals. Selected ones were also dried and analyzed as sediment for total heavy metals. Tables 462 and 463 show the soluble metals concentrations in the Perth Amboy and Bay Ridge Channel hopper samples.

In the Perth Amboy Channel hopper samples (Table 462), soluble manganese ranged from less than 10 μg/l (detection limit) to 1286 μg/l during dredging. During transport to the disposal site, manganese concentrations of all samples were less than 10 μg/l. The iron concentrations during the dredging cycles ranged from 32 to about 11,900 μg/l. During transport they ranged from 9 to 2000 μg/l. Concentrations of lead, zinc, copper, and cadmium were below the detection limit in almost all samples. Chromium concentrations ranged from less than 2 μg/l (detection limit) to 4.2 μg/l during dredging but remained below the detection limit during transport. Nickel concentrations on the other hand were near or below the detection limit (1 μg/l) during dredging but rose during transport when they ranged from less than 1 μg/l to 6.2 μg/l. Arsenic followed a similar pattern with somewhat higher concentrations found during transport.

Bay Ridge Channel hopper samples metals concentrations were similar to the Perth Amboy Channel samples in general trends. The manganese concentrations during dredging ranged from less than 10 μg/l to 1439 μg/l and remained below the detection limit during transport to the disposal site. Iron concentrations ranged from below 5 μg/l to 3234 μg/l during

Table 462

Soluble Heavy Metals: Perth Amboy Channel

Hopper Dredge Samples

(μg/l)

Time (hr:min)	Mn	Cd	Cr	Zn	Ni	Pb	Cu	Fe	As
7:15 - Run 1 Began									
7:25	<10	<0.5	<2	<1	<1	<1	<1	2206	4.9
7:27 - Run 1 Ended									
7:30	735	<0.5	<2	4.3	<1	<1	<1	76	<2
7:35	<10	<0.5	3.2	<1	<1	<1	<1	3352	3.7
7:43	520	<0.5	<2	<1	<1	<1	<1	48	7.1
7:44 - Run 2 Began									
7:45	<10	<0.5	3.9	<1	<1	<1	<1	6117	6.0
7:50	<10	<0.5	3.7	<1	<1	<1	<1	689	<2
7:55	919	<0.5	2.4	<1	<1	<1	<1	28	3.7
- Run 2 Ended									
8:00	674	<0.5	2.4	<1	<1	<1	<1	29	23.7
8:05	1286	<0.5	<2	<1	<1	<1	<1	60	9.3
8:10	28	<0.5	<2	<1	<1	<1	<1	2471	<2
8:13 - Run 3 Began									
8:15	<10	<0.5	2.9	<1	1.1	<1	<1	11936	<2
8:30 -	<10	<0.5	<2	<1	1.1	<1	<1	3626	<2
- Run 3 Ended									
8:44 - Run 4 Began									
8:45	<10	<0.5	4.2	<1	<1	<1	<1	1805	9.3
- Run 4 Ended									
9:00	490	<0.5	<2	<1	<1	<1	<1	36	2.6
9:06 - Run 5 Began									
9:15	735	<0.5	3.7	<1	<1	<1	<1	32	13.7
9:23 - Run 5 Ended									
9:30	<10	<0.5	<2	<1	3.9	<1	<1	767	14.8
9:45	<10	<0.5	<2	<1	3.5	<1	<1	2000	7.1
10:00	<10	<0.5	<2	<1	3.3	<1	<1	22	20.4
10:15	<10	1.2	<2	<1	3.7	<1	<1	523	29.3
10:30	<10	<0.5	<2	<1	<1	<1	<1	9	7.1
10:45	<10	<0.5	<2	<1	3.7	<1	<1	142	16.0

(Continued)

Table 462 (Concluded)

Time (hr:min)	Mn	Cd	Cr	Zn	Ni	Pb	Cu	Fe	As
11:03	<10	<0.5	<2	<1	<1	<1	<1	699	14.8
11:17	<10	<0.5	<2	<1	2.9	<1	<1	1609	18.2
11:30	<10	<0.5	<2	<1	3.9	<1	<1	415	10.4
11:50	<10	<0.5	<2	<1	3.5	<1	<1	87	<2
12:02	<10	<0.5	<2	<1	4.9	<1	<1	395	14.8
12:15	<10	<0.5	<2	<1	6.2	<1	<1	875	13.7
12:30	<10	<0.5	<2	<1	4.7	<1	<1	640	9.3
12:45	<10	<0.5	<2	<1	5.4	<1	<1	376	29.3
13:05	17	<0.5	<2	<1	4.9	<1	<1	483	10.4

Table 463

Soluble Heavy Metals: Bay Ridge Channel

Hopper Dredge Samples

(μg/l)

Time (hr:min)	Mn	Cd	Cr	Zn	Ni	Pb	Cu	Fe	As
6:24 - Run 1 Began									
6:24	<10	<0.5	2.0	<1	<1	<1	<1	855	2.6
6:29	11	<0.5	2.4	<1	<1	1.2	<1	1521	9.3
6:33	<10	<0.5	<2	<1	<1	1.4	<1	3234	3.8
6:40	28	<0.5	2.1	<1	<1	2.6	<1	2109	11.5
6:45	28	<0.5	<2	<1	8.8	<1	1.2	1834	14.8
6:47 - Run 1 Ended									
7:00 - Run 2 Began									
7:07	-	-	-	-	-	-	-	-	-
7:22	11	<0.5	<2	<1	1.5	<1	<1	-	<2
7:22 - Run 2 Ended									
7:37	<10	<0.5	2.1	<1	2.7	<1	<1	846	-
7:38 - Run 3 Began									
7:50	<10	<0.5	2.1	<1	<1	<1	1.7	904	8.2
8:00	1439	<0.5	<2	2.4	<1	<1	<1	<5	<2
8:13 - Run 3 Ended									
8:15	<10	<0.5	<2	<1	<1	<1	<1	1365	27.0
8:30	<10	<0.5	2.8	<1	<1	<1	<1	552	7.1
8:45	<10	<0.5	<2	<1	<1	<1	<1	2872	2.6
9:00	<10	<0.5	<2	<1	<1	<1	<1	1443	8.2
9:17	<10	<0.5	<2	<1	3.2	<1	<1	483	4.7

Dash (-) indicates not determined.

dredging and from 483 to 2872 μg/l during transport. There was some chromium, nickel, and lead release during dredging. Cadmium concentrations were below the detection limit in all samples. Zinc and copper concentrations were below the detection limit in all but one and two samples, respectively. Arsenic concentrations ranged from below 2 μg/l to 14.8 μg/l during dredging and from 2.6 to 27 μg/l during transport.

Total heavy metal concentrations in the sediment phase of selected hopper samples from both sites are shown in Table 464. The concentrations in the Perth Amboy hopper samples were higher than those in the Bay Ridge Channel samples. The heavy metal concentrations in the sediment phase of the hopper samples did not necessarily correspond to those of the sediment grabs used for elutriate tests. In some cases hopper sample concentrations were higher; in others they were lower.

The Perth Amboy Channel hopper sample sediment phase had higher concentrations than the Perth Amboy Channel sediment sample of manganese, chromium, zinc, nickel, lead, iron, and arsenic. The hopper samples contained from 142 to 614 mg/kg manganese, 45 to 60 mg/kg chromium, 154 to 199 mg/kg zinc, 82 to 508 mg/kg nickel, less than one to 154 mg/kg lead, 19 to 20 g/kg iron, and 26 to 52 mg/kg arsenic. Their copper content (162 to 204 mg/kg) and mercury content (2.9 to 4.0 mg/kg) ranges were below those of the corresponding sediment. The cadmium range, less than 0.01 to 3.8 mg/kg, was close to the grab sample concentration of 1.7 mg/kg.

The Bay Ridge Channel hopper samples ranges in chromium (6 to 75 mg/kg), nickel (133 to 374 mg/kg), and arsenic (14 to 26 mg/kg) were higher than those of the sediment grab sample. The cadmium (less than 0.01 to about 3 mg/kg) and copper (37 to 152 mg/kg) contents, however, were lower than those in the Bay Ridge Channel sediment sample. The concentrations of manganese, zinc, lead, iron, and mercury in the sediment phase of the hopper samples were within the

Table 464

Heavy Metal Concentrations: Bulk Hopper Slurry, Perth Amboy Channel and Bay Ridge Channel

(mg/kg)

Time (hr:min)	Dredging Operations**	Mn	Cd	Cr	Zn	Ni	Pb	Cu	Fe*	Hg	As
Perth Amboy Channel:											
7:45	During Second Run-T	200	3.8	48	154	277	49	162	20	3.2	44
8:10	Between Second and Third-C	264	2.1	50	168	399	24	165	20	-	34
8:45	During Fourth Run-T	614	2.6	45	199	508	154	163	20	2.9	52
9:00	Between Fourth and Fifth-C	142	<0.01	60	163	82	<1	204	19	4.0	26
Bay Ridge Channel:											
6:29	During First Run-T	375	2.7	32	118	136	75	152	15	2.2	23
6:45	During First Run-T	153	<0.01	75	97	133	123	37	17	2.4	14
7:22	During Second Run-T	147	<0.01	6	55	205	<1	38	12	1.5	15
9:17	After Dredging Ceased-C	387	2.4	24	150	374	<1.3	148	15	2.3	26

*Iron concentration in g/kg.

**T indicates turbulence in hopper.
C indicates calm in hopper.
Dash (-) indicates no analysis made.

ranges found for these metals in the sediment grabs. Hopper sample ranges were 147 to 387 mg/kg manganese, 55 to 150 mg/kg zinc, less than 1 to 123 mg/kg lead, 12 to 17 g/kg iron, and 1.5 to 2.4 mg/kg mercury.

Nitrogen Compounds

The ammonium data for selected hopper dredge samples collected during dredging of the Perth Amboy Channel and transport to disposal site are presented in Table 465. The ammonium concentrations of samples collected when the dredging was in progress ranged between 8.3 and 40.7 mg N/l. The samples collected while the Essayons was in transit from the dredging site to the disposal site ranged from 5.0 to 23.1 mg N/l. The conditions in the surface of hoppers (presented in Table 460) did not seem to affect the ammonium concentrations.

The ammonium data for the selected Bay Ridge hopper dredge samples collected are presented in Table 466. The ammonium concentrations ranged from below 0.05 to 69.6 mg N/l while dredging was in progress and between 13.5 and 49.4 mg N/l after dredging stopped.

Phosphorus Compounds

Table 467 presents the soluble orthophosphate concentrations in samples collected from the hoppers of the Essayons during dredging of the Perth Amboy Channel and transport to the disposal site. After filtration through a 0.45 μ pore size filter, suspended material was present in all samples. They were, therefore, refiltered (in their acidified condition) through a 0.2 μ pore size membrane filter just prior to analysis.

For four of the five dredging runs, soluble orthophosphate concentrations were lowest in the samples taken at the beginning of the run. Concentrations tended to increase during the interim between runs, only to decrease again at the beginning of the next run. The lowest concentration at

Table 465

Ammonium Data: Perth Amboy Channel

Hopper Dredge Samples*

Time (hr:min)	Ammonium (mg N/l)
7:25	35.1
7:30	8.3
7:35	26.4
7:43	8.5
7:45	28.0
7:50	31.2
7:55	12.3
8:00	10.5
8:05	26.8
8:10	37.7
8:15	11.0
8:30	33.3
8:45	40.7
9:00	37.7
9:15	26.8
9:30	5.2
9:45	9.5
10:00	5.0
10:15	18.6
10:30	23.1
10:45	5.3
11:03	6.4
11:17	19.7
11:30	5.4
11:50	6.4
12:02	23.0
12:15	5.8
12:30	5.3
12:45	5.9
13:05	6.3

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*For conditions in hopper as well as information on Essayons dredging activities for time of each sample, see Table 460.

Table 466

Ammonium Data: Bay Ridge Channel

Hopper Dredge Samples

Time (hr:min)	Ammonium (mg N/1)
6:24	3.5
6:29	20.7
6:33	8.5
6:40	< 0.05
6:45	21.9
7:07	19.6
7:22	69.6
7:37	19.3
7:50	9.5
8:00	11.7
8:15	14.6
8:30	13.5
8:45	49.4
9:00	44.1
9:17	9.2

that point ranged from 0.14 to 0.4 mg P/1. During transport to the disposal site the soluble ortho P concentrations showed a tendency to increase but still fluctuated.

Concentrations of soluble orthophosphate in the hopper of the *Essayons* during dredging of Bay Ridge Channel and transport to the disposal site are presented in Table 468. The concentration varied from 0.052 mg P/1 to 18 mg P/1 in a smooth pattern gradually rising from the initial 0.29 mg P/1 to a maximum at the beginning of the second dredging run. After decreasing to approximately 0.7 mg P/1 after the third run, the concentration increased to 10 mg P/1 and then began to decrease.

Table 467

Soluble Orthophosphate Concentrations: Perth Amboy Channel Hopper Dredge Samples*

Time (hr:min)	Soluble Ortho P (mg P/l) $\overline{X}$	SD
7:25	0.40	0.025
7:30	0.28	0
7:35	0.85	0.025
7:43	0.72	0
7:45	2.0	-
7:50	0.78	0
7:55	1.4	0
8:00	0.35	0
8:05	0.78	0
8:10	0.35	-
8:15	1.2	0.025
8:30	1.4	0
8:45	0.32	0
9:00	2.0	0
9:15	0.14	0
9:30	1.3	0
9:45	0.78	-
10:00	0.95	0
10:15	1.5	0.025
10:30	2.1	0.025
10:45	1.6	0.025
11:03	3.1	0.025
11:17	2.4	0.1
11:30	1.7	0
11:50	1.3	0.025
12:02	2.2	-
12:15	6.8	0
12:30	1.2	0
12:45	2.2	0
13:05	1.8	0

Mean and standard deviation calculated from duplicate analyses of one sample.

*Samples were refiltered through a 0.2 µg/l pore size membrane filter prior to analysis.

Dash (-) indicates only one analysis made.

Table 468

Soluble Orthophosphate Concentrations: Bay Ridge Channel Hopper Dredge Samples*

Time (hr:min)	Soluble Ortho P (mg P/l) $\overline{X}$	SD
6:24	0.29	0.001
6:29	0.052	0
6:33	4.5	0.025
6:40	7.4	0
6:45	8.2	-
7:07	18	0.1
7:22	6.0	0.025
7:37	10.2	0.025
7:50	4.6	0.025
8:00	2.8	-
8:15	0.68	0
8:30	0.72	0
8:45	10	0.025
9:00	8.6	0
9:17	4.0	-

Mean and standard deviation calculated from duplicate analysis of one sample.

Dash (-) indicates only one analysis made.

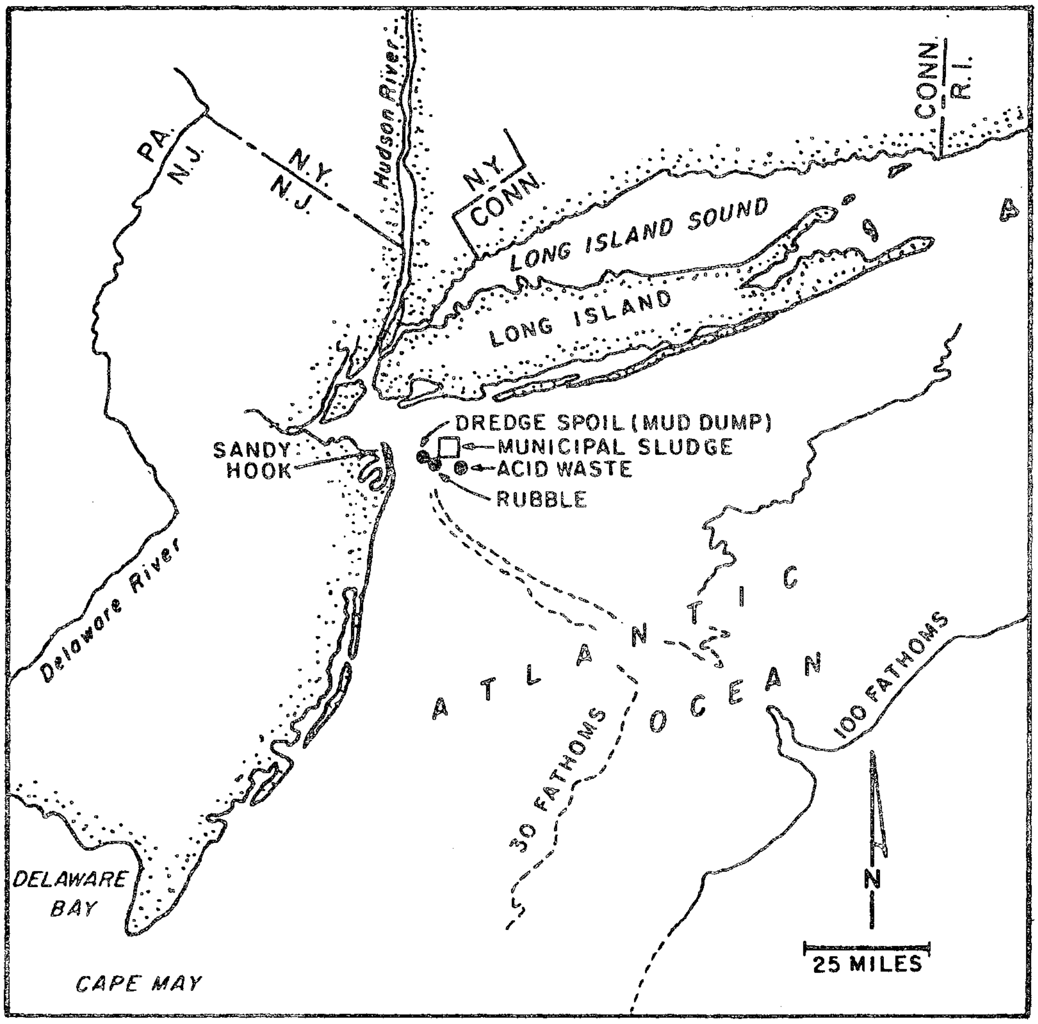
*These samples were refiltered through a 0.2 µ pore size membrane filter prior to analysis due to the presence of some suspended material.

Field Studies

Three dredged material disposal operations were monitored on August 31 and September 1, 1976 in order to evaluate the reliability of elutriate tests in predicting the amounts of contaminants released from dredged sediments during their openwater dumping. The combinations of dredging sites and modes of disposal were chosen so that an evaluation could be made of the differences in contaminant release during barge dumping (of mechanically dredged sediment) versus hopper dumping (of hydraulically dredged sediment) of sediment from the same general area. In addition, comparisons were made between contaminant release patterns resulting from hopper dumping of sediments from the different waterways. All dumping took place at the New York Bight mud dump site. The location of the mud dump site relative to the New York-New Jersey coast is shown in Figure 143.

The disposal operations were monitored using two Corps of Engineers ships, the Hatton and the Hudson. Monitoring the disposal from two properly positioned vessels allowed estimations to be made of the time-concentration relationships for the contaminants released to the water column during dredged material disposal. In addition, since the surface and bottom currents were moving in opposite directions, the use of two sampling vessels allowed simultaneous monitoring of contaminant release in both surface and near-bottom waters during one disposal operation.

In conjunction with these monitoring studies, Dr. R. Gordon and study group from Yale University conducted a study of transmissivity at the disposal site during dredged material disposal. In addition to making this information available to the UTD dredged material study group, they provided information on sampling vessel positioning relative to the hopper dredge or barge during disposal operations. Further, B. Holliday of the US Army Corps of Engineer Waterways Experiment Station conducted current studies at the disposal site during these



After Mueller et al. (1976b)

Figure 143
New York Bight Area

operations. This information was also made available to the UTD study group.

The general procedure followed for monitoring of the dumping operations involved temporarily anchoring the sampling vessel near the disposal site and making a number of current measurements to define current speed and direction in the area. Based on this information, the sampling vessels were positioned and anchored. The captain of the Essayons or of the barge towboat was instructed to pass the anchored ships at a certain distance from them. The dumping was to take place in accord with normal dumping procedures. The initiation of the dump was controlled from the sampling ships so that the main turbid cloud arising from the dump would pass beneath the anchored sampling vessels within a short time after the dump.

During disposal operations, the velocity and direction of the current were monitored with a current meter on board the Hatton. Profiles of percent light transmission, D.O., temperature, salinity, and pH were also made. Duplicate water samples were taken near the surface, mid-depth, and near the bottom with submersible pumps throughout the monitoring period. The hopper dredge Essayons, used in connection with Perth Amboy Channel and Bay Ridge Channel dredging-disposal operations, is the largest hopper dredge owned by the Corps of Engineers. It is approximately 525 feet in length and has 12 hoppers with a total capacity of 8,270 cubic yards. It dredges by sucking sediment through a 32 inch diameter pipe and discharging the material to the hoppers. Dredged material moves through the discharge pipe at a rate of 20 feet per second. Dumping of the dredged material generally takes place over a period of several minutes during which time each of the hoppers is dumped in sequence.

Dump No. 1

During the first two monitored disposal operations, August 31, 1976, the weather was fair, and the water was calm. The air temperature was approximately 70°F (22°C). The depth of the water column at the disposal site was about 28 m; the Secchi depth was 3.0 meters. The physical setting at the dump site during Dump No. 1, for which 8,270 cubic yards of sediment were dredged by the *Essayons* from Perth Amboy Channel, is shown in Figure 144.

Water column optical properties. The optical properties of the water column were monitored with transmissometers from both sampling vessels. In addition, turbidity measurements were made on the water samples collected. R. Gordon's group from Yale University was aboard the *Hatton*. They used two different transmissometers. One, with a 2 cm light path, was generally at a fixed position near the bottom; the other, with a 12 cm light path, was moved up and down through the water column during the study period in order to define the height of the turbid plume arising from the dumping operation.

On the *Hudson*, a Hydroproducts Model 612-S Transmissometer with a 10 cm light path was used. Vertical profiles of percent light transmission were obtained before and after each disposal operation. During the dumping operations, the transmissometer was maintained at a fixed depth from which percent light transmission was monitored during passage of the turbid plume.

Figure 145 presents the turbidity values of samples collected aboard the *Hatton* in near-bottom waters during Dumps No. 1 and 2. These values, as well as data from samples collected at other depths, are presented in Table 469. Table 470 presents similar data for the water samples collected aboard the *Hudson* in association with Dump No. 1. Examination of these tables shows that during Dump No. 1, the surface water did not significantly change as a result of the dumping operation. As

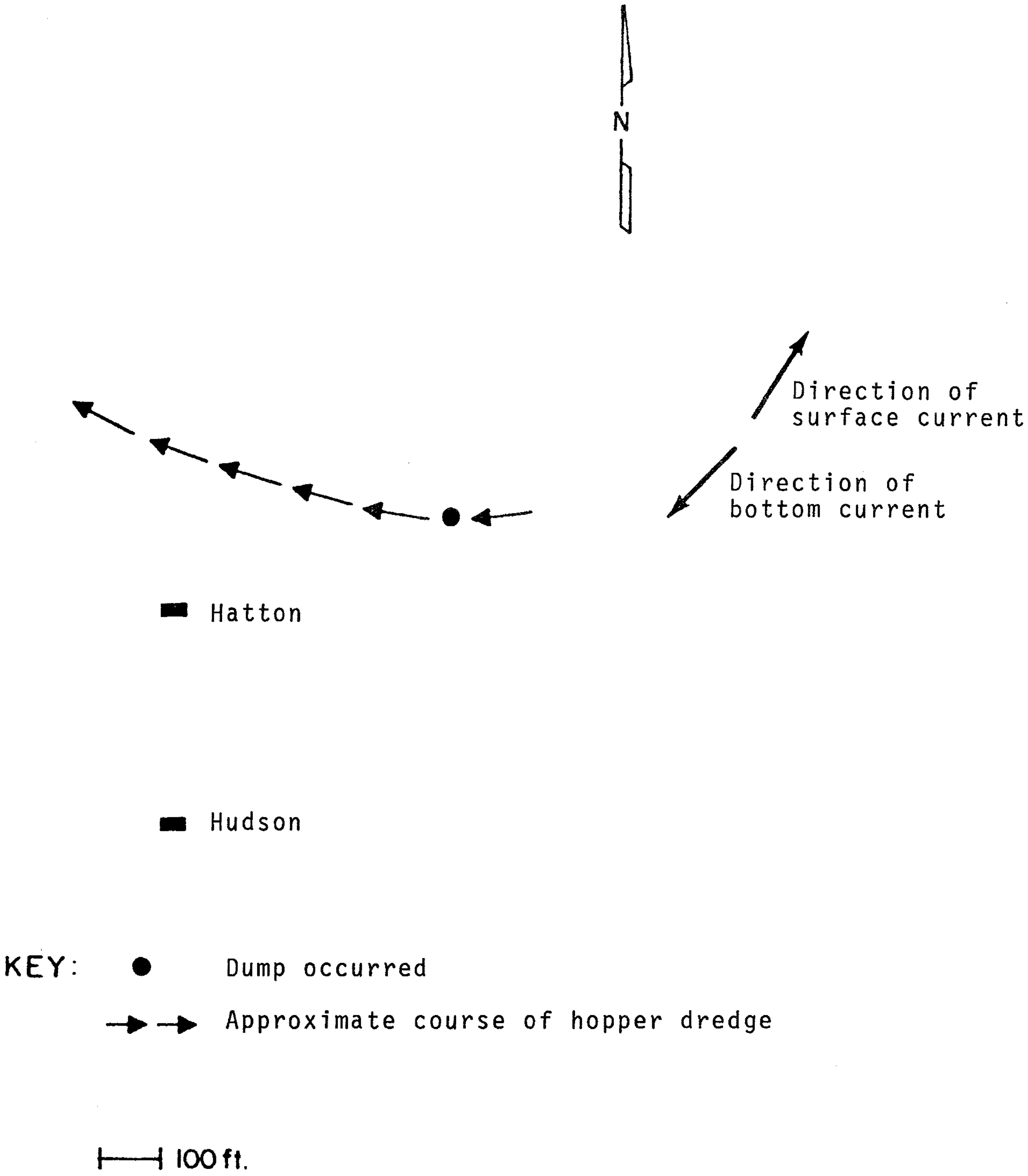


Figure 144
Positions of Sampling Vessels at Mud Dump Site
During Monitoring of New York Bight Dump No. 1

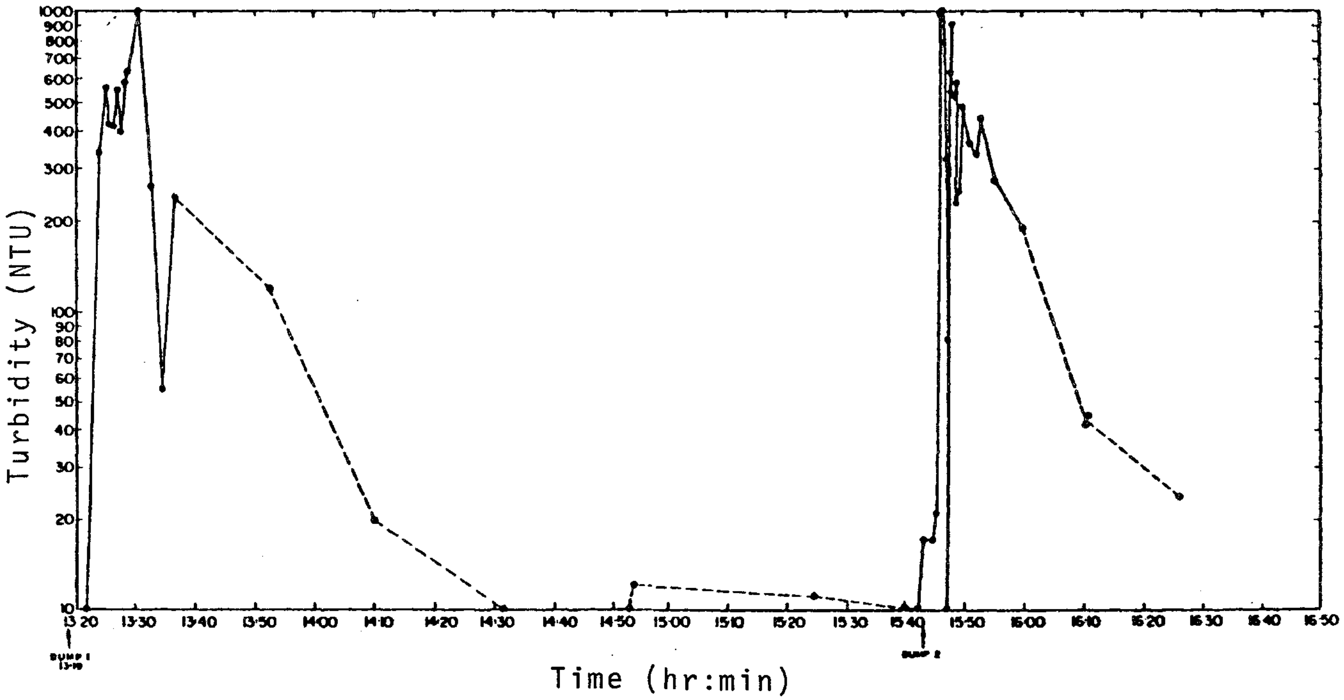


Figure 145
Turbidity in Near Bottom (24 m) Water during
New York Dump Nos. 1 and 2 - Hatton

Table 469

Turbidity Values: New York Bight Dump Nos. 1 and 2 Dredged Material From Perth Amboy Channel and Perth Amboy Anchorage

(Collected from the *Hatton*)

Time (hr:min:sec)	Depth (m)	Turbidity (NTU)
12:43:45	0.5	0.7
12:44:00	12	3
13:19 - Dump No. 1 occurred.		
13:21:15	0.5	3
13:21:50	24	0.4
13:23:15	24	-
13:23:30	0.5	1
13:23:50	24	340
13:25:00	24	550
13:25:30	24	420
13:26:00	24	420
13:26:30	0.5	2
13:27:00	24	550
13:27:15	24	400
13:28:00	24	580
13:28:30	24	630
13:30:30	24	1020
13:32:30	24	260
13:34:30	24	55
13:36:30	24	240
13:38:00	22	33
13:41:30	22	150
13:42:15	0.5	1
13:52:30	24	120
14:10:30	24	20
14:31:30	24	6
14:52:30	24	1
14:53:30	24	12
15:23:55	0.5	0.6
15:24:30	24	11
15:32:30	0.5	1
15:41:30	0.5	0.8
15:42:00	24	16
15:42:30	0.5	0.9
15:43 - Dump No. 2 occurred.		
15:43:00	24	17
15:44:00	0.5	0.6
15:44:30	24	17
15:45:00	24	21
15:45:30	24	980

(Continued)

Table 469 (Concluded)

Time (hr:min:sec)	Depth (m)	Turbidity (NTU)
15:46:00	24	1100
15:46:30	24	320
15:46:45	24	80
15:47:00	24	0.7
15:47:15	24	620
15:47:15	0.5	0.9
15:47:30	24	900
15:47:45	24	540
15:48:00	24	520
15:48:15	24	580
15:48:30	24	230
15:48:45	24	250
15:49:30	24	480
15:50:30	24	360
15:51:45	24	330
15:52:30	24	440
15:54:30	0.5	1
15:55:00	24	270
15:59:30	24	190
16:10:00	0.5	0.9
16:10:30	24	42
16:10:30	24	45
16:25:30	0.5	0.5
16:26:00	24	24

Dash (-) indicates no analysis made.

shown in Figures 146 and 147, the turbidity of the near-bottom water samples did change significantly immediately following dumping. As expected, there was a marked increase in the turbidity of these waters during the passage of the turbid plume. Comparison of Figures 145 and 146 shows that there was a six-minute delay in the passage of the turbid plume between the Hatton and the Hudson. Markedly elevated turbidities were present in the near-bottom waters at the location of the Hatton for slightly over one hour. At the Hudson the duration of the

Table 470

Turbidity Values: New York Bight Dump No. 1

Dredged Material From Perth Amboy Channel

(Collected from the Hudson)

Time (hr:min:sec)	Depth (m)	Turbidity (NTU)
12:51:20	1	0.4
12:52:55	12	0.4
12:52:55	23	28
12:55:30	1	0.6
12:55:35	12	0.3
12:55:45	23	20
13:01:25	1	0.7
13:01:35	23	3
13:01:55	12	0.3
13:19 - Dump No. 1 occurred.		
13:21:50	1	0.6
13:22:05	12	0.6
13:22:10	23	2
13:26:00	1	0.4
13:26:35	23	7
13:26:55	12	0.3
13:27:25	23	12
13:27:55	23	1120
13:28:00	12	0.4
13:28:30	23	460
13:28:50	1	1
13:29:10	23	300
13:29:45	12	0.7
13:29:55	23	90
13:30:35	23	24
13:30:45	12	1
13:31:15	23	165
13:31:50	23	120
13:32:00	1	0.7
13:32:30	23	135
13:32:45	12	1
13:33:10	23	190
13:33:45	23	215
13:34:30	23	180
13:35:30	23	230
13:36:05	1	0.7
13:36:10	12	1
13:36:25	23	175
13:38:20	23	33

(Continued)

Table 470 (Concluded)

Time (hr:min:sec)	Depth (m)	Turbidity (NTU)
13:52:00	1	0.6
13:52:00	12	0.8
13:52:00	23	25
14:00:00	23	17
14:12:00	23	155
14:20:55	1	2
14:21:15	12	0.9
14:21:15	23	24
14:31:05	1	1
14:31:25	12	0.9
14:31:30	23	19
14:58:55	1	4
14:58:35	12	1
14:59:30	23	3

elevated turbidity, based on turbidity data collected, was also approximately one hour.

A comparison between Figures 145 and 146 shows that during the time period when few water samples were taken and, therefore, few turbidity measurements made, there was considerable fluctuation in the amount of particulates in these waters as reflected by the percent light transmission data.

Generalized, somewhat smoothed plots of the data from Gordon's study are presented in Figures 148 and 149. Examination of Figure 148 shows that the transmissometer located 1 m off the bottom read zero percent light transmission for a period of 30 minutes during the passage of the turbid plume. After that time, there was a general trend for increasing bottom water percent light transmission with time. Figure 149 shows a similar pattern for the percent light transmission at 23 m (2 m off the bottom). However, the percent light transmission data for 1 m and 14 m below the surface were 100 percent throughout the passage of the turbid plume. These results indicate that the turbidity associated with the turbid plume moved toward the Hatton below the thermocline.

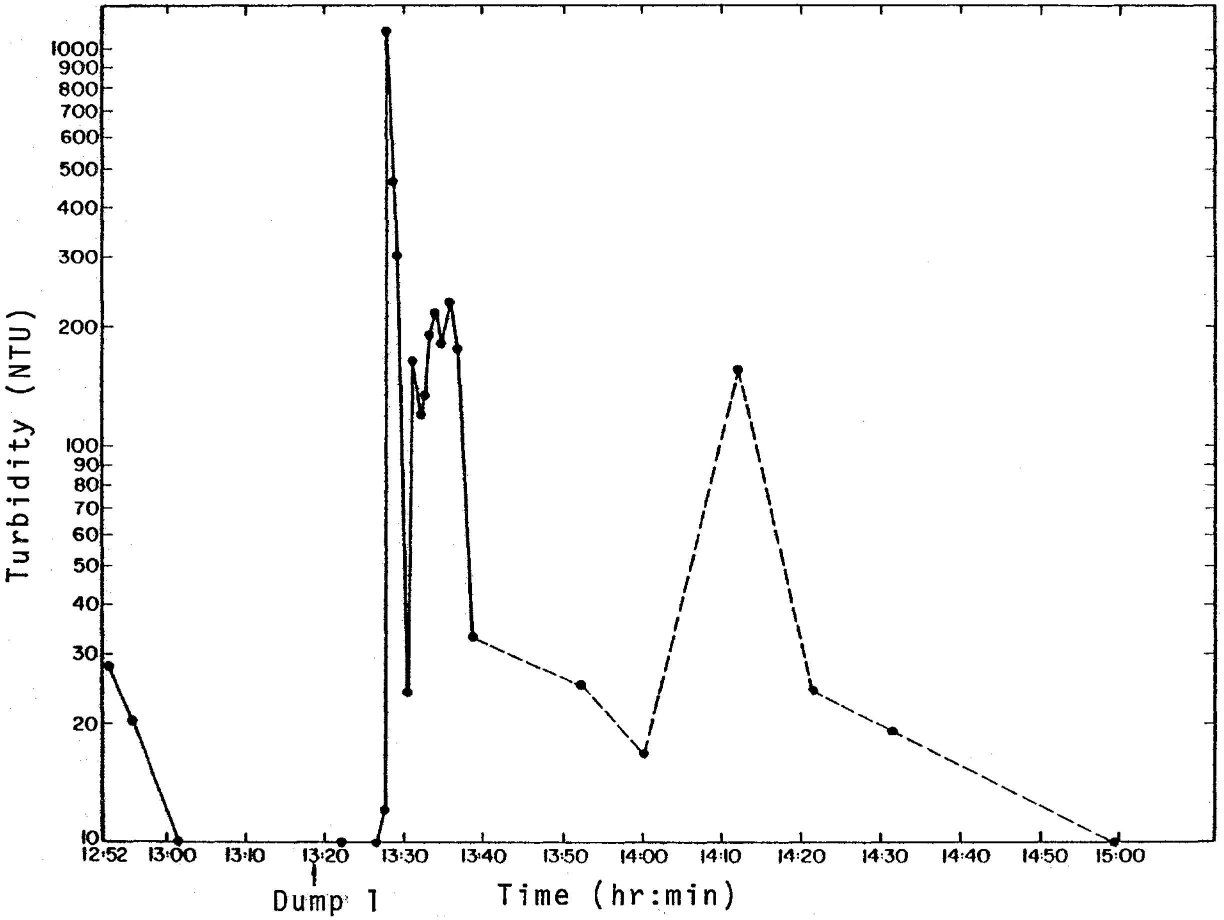


Figure 146

Turbidity in Near Bottom (23 m) Water during New York Bight Dump No.1 - Hudson

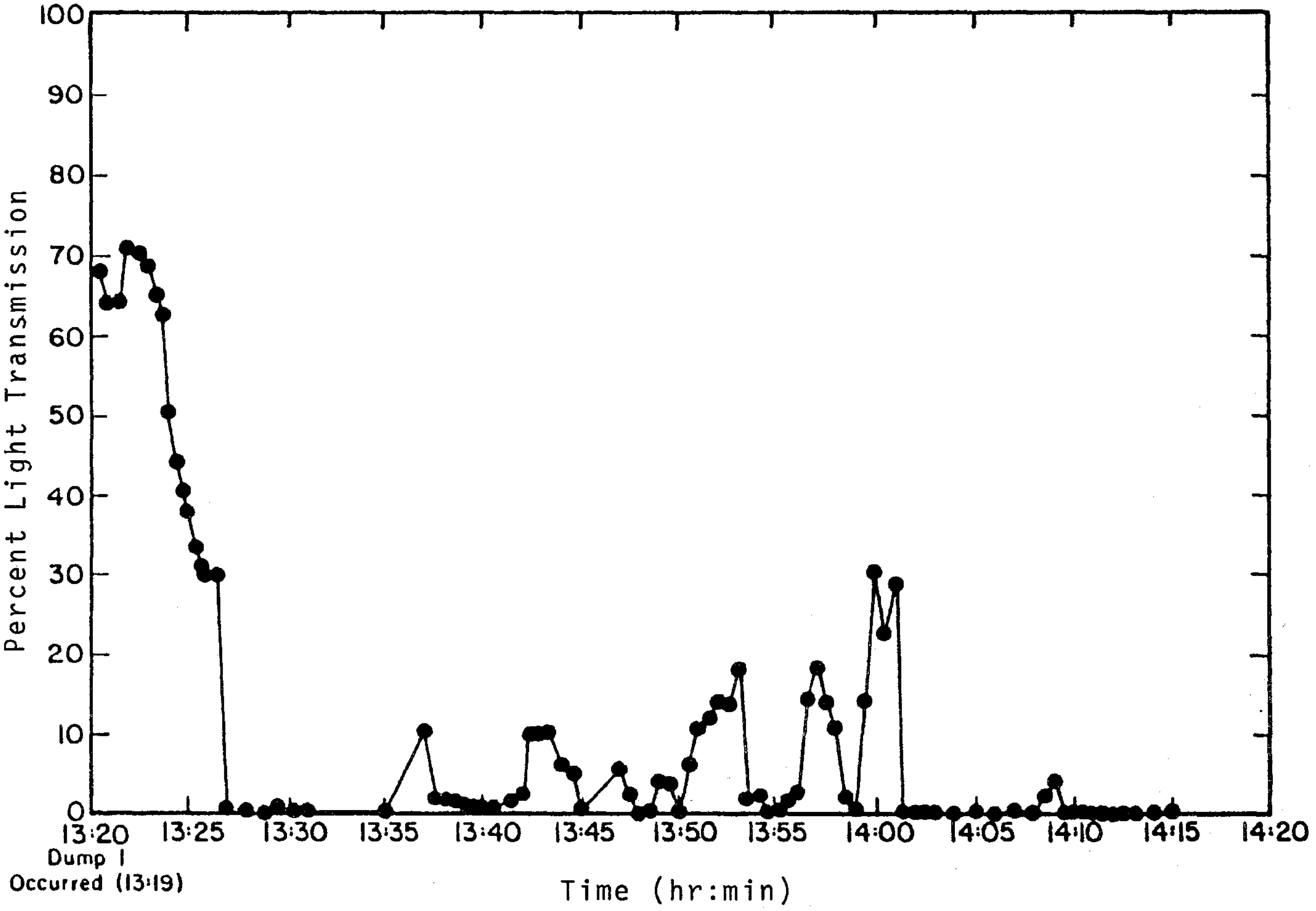


Figure 147

Percent Light Transmission: New York Bight Dump No.1

Depth 25 m - <u>Hudson</u>

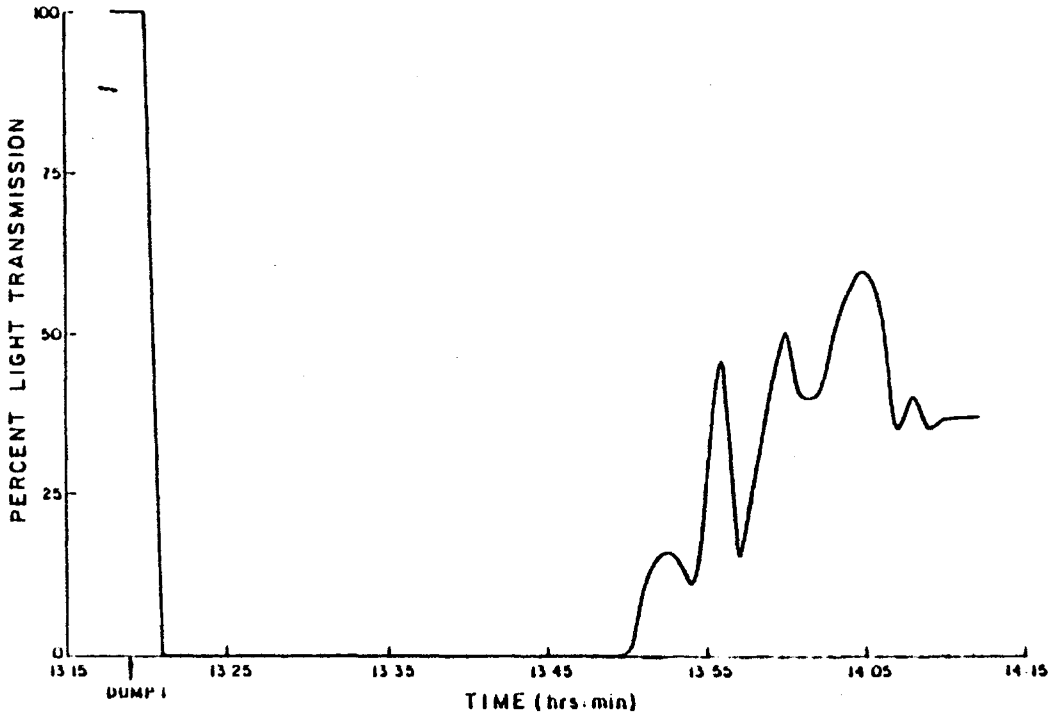


Figure 148
Percent Light Transmission in Near Bottom Water as a Function of Time during Dump No. 1 - Hatton
(2 cm path length)

From data provided by R. Gordon

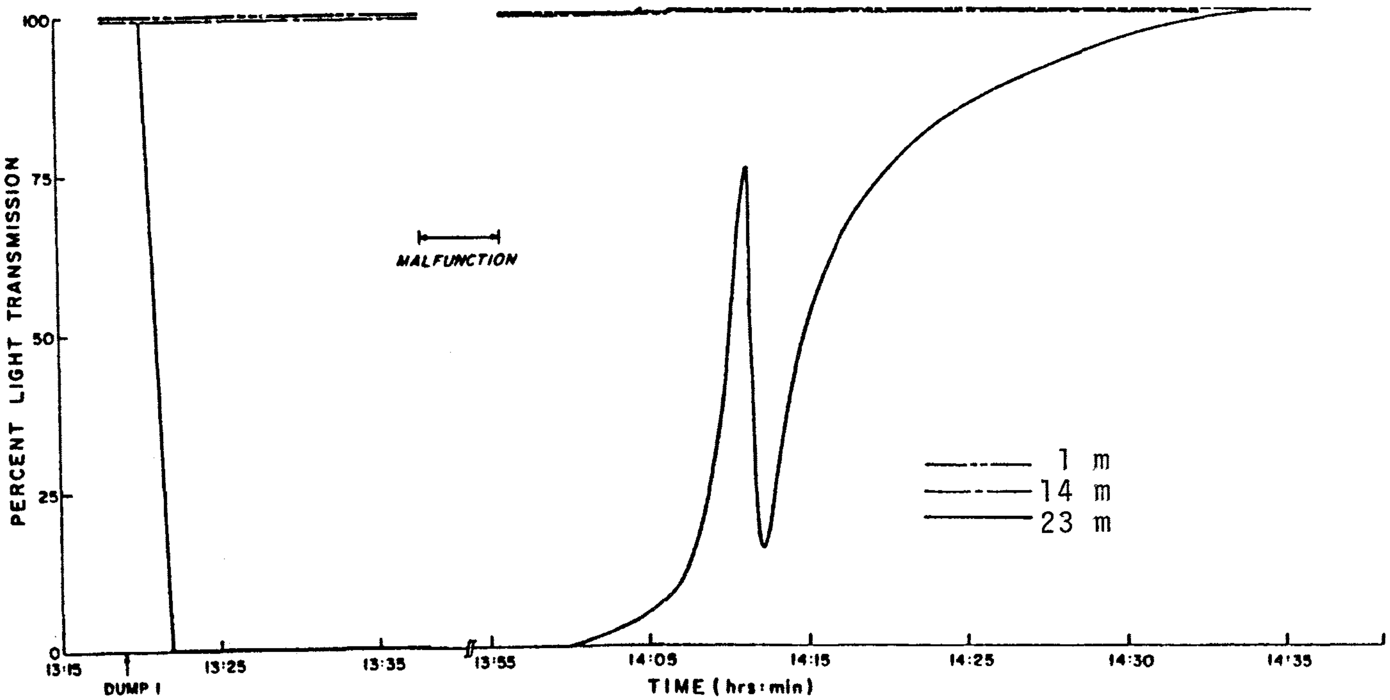


Figure 149

Percent Light Transmission as a Function of Depth and Time during New York Bight Dump No. 1 - Hatton (12 cm path length)

From data provided by R. Gordon

Percent light transmission was measured in the water column at the Hudson before and after the first disposal operation. The plot of the data is presented in Figure 150. The pre-disposal profile shows that the water down to the depth of 20 meters had relatively homogeneous percent light transmission with a range of 80 to 90 percent. Below 20 meters the transmissivity of the water decreased rapidly with depth.

The post-disposal profile showed a slight increase over pre-disposal values in the percent transmission to a depth of 16 meters where the light transmission decreased rapidly. These results also indicate that about one hour after the dump the turbidity of the bottom waters was slightly higher than it had been prior to the dump.

During the first disposal operation, the transmissometer was kept at a depth of 25 meters, and readings were taken periodically during the disposal operations for approximately one hour. The data collected are presented in Figure 147. A sharp decrease in the percent light transmission at a depth of 2.5 meters was noted shortly after the disposal occurred. The values fluctuated after the disposal, remaining mostly below the 15 percent light transmission level. The reading did not return to pre-disposal values during the one-hour monitoring period.

Currents. As shown in Table 471, mid-depth to bottom, pre-dump currents at the mud-dump site ranged in speed from 0.42 to 0.61 knots and appeared to decrease with depth below 19 m. The currents ranged in direction from 330 to 229° magnetic with increasing depth. Table 472 presents the current data which show the effect of the disposal on the speed and direction of currents 2 meters off the bottom. Current velocity rose from 0.2 to 0.25 knots before disposal began, to 0.79 knots two minutes after disposal ceased. It then decreased. The direction of the current did not appear to have been greatly affected by the disposal of the dredged material.

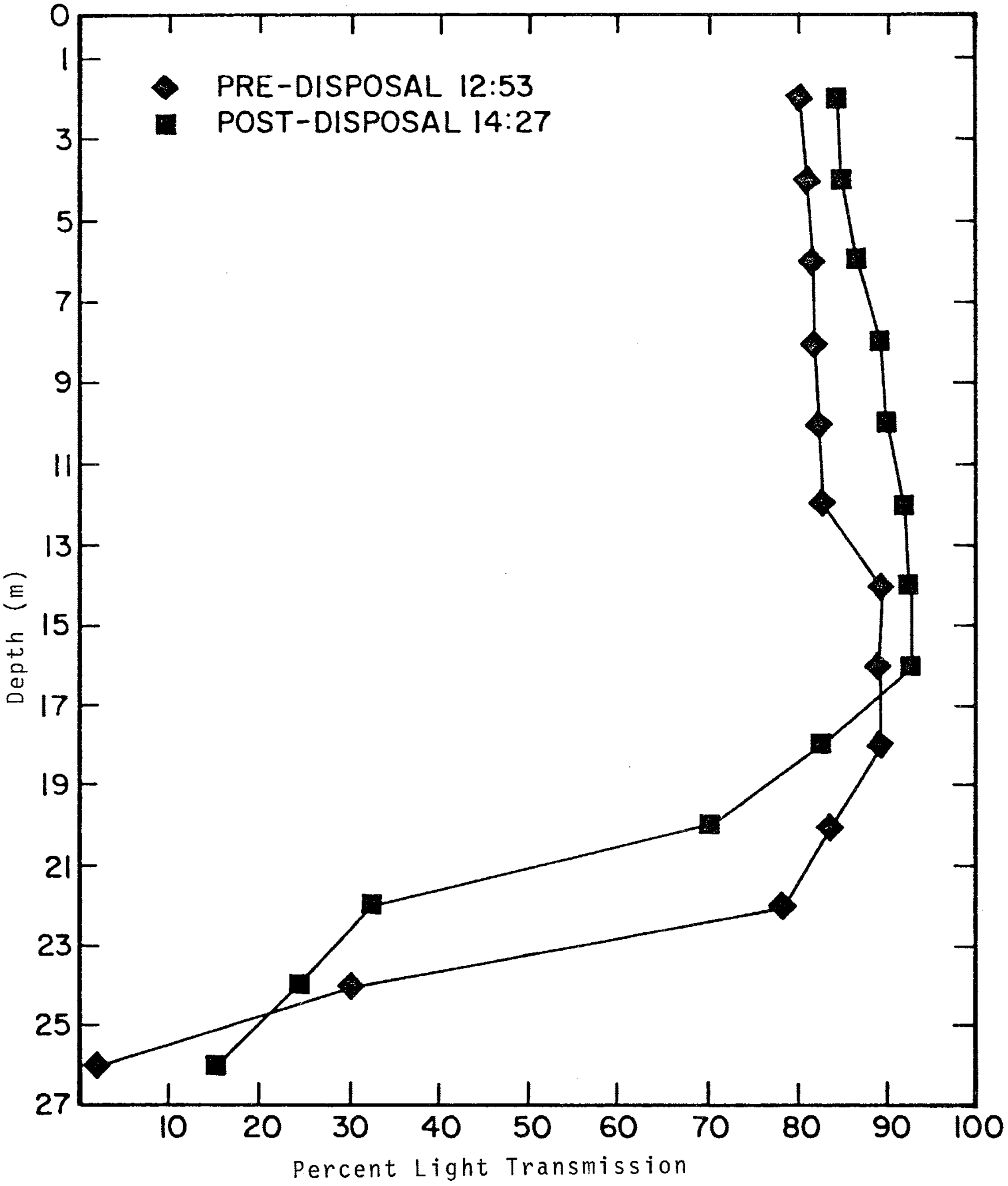


Figure 150

Water Column Profiles: Percent Light Transmission

New York Bight Dump No. 1 <u>Hudson</u>

Table 471

Background Current Data: New York Bight Disposal Operations

August 31, 1976

Depth (m)	Direction (°magnetic)	Speed (knots)
10	330	0.50
15	290	0.47
19	272	0.61
22	270	0.53
25	239	0.50
27	229	0.42

Data provided by B. Holliday, CE-WES.

Dissolved oxygen, temperature, salinity, and pH. Prior to the disposal operations, water column profiles of D.O., temperature, salinity, and pH were made at the disposal site; the data are presented in Table 473. These data indicate that the depth to the thermocline was between 16 and 18 meters. The temperature ranged from 19.5°C at the surface to 10.5°C at the bottom. Dissolved oxygen concentrations ranged from 8.1 mg/l at the surface to 1.4 mg/l at the bottom. Figure 151 graphically shows the sharp decrease in both parameters below 16 meters. The salinity increased from 29.0 $^{o}/oo$ to 32.8 $^{o}/oo$, surface to bottom. The pH of the disposal site water decreased with depth from 7.7 to 7.0.

Table 472

Bottom Current Velocity and Direction:*

New York Bight Dump No. 1

Time (hr:min:sec)	Speed (knots)	Direction (°magnetic)
12:46:00	0.25	230
13:02:00	0.22	182
13:07:00	0.24	214
13:16:00	0.18	190
13:19 - Dump began.		
13:19:00	0.29	222
13:20:00	0.35	235
13:20:30	0.38	238
13:21:00	0.40	239
13:21 - Dump stopped.		
13:21:30	0.41	241
13:22:00	0.45	240
13:22:30	0.68	220
13:23:00	0.79	220
13:23:30	0.62	190
13:24:00	0.52	155
13:24:30	0.46	170
13:25:00	0.35	220
13:26:00	0.35	240
13:26:30	0.42	235
13:27:30	0.33	220
13:28:00	0.20	188
13:29:00	0.10	155
13:30:00	0.10	215
13:31:00	0.21	221
13:32:30	0.33	240
13:33:00	0.38	248
13:33:30	0.40	248
13:34:00	0.39	245
13:35:00	0.21	215
13:35:30	0.18	180

*Current meter set at 29 m, about 2 m off bottom. Data provided by B. Holliday, CE-WES.

Table 473

Pre-Disposal* Water Column Profile: New York Bight Disposal Site

August 31, 1976

Depth (m)	Temp (°C)	D.O. (mg/l)	Salinity (°/oo)	pH
0.5	19.5	8.1	29.0	7.7
3	19.5	7.6	30.5	7.6
6	19.5	7.3	30.5	7.6
9	19.5	7.4	31.2	7.7
12	19.0	6.2	31.2	7.6
15	17.0	6.5	32.8	7.6
16	16.0	7.3	32.8	7.7
17	15.5	6.3	32.8	7.6
18	15.0	5.8	32.8	7.6
19	14.0	4.6	32.8	7.5
20	13.0	3.7	32.8	7.3
21	11.0	2.7	32.8	7.0
24	10.5	1.8	32.8	7.0
25.5	10.5	1.4	32.8	7.0

*Time - 10:28.

Table 474 and Figures 152 and 153 present the data for the pre- and post-disposal D.O., temperature, salinity, and pH profiles. There was no appreciable change noted in the salinity and pH between the two profiles. The pre-disposal profiles showed a decrease in both temperature and D.O. in the bottom 8 meters (18, 21, 24.5 meter samples). The post-disposal profiles indicate a relatively homogeneous system below 18 m with an increased D.O. level near the bottom as compared to pre-disposal levels.

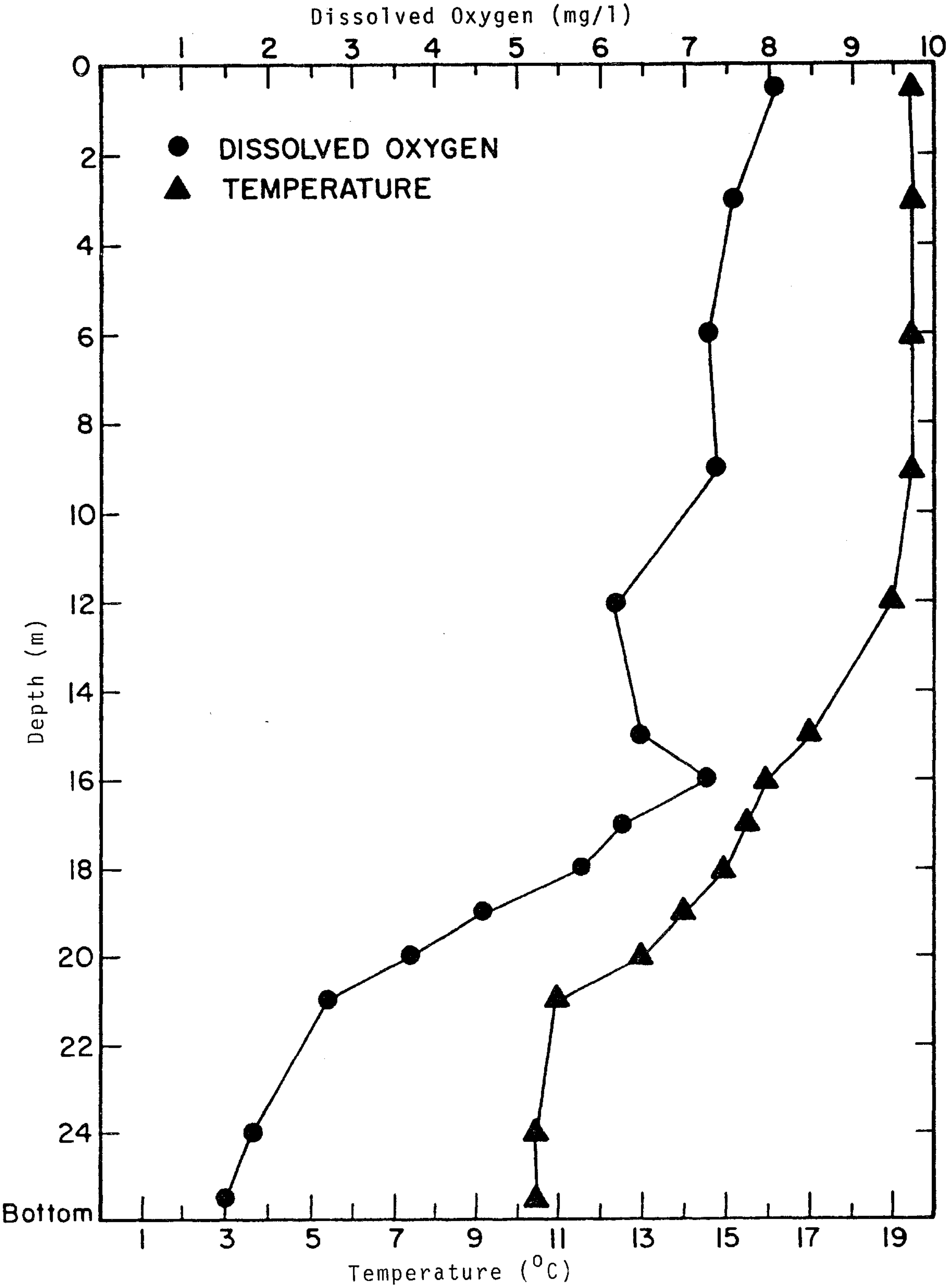


Figure 151

Pre-Disposal Temperature and Dissolved Oxygen Profiles: New York **Bight** Mud Dump Site Hatton

Table 474

Pre- and Post-Disposal Water Column Profile: New York Bight Dump No. 1, Dredged Material from Perth Amboy Channel

Designation and Time	Depth (m)	Temp (°C)	D.O. (mg/l)	Salinity (°/oo)	pH
Pre-Disposal (12:25)					
	0.5	19.5	7.5	30.5	8.5
	3	19.5	7.4	30.5	8.3
	6	19.0	6.8	30.5	8.0
	9	19.0	6.6	30.5	7.9
	12	19.0	6.2	31.2	7.8
	15	17.0	6.2	32.0	7.9
	18	15.0	5.2	32.8	7.8
	21	12.2	3.1	32.8	7.5
	25.5	10.0	1.7	32.8	7.4
Post-Disposal (13:37)					
	0.5	19.5	7.8	30.5	8.0
	3	19	7.8	30.5	8.1
	6	19	7.0	30.5	8.1
	9	18.5	6.6	31.2	8.1
	12	17	6.3	32.8	8.2
	15	15	5.4	32.8	8.1
	18	12.5	2.6	32.8	7.7
	21	12	2.4	32.8	7.7
	24.5	12	2.3	33.5	7.8

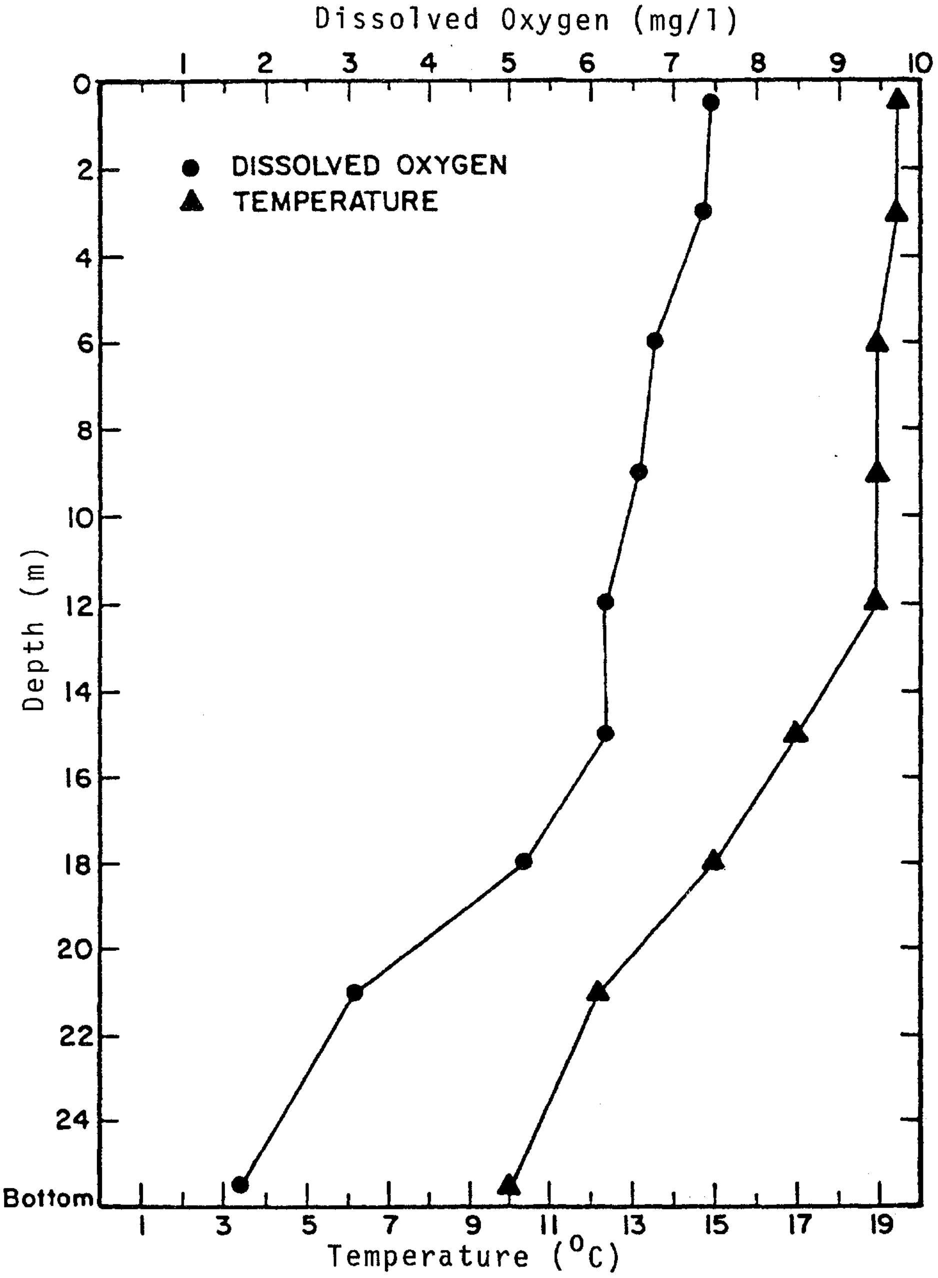


Figure 152
Pre-Disposal Water Column Temperature and Dissolved Oxygen Profile: New York Bight Dump No. 1

<u>Hatton</u>

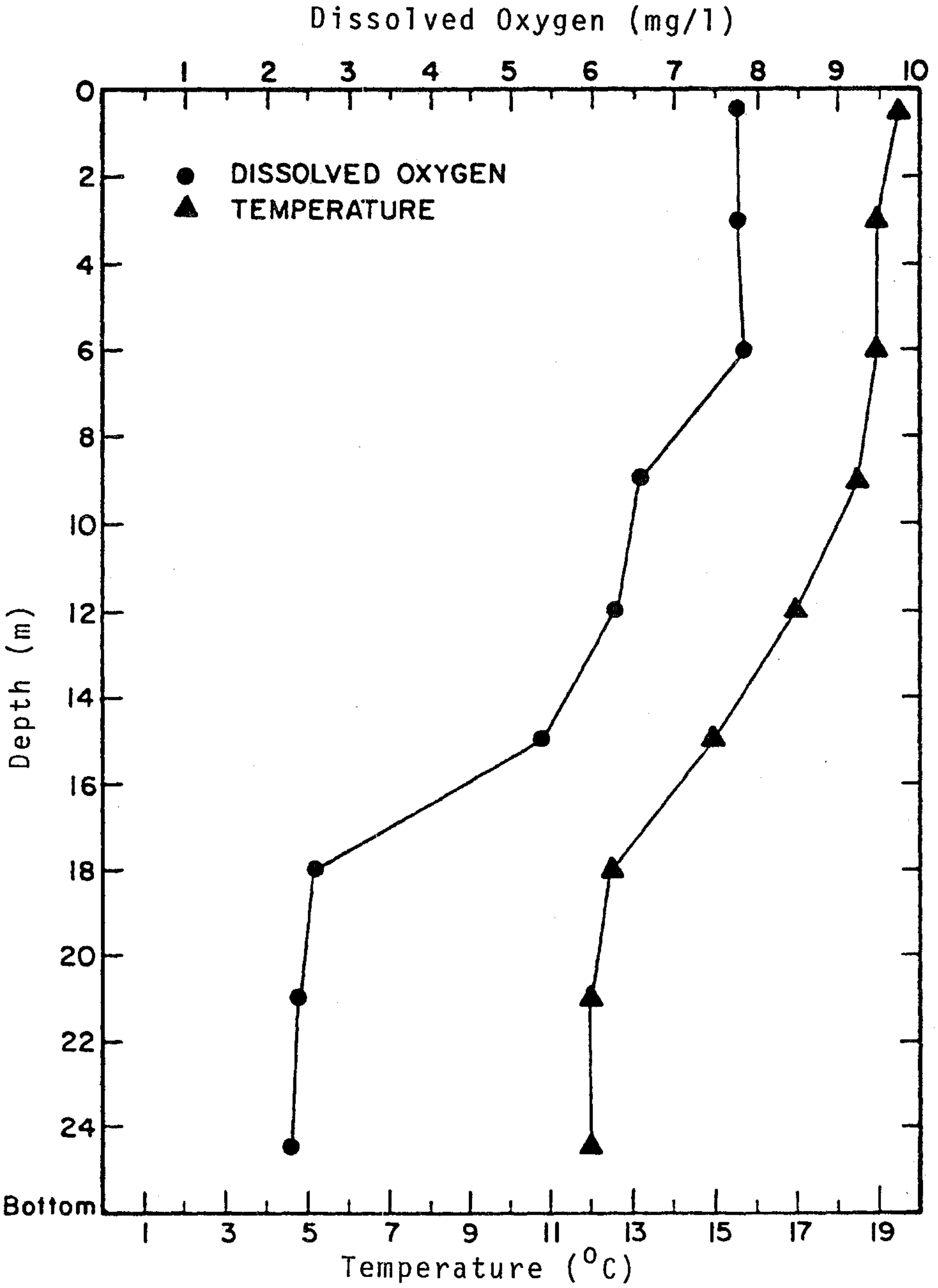


Figure 153
Post-Disposal Water Column Temperature and Dissolved Oxygen Profile: New York Bight Dump No. 1: Hatton

Figure 154 is a plot of the D.O. concentrations at 24.5 m at the Hatton during disposal. Approximately four minutes after disposal was completed, there was an increase in the D.O. levels. The highest concentration (a 1.4 mg/l increase over background levels) was the 2.9 mg/l observed at 13:26:45 hours. The D.O. remained elevated at approximately 2.3 mg/l for a period but returned to background concentrations at 15:38, when the pre-disposal profile for Dump No. 2 was made. The observed increase in D.O. concentrations near the bottom and the homogeneity of the lower 8 meters of water was most likely caused by mixing of surface waters with the waters below the thermocline. The rapid descent of the dredged sediments upon dumping and entrainment of surface waters into the bottom waters resulted in an increased D.O. in these waters.

Temperature, D.O. pH, and specific conductance in the water column were also monitored from the Hudson by the Corps of Engineers-New York District personnel using their PLESSEY Environmental Systems (Model 8500). This unit's sensor was raised and lowered through the water column during the monitoring of the dump to determine changes in these parameters throughout the water column during the course of the study. Data collected with the PLESSEY unit during Dump No. 1 are presented in Table 475. Pre-dump (12:43-13:07 hours) and post-dump (15:00-15:07 hours, after passage of the turbid cloud), temperature, and D.O. profiles are also presented in Figure 155. This figure shows that before disposal, D.O. concentrations ranged from about 8 mg/l near the surface to zero near the bottom, with a thermocline at about the 16-18 m depth. Temperature varied with depth from 19.5 to about 10°C near bottom. The patterns and values of these two parameters were essentially the same as they had been just prior to disposal near the Hatton (Table 474, Figure 152) except that D.O. concentrations below the 15 m depth were somewhat lower at the Hudson than at the Hatton.

As shown in Figure 155, the post-dump D.O. levels were higher than pre-dump levels down to about 4.5 m. Between 10 and about 20 m, post-dump levels were less than pre-dump levels.

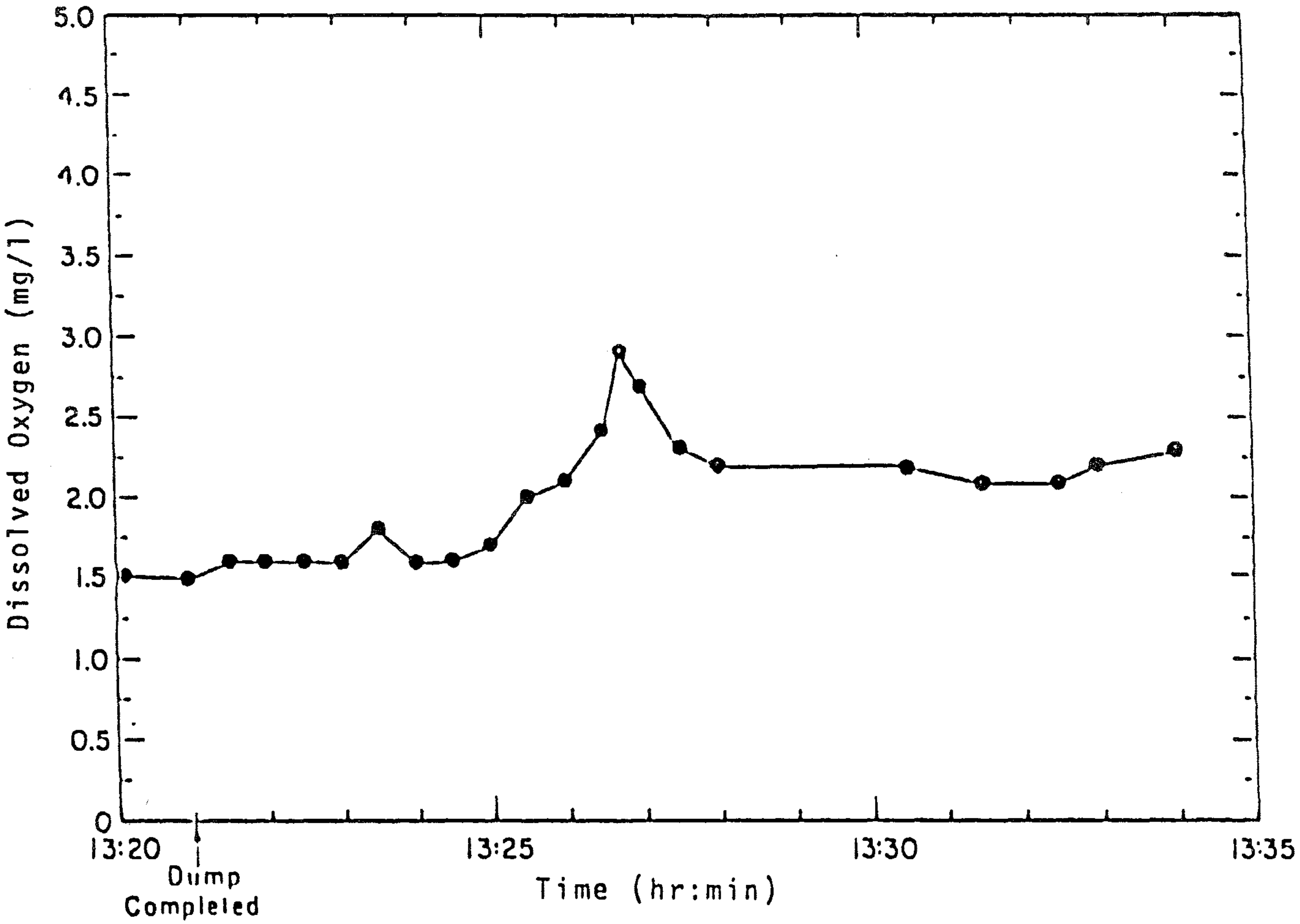


Figure 154

Dissolved Oxygen Following New York Bight Dump No. 1

Depth - 24.5 meters - Hatton

Table 475

Dissolved Oxygen, Temperature, pH and Specific Conductance Profiles:* New York Bight

Dump No. 1

(Collected from the Hudson)

Time (hr:min)	Depth (m)	Dissolved Oxygen (mg/l)	Temperature (°C)	pH	Salinity (^{o}/oo)
12:43	1	7.5	19.5	8.1	30.2
12:45	2	7.1	19.1	8.0	30.3
12:46	3	6.9	18.9	8.7	30.4
12:47	4.5	6.9	18.9	8.0	30.3
	6	6.4	18.9	8.0	30.3
	8	5.9	18.8	8.0	30.4
	10	5.8	18.8	8.0	30.4
12:49	12	5.0	18.5	8.0	30.9
12:52	14	5.9	17.5	8.0	32.1
	16	5.8	16.5	8.0	32.1
	17	4.0	14.5	7.7	32.1
12:54	19	2.2	13.1	7.6	31.2
	21	0	10.4	7.5	32.6
	23	0	9.9	7.4	32.5
12:58	25	1.6	9.8	7.4	32.5
13:00	1	8.5	19.5	8.1	30.2
	2	7.7	19.3	8.1	30.2
	3	7.4	19.0	8.1	30.2
	4.5	6.9	18.9	8.1	30.3
	6	6.9	18.8	8.1	30.3
	8	6.1	18.8	8.0	30.3
	10	5.8	18.7	8.0	30.4
	12	5.5	18.5	8.0	30.6
	14	5.9	17.5	8.0	32.3
	16	5.6	16.1	7.9	32.3
13:05	17	4.2	14.3	7.8	32.0
	19	2.3	12.9	7.6	32.0
13:07	21	0	11.5	7.5	32.2
	23	0	10.1	7.4	-
	13:19 - Dump No. 1 occurred.				
13:25	1	8.2	19.6	8.1	-
	2	8.3	19.5	8.1	-
	3	8.1	19.1	8.0	-
	4.5	6.7	18.8	8.0	-
	6	6.2	18.8	8.0	-
13:25	8	6.1	18.8	8.0	-
	10	6.1	18.7	8.0	-
	12	5.2	18.3	7.9	-
	14	5.8	17.6	7.9	-

(Continued)

Table 475 (Continued)

Time (hr:min)	Depth (m)	Dissolved Oxygen (mg/l)	Temperature (°C)	pH	Salinity (°/oo)
	16	5.8	16.4	7.8	-
	17	4.1	14.1	7.7	-
	19	2.0	12.4	7.5	-
	21	0	10.2	7.4	-
	23	0	9.9	7.4	-
13:29	25	0	9.8	7.4	-
	24	0	11.6	7.4	-
	23	0	10.3	7.4	-
	21	0	11.6	7.4	-
	19	0	13.2	7.5	-
	17	4.2	15.9	7.7	-
	16	6.5	17.2	7.8	-
	14	7.0	18.0	7.9	-
	12	4.7	18.5	7.9	-
	10	5.9	18.7	8.0	-
	8	6.5	18.7	8.0	-
	6	6.1	18.8	8.0	-
	4.5	6.0	18.8	8.0	-
	3	6.4	19.1	8.1	-
	2	8.0	19.5	8.1	-
13:34	1	8.0	19.5	8.1	-
13:38	1	7.5	19.5	8.1	-
	2	7.8	19.5	8.1	-
	3	7.5	19.1	8.0	-
	4.5	6.5	18.8	8.0	-
	6	5.9	18.8	8.0	-
	8	5.8	18.7	7.9	-
	10	5.1	18.4	7.9	-
	12	4.0	17.7	7.9	-
	14	5.5	17.1	7.9	-
	16	5.5	16.3	7.8	-
	17	4.3	14.5	7.7	-
	19	2.5	12.8	7.5	-
	21	0.3	11.5	7.5	-
	23	0	11.0	7.4	-
13:44	24	0	10.7	7.4	-
13:38	1	7.5	19.5	8.1	-
	2	7.8	19.5	8.1	-
	3	7.5	19.1	8.0	-

(Continued)

Table 475 (Concluded)

Time (hr:min)	Depth (m)	Dissolved Oxygen (mg/l)	Temperature (°C)	pH	Salinity (°/oo)
	4.5	6.5	18.8	8.0	-
	6	5.9	18.8	8.0	-
	8	5.8	18.7	7.9	-
	10	5.1	18.4	7.9	-
	12	4.0	17.7	7.9	-
	14	5.5	17.1	7.9	-
	16	5.5	16.3	7.8	-
	17	4.3	14.5	7.7	-
	19	2.5	12.8	7.5	-
	21	0.3	11.5	7.5	-
	23	0	11.0	7.4	-
	24	0	10.7	7.4	-
15:00	1	8.7	19.5	8.1	30.3
	2	9.0	19.5	8.1	30.2
	3	8.8	19.2	8.1	30.2
	4.5	7.6	18.8	7.9	30.4
	6	6.4	18.8	7.9	30.4
	8	6.5	18.7	7.9	30.4
	10	5.8	18.6	7.9	30.4
	12	4.4	17.1	7.8	31.5
	14	3.5	17.6	7.9	32.0
15:05	16	5.6	15.9	7.8	32.0
	17	3.0	13.6	7.6	32.1
	19	1.3	12.0	7.5	32.1
	21	0.15	11.1	7.4	-
15:07	23	0	5.8	7.4	-

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*Measurements made using PLESSEY Environmental Systems Model 8500 Digital Display - owned and operated by Corps of Engineers New York District.

Dash (-) indicates no measurement made.

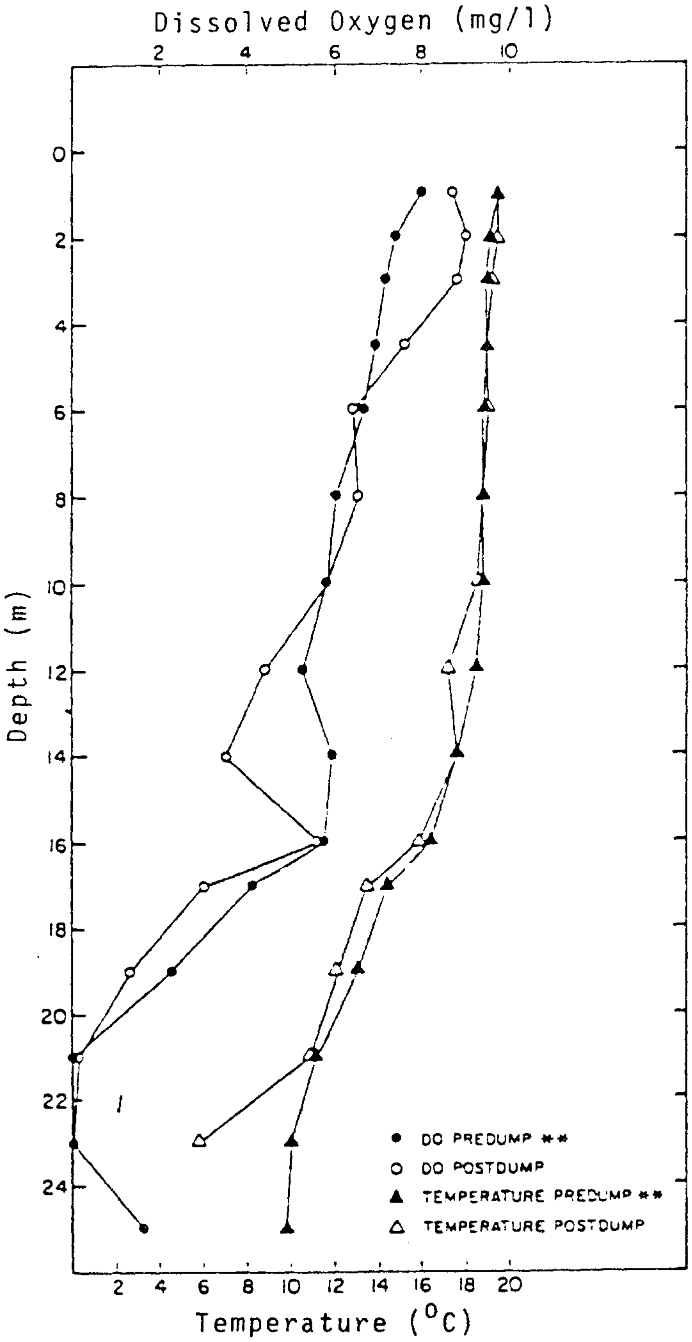

Figure 155

Pre- and Post-Dump Water Column D.O. and Temperature Profiles:*
New York Bight Dump No. 1 - Hudson

*Measurements made by COE Personnel using PLESSEY profiling system.

**Plotted values are means of two profile measurements made approximately 15 min. apart, 10 to 40 min. prior to dump.

The D.O. levels at 21 m and below, both pre- and post-dump were zero or essentially zero. The surface waters were at essentially saturation for the temperature and salinity of that water.

It is difficult to interpret the profile data during the dump since, as shown by the data collected at the *Hatton*, the measured parameters are highly variable during the passage of the turbid plume.

Heavy metals. Tables 476 and 477 present heavy metal data for Dump No. 1. At the *Hatton*, which was the closer sampling vessel to the disposal area, small increases of zinc and iron were found near the bottom within three or four minutes after the dump. The increases coincided with the onset of high turbidity. Zinc concentrations reached 50 µg/l 11.5 minutes after the dump. In the near-bottom waters they remained elevated for 35 minutes. There was an increase in soluble iron which also coincided with the passage of the turbid plume. The peak concentrations were 82 to 75 µg/l at 6 minutes after the disposal. Background concentrations were below the detection limit of 5 µg/l. A second increase occurred 8 to 9 minutes after disposal. There was also a slight increase in nickel between 8 and 13.5 minutes after the dump.

Increases in manganese, cadmium, iron, and mercury occurred after the plume had passed. Manganese reached 67 µg/l 33.5 minutes after the dump, and cadmium reached 1.0 µg/l within 22.5 minutes of the dump. Iron ranged from 22 to 65 µg/l during the period from 22.5 to 73.5 minutes after disposal. Mercury concentrations increased to 0.026 µg/l in several samples taken during this period. There were no significant changes in chromium, copper,or arsenic concentrations as a result of this dump.

The *Hudson* was approximately 100 m down bottom current from the *Hatton*. The bottom plume reached the *Hudson* about 8 minutes after the dump. Soluble heavy metals on *Hatton* samples showed trends similar to those seen in the

Table 476

Soluble Heavy Metal Concentrations: New York Bight Dump No. 1

Dredged Material from Perth Amboy Channel

(Collected from the Hatton)

(µg/l)

Time (hr:min:sec)	Depth (m)	Mn	Cd	Cr	Zn	Ni	Pb	Cu	Fe	Hg	As
12:43:45	0.5	< 10	< 0.5	2.2	4.2	< 2	1.1	< 1	< 5	0.014	-
12:44:00	12	< 10	< 0.5	< 2	3.1	< 2	1.4	< 1	< 5	< 0.005	-
13:19:00 - Dump-No. 1 occurred.											
13:21:15	0.5	< 10	< 0.5	3.9	< 1	2.0	< 1	< 1	< 5	< 0.005	-
13:21:50	24	< 10	< 0.5	2.2	< 1	< 2	2.3	< 1	< 5	0.014	-
13:23:15	24	< 10	< 0.5	< 2	10.9	< 2	2.3	< 1	< 5	< 0.005	-
13:23:30	0.5	< 10	< 0.5	2.6	4.4	< 2	2.0	< 1	< 5	< 0.005	-
13:23:50	24	< 10	< 0.5	< 2	19.7	< 2	2.5	< 1	26	0.014	-
13:25:00	24	< 10	< 0.5	< 2	13.9	< 2	2.3	1.1	82	< 0.005	-
13:25:30	24	< 10	< 0.5	< 2	2.1	< 2	2.3	< 1	75	< 0.005	-
13:26:00	24	< 10	< 0.5	< 2	2.4	< 2	1.7	< 1	< 5	0.014	-
13:26:30	0.5	< 10	< 0.5	< 2	< 1	2.0	1.4	< 1	< 5	0.014	-
13:27:00	24	< 10	< 0.5	3.4	3.0	2.4	2.5	1.3	21	0.014	-
13:27:15	24	< 10	< 0.5	2.2	14.2	< 2	1.7	1.4	30	< 0.005	-
13:28:00	24	< 10	< 0.5	< 2	15.5	2.7	2.5	1.3	40	0.014	-
13:28:30	24	< 10	< 0.5	2.6	36.7	< 2	2.3	< 1	< 5	0.014	-
13:30:30	24	< 10	< 0.5	< 2	49.9	2.7	1.4	< 1	16	< 0.005	-
13:32:30	24	< 10	< 0.5	2.2	8.8	3.1	2.0	2.6	< 5	< 0.005	-
13:34:30	24	< 10	< 0.5	< 2	23.6	< 2	2.3	< 1	< 5	< 0.005	-
13:36:30	24	< 10	< 0.5	2.2	< 1	< 2	< 1	1.1	< 5	0.014	-
13:38:00	22	< 10	< 0.5	< 2	5.1	< 2	2.5	< 1	10	0.014	-
13:41:30	22	< 10	1.0	< 2	5.7	< 2	7.6	< 1	56	0.026	10.1
13:42:15	0.5	67	0.8	< 2	8.3	< 2	4.5	< 1	8	< 0.005	6.8
13:52:30	24	67	0.9	< 2	11.5	< 2	4.5	1.3	26	< 0.005	6.5
14:10:30	24	17	1.0	< 2	< 1	< 2	6.6	1.3	57	0.026	10.1
14:31:30	24	33	< 0.5	< 2	< 1	< 2	4.0	< 1	65	< 0.005	6.5
14:52:30	24	67	< 0.5	< 2	< 1	< 2	4.0	< 1	22	0.026	5.9
14:53:30	24	17	0.7	< 2	< 1	< 2	7.6	< 1	56	< 0.005	9.3
15:23:55	0.5	50	0.7	< 2	< 1	< 2	4.5	< 1	5	< 0.005	5.1
15:24:30	24	50	< 0.5	2.3	< 1	< 2	5.1	1.3	2	0.026	10.1
15:32:30	0.5	< 10	0.7	< 2	< 1	< 2	6.1	< 1	39	< 0.005	10.4

Dash (-) indicates insufficient sample for analysis.

Table 477

Soluble Heavy Metal Concentrations: New York Bight

Dump No. 1, Dredged Material from Perth Amboy Channel

(Collected from the Hudson)

(μg/l)

Time (hr:min:sec)	Depth (m)	Mn	Cd	Cr	Zn	Ni	Pb	Cu	Fe	Hg	As
12:51:20	1	< 10	<0.5	< 2	< 1	6.4	2.6	< 1	31	0.012	-
12:52:55	12		< 0.5	< 2	< 1	5.8	1.2	<1	17	0.012	-
12:52:55	23	< 10	< 0.5	3.7	<1	5.4	3.4	3.6	57	<0.005	-
12:55:30	1	<10	< 0.5	< 2	< 1	< 2	1.9	<1	13		
12:55:35	12	<10	< 0.5	< 2	< 1	3.1	< 1	<1	16	<0.005	7.3
12:55:45	23	<10	< 0.5	2.8	< 1	5.0	1.0	2.1	35	<0.005	-
13:01:25	1	<10	<0.5	< 2	< 1	6.8	1.7	<1	44	<0.005	-
13:01:35	23	44	<0.5	< 2	< 1	6.4	1.7	< 1	40	0.012	8.8
13:01:55	12	< 10	0.6	< 2	<1	< 2	<1	<1	25	0.012	-
13:19:00 - Dump No. 2 occurred.											
13:21:50	1	<10	< 0.5	<2	< 1	2.2	2.0	<1	40	0.085	-
13:22:05	12	< 10	< 0.5	< 2	< 1	3.5	<1	<1	< 5	< 0.005	-
13:22:10	23	< 10	< 0.5	< 2	< 1	4.6	1.4	<1	10	< 0.005	-
13:26:00	1	< 10	< 0.5	< 2	<1	< 2	3.1	1.6	5	0.012	-
13:26:35	23	54	< 0.5	2.4	< 1	< 2	3.8	1.9	24	0.012	-
13:26:55	12	33	<0.5	< 2	< 1	< 2	2.9	<1	66	0.012	4.9
13:27:25	23	54	< 0.5	3.2	< 1	4.2	2.0	3.3	59	0.012	-
13:27:55	23	< 10	<0.5	< 2	< 1	2.3	< 1	<1	515	0.014	29.7
13:28:00	12	<10	<0.5	< 2	<1	4.4	2.0	<1	38	0.012	-
13:28:30	23	11	< 0.5	< 2	16.1	< 2	<1	1.3	125	0.020	9.3
13:28:50	1	11	0.5	< 2	7.3	< 2	< 1	1.3	10	0.020	6.8
13:29:10	24	59	1.5	2.2	28.4	2.6	2.6	4.5	167	0.075	14.5
13:29:45	12	< 10	< 0.5	< 2	<1	< 2	<1	1.0	85	0.030	6.8
13:29:55	23	11	< 0.5	< 2	19.9	< 2	7.7	18.2	439	0.125	6.3
13:30:35	23	< 10	1.0	<2	27.7	< 2	1.7	< 1	95	0.075	35.8
13:30:45	12	44	<0.5	< 2	2.5	< 2	<1	1.8	7	0.080	3.9
13:31:15	23	< 10	0.9	<2	16.1	2.8	1.3	2.9	164	0.090	18.2
13:31:50	23	<10	1.4	< 2	21.6	2.4	1.7	6.0	174	0.014	-
13:32:00	1	< 10	<0.5	< 2	15.7	<2	< 1	1.7	14	0.030	5.4
13:32:30	23	< 10	<0.5	2.2	13.7	3.4	2.2	4.4	160	0.014	10.9

(Continued)

Table 477 (Concluded)

Time (hr:min:sec)	Depth (m)	Mn	Cd	Cr	Zn	Ni	Pb	Cu	Fe	Hg	As
13:32:45	12	18	1.0	2.2	59.2	< 2	1.7	< 1	< 5	0.185	32.7
13:33:10	23	89	< 0.5	< 2	33.3	2.4	1.7	4.4	116	0.014	-
13:33:45	23	29	1.2	< 2	18.9	2.6	2.2	2.3	159	0.030	14.5
13:34:30	23	< 10	< 0.5	2.8	18.7	4.5	4.4	6.5	74	0.030	60.0
13:36:05	1	28	< 0.5	< 2	6.1	< 2	< 1	1.1	3	0.050	67.8
13:36:10	12	< 10	< 0.5	2.2	< 1	< 2	1.7	< 1	< 5	0.020	3.4
13:36:25	23	< 10	< 0.5	< 2	2.2	3.2	< 1	< 1	117	0.030	22.4
13:38:20	23	< 10	1.1	2.2	< 1	2.3	6.7	12.8	126	0.030	48.5
13:52:00	1	11	< 0.5	< 2	19.6	2.5	< 1	3.6	37	0.075	98.9
13:52:00	12	< 10	0.7	2.5	< 1	< 2	< 1	< 1	5	0.020	37.6
13:52:00	23	< 10	< 0.5	< 2	16.7	< 2	5.3	9.5	97	0.014	14.5
14:00:00	23	< 10	< 0.5	< 2	< 1	< 2	3.4	1.8	78	0.014	-
14:12:00	23	< 10	1.2	< 2	13.8	< 2	3.1	1.5	33	0.014	12.7
14:20:55	1	23	< 0.5	< 2	< 1	4.2	4.1	< 1	13	0.026	-
14:21:15	12	< 10	1.1	< 2	3.3	< 2	< 1	< 1	28	0.090	20.0
14:21:15	23	< 10	< 0.5	2.6	< 1	6.4	5.2	2.6	99	0.012	-
14:31:05	1	59	1.0	< 2	< 1	< 2	< 1	< 1	193	0.030	27.2
14:31:25	12	< 10	1.2	2.5	< 1	< 2	3.5	< 1	24	0.030	10.9
14:31:30	23	< 10	< 0.5	2.8	2.2	< 2	< 1	< 1	98	0.075	41.2
14:58:55	1	11	< 0.5	< 2	6.0	< 2	< 1	2.2	66	0.020	6.3
14:58:35	12	< 10	< 0.5	< 2	8.1	2.9	1.3	1.5	9	0.010	3.4
14:59:30	23	11	< 0.5	< 2	6.0	< 2	< 1	2.8	91	0.115	4.4

Dash (-) indicates insufficient sample for analysis.

samples collected aboard the Hudson. There were releases of zinc and iron in the mid-depth and near-bottom waters which corresponded with the arrival of the turbid plume. During the passage of the plume, zinc concentrations ranged from 13.7 to 33.3 µg/l in the near-bottom waters and from below 1 to 59.2 µg/l in the mid-depth samples. The elevated levels seen in the surface samples were probably due to contamination from the discharge of the deep water sample hose pump to the surface waters at the side of the ship. The iron concentrations in the near-bottom water samples ranged from 74 to 439 µg/l. There were two mid-depth samples that contained elevated iron concentrations (38 and 85 µg/l).

The patterns of delayed increase of manganese, cadmium,and iron seen at the Hatton were not seen at the Hudson, 100 m down bottom current. After arrival of the plume, there were occasional elevated levels of manganese and cadmium. The highest manganese level was 89 µg/l at 13:33:10 hrs, and the highest cadmium concentration was 1.5 µg/l at 13:29:10 hrs. Iron concentrations continued to increase after the plume passed, rather than decreasing to below the detection limit and rising again (as they had done at the Hatton).

Mercury concentrations rose during the plume passage, from less than 0.005 µg/l background levels to peaks of 0.125 µg/l at the bottom (13:29:55 hrs)and 0.185 µg/l at mid-depth (13:32:45 hrs). Arsenic also increased, from background levels below 10 µg/l to 60 µg/l near the bottom, 32.7 µg/l at mid-depth and 98.9 µg/l at the surface. The latter concentrations probably resulted from the contamination of surface waters from the discharge of the deep water sample hose pump. There were no changes in concentrations of nickel, chromium, lead, or copper during the monitoring period.

Nitrogen compounds. The ammonium data for the water samples collected from the Hatton during Dumps No. 1 and 2 are presented in Table 478. This table shows that during Dump No. 1, ammonium concentrations in the surface water samples were not affected by the dumping operation. Table 478 and Figure 156 show that in the bottom waters, ammonium increased sharply and then decreased. This was followed by two more peaks; concentrations finally leveled off near pre-dump ambient concentrations. The first increase in concentration was observed about five minutes after the disposal concentration returned to essentially ambient levels after one hour. All samples collected during Dump No. 1 had nitrate concentrations less than 0.04 mg N/l.

The ammonium and nitrate data for the water samples collected from the Hudson during Dump No. 1 are shown in Table 479. Surface and mid-depth concentrations were not affected by Dump No. 1 as was also observed for samples collected from the Hatton. Ammonium concentrations in the near-bottom waters are presented graphically in Figure 157. Ammonium in the near-bottom water increased sharply about nine minutes after the dump; the magnitude of release was almost the same as that observed from samples collected aboard the Hatton. Ammonium showed some fluctuation and finally returned to the ambient level after about 1.5 hours. There were no apparent effects of the dump on nitrate concentration.

Phosphorus compounds. Table 480 presents the soluble orthophosphate concentrations in samples collected from the Hatton during Dumps Nos. 1 and 2. The soluble ortho P concentrations at the Hudson's location during Dump No. 1 are presented in Table 481. Prior to the disposal of the Perth Amboy Channel sediment, the surface soluble ortho P concentration was 0.044 mg P/l at the Hatton and at or less than 0.01 mg P/l (detection limit) at the Hudson. Mid-depth, pre-disposal concentrations were 0.032 mg P/l at the Hatton and at or less than

Table 478

Ammonium Concentration: New York Bight Dump Nos. 1 and 2, Dredged Material from Perth Amboy Channel

(Collected from the *Hatton*)

Time (hr:min:sec)	Depth (m)	Ammonium (mg N/l)
12:43:45	0.5	0.08
12:44:00	12	0.12
13:19:00 - Dump No. 1 occurred.		
13:21:15	0.5	0.10
13:21:50	24	0.17
13:23:15	24	0.17
13:23:30	0.5	0.10
13:23:50	24	1.37
13:25:00	24	0.74
13:25:30	24	0.78
13:26:00	24	0.71
13:26:30	0.5	0.11
13:27:00	24	0.57
13:27:15	24	0.57
13:28:00	25	0.91
13:28:30	24	0.35
13:30:30	24	0.92
13:32:30	24	0.11
13:34:30	24	0.28
13:36:30	24	0.39
13:38:00	22	0.25
13:41:30	22	0.39
13:42:15	0.5	0.09
13:52:30	24	0.52
14:10:30	24	0.39
14:31:30	24	0.27
14:52:30	24	0.09
14:53:30	24	0.21

(Continued)

Table 478 (continued)

Time (hr:min:sec)	Depth (m)	Ammonium (mg N/l)
15:23:55	0.5	0.09
15:24:30	24	0.21
15:32:30	0.5	0.06
15:41:30	0.5	0.07
15:42:00	24	0.20
15:42:30	0.5	0.07
15:43:00	24	0.23
15:44:00	0.5	0.08
15:44:30 - Dump No. 2 occurred.		
15:44:30	24	0.20
15:45:00	24	0.11
15:45:30	24	2.43
15:46:00	24	1.26
15:46:30	24	1.94
15:46:45	24	0.14
15:47:00	24	0.20
15:47:15	24	1.75
15:47:15	0.5	0.11
15:47:30	24	1.86
15:47:45	24	1.40
15:48:00	24	0.89
15:48:15	24	1.00
15:48:30	24	0.95
15:48:45	24	0.34
15:49:30	24	0.55
15:50:30	24	0.83
15:51:45	24	0.75
15:52:30	24	1.34

(Continued)

Table 478 (Concluded)

Time (hr:min:sec)	Depth (m)	Ammonium (mg N/l)
15:54:30	0.5	0.08
15:56:00	24	0.61
15:59:30	24	0.33
16:10:00	0.5	0.08
16:10:30	24	0.40
16:10:30	24	0.41
16:25:30	0.5	0.11
16:26:00	24	0.24

0.01 mg P/l at the Hudson. Concentrations in the bottom water prior to the increase in turbidity due to the bottom turbid plume were about 0.055 mg P/l at the Hatton and ranged from below 0.01 to 0.049 mg P/l at the Hudson's location.

There appeared to be an increase in soluble ortho P concentrations in the bottom waters at both sampling locations with concomitant increases in turbidity. At the Hatton, which was 250-450 m down bottom current from the hopper dredge during disposal, maximum concentration in the bottom water (0.24 mg P/l) was observed eight minutes after disposal. At the Hudson, the maximum concentration in the bottom water was found about nine minutes after the dump took place. Although the turbidity values corresponding to two maxima were approximately the same, the maximum soluble ortho P in the bottom waters at the Hudson, 0.16 mg P/l, was less than it had been at the Hatton. The elevated soluble ortho P concentrations at the Hatton lasted for about 15 minutes. However, instead of returning to pre-disposal levels, they leveled off between 0.087 and 0.10 mg P/l until the next dump (about 1.5 hours after the first dump). The high

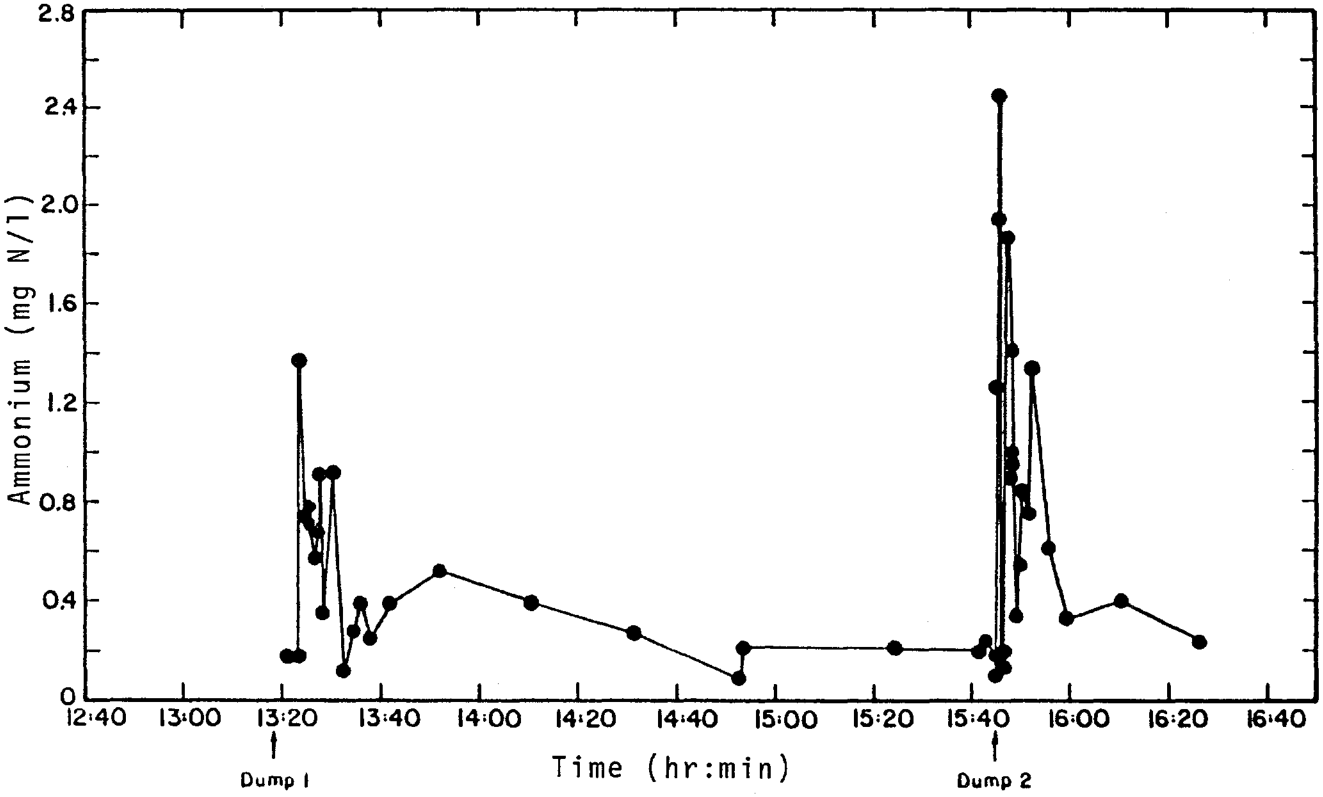

Figure 156

Ammonium Concentration Changes as a Function of Time:

New York Bight Dump Nos. 1 and 2

Bottom Water Samples Collected from Hatton

Table 479

Ammonium and Nitrate Data: Dump No. 1

New York Bight Mud Dump Site

(Collected from the Hudson)

(mg N/1)

Time (hr:min:sec)	Depth (m)	Ammonium (mg N/1)	Nitrate
12:51:20	1	0.08	0.04
12:52:55	12	<0.05	<0.04
12:52:55	23	0.11	0.04
12:55:30	1	<0.05	<0.04
12:55:35	12	0.24	0.04
12:55:45	23	0.18	0.04
13:01:25	1	<0.05	0.04
13:01:35	23	0.16	0.04
13:01:55	12	0.09	0.04
13:19:00	Dump 1 occurred		
13:21:50	1	0.06	0.04
13:22:05	12	0.10	0.04
13:22:10	23	0.16	0.04
13:26:00	1	0.08	0.04
13:26:35	23	0.13	0.04
13:26:55	12	0.05	< 0.04
13:27:25	23	0.16	0.04
13:27:55	23	1.30	0.04
13:28:00	12	< 0.05	0.04
13:28:30	23	0.60	< 0.04
13:28:50	1	0.10	0.04
13:29:10	23	0.12	0.04
13:29:45	12	0.12	0.04
13:29:55	23	0.25	0.04
13:30:35	23	< 0.05	0.04
13:30:45	12	0.10	< 0.04

(Continued)

Table 479 (Concluded)

Time (hr:min:sec)	Depth (m)	Ammonium (mg N/l)	Nitrate
13:31:15	23	0.16	0.05
13:31:50	23	0.08	0.04
13:32:00	1	0.10	< 0.04
13:32:30	23	0.09	0.05
13:32:45	12	0.12	0.04
13:33:10	23	0.10	0.04
13:33:45	23	0.40	0.04
13:34:30	23	0.28	0.05
13:35:30	23	0.28	0.04
13:36:05	1	0.07	< 0.04
13:36:10	12	0.06	< 0.04
13:36:25	23	0.41	0.04
13:38:20	23	0.29	< 0.04
13:52:00	1	< 0.05	< 0.04
13:52:00	12	0.06	0.04
13:52:00	23	0.30	0.04
14:00:00	23	0.24	0.04
14:12:00	23	0.40	0.04
14:20:55	1	< 0.05	0.04
14:21:15	12	0.12	< 0.04
14:21:15	23	0.25	< 0.04
14:31:05	1	0.06	0.04
14:31:25	12	0.14	0.05
14:31:30	23	0.21	< 0.04
14:58:55	1	0.08	<0.04
14:58:35	12	0.11	<0.04
14:59:30	23	0.09	<0.04

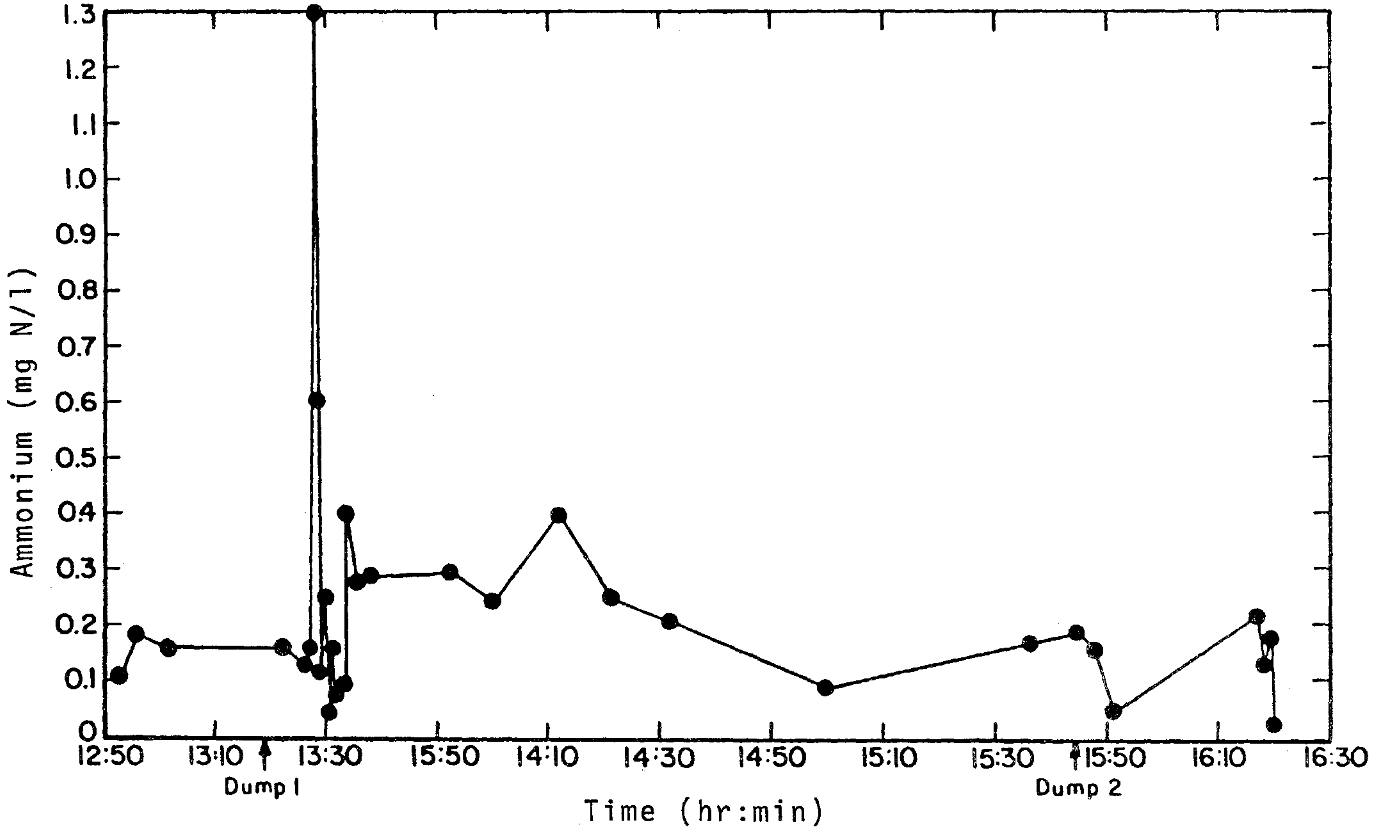

Figure 157

Ammonium Concentrations in Near Bottom Water as a Function of Time: New York Bight Dump Nos. 1 and 2 - Hudson

Table 480

Soluble Orthophosphate Concentrations: New York Bight Dumps Nos. 1 and 2, Dredged Materials from Perth Amboy Channel and Perth Amboy Anchorage

(Collected from the *Hatton*)

Time	Depth	Soluble Ortho P (mg P/l)	
hr:min:sec)	(m)	$\bar{X}$	SD
12:43:45	0.5	0.044	0.001
12:44:00	12	0.032	-
13:19 - Dump No. 1 occurred.			
13:21:15	0.5	0.038	-
13:21:50	24	0.056	0.001
13:23:15	24	0.054	-
13:23:30	0.5	0.11	0.001
13:23:50	24	0.096	0.001
13:25:00	24	0.19	0
13:25:30	24	0.20	-
13:26:00	24	0.19	-
13:26:30	0.5	0.040	-
13:27:00	24	0.24	0.001
13:27:15	24	0.16	-
13:28:00	24	0.23	0.001
13:28:30	24	0.20	-
13:30:30	24	0.24	0.001
13:32:30	24	0.23	0.001
13:34:30	24	0.087	-
13:36:30	24	0.17	-
13:38:00	22	0.060	0.001
13:41:30	22	0.10	-
13:42:15	0.5	0.050	-
13:52:30	24	0.097	-
14:10:30	24	0.094	-
14:31:30	24	0.073	-
14:52:30	24	0.084	-
14:53:30	24	0.082	-
15:23:55	0.5	0.076	-
15:24:30	24	0.079	-
15:32:30	0.5	0.068	-
15:41:30	0.5	0.045	-
15:42:00	24	0.098	0.001
15:42:30	0.5	0.12	-
15:43 - Dump No. 2 occurred.			
15:43:00	24	0.091	-
15:44:00	0.5	0.087	-
15:44:30	24	0.080	-
15:45:00	24	0.049	-
15:45:30	24	0.01*	0

(Continued)

Table 480 (Concluded)

Time hr:min:sec)	Depth (m)	Soluble Ortho P (mg P/l)	
		$\overline{X}$	SD
15:46:00	24	0.12	-
15:46:30	24	0.047	0.001
15:46:45	24	0.084	0
15:47:00	24	0.17	0
15:47:15	24	0.044	0.001
15:47:15	0.5	0.28	0.001
15:47:30	24	0.034	0.001
15:47:45	24	0.11	0.001
15:48:00	24	0.11	0.001
15:48:15	24	0.14	0.001
15:48:30	24	0.17	0.001
15:48:45	24	0.14	0.001
15:49:30	24	0.17	0.001
15:50:30	24	0.18	0.001
15:51:45	24	0.19	0.001
15:52:30	24	<0.22*	0
15:54:30	0.5	0.29	0
15:55:00	24	0.15	0
15:59:30	24	0.20	0.001
16:10:00	0.5	0.086	0.001
16:10:30	24	0.22	0.001
16:10:30	24	0.17	0
16:25:30	0.5	0.15	0.001
16:26:00	24	0.18	0.001

Mean and standard deviation calculated from duplicate analyses of one sample.

Dash indicates only one sample was analyzed.

*At time of analysis, there was material suspended in the sample. Therefore, it was refiltered through a 0.2 μ pore size membrane filter.

soluble ortho P concentrations in the bottom waters at the <u>Hudson</u> lasted for about 5 minutes and then fluctuated between 0.037 and 0.075 mg P/l for about 45 minutes.

There were not enough mid-depth samples collected from the <u>Hatton</u> to characterize the water column during hopper dredge sediment disposal. However, from samples collected from the <u>Hudson</u>, it was apparent that there was neither an increase

Table 481

Soluble Orthophosphate Concentrations: New York Bight Dump No. 1, Dredged Material from Perth Amboy Channel

(Collected from the Hudson)

Time hr:min:sec)	Depth (m)	Soluble Ortho P (mg P/l) $\overline{X}$	 SD
12:51:20	1	<0.01	-
12:52:55	12	<0.01	-
12:52:55	23	0.011	-
12:55:30	1	<0.01	-
12:55:35	12	0.014	-
12:55:45	23	0.049	-
13:01:25	1	0.012	-
13:01:35	23	0.038	0.001
13:01:55	12	<0.01	-
13:19- Dump No. 1 occurred.			
13:21:50	1	0.010	-
13:22:05	12	0.022	-
13:22:10	23	<0.01	-
13:26:00	1	<0.01	-
13:26:35	23	0.034	-
13:26:55	12	<0.01	-
13:27:25	23	0.024	-
13:27:55	23	0.16	-
13:28:00	12	<0.01	-
13:28:30	23	0.093	0
13:28:50	1	0.028	-
13:29:10	23	0.064	-
13:29:45	12	0.032	-
13:29:55	23	0.13*	0
13:30:35	23	0.033	-
13:30:45	12	0.014	-
13:31:15	23	0.067	-
13:31:50	23	0.061	-
13:32:00	1	0.028	-
13:32:30	23	0.057	-
13:32:45	12	0.031	-
13:33:10	23	0.047	-
13:33:45	23	0.091	-
13:34:30	23	0.059	-
13:35:30	23	0.037	-
13:36:05	1	0.025	0
13:36:10	12	0.012	-
13:36:25	23	0.071	-
13:38:20	23	0.072	-

(Continued)

Table 481 (Concluded)

Time (hr:min:sec)	Depth (m)	Soluble Ortho P (mg P/l)	
		X̄	SD
13:52:00	1	0.021	-
13:52:00	12	0.022	-
13:52:00	23	0.060	-
14:00:00	23	0.044	-
14:12:00	23	0.075	-
14:20:55	1	<0.01	-
14:21:15	12	0.029	-
14:21:15	23	0.043	-
14:31:05	1	0.016	-
14:31:25	12	0.042	-
14:31:30	23	0.031	0
14:58:55	1	01025	-
14:58:35	12	0.031	-
14:59:30	23	0.038	0.001

Mean and standard deviation calculated from duplicate analyses of one sample.

Dash (-) indicates only one sample was analyzed.

*Sample refiltered through 0.2 μ pore size membrane filter prior to analysis.

in turbidity nor a substantial increase (to 0.034 mg P/l) in soluble ortho P.

There did appear to be an increase in soluble ortho P concentrations (to 0.11 mg P/l) in the surface water samples collected on the Hatton a few minutes after Dump No. 1. This is likely to be spurious since there was no corresponding increase in turbidity. There appeared to be no increase in soluble ortho P in the surface waters near the Hudson during monitoring.

Dump No. 2

When monitoring of New York Bight Dump No. 1 was completed, the Hudson repositioned down surface current from the disposal area for the monitoring of the second disposal operation. During Dump No. 2, 2,500 cubic yards of material dredged by clamshell dredge from the Perth Amboy Anchorage were dumped, by scow, at the mud dump site. Figure 158 shows the physical setting during this dump in which the Hudson was positioned down surface current, and the Hatton, down bottom current from the dump location. The captain of the tow boat was instructed to tow the scow between the two boats and dump upon command.

Water column optical properties. Tables 469 and 482 present the turbidity values for water samples collected aboard the Hatton and Hudson, respectively during Dump No. 2. It appears from these tables and Figures 145 and 159 that the only significant increase in turbidity occurred in the near bottom water at the Hatton. It took in excess of 40 minutes for the turbid plume near the bottom to pass the Hatton's location.

Examination of the near bottom percent light transmission data (Figure 160)obtained by Gordon's group aboard the Hatton shows that the bottom water tubidity had returned to essentially pre-dump levels by about 0.5 hrs after the dump. Figure 161 shows that at the position of the Hatton, no increased turbidity was observed in the surface waters. However, the waters below 9 m did show several periods of decreased percent light transmission, indicating the passage of the turbid plume. The percent light transmission values are highly variable at this location, indicating a billowing characteristic of the turbid plume.

Since the Hudson was positioned down surface current from the dump site, the transmissometer was fixed at the 3 m depth to monitor near surface percent light transmission during the passage of the turbid plume. The data are presented in Figure 162. Essentially no change was observed at the 3 m depth during Dump No. 2. These results indicate that the suspended sediment associated with the dump moved with the bottom currents, below the thermocline, from the dump site. Little or no increase in surface water turbidity was noted at either sampling site.

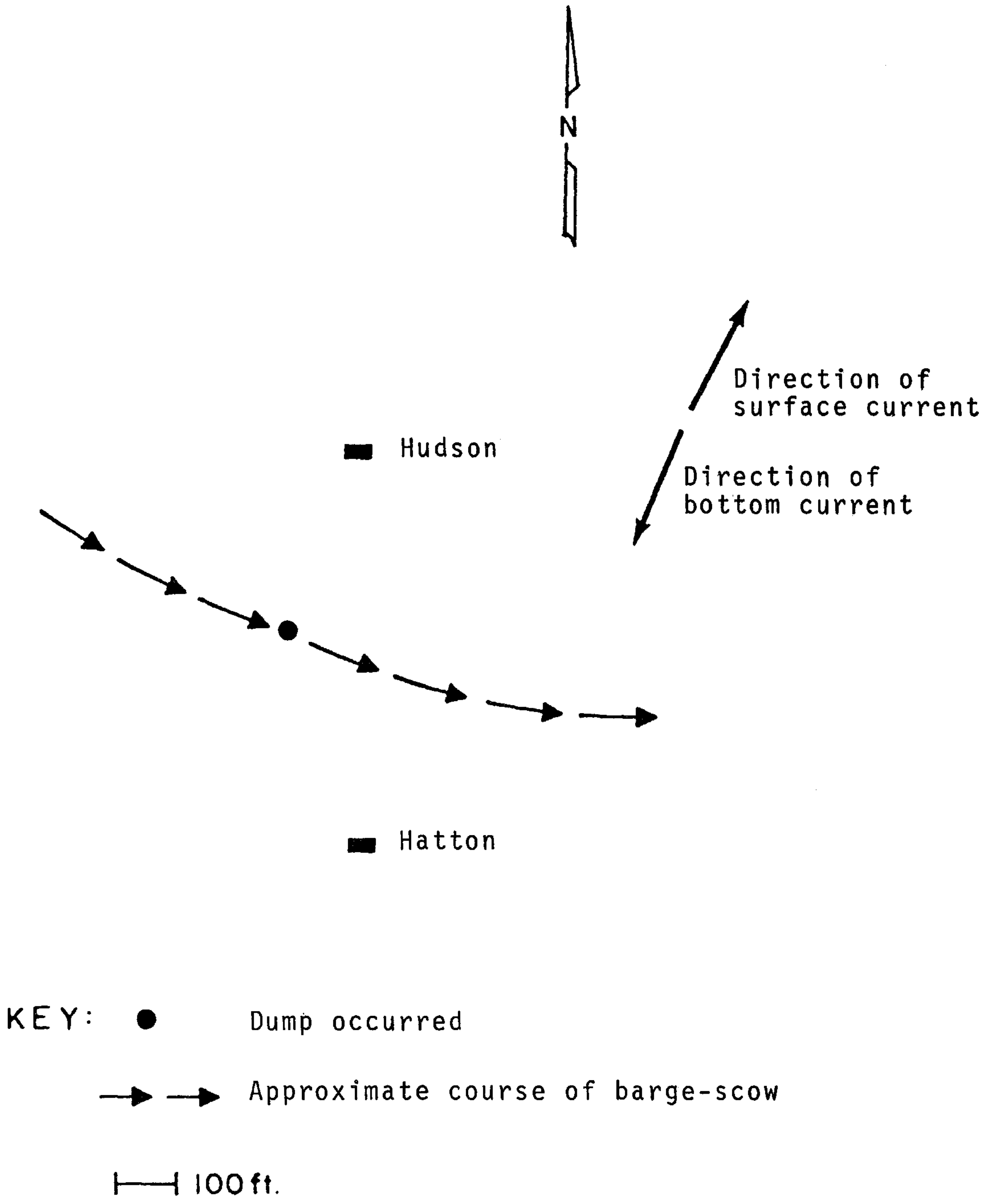

Figure 158

Positions of Sampling Vessels at Mud Dump Site During Monitoring of New York Bight Dump No. 2

Table 482

Turbidity Values: New York Bight Dump No. 2,

Material Dredged from Perth Amboy Anchorage

(Collected from the *Hudson*)

Time (hr:min:sec)	Depth (m)	Turbidity (NTU)
15:35:00	12	1
15:35:30	1	1
15:36:00	23	27
15;43 - Dump No. 2 occurred.		
15:44:20	12	1
15:44:30	1	1
15:44:45	23	33
15:47:10	12	0.6
15:47:30	23	27
15:47:30	1	0.5
15:51:05	1	1
15:51:20	23	44
15:51:40	12	0.5
15:52:00	1	1
16:16:55	1	0.7
16:17:15	12	0.8
16:17:15	23	8
16:18:15	23	7
16:19:15	23	2
16:19:30	1	0.6
16:20:00	12	0.5
16:20:20	23	23

Currents. Table 483 shows the effects of the dump on the bottom currents at the *Hatton's* position. The results were similar to those seen during Dump No. 1. There was a surge in current velocity as the bottom plume passed the sampling vessel. The peak speed, 2.1 knots, was observed 2 minutes after disposal. As with Dump No. 1, the direction of the current fluctuated slightly during monitoring.

Dissolved oxygen, temperature, salinity, and pH. Material mechanically dredged from the Perth Amboy Anchorage was disposed of at 15:43 hrs. Pre- and post-disposal D.O., temperature, salinity, and pH profiles were made at the *Hatton*. The data presented in Table 484 and Figures 163 and 164 show

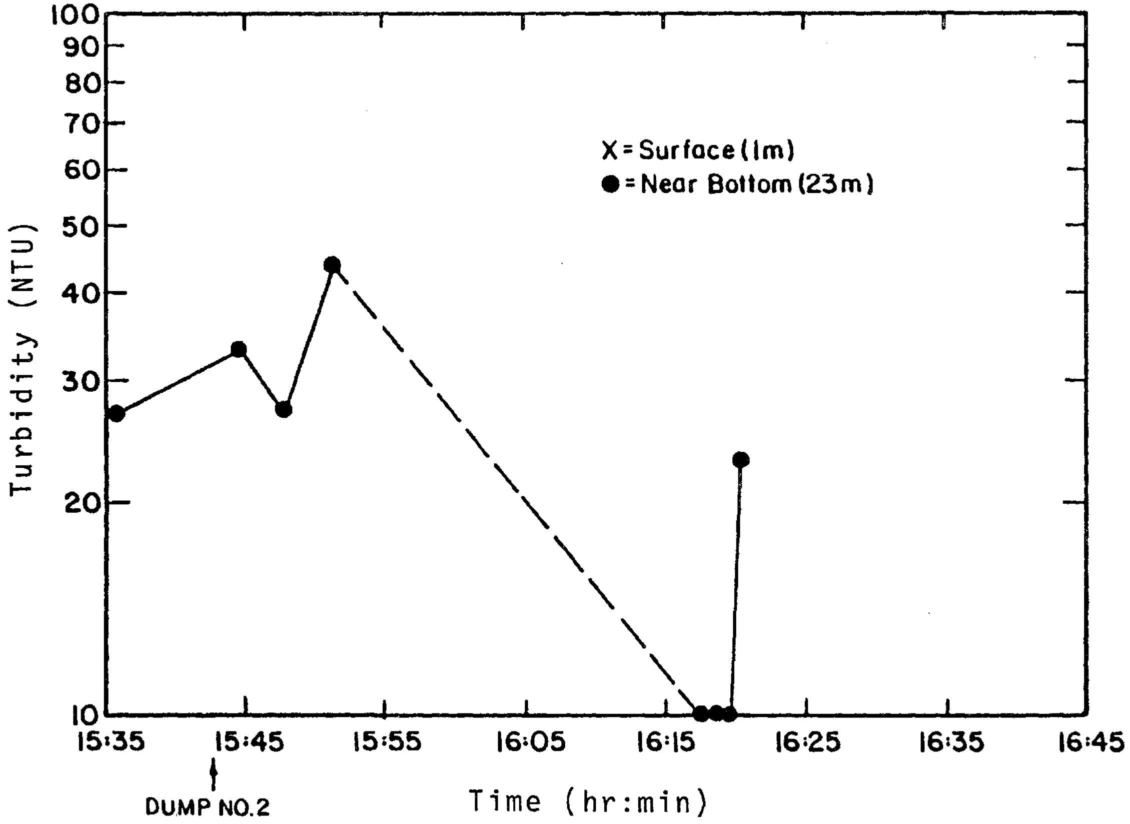

Figure 159
Turbidity in Surface and Near Bottom Water during
New York Bight Dump No. 2 - Hudson

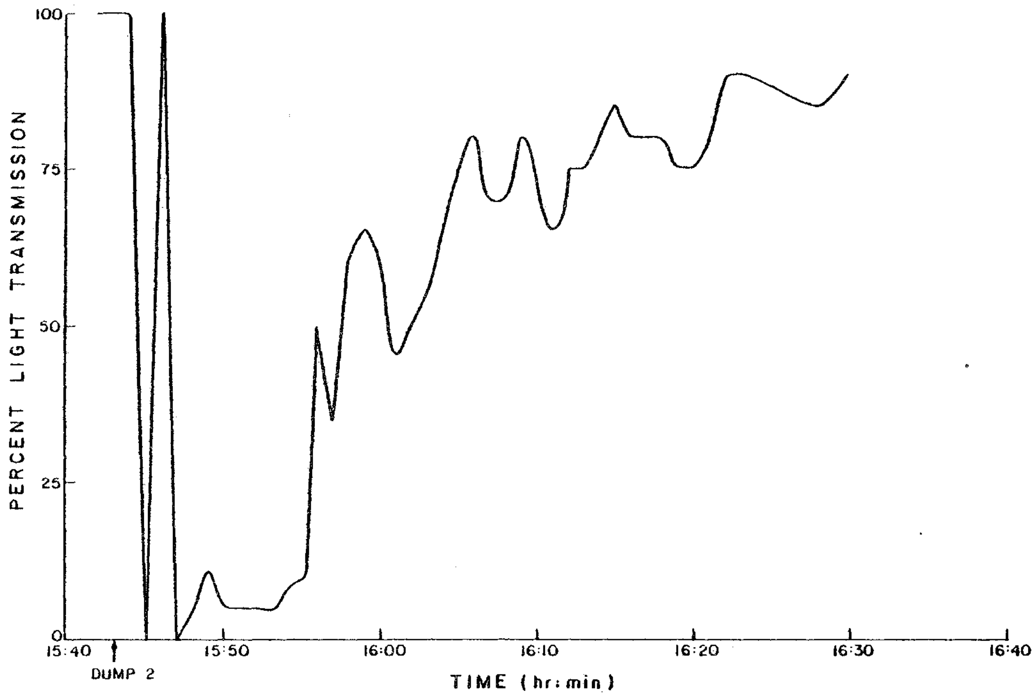

Figure 160
Percent Light Transmission in Near Bottom Water as a Function of Time during New York Bight Dump No. 2 - <u>Hatton</u>
(2 cm path length)

From data provided by R. Gordon

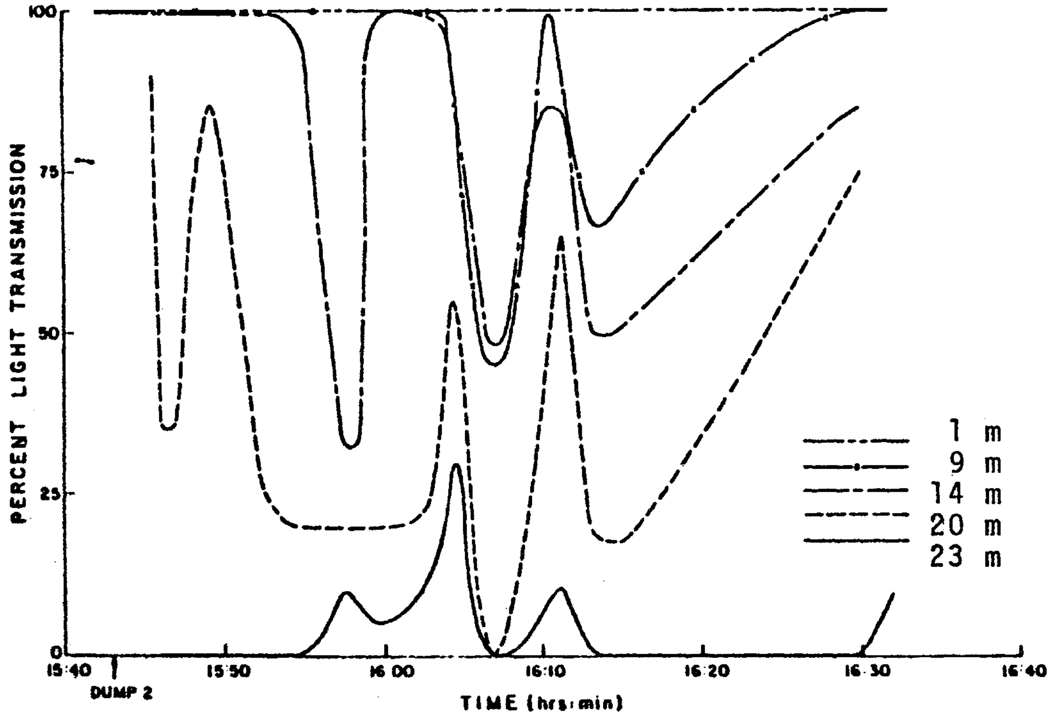

Figure 161

Percent Light Transmission as a Function of Depth and Time during New York Bight Dump No. 2 - Hatton (12 cm path length)

From data provided by R. Gordon

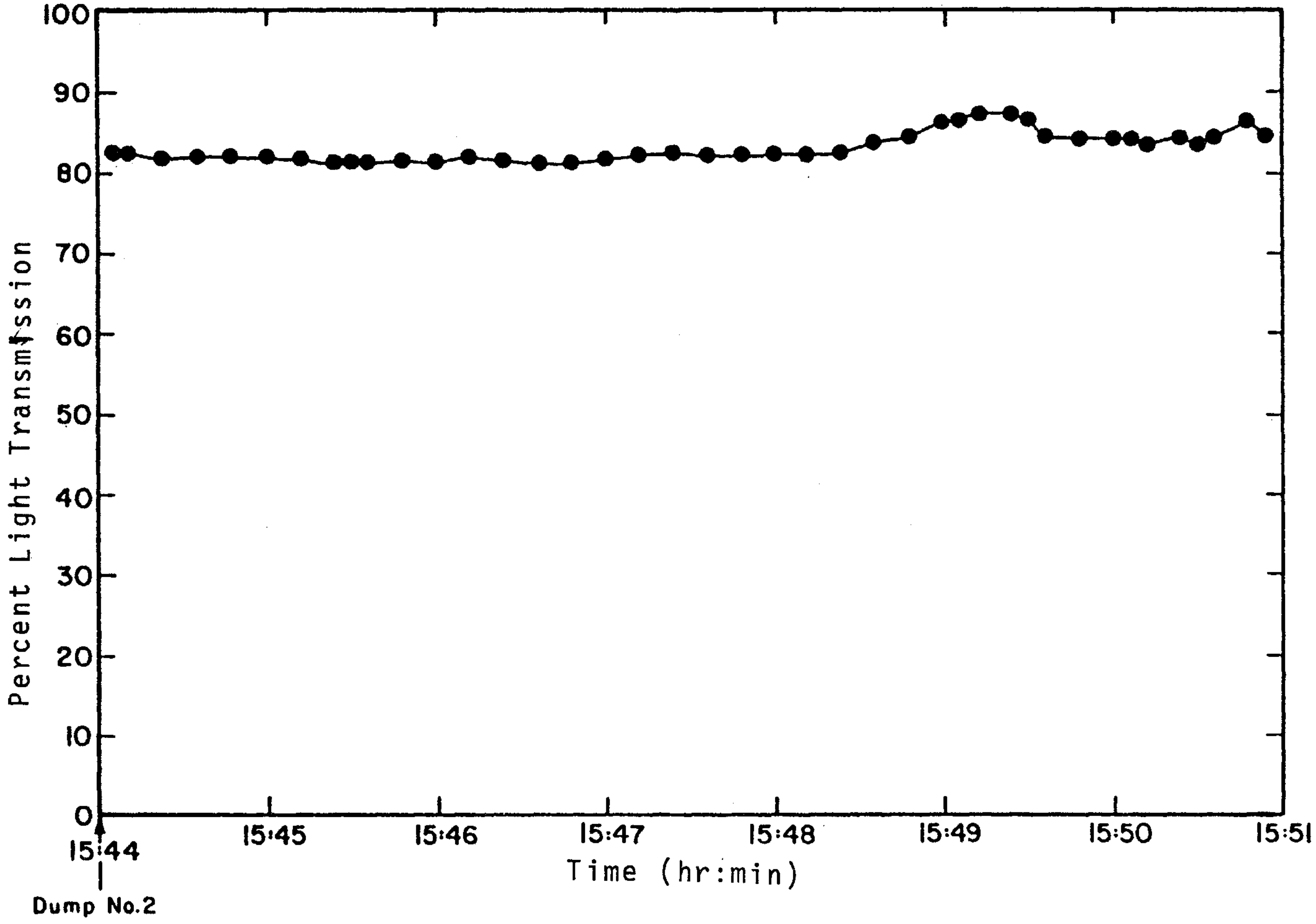

Figure 162

Percent Light Transmission during New York Bight Dump No. 2

Depth - 3 meters - Hudson

Table 483

Bottom Current Velocity and Direction:*

New York Bight Dump No. 2

Time (hr:min:sec)	Speed (knots)	Direction (°magnetic)
15:35:00	0.33	225
15:37:00	0.38	260
15:38:00	0.46	265
15:39:00	0.55	280
15:40:00	0.41	175
15:41:00	0.39	153
15:42:00	0.34	146
15:42:30	0.26	130
15:43- Dump No. 2 began.		
15:43:30	0.25	140
15:44:00	0.31	172
15:44:18	0.38	230
15:44:36	0.80	228
15:45:00	2.10	219
15:45:18	1.20	210
15:45:30	0.60	195
15:46:00	0.30	219
15:46:30	0.46	211
15:47:00	0.41	190
15:47:30	0.23	190
15:48:00	0.12	142
15:48:30	0.13	170
15:49:00	0.18	190
15:50:00	0.31	204
15:52:00	0.22	230
15:58:00	0.30	180

---

*Current meter set at 27 m, 1 m off bottom.

no appreciable difference between these profiles. As shown in Figure 165 , the D.O. at 24.5 increased to 3.2 mg/l from 1.3 mg/l (the background level) six minutes after disposal. There was a steady decrease in D.O. levels thereafter. By 16:00 hrs, they returned to 1.4 mg/l.

The D.O., temperature, and pH profiles made aboard the Hudson are presented in Table 485 . While infrequent measurements were made at any single depth, from the data

Table 484

Pre- and Post-Disposal Water Column Profile: New York Bight Dump No. 2, Dredged Material from Perth Amboy Anchorage

Destination and Time	Depth (m)	Temp (°C)	D.O. (mg/l)	Salinity (°/oo)	pH
Pre-Disposal (15:30)					
	0.5	20	9.6	30.5	8.2
	3	20	9.7	30.5	8.2
	6	19.5	7.2	30.5	8.1
	9	19	6.4	30,5	8,0
	12	18	6.3	31.2	7.8
	15	17	6.4	32.0	8.1
	18	15	5.4	31,2	8,0
	21	12,5	3,3	32.0	7.8
	24	11	1.4	32,8	7,6
	25	11	1.3	32.8	7.6
Post-Disposal (16:05)					
	0.5	20	9,3	30.5	8.4
	3	20	9.4	30.5	8,4
	6	19	7.7	30,5	8,3
	9	18	6.3	31.2	8,1
	12	17	5.8	32,8	8,2
	15	15.5	6.3	32,8	8.3
	18	14	4.6	32,8	8,1
	21	11,5	2.1	32.8	7,7
	24	11	1.3	32,8	7,8

available there were no significant changes in D.O. resulting from the dumping operations. The differences noted in the D.O. profiles pre- and post-Dump No. 2 (Figure 166) at the location of the Hudson, from 0.5 to 1 mg/l, are probably related to different water masses passing through the region and not associated with the dump. This is based on the fact that the Hudson was positioned down surface current from the dump and that the pre- and post-dump surface concentrations were essentially the same.

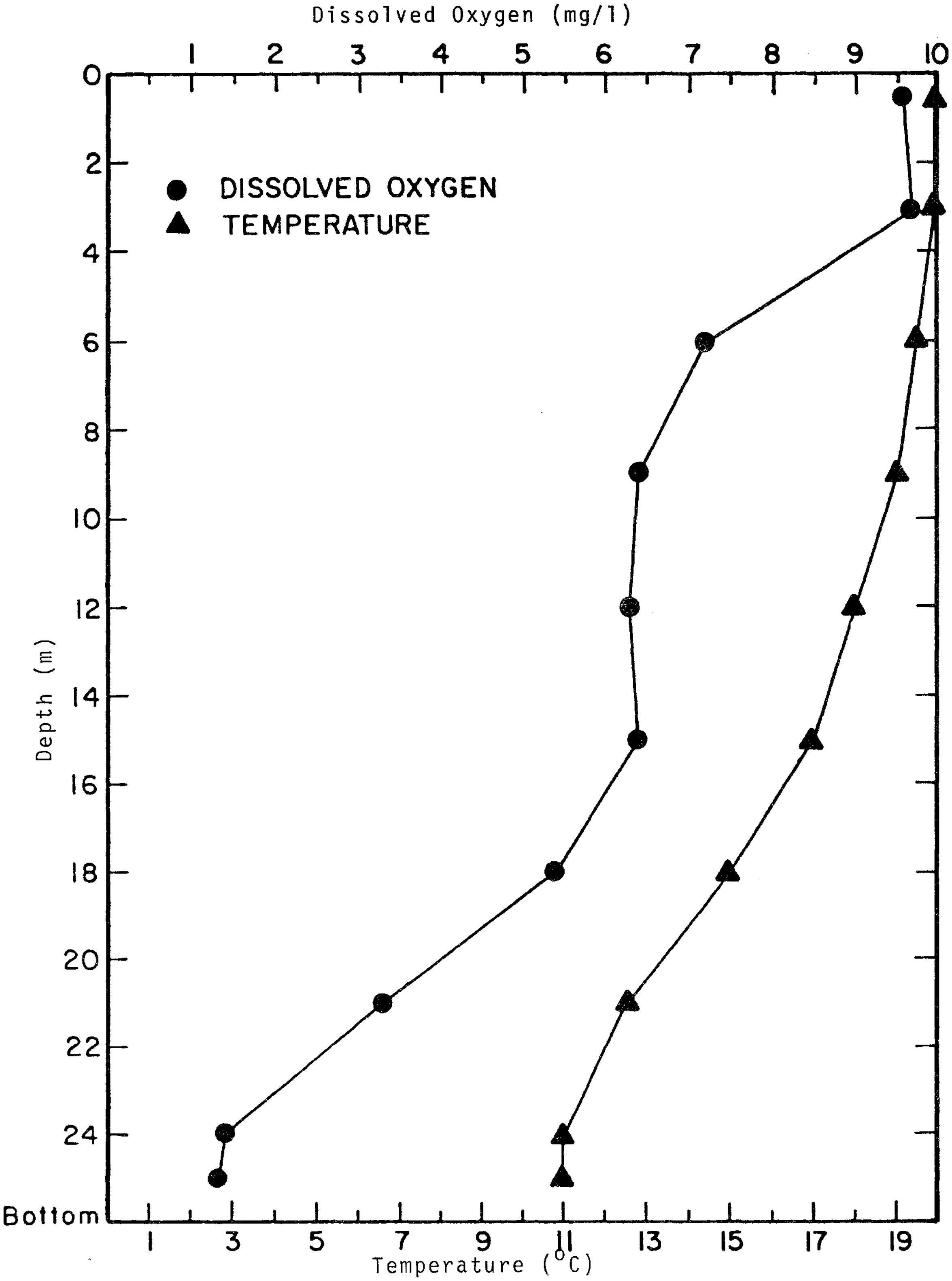

Figure 163

Pre-Disposal Water Column Temperature and Dissolved Oxygen Profiles: New York Bight Dump No. 2 Hatton

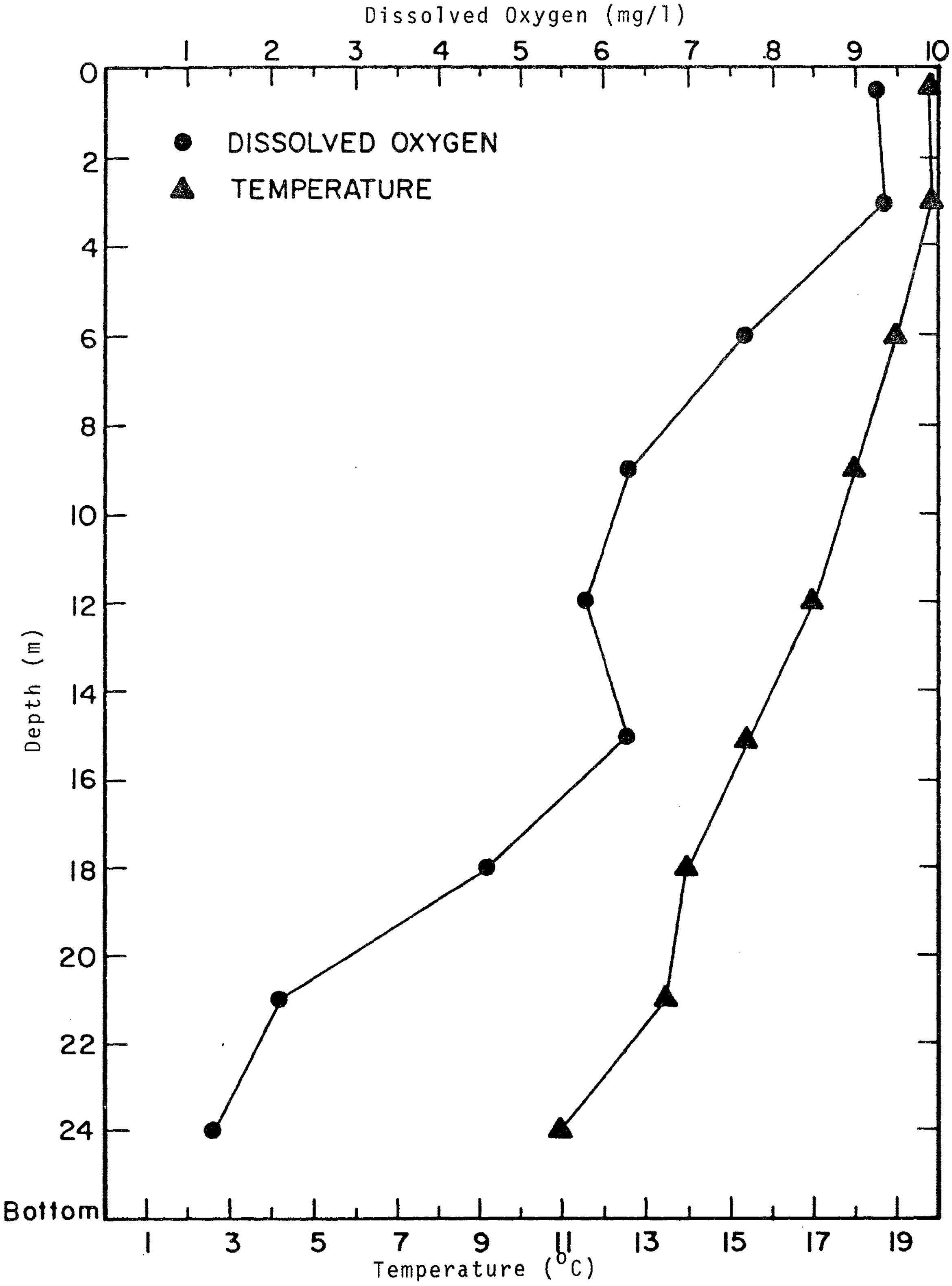

Figure 164
Post-Disposal Temperature and Dissolved Oxygen Water Column Profiles: New York Bight Dump No. 2 - Hatton

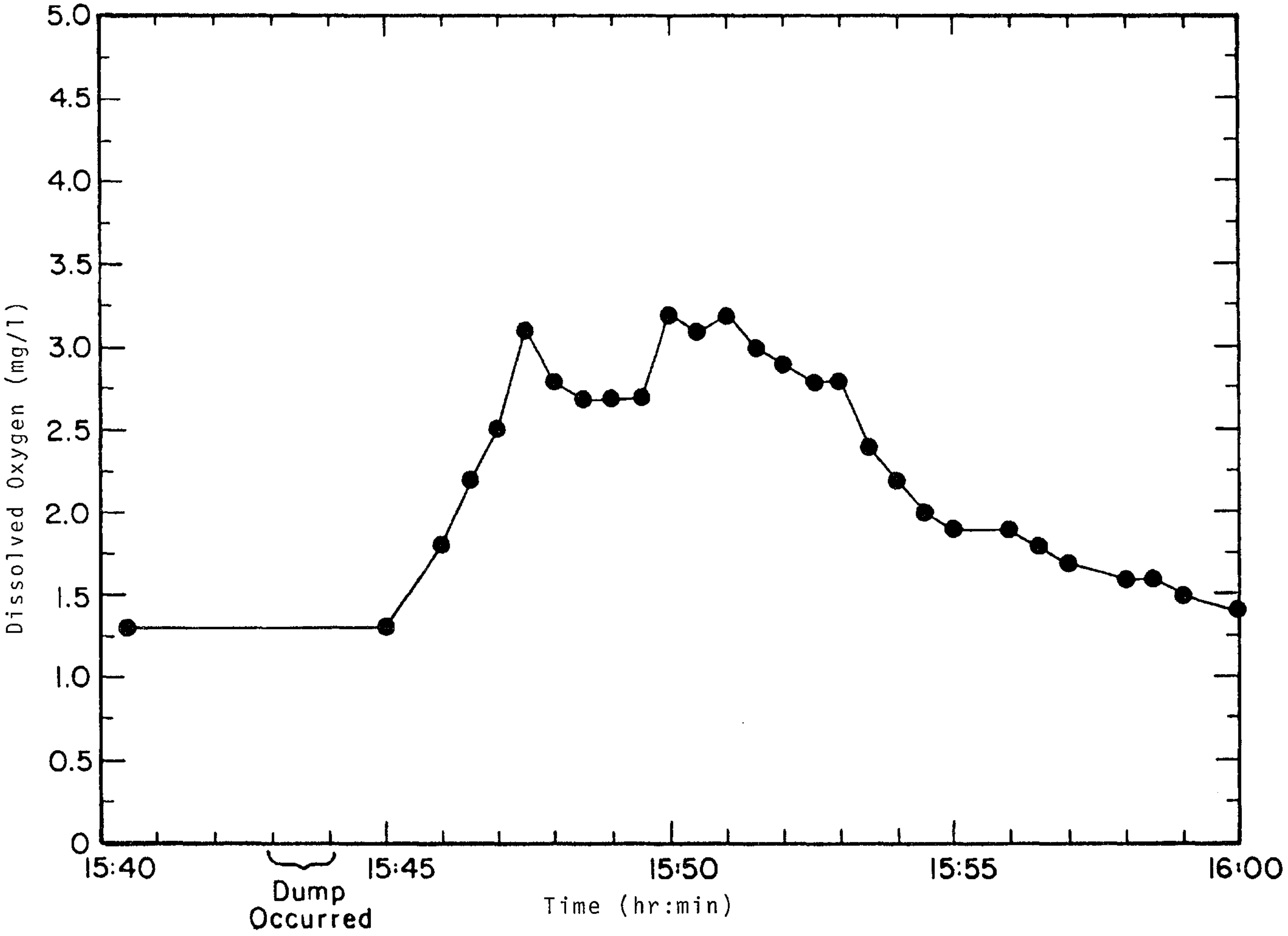

Figure 165

Dissolved Oxygen: New York Bight Dump No. 2

Depth 24.5 meters Hatton

Table 485

Dissolved Oxygen, Temperature, and pH Profiles*

New York Bight Dump No. 2

(Collected from the Hudson)

Time (hr:min)	Depth (m)	Dissolved Oxygen (mg/l)	Temperature (°C)	pH
15:32	1	9.5	19.6	8.0
	2	9.7	19.6	8.0
	3	9.6	19.6	8.0
	4.5	8.8	18.9	8.0
	6	7.4	18.8	7.9
	8	6.8	18.7	7.9
	10	5.7	18.5	7.9
	12	4.4	17.3	7.8
15:36	14	6.1	17.0	7.8
	16	5.8	15.7	7.8
	17	4.3	13.8	7.6
	19	2.5	12.8	7.5
	21	0.75	11.4	7.4
	23	0	10.3	7.3
	15:44:30 - Dump No. 2 occurred.			
15:45	1	10.0	19.5	8.1
	2	10.2	19.5	8.1
	3	9.8	19.2	8.1
	3.5	9.1	19.1	8.0
	5.5	7.4	18.8	8.0
15:47	1	9.6	17.5	8.1
	2	9.9	19.4	8.1
	3	9.3	19.2	8.1
	4	8.6	19.1	8.1
	4.5	8.0	18.8	8.0
	5.5	7.7	18.8	8.0
	1	9.3	19.6	8.1
	2	9.2	19.5	8.1
	3	9.3	19.4	8.1
	4	8.8	19.3	8.1
	4.5	8.7	18.9	8.1
15:50	5.5	8.1	18.8	8.0
	1	8.8	19.5	8.1
	2	9.0	19.4	8.1
	3	8.8	19.2	8.1
	4	8.8	18.9	8.0
	4.5	8.2	18.8	8.0
15:52	5.5	7.4	18.8	8.0

(Continued)

Table 485 (Concluded)

Time (hr:min)	Depth (m)	Dissolved Oxygen (mg/l)	Temperature (°C)	pH
	1	8.6	19.4	8.1
	2	8.7	19.4	8.1
	3	8.1	19.4	8.1
	4	9.2	19.4	8.1
	4.5	9.1	18.9	8.0
15:58	5.5	9.1	18.8	8.0
16:13	1	9.8	19.5	8.1
	2	10.1	19.5	8.1
	3	9.9	19.4	8.1
	3.5	9.7	19.2	8.1
	4.5	9.2	18.9	8.1
	5.5	7.1	18.8	8.0
	1	9.5	19.5	8.1
	2	9.7	19.5	8.1
	3	9.1	19.4	8.1
	4.5	9.4	19.0	8.0
	6	7.2	18.8	8.0
	8	6.5	18.7	8.0
	10	4.8	17.9	7.9
	12	2.8	17.0	7.8
	14	4.9	16.5	7.8
	16	5.0	15.3	7.8
	17	3.9	13.7	7.6
	19	1.1	11.7	7.5
16:20	21	0	11.1	7.4

*Measurements made using PLESSEY Environmental Systems Environmental Profiling System Model 8500 Digital Display-owned and operated by Corps of Engineers, New York District.

<u>Heavy metals.</u> Tables 486 and 487 show the soluble heavy metals in the samples collected aboard the <u>Hatton</u> and the <u>Hudson</u> during Dump No. 2. Manganese concentrations prior to the disposal ranged from 17 to 100 µg/l in the near bottom water samples. These high concentrations were most likely related to the first dump. Two samples collected during passage of the turbid plume had concentrations of 93 µg/l manganese, indicating release of manganese. There was also a large release of iron. Background concentrations of iron ranged from less than 5 to 38 µg/l in the surface waters and

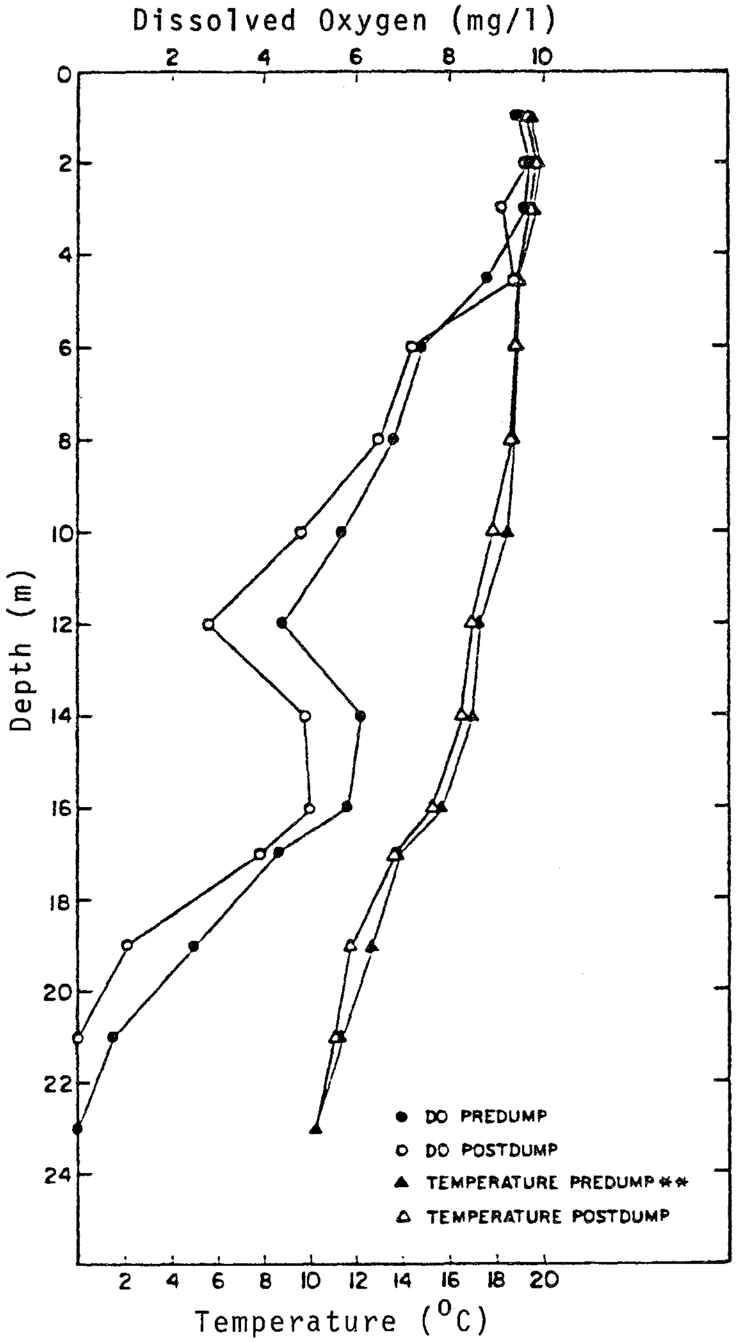

Figure 166

Pre- and Post-Dump Water Column D.O. and Temperature Profiles* New York Bight Dump No. 2 - Hudson

*Measurements made by COE personnel using PLESSEY profiling system.

Table 486

Soluble Heavy Metal Concentrations: New York Bight
Dump No. 2, Dredged Material from Perth Amboy Anchorage
(Collected from the Hatton)
(μg/l)

Time (hr:min:sec)	Depth (m)	Mn	Cd	Cr	Zn	Ni	Pb	Cu	Fe	Hg	As
15:41:30	0.5	100	0.8	<2	1.3	<2	3.5	<1	<5	<0.005	7.0
15:42:00	24	17	0.9	<2	2.5	<2	6.6	1.0	59	0.026	9.8
15:42:30	0.5	<10	<0.5	<2	<1	<2	3.5	<1	38	0.026	9.0
15:43:00	24	83	<0.5	2.3	<1	<2	3.5	<1	34	0.026	6.5
15:44:00	0.5	67	0.8	<2	2.9	<2	4.5	<1	4	<0.005	7.0
15:44:30	24	50	0.7	<2	1.6	<2	4.5	<1	100	0.026	8.7
			15:44:30 - Dump Occurred.								
15:45:00	24	67	<0.5	2.0	<1	<2	4.5	<1	35	<0.005	11.0
15:45:30	24	<10	<0.5	<2	<1	<2	1.8	<1	1301	0.026	11.5
15:46:00	24	83	1.0	<2	<1	<2	5.6	<1	1315	<0.005	11.0
15:46:30	24	<10	1.5	2.0	21.0	<2	<1	<1	1396	0.015	9.2
15:46:45	24	44	2.2	<2	11.5	7.4	12.1	2.1	23	<0.005	6.6
15:47:00	24	93	<0.5	2.8	29.0	<2	<1	1.9	68	<0.005	6.1
15:47:15	24	11	1.3	<2	10.1	6.7	22.4	1.4	1418	0.015	11.8
15:47:15	0.5	11	0.9	<2	2.7	6.7	8.7	<1	24	0.139	6.8
15:47:30	24	44	1.9	<2	4.4	<2	11.5	4.6	1965	<0.005	9.2
15:47:45	24	<10	2.2	<2	<1	8.0	8.2	<1	1250	<0.005	12.5
15:48:00	24	<10	0.9	3.2	<1	7.1	6.2	<1	1074	<0.005	12.7
15:48:15	24	<10	0.9	<2	<1	7.6	8.1	<1	1732	<0.005	12.7
15:48:30	24	<10	2.0	<2	15.9	4.4	10.4	<1	202	0.051	5.6
15:48:45	24	44	1.8	2.4	3.7	9.7	13.0	4.5	28	<0.005	11.1
15:49:30	24	<10	2.5	2.4	16.6	<2	<1	<1	78	<0.005	9.4
15:50:30	24	<10	<0.5	2.4	25.9	<2	<1	<1	127	<0.005	11.5
15:51:45	24	60	0.9	2.7	<1	8.1	5.3	<1	110	0.015	8.0
15:52:30	24	93	<0.5	2.4	17.6	11.0	7.8	<1	1089	<0.005	10.6
15:54:30	0.5	60	0.7	5.6	4.9	3.4	13.8	<1	23	<0.005	6.1
15:55:00	24	<10	0.7	2.0	25.1	<2	<1	<1	176	0.006	10.4
15:59:30	24	28	2.5	2.0	26.2	3.7	4.0	2.1	88	<0.005	12.0
16:10:00	0.5	<10	<0.5	3.6	291	<2	5.7	<1	26	<0.005	8.9
16:10:30	24	28	0.5	2.4	25.7	10.0	2.7	4.0	99	<0.005	9.2
	24	<10	1.1	3.2	<1	9.7	6.0	4.4	104	0.068	7.1
16:25:30	0.5	<10	1.0	<2	1.4	5.4	5.3	<1	414	<0.005	8.0
16:26:00	24	44	<0.5	<2	<1	2.7	<1	8.3	88	0.015	9.4

Table 487

Soluble Heavy Metal Concentrations: New York Bight
Dump No. 2, Dredged Material from Perth Amboy Anchorage
(Collected from the Hudson)
(μg/l)

Time (hr:min:sec)	Depth (m)	Mn	Cd	Cr	Zn	Ni	Pb	Cu	Fe	Hg	As
15:35:00	12	11	< 0.5	< 2	8.1	1.7	< 1	1.4	< 5	0.020	< 2
15:35:30	1	28	< 0.5	< 2	5.1	< 2	< 1	2.6	40	0.020	5.4
15:36:00	23	93	< 0.5	< 2	25.4	< 2	< 1	3.5	36	0.030	6.3
15:44:20	12	< 10	< 0.5	< 2	55.5	6.5	< 1	< 1	14	0.014	-
15:44:30	1	52	< 0.5	< 2	8.8	3.7	1.7	< 1	5	0.014	-
15:44:45	23	20	< 0.5	< 2	9.7	< 2	1.7	1.6	42	0.030	-
15:47:10	12	52	< 0.5	< 2	2.6	3.7	3.6	< 2	20	<0.005	-
15:47:30	23	< 10	< 0.5	< 2	8.9	3.6	2.5	< 1	41	0.014	-
15:47:30	1	488	< 0.5	4.1	< 1	5.7	2.6	1.6	6	0.020	20.5
15:51:05	1	< 10	< 0.5	4.8	< 1	7.1	2.1	1.3	11	-	
15:51:20	23	20	0.7	< 2	10.9	3.9	2.5	2.0	120	0.135	-
15:51:40	12	60	< 0.5	2.3	< 1	1.1	2.1	< 1	6	0.055	4.4
15:52:00	1	< 10	< 0.5	2.7	< 1	5.1	4.9	1.1	7	0.055	22.9
16:16:55	1	60	< 0.5	< 2	< 1	4.9	3.0	1.0	13	-	4.4
16:17:15	12	< 10	< 0.5	< 2	44.2	4.4	2.5	< 1	10	0.135	-
16:17:15	23	20	< 0.5	< 2	8.1	3.1	2.0	< 1	24	0.014	-
16:18:15	23	52	< 0.5	< 2	3.8	1.1	1.1	< 1	24	0.135	-
16:19:15	23	36	< 0.5	< 2	8.4	1.4	1.4	< 1	<5	0.135	-
16:19:30	1	< 10	< 0.5	< 2	14.1	3.0	2.9	< 1	13	-	4.9
16:20:00	12	< 10	< 0.5	< 2	9.7	5.6	< 1	< 1	8	-	6.8
16:20:20	23	< 10	< 0.5	< 2	14.9	1.4	3.6	< 1	53	0.014	-

Dash (-) indicates not analyzed.

34 to 59 µg/l in the near bottom water. Iron release showed two peaks: 1396 µg/l 2 minutes after disposal and 1965 µg/l (at 15:47:30 hrs). Zinc was released in three waves. The zinc concentrations ranged from 10.1 to 29 µg/l in the first wave (between 2 and 3 minutes after disposal), from 3.7 to 25.9 µg/l in the second wave (between 4 and 5.5 minutes after disposal), and from 17.6 to 26.2 µg/l in the third wave (from 8 to 26 minutes after disposal). This wave-like pattern followed the general patterns seen for changes in percent light transmission during passage of the turbid plume. The 291 µg/l value of zinc in the surface sample collected at 16:10:00 hrs was likely due to contamination during sampling or analysis.

Cadmium, chromium, nickel, lead, arsenic, mercury, and copper were released in small amounts. Maximum concentrations were 2.5 µg/l cadmium, 5.6 µg/l chromium, 11.0 µg/l nickel, 22.4 µg/l lead, 12.7 µg/l arsenic, 0.051 µg/l mercury, and 8.3 µg/l copper. The single surface concentration of 0.139 µg/l mercury was also likely a result of contamination.

Table 487 shows the soluble metals in samples collected at the Hudson, which was down surface current from the dump. One surface sample collected three minutes after the dump had a high concentration of manganese, 488 µg/l and a slightly elevated arsenic concentration, 20.5 µg/l. Other surface water samples had metals concentrations generally in the background range or slightly above it. Some near bottom water samples showed elevated iron concentrations, up to 120 µg/l at seven minutes after the dump.

Nitrogen compounds. The surface water ammonium concentration at the Hatton during Dump No. 2 was not affected by the dump. As shown in Table 488, in the bottom water, ammonium rose sharply one minute after the disposal, followed by three increases and a leveling off near ambient concentration after about 40 minutes. Higher ammonium concentrations were found

Table 488

Ammonium and Nitrate Data: New York Dump No. 2

(Collected from the Hudson)

(mg N/l)

Time (hr:min:sec)	Depth (m)	Ammonium (mg N/l)	Nitrate
15:35:00	12	0.14	<0.04
15:35:30	1	0.06	<0.04
15:36:00	23	0.17	<0.04
15:44:30 - Dump No. 2 occurred.			
15:44:30	1	0.16	0.05
15:44:45	23	0.19	0.05
15:47:10	12	0.11	0.05
15:47:30	23	0.16	0.05
15:47:30	1	0.12	<0.04
15:51:05	1	0.10	<0.04
15:51:20	23	0.05	0.05
15:51:40	12	0.11	<0.04
15:52:00	1	0.11	<0.04
16:17:15	23	0.22	0.05
16:18:15	23	0.13	0.05
16:19:15	23	0.18	0.05
16:20:20	23	<0.05	0.05

during Dump No. 2 than during Dump No. 1. Nitrate concentrations were again below the detection limit of 0.04 mg N/l for all samples collected. Dump No. 2 appeared to have no effect on the ammonium and nitrate concentrations in the water column near the Hudson.

Phosphorus compounds. During Dump No. 2, the soluble ortho P concentrations (Table 480) of the Hatton's bottom water samples fluctuated greatly but appeared to increase overall. As with the other chemical parameters, the fluctuations in phosphorus seemed to follow the wave-like character of the turbid plume. This fluctuation and increase roughly corresponded to changes in percent light transmission and turbidity level. Concentrations rose from the pre-disposal range of 0.08 to 0.1 mg P/l to as high as 0.22 mg P/l after the dump. Forty minutes after the dump, the concentrations near bottom had not returned to pre-disposal levels.

In the near bottom waters, near the Hudson (Table 489), there appeared to have been some release of soluble ortho P following the dump; however, there was no corresponding increase in turbidity. There also appeared to be a slight increase in mid-depth water, from 0.046 mg P/l before the dump to 0.11 mg P/l after it. Again, this increase may have been spurious or related to a factor other than turbidity since the turbidity did not increase in the mid-depth waters during the disposal operation.

The surface turbidity did not appear to have increased at either sampling location during Dump No. 2. There did appear to be a slight increase of soluble ortho P in the surface water at both locations following the dump. Near the Hatton, concentrations increased from 0.045 to 0.12 mg P/l before disposal to 0.28 mg P/l four minutes after the disposal. About 20 minutes later the concentration was found to be 0.086 mg P/l. Down surface current from the disposal at the Hudson the surface, pre-disposal soluble ortho P concentration was 0.021 to 0.031 mg P/l. The concentrations reached 0.17 mg P/l one minute after disposal but decreased to ambient levels three minutes later.

Dump No. 3

Hopper dredged material from Bay Ridge Channel was disposed of in New York Bight Dump No. 3 on September 1, 1976.

Table 489

Soluble Orthophosphate Concentrations: New York Bight Dump No. 2, Dredged Materials from Perth Amboy Anchorage

(Collected from the Hudson)

Time hr:min:sec)	Depth (m)	Soluble Ortho P (mg P/1) $\overline{X}$	 SD
15:35:00	12	0.046	0
15:35:30	1	0.021	-
15:36:00	23	0.055	-
15:43 - Dump No. 2 occurred.			
15:44:20	12	0.062	0
15:44:30	1	0.18	0
15:44:45	23	0.13	0.001
15:47:10	12	0.11	0.001
15:47:30	23	0.10	0.001
15:47:30	1	0.030	-
15:51:05	1	0.028	0
15:51:20	23	0.094	0.001
15:51:40	12	0.034	-
15:52:00	1	0.031	-
16:16:55	1	0.051	0.001
16:17:15	12	0.050	0
16:17:15	23	0.060	0
16:18:15	23	0.084	0.001
16:19:15	23	0.16	0
16:19:30	1	0.036	0
16:20:00	12	0.040	0
16:20:20	23	0.067	0

Mean and standard deviation claculated from duplicate analyses of one sample.

Dash (-) indicates only one sample was analyzed.

Figure 167 shows the locations of the two sampling vessels with respect to the path of the Essayons. The weather on this day was fair with air temperatures around 65°F (19°C). The seas were rolling with three to four foot swells, and some white caps were visible. By noon, the swells had increased in size to 12 to 15 ft.

The dredge released approximately half (3000 cu yds) of its load on a course northwest/southwest. It then turned and made a pass northeast/southwest and dumped the remainder of the load. These dumps are referred to as Dump Nos. 3A and 3B. The Hudson was located 60 m down bottom current from the Hatton. The direction of the currents during the dump were such that both sampling vessels were able to monitor the turbid plumes that occurred below the thermocline arising from both dumps.

Figures 168 and 169 present turbidity data for water samples collected near bottom during Dump No. 3 from aboard the Hatton and Hudson, respectively. This data, as well as turbidity values at other depths at these locations are presented in Tables 490 and 491. The data in the tables show that there was no discernible increase in turbidity in the surface waters at the locations of either of the sampling vessels. There appeared to have been one slightly elevated value at mid-depth at the Hudson, but there was no corresponding increase in mid-depth water at the Hatton. There appeared to have been three turbidity peaks in near bottom waters in association with Dump Nos. 3A and 3B. At the Hatton, the first two of these occurred four and eight minutes after Dump No. 3A; the third occurred five minutes after Dump No. 3B. Duration of these elevated concentrations were approximately 2, 11, and 25 minutes, respectively. Corresponding but less intense peaks were found at the Hudson; the time of the peaks at the Hudson lagged those at the Hatton by about two to 15 minutes.

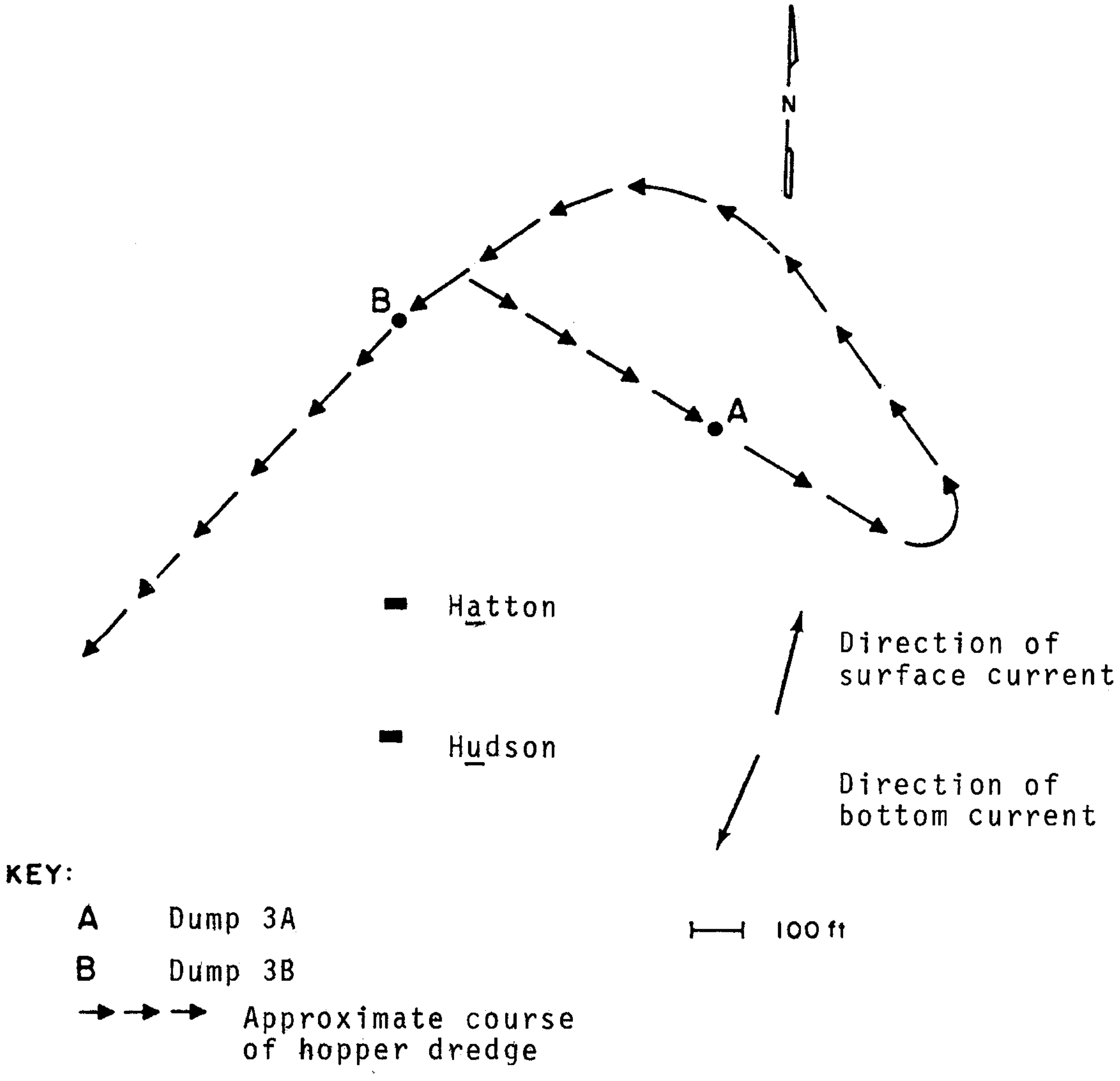

Figure 167

Positions of Sampling Vessels at Mud Dump Site During Monitoring of New York Bight Dump No.3

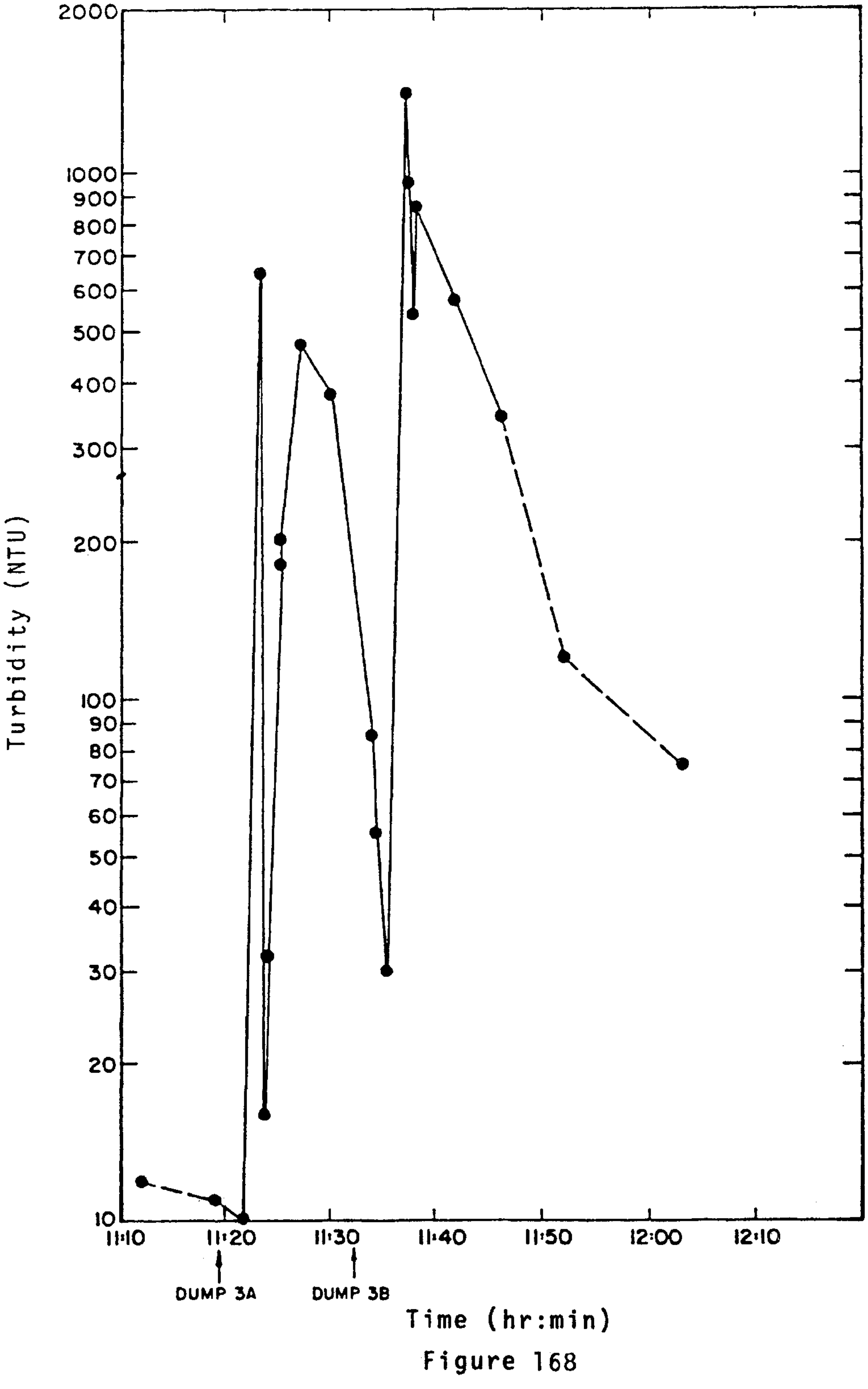

Figure 168

Turbidity in Near Bottom (24 m) Water During New York Bight Dump No.3 - Hatton

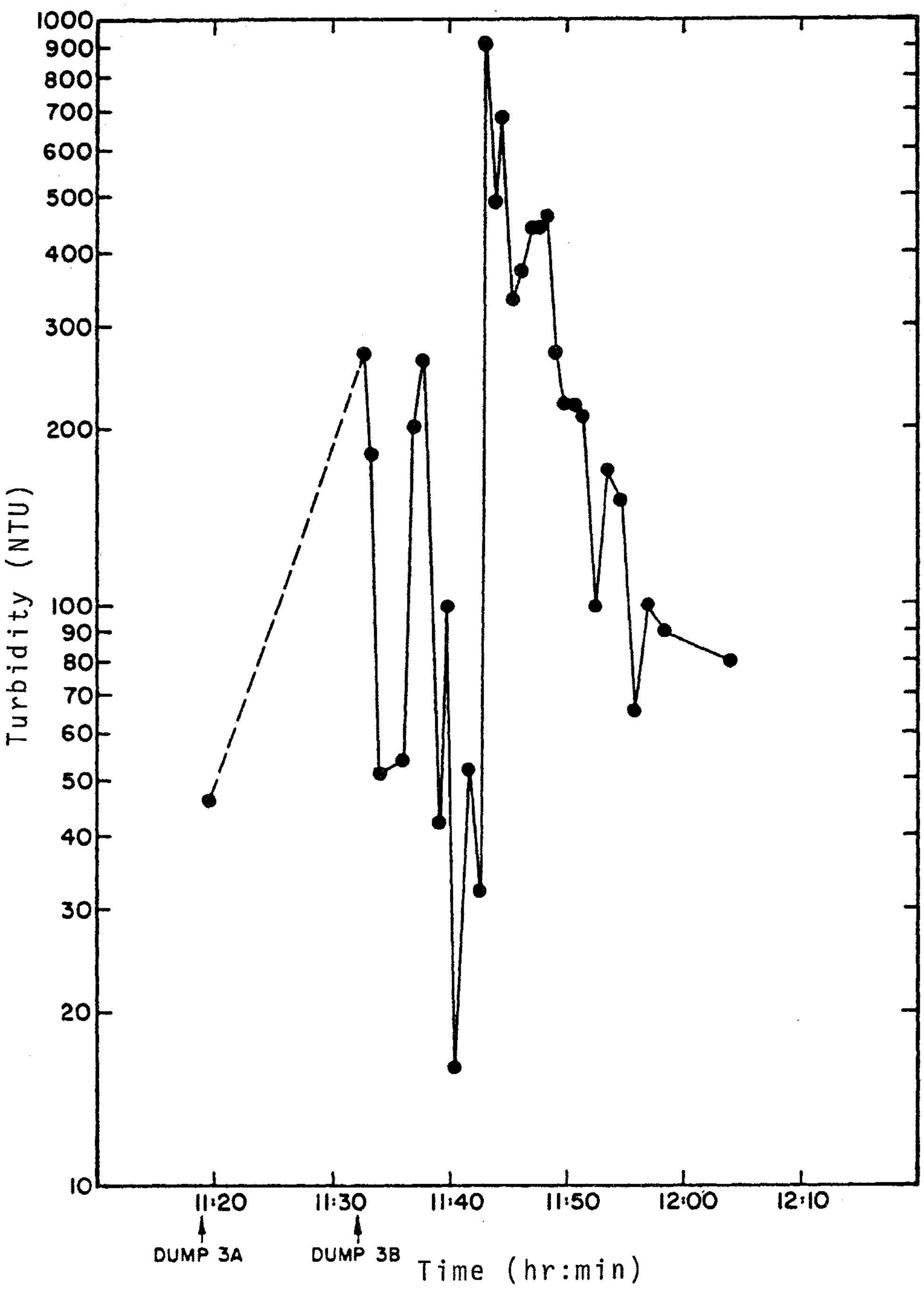

Figure 169
Turbidity in Near Bottom (23 m) Water during
New York Bight Dump No.3 - <u>Hudson</u>

Table 490

Turbidity Values: New York Bight Dump No. 3 Dredged Material from Bay Ridge Channel

(Collected from the *Hatton*)

Time (hr:min:sec)	Depth (m)	Turbidity (NTU)
11:11:00	0.5	0.6
11:11:45	12	0.5
11:12:10	24	12
11:18:15	0.5	0.6
11:18:45	12	0.5
11:19:00 - Dump No. 3A occurred.		
11:19:00	24	11
11:21:30	24	10
11:22:30	0.5	0.8
11:22:45	12	0.5
11:23:00	24	640
11:23:30	12	0.5
11:23:45	24	16
11:24:00	24	32
11:24:30	12	0.5
11:25:15	24	180
11:25:15	24	200
11:26:00	12	0.5
11:27:00	24	470
11:27:30	12	0.5
11:29:00	0.5	2
11:29:30	12	2
11:30:00	24	380
11:32:15 - Dump No. 3B occurred.		
11:32:30	0.5	0.5
11:32:45	12	0.5
11:33:00	24	-
11:33:45	12	2
11:34:00	24	86
11:34:20	12	0.7
11:34:40	24	56
11:35:00	12	1
11:35:30	24	30
11:36:00	12	2
11:36:15	24	-
11:36:45	12	0.5
11:37:00	24	1410

(Continued)

Table 490 (Concluded)

Time (hr:min:sec)	Depth (m)	Turbidity (NTU)
11:37:15	24	960
11:37:45	24	540
11:38:00	24	860
11:41:15	0.5	2
11:41:30	12	2
11:41:45	24	570
11:46:00	24	345
11:50:45	0.5	3
11:51:30	12	2
11:52:00	24	120
12:03:15	24	76

Dash (-) indicates no analysis made.

Figures 170 and 171 show the major trends in percent light transmission near bottom and at several other depths during Dumps Nos. 3A and 3B as monitored by Gordon's group aboard the Hatton. The patterns and times of decreases and increases in percent light transmission in the near bottom waters during the dump monitoring corresponded to the increases and decreases in turbidity as presented in Figure 168. As was indicated by the turbidity values, the percent light transmission in the surface water near the Hatton remained at 100 percent transmission during the monitoring period (Figure 171). The decrease in percent light transmission found at mid-depth at about 11:42 hrs was not reflected in the turbidity measurements because the decrease and increase to ambient levels was rapid, and mid-depth was not sampled at the time of the decreased light transmission. For all other times, percent light transmission was 100 percent in mid-depth waters.

Table 491

Turbidity Values: New York Bight Dump No. 3

Dredged Material from Bay Ridge Channel

(Collected from the Hudson)

Time (hr:min:sec)	Depth (m)	Turbidity (NTU)
	11:19:00 - Dump No. 3A occurred.	
11:19:30	1	0.5
11:19:35	12	0.5
11:19:40	23	46
	11:32:15 - Dump No. 3B occurred.	
11:32:50	23	270
11:32:59	12	0.3
11:33:15	23	185
11:34:00	23	52
11:35:55	12	0.4
11:35:55	23	54
11:36:00	1	0.5
11:37:00	23	200
11:37:10	12	0.3
11:37:40	23	260
11:38:25	12	160
11:39:05	23	42
11:39:50	23	100
11:40:30	1	0.5
11:40:35	23	16
11:41:20	12	0.4
11:41:25	23	52
11:42:20	23	32
11:43:00	23	900
11:43:45	23	480
11:44:35	23	680
11:45:15	23	330
11:46:00	23	370
11:47:00	23	440
11:47:35	23	440
11:48:20	23	460
11:49:05	23	270
11:49:50	23	220
11:50:45	23	220
11:51:35	23	210
11:52:30	23	100
11:53:30	23	170
11:54:25	12	0.7
11:54:32	1	0.6
11:54:32	23	150

(Continued)

Table 491 (Concluded)

Time (hr:min:sec)	Depth (m)	Turbidity (NTU)
11:55:50	23	65
11:57:05	23	100
11:58:20	23	90
12:04:05	12	1
12:04:10	23	80
12:04:40	1	0.6

The water column profiles of the percent light transmission near the Hudson before and after Dump No. 3 are presented in Figure 172. The water above 20 meters exhibited no detectable change after the dump. There was, however, a reduction of transmissibility below that depth. This follows the pattern seen during Dump No. 1 (Figure 150).

The transmissometer was kept at a fixed depth of 23 m to monitor the changes in percent light transmission at that depth. The plot of the data is presented in Figure 173. The fluctuations in percent light transmission prior to Dump No. 3B were the result of Dump No. 3A which occurred at 11:10 hrs. The low percent light transmission values found at about 11:25 hrs corresponded to increased turbidity at that depth at that time (Figure 169). The percent light transmission decreased from about 74 percent to zero within about two minutes of Dump No. 2B. It increased to 60 percent about four minutes later but returned to zero percent light transmission by about 11:40 hrs. These changes correspond to turbidity values found in the water samples collected at the Hudson (Figure 169). The clarity of these waters did not return to ambient levels during the monitoring period. The most likely explanation was that the

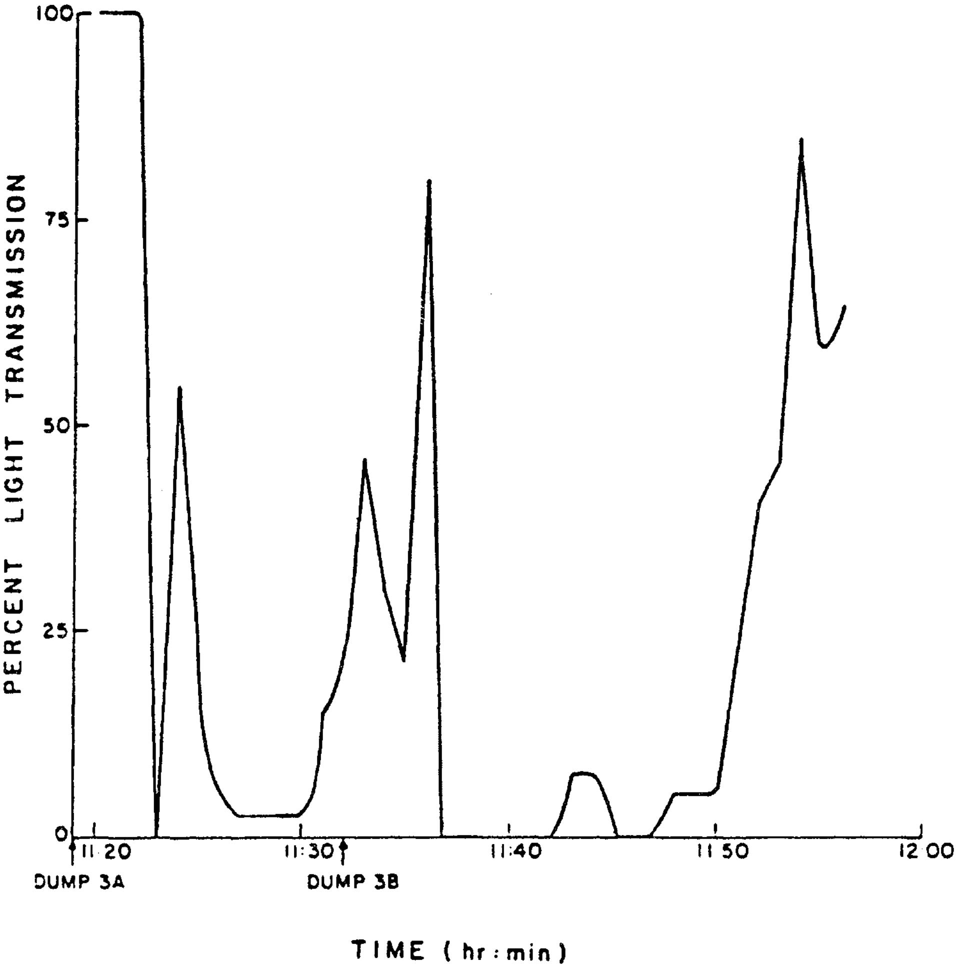

Figure 170
Percent Light Transmission in Near Bottom Water as a
Function of Time during New York Bight Dump No. 3
Depth - 24 m - Hatton
(2 cm path length)

From data provided by R. Gordon

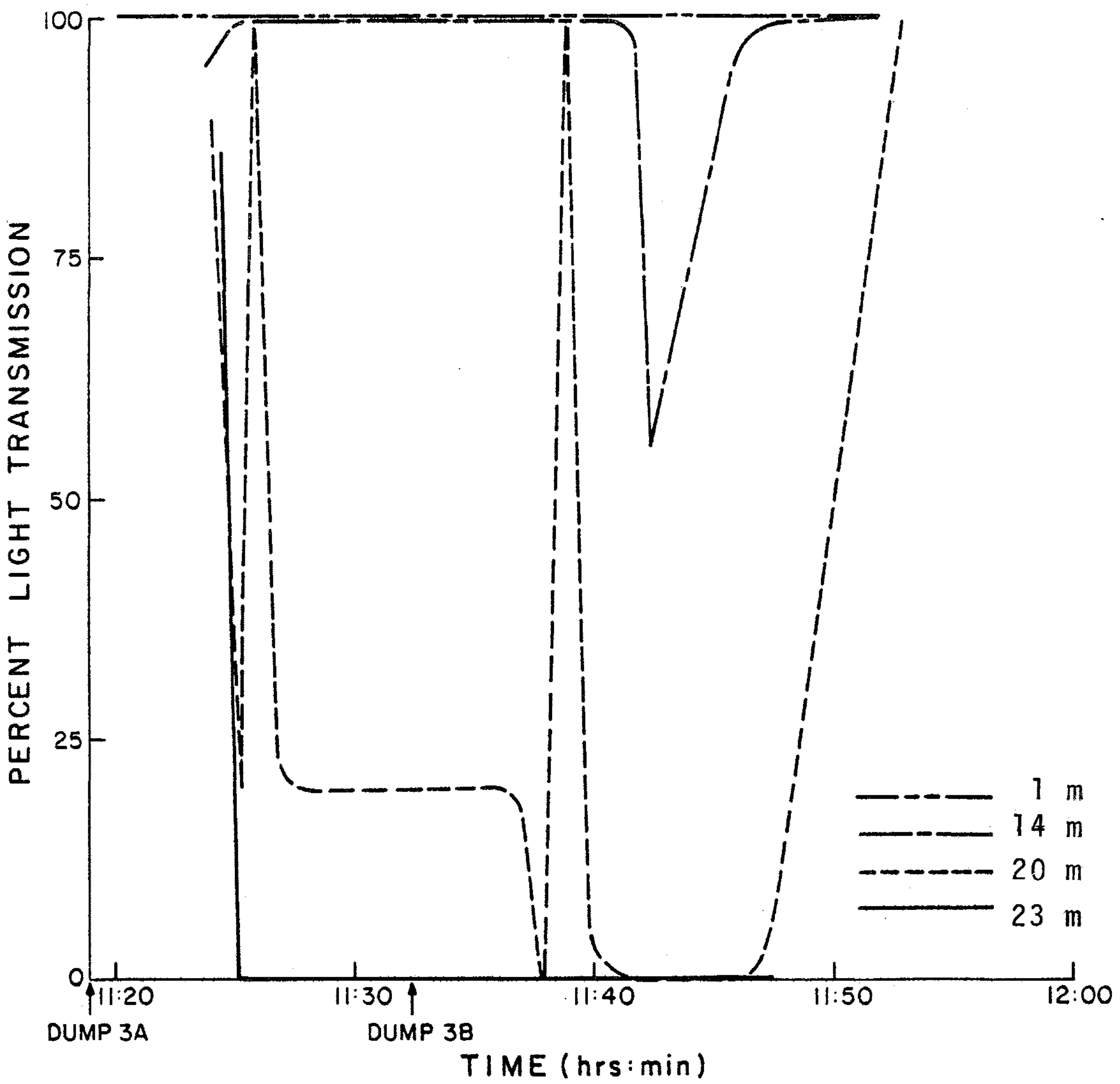

Figure 171
Percent Light Transmission as a Function of Depth and Time during New York Bight Dump No. 3 - Hatton
(12 cm path length)

From data provided by R. Gordon

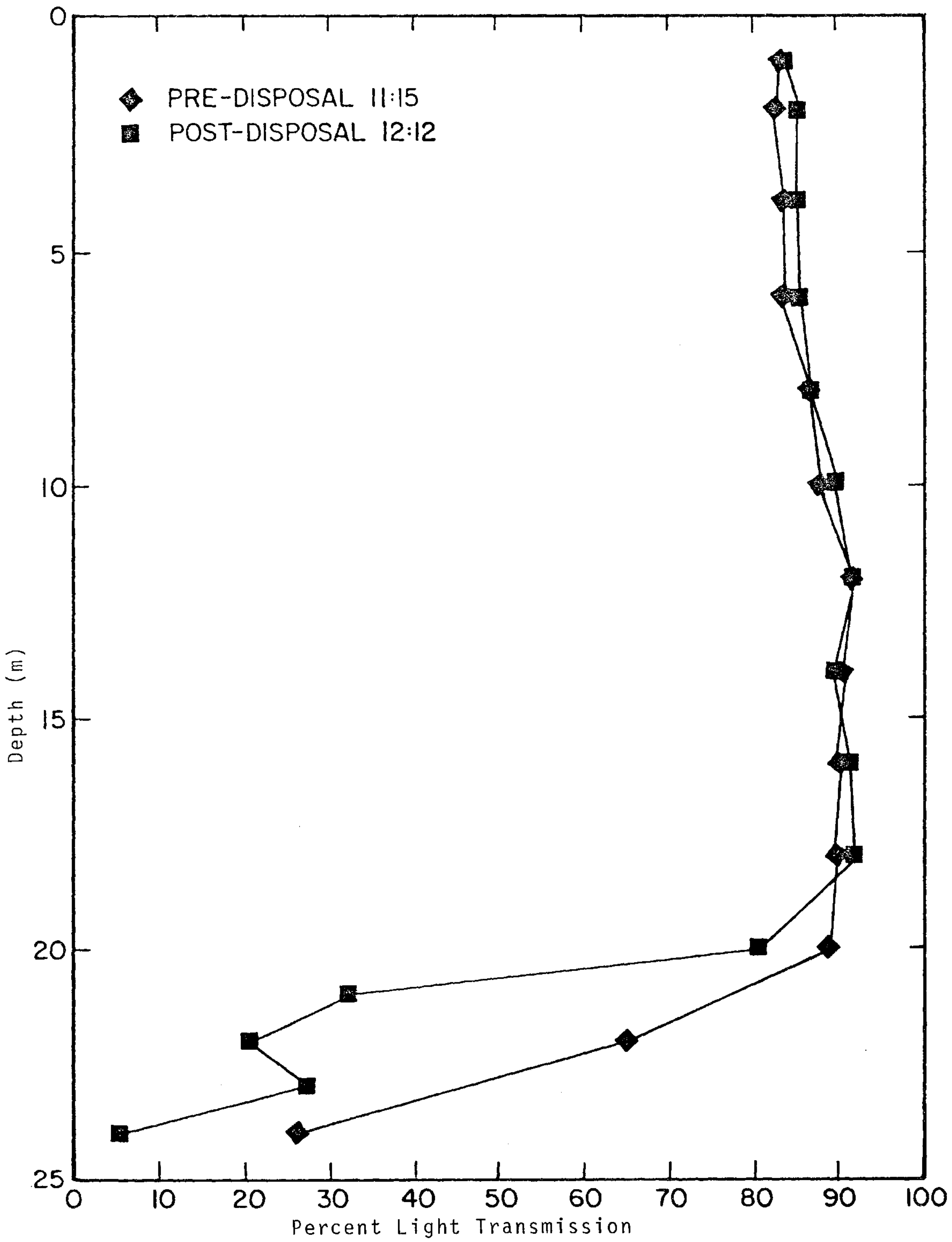

Figure 172
Water Column Profiles: Percent Light Transmission during New York Bight Dump No. 3 - Hudson

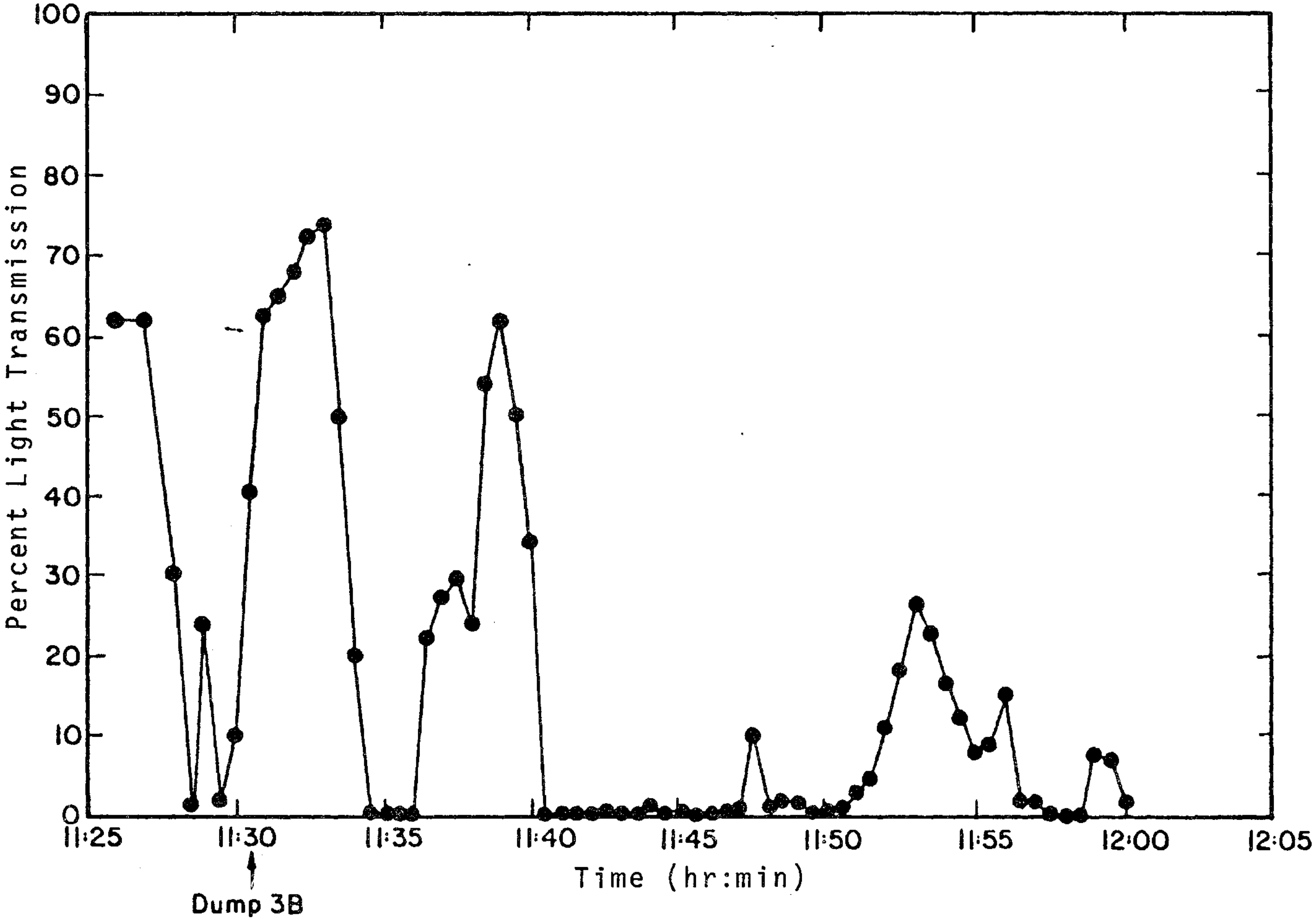

Figure 173

Percent Light Transmission: New York Bight Dump No.3

Depth 23 m - Hudson

thermocline (at 13 to 14 m depth) reduced or slowed down the dilution processes that would normally occur.

Currents. Table 492 presents the relevant current velocity and direction data as measured by B. Holliday, CE-WES, aboard the Hatton. There was a surge in speed approximately eight minutes after Dump No. 3A and a longer but less intense surge beginning about four minutes after Dump No. 3B. There was no change in direction of the current due to these dumps.

Dissolved oxygen, temperature, salinity and pH. The D.O., temperature, salinity, and pH profiles were made prior to Dump No. 3. The data are presented in Table 493. The thermocline, at 12 to 14 m, appears to have migrated somewhat toward the surface compared to similar profiles taken the previous day. In the earlier profiles (Table 473 and Figure 151), the thermocline appeared to be located at 16 to 18 meters. The higher thermocline is readily seen in Figure 174.

The surface D.O. readings were somewhat higher than they had been the previous day, 9.0 mg/l compared to 8.1 mg/l. The temperature values fell within the range established the day before, as did salinity.

Figure 175 presents the D.O. concentrations at 24.5 m during Dump No. 3. There was an increase to 2.0 mg/l from 1.4 mg/l shortly after Dump No. 3A. The D.O. levels returned to the background range soon after but again increased after Dump No. 3B. This time the levels remained elevated for over 30 minutes.

Data for the D.O., temperature, and pH profiles made aboard the Hudson during Dump No. 3 using the Corps of Engineers PLESSEY unit are presented in Table 494. Table 495 presents D.O. concentration profiles during the monitoring period. Examination of these tables shows that even though only samples collected to a depth of 4.5 m were collected prior to dumping, the D.O. values in the upper 14.5 m appeared to increase by about 1 to 2 mg/l during the first 19 min following Dump No. 3A.

Table 492

Bottom Current Velocity and Direction:*

New York Bight Dump No. 3

Time (hr:min:sec)	Speed (knots)	Direction (°magnetic)
11:11:00	0.15	260
11:13:00	0.08	160
11:15:00	0.05	210
11:19:00	0.10	255
11:19- Dump No 3A began.		
11:21:00	0.09	215
11:22:00	0.20	235
11:22:30	0.30	230
11:23:00	0.53	235
11:23:30	0.47	230
11:24:00	0.28	221
11:24:30	0.13	205
11:25:00	0.07	195
11:27:00	0.00	-
11:28:00	0.07	200
11:29:00	0.15	210
11:30:00	0.12	168
11:30:30	1.50	210
11:32:00	0.10	180
11:32:15 - Dump No 3B began.		
11:32:18	0.15	220
11:33:00	0.13	170
11:33:30	0.12	149
11:34:00	0.13	142
11:34:30	0.04	120
11:35:00	0.05	250
11:35:30	0.08	200
11:36:00	0.20	190
11:36:18	0.48	165
11:36:30	0.60	165
11:36:42	0.73	160
11:37:00	0.77	165
11:37:18	0.68	179
11:37:30	0.64	195
11:37:42	0.58	207
11:38:00	0.52	221
11:38:18	0.45	208
11:38:30	0.41	202
11:38:42	0.39	196
11:39:00	0.36	172
11:39:30	0.30	182
11:40:00	0.26	236
11:40:30	0.24	243
11:41:00	0.12	270
11:41:30	0.18	210
11:42:00	0.16	218

*Current meter set at 24 m, 1.5 m off bottom.

Data collected by B. Holliday, CE-WES.

Table 493

Pre-Disposal* Water Column Profile: New York Bight Dump No. 3, Dredged Material from Bay Ridge Channel

(Collected at the Hatton)

Depth (m)	Temp (°C)	D.O. (mg/l)	Salinity (⁰/oo)	pH
0.5	19.5	9.0	29.9	8.7
3	19.5	8.8	29.0	8.7
6	19.5	8.6	29.8	8.7
9	19.5	8.0	29.8	8.7
12	19.0	6.5	30.5	8.7
13	16	5.8	31.2	8.6
14	15	4.5	31.2	8.6
15	14.5	3.2	31.2	8.3
18	13	2.6	32.0	8.3
21	12	2.2	32.0	8.2
24	11	1.6	31.2	8.0

*Time - 14:00.

Insufficient measurements were made in the upper water (surface to about 14.5 m) after Dump No. 3B to characterize changes in D.O. that may have resulted from the dump. The D.O. concentrations in the upper waters about 30 minutes after Dump No. 3B were higher than they had been at the time of Dump No. 3A.

The D.O. values at 16.5 to 18 m ranged from zero to 1.8 mg/l during monitoring while below 18 m all values were essentially zero during monitoring. Since a complete predisposal bottom water D.O. profile was not made, any change in bottom concentrations resulting from the dumps is unclear, indicating that there may have been a reduction in D.O. in the near bottom waters at the Hudson following Dump No. 3A.

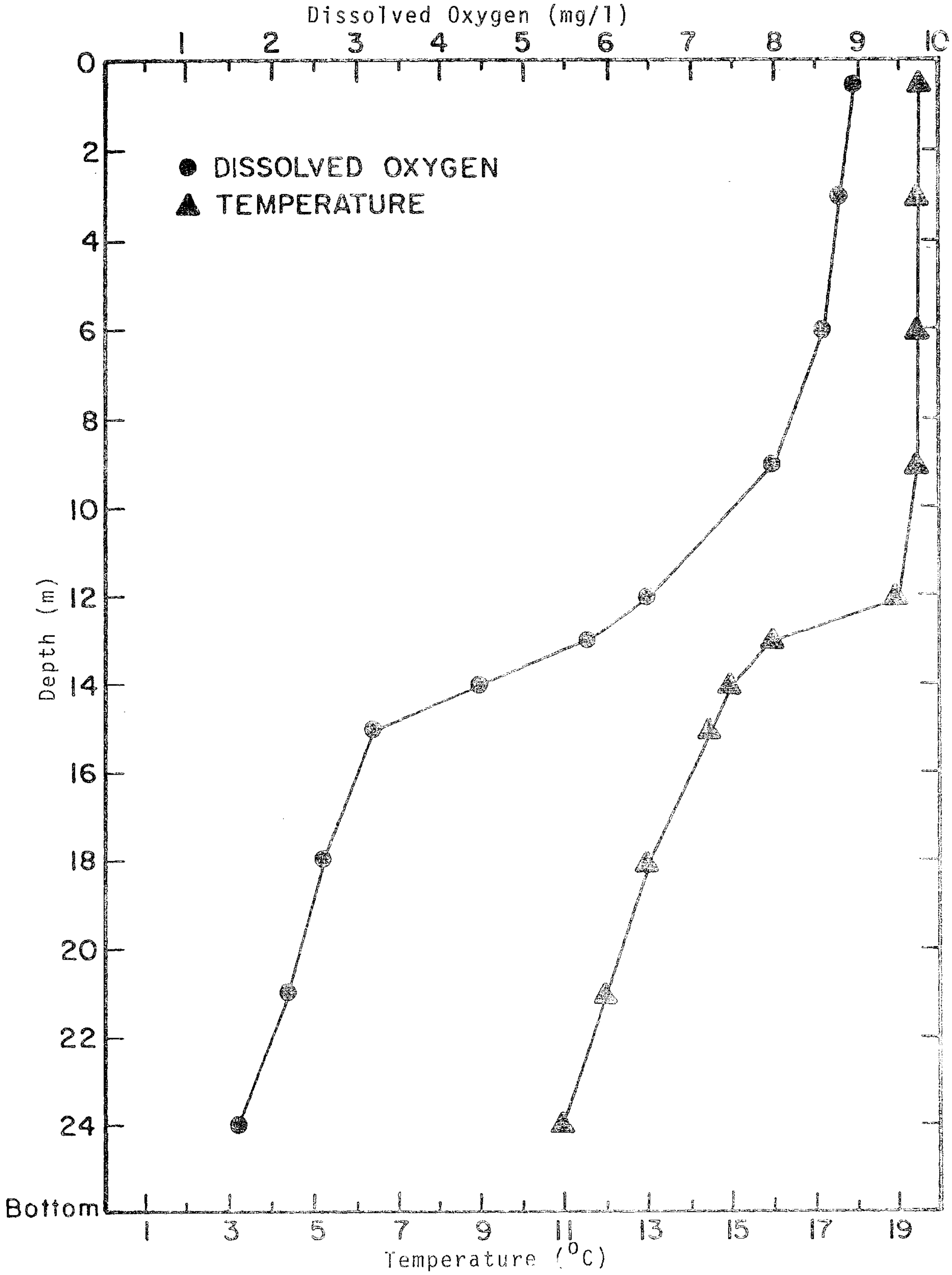

Figure 174

Water Column Temperature and Dissolved Oxygen Profile:
New York Bight Dump No. 3

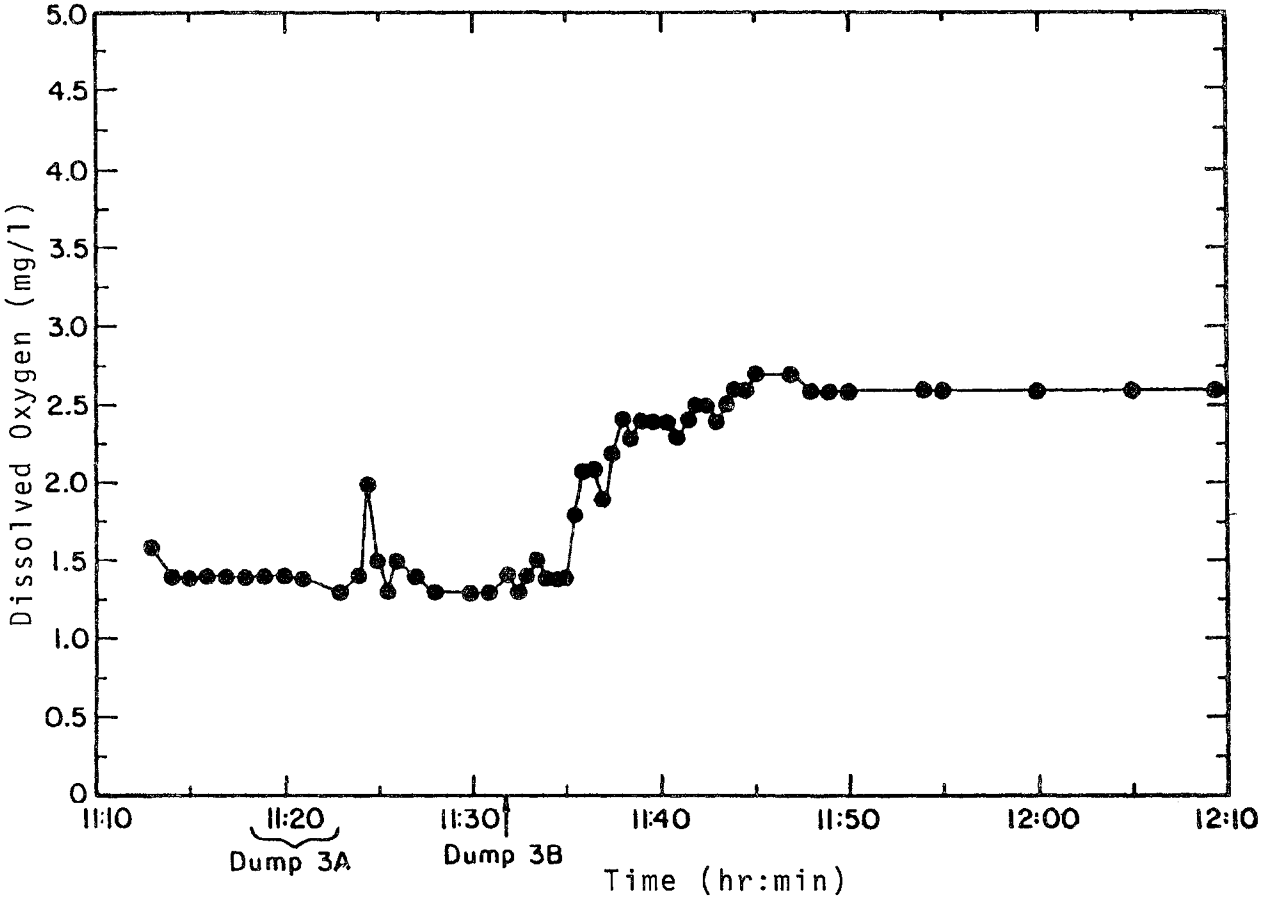

Figure 175
Dissolved Oxygen during New York Bight Dump No.3
Depth - 24.5 meters - Hatton

Table 494

Dissolved Oxygen, Temperature, and pH Profiles: New York Bight Dump No. 3, Dredged Material from Bay Ridge Channel

(Collected at the Hudson)

Time (hr:min)	Depth (m)	Dissolved Oxygen (mg/l)	Temperature (°C)	pH
11:15	1	7.9	19.4	8.0
11:17	2	8.3	19.4	8.0
11:18	3	8.2	19.4	8.0
11:18	4	8.2	19.4	8.0
11:18	4.5	8.2	19.4	8.1
	5.5	8.3	19.4	8.1
11:19 - Dump No. 3A occurred.				
11:19	6	8.2	19.3	8.1
11:19	7	7.7	19.4	8.1
11:20	8	7.6	19.5	8.1
11:20	9	7.6	19.5	8.1
11:20	11	6.6	19.4	8.0
11:21	13	5.1	15.9	7.9
11:21	14.5	10.2?	13.8	7.7
11:21	16.5	1.3	13.1	7.6
11:22	18	0.8	12.1	7.5
11:22	20	0.3	10.9	7.4
11:23	22	0.2	10.6	7.4
11:23	24	0.3	10.2	7.4
11:24	22	0.3	10.6	7.4
11:24	20	0	11.1	7.5
11:24	18	0.4	12.1	7.5
11:25	16.5	0.5	13.1	7.5
11:25	14.5	1.5	13.2	7.6
11:25	13	3.1	15.4	7.7
11:26	11	6.4	19.2	8.0
11:26	9	7.5	19.5	8.1
11:26	7	8.9	19.4	8.1
11:27	5.5	10.0	19.4	8.2
11:27	4	10.1	19.4	8.2
11:27	2	9.8	19.4	8.2
11:28	1	9.9	19.4	8.2
11:28	2	9.7	19.4	8.2
11:28	4	9.6	19.4	8.2
11:29	5.5	9.4	19.4	8.2
11:29	7	8.8	19.4	8.2
11:30	9	7.8	19.5	8.1
11:30	11	6.8	19.3	8.1
11:31	13	5.2	15.0	7.8

(Continued)

Table 494 (Continued)

Time (hr:min)	Depth (m)	Dissolved Oxygen (mg/l)	Temperature (°C)	pH
11:31	14.5	3.0	14.1	7.7
11:31	16.5	1.3	12.9	7.6
11:32	18	0.6	12.0	7.6
11:32	20	0.2	10.8	7.5
11:32	22	0	10.3	7.5
11:32:15 - Dump No. 3B occurred.				
11:33	24	0	10.0	7.4
11:33	22	0	10.4	7.5
11:33	20	0.1	11.6	7.5
11:34	18	0.3	12.7	7.5
11:34	16.5	1.2	13.9	7.6
11:34	14.5	4.9	18.6	7.9
11:35	13	6.9	19.3	8.0
11:35	11	7.7	19.6	8.1
11:35	9	8.5	19.5	8.1
11:36	7	8.5	19.4	8.2
11:36	5.5	9.5	19.4	8.2
11:36	4	9.6	19.4	8.2
11:37	2	9.4	19.4	8.2
11:37	1	9.4	19.4	8.2
11:37	2	9.4	19.4	8.2
11:37	4	0.4	19.4	8.2
11:37	5.5	9.4	19.4	8.1
11:38	7	8.7	19.4	8.1
11:38	18	0.7	12.2	7.6
11:39	20	0.3	10.9	7.5
11:39	22	0.2	10.5	7.5
11:40	24	0	10.1	7.5
11:40	22	0	10.4	7.5
11:40	20	0.1	11.7	7.5
11:40	18	0.30	12.4	7.5
11:41	16.5	1.0	13.0	7.6
11:41	18	1.0	12.4	7.5
11:41	20	0.1	10.9	7.5
11:42	22	0	12.6	7.5
11:42	24	0	12.6	7.5
11:42	22	0	11.8	7.5
11:43	20	0	10.6	7.5
11:43	18	0	10.8	7.5
11:43	16.5	0	12.2	7.5
11:44	18	0.2	11.8	7.5
11:44	20	0	11.1	7.5
11:44	22	0	10.6	7.5
11:44	24	0	10.7	7.5
11:45	22	0	10.4	7.5

(Continued)

Table 494 (Continued)

Time (hr:min)	Depth (m)	Dissolved Oxygen (mg/l)	Temperature (°C)	pH
11:45	20	0	10.9	7.5
11:45	18	0	12.4	7.5
11:46	16.5	1.4	14.4	7.6
11:46	18	2.0	12.7	7.6
11:46	20	0.5	12.1	7.5
11:47	22	0	10.9	7.5
11:47	24	0	10.7	7.5
11:47	22	0	10.7	7.5
11:47	20	0	11.3	7.5
11:48	18	0	12.4	7.6
11:48	16.5	0.6	13.1	7.6
11:48	18	0.7	12.6	7.6
11:49	20	0.4	11.7	7.5
11:49	22	0	10.6	7.5
11:49	24	0	10.5	7.5
11:50	22	0	10.5	7.5
11:50	20	0	11.1	7.5
11:50	18	0	12.3	7.5
11:51	16.5	0.7	13.4	7.6
11:51	18	1.1	12.3	7.6
11:51	20	0	11.1	7.5
11:51	22	0	10.7	7.5
11:52	24	0	10.5	7.5
11:52	22	0	10.8	7.5
11:52	20	0	12.0	7.5
11:52	18	0	12.4	7.5
11:53	16.5	0.8	13.4	7.6
11:53	18	1.2	12.7	7.6
11:53	20	0.4	12.0	7.6
11:54	22	0	10.7	7.5
11:54	24	0	10.6	7.5
11:54	22	0	10.7	7.5
11:54	20	0	11.9	7.5
11:55	18	0.6	12.7	7.6
11:55	16.5	1.8	14.1	7.6
11:55	18	1.3	12.7	7.6
11:56	20	0.5	11.9	7.6
11:56	22	0	10.9	7.5
11:56	24	0	10.6	7.5
11:57	22	0	10.8	7.5
11:57	20	0	11.5	7.5
11:57	18	0.1	12.3	7.5
11:57	16.5	0.6	13.1	7.6
11:58	18	0.5	12.1	7.6

(Continued)

Table 494 (Concluded)

Time (hr:min)	Depth (m)	Dissolved Oxygen (mg/l)	Temperature (°C)	pH
11:58	20	0.3	11.8	7.5
11:58	22	0	10.8	7.5
11:59	24	0	10.7	7.5
11:59	22	0	10.6	7.5
11:59	20	0	11.3	7.5
12:00	18	0	12.2	7.5
12:00	16.5	0.6	12.9	8.6
12:00	18	0.7	12.4	7.6
12:01	20	0.2	11.3	7.5
12:01	22	0.4	10.7	7.5
12:01	24	0	10.8	7.5
12:01	22	0	10.7	7.5
12:02	20	0	11.2	7.5
12:02	18	0	12.1	7.5
12:02	16.5	0.5	13.3	7.6
12:03	18	1.1	12.2	7.6
12:03	20	0.3	11.5	7.5
12:03	22	0	10.8	7.5
11:03	24	0	10.8	7.5
12:04	22	0	10.7	7.5
12:04	20	0	11.6	7.5
12:04	18	0.1	12.4	7.5
12:05	16.5	0.8	13.7	7.6
12:05	18	1.2	12.4	7.6
12:05	20	0.5	11.6	7.5
12:05	22	0	10.8	7.5
12:06	24	0	10.9	7.5
12:06	22	0	10.9	7.5
12:06	20	0	11.7	7.5
12:07	18	0.4	12.4	7.6
12:07	16.5	1.0	13.7	7.6
12:08	14.5	4.5	15.3	7.8
12:08	13	5.8	18.9	8.0
12:08	11	7.8	19.6	8.1
12:09	9	8.6	19.5	8.2
12:09	7	8.7	19.4	8.2
12:09	55	10.3	19.5	8.2
12:10	4	10.3	19.6	8.2
12:10	2	10.1	19.6	8.2
12:10	1	9.6	19.6	8.2

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*Measurements made using PLESSEY Environmental Systems Model 8500 Ditital Display - owned and operated by Corps of Engineers - New York District.

Table 495

Dissolved Oxygen Concentrations:* New York Bight Dump No. 3

Time (hr:min)	Depth (m)	Dissolved Oxygen (mg/l)	Time (hr:min)	Depth (m)	Dissolved Oxygen (mg/l)	Time (hr:min)	Depth (m)	Dissolved Oxygen (mg/l)
11:20	1	7.9	11:30	1	-	11:38	1	-
	2	8.3		2	9.7		2	9.4
	3	8.2		3	-		3	-
	4	8.2		4	9.6		4	9.4
	4.5	8.2		4.5	-		4.5	-
	5.5	8.3		5.5	9.4		5.5	9.4
	6	8.2		6	-		6	-
	7	7.7		7	8.8		7	8.7
	8	7.6		8	-		8	-
	9	7.6		9	7.8		9	-
	11	6.6		11	6.8		11	-
	13	5.1		13	5.2		13	-
	14.5	10.2		14.5	3.0		14.5	-
	16.5	1.3		16.5	1.3		16.5	-
	18	0.8		18	0.6		18	-
	20	0.3		20	0.2		20	0.3
	22	0.2		22	0		22	0.2
	24	0.3		24	0		24	0
11:25	1	9.9	11:35	1	9.4	11:40	1	-
	2	9.8		2	9.4		2	-
	3	-		3	-		3	-
	4	10.1		4	9.6		4	-
	4.5	-		4.5	-		4.5	-
	5.5	8.3		5.5	9.5		5.5	-
	6	-		6	-		6	-
	7	8.9		7	8.5		7	-
	8	-		8	-		8	-
	9	7.5		9	8.5		9	-
	11	6.4		11	7.7		11	-
	13	3.1		13	6.9		13	-
	14.5	1.5		14.5	4.9		14.5	-
	16.5	0.5		16.5	1.2		16.5	1.0
	18	0.4		18	0.3		18	0.3
	20	0		20	0.1		20	0.1
	22	0.3		22	0		22	0
	24	-		24	-		24	-

(Continued)

Table 495 (Continued)

Time (hr:min)	Depth (m)	Dissolved Oxygen (mg/l)	Time (hr:min)	Depth (m)	Dissolved Oxygen (mg/l)	Time (hr:min)	Depth (m)	Dissolved Oxygen (mg/l)
11:41	1	-	11:44	1	-	11:46	1	-
	2	-		2	-		2	-
	3	-		3	-		3	-
	4	-		4	-		4	-
	4.5	-		4.5	-		4.5	-
	5.5	-		5.5	-		5.5	-
	6	-		6	-		6	-
	7	-		7	-		7	-
	8	-		8	-		8	-
	9	-		9	-		9	-
	11	-		11	-		11	-
	13	-		13	-		13	-
	14.5	-		14.5	-		14.5	-
	16.5	-		16.5	-		16.5	-
	18	1.0		18	0.2		18	2.0
	20	0.1		20	0		20	0.5
	22	0		22	0		22	0
	24	0		24	0		24	0
11:43	1	-	11:45	1	-	11:47	1	-
	2	-		2	-		2	-
	3	-		3	-		2	-
	4	-		4	-		4	-
	4.5	-		4.5	-		4.5	-
	5.5	-		5.5	-		5.5	-
	6	-		6	-		6	-
	7	-		7	-		7	-
	8	-		8	-		8	-
	9	-		9	-		9	-
	11	-		11	-		11	-
	13	-		13	-		13	-
	14.5	-		14.5	-		14.5	-
	16.5	0		16.5	1.4		16.5	0.6
	18	0		18	0		18	0
	20	0		20	0		20	0
	22	0		22	0		22	0
	24	0		24	-		24	-

(Continued)

Table 495 (Continued)

Time (hr:min)	Depth (m)	Dissolved Oxygen (mg/l)	Time (hr:min)	Depth (m)	Dissolved Oxygen (mg/l)	Time (hr:min)	Depth (m)	Dissolved Oxygen (mg/l)
11:49	1	-	11:51	1	-	11:53	1	-
	2	-		2	-		2	-
	3	-		3	-		3	-
	4	-		4	-		4	-
	4.5	-		4.5	-		4.5	-
	5.5	-		5.5	-		5.5	-
	6	-		6	-		6	-
	7	-		7	-		7	-
	8	-		8	-		8	-
	9	-		9	-		9	-
	11	-		11	-		11	-
	13	-		13	-		13	-
	14.5	-		14.5	-		14.5	-
	16.5	-		16.5	-		16.5	-
	18	0.7		18	1.1		18	1.2
	20	0.4		20	0		20	0.4
	22	0		22	0		22	0
	24	0		24	0		24	0
11:50	1	-	11:52	1	-	11:54	1	-
	2	-		2	-		2	-
	3	-		3	-		3	-
	4	-		4	-		4	-
	4.5	-		4.5	-		4.5	-
	5.5	-		5.5	-		6	-
	6	-		6	-		7	-
	7	-		7	-		8	-
	8	-		8	-		9	-
	9	-		9	-		11	-
	11	-		11	-		13	-
	13	-		13	-		14.5	-
	14.5	-		14.5	-		16.5	1.8
	16.5	0.7		16.5	0.8		18	0.6
	18	0		18	0		20	0
	20	0		20	0		22	0
	22	0		22	0		24	-
	24	-		24	-			

(Continued)

Table 495 (Continued)

Time (hr:min)	Depth (m)	Dissolved Oxygen (mg/l)	Time (hr:min)	Depth (m)	Dissolved Oxygen (mg/l)	Time (hr:min)	Depth (m)	Dissolved Oxygen (mg/l)
11:56	1	-	11:58	1	-	12:01	1	-
	2	-		2	-		2	-
	3	-		3	-		3	-
	4	-		4	-		4	-
	4.5	-		4.5	-		4.5	-
	5.5	-		5.5	-		5.5	-
	6	-		6	-		6	-
	7	-		7	-		7	-
	8	-		8	-		8	-
	9	-		9	-		9	-
	11	-		11	-		11	-
	13	-		13	-		13	-
	14.5	-		14.5	-		14.5	-
	16.5	-		16.5	-		16.5	-
	18	1.3		18	0.5		18	0.7
	20	0.5		20	0.3		20	0.2
	22	0		22	0		22	0.4
	24	0		24	0		24	0
11:57	1	-	11:59	1	-	12:02	1	-
	2	-		2	-		2	-
	3	-		3	-		3	-
	4	-		4	-		4	-
	4.5	-		4.5	-		4.5	-
	5.5	-		5.5	-		5.5	-
	6	-		6	-		6	-
	7	-		7	-		7	-
	8	-		8	-		8	-
	9	-		9	-		9	-
	11	-		11	-		11	-
	13	-		13	-		13	-
	14.5	-		14.5	-		14.5	-
	16.5	0.6		16.5	0.6		16.5	0.5
	18	0.1		18	0		18	0
	20	0		20	0		20	0
	22	0		22	0		22	0
	24	-		24	-		24	-

(Continued)

Table 495(Concluded)

Time (hr:min)	Depth (m)	Dissolved Oxygen (mg/1)	Time (hr:min)	Depth (m)	Dissolved Oxygen (mg/1)
12:03	1	-	12:05	1	-
	2	-		2	-
	3	-		3	-
	4	-		4	-
	4.5	-		4.5	-
	5.5	-		5.5	-
	6	-		6	-
	7	-		7	-
	8	-		8	-
	9	-		9	-
	11	-		11	-
	13	-		13	-
	14.5	-		14.5	-
	16.5	-		16.5	-
	18	1.1		18	1.2
	20	0.3		20	0.5
	22	0		22	0
	24	0		24	0
12:04	1	-	12:08	1	9.6
	2	-		2	10.1
	3	-		3	-
	4	-		4	10.3
	4.5	-		4.5	-
	5.5	-		5.5	10.3
	6	-		6	-
	7	-		7	8.7
	8	-		8	-
	9	-		9	-
	11	-		11	7.8
	13	-		13	5.8
	14.5	-		14.5	4.5
	16.5	0.8		16.5	1.0
	18	0.1		18	0.4
	20	0		20	0
	22	0		22	0
	24	-		24	-

*Measurements made using PLESSEY Environmental Systems (Model 8500) owned and operated by Corps of Engineers-New York District.
**Time is the value approximately midway through profile monitoring.
Dump No. 3A occurred at 11:19 hrs; Dump No. 3B occurred at 11:32:15 hrs.
Dash (-) indicates no measurement made.

However, the pre-disposal measurements made aboard the Hatton showed that the D.O. below 15 m ranged with depth from 3.2 to 1.6 mg/l.

Water column temperature generally ranged from about 19.5°C in the surface water to about 10.5°C in the near bottom water. The dumping did not appear to have affected water column temperatures. The D.O. concentrations in the surface waters were at or above D.O. saturation for this temperature and salinity.

Heavy metals. Tables 496 and 497 show the soluble metal concentrations in the samples taken from the two locations during Dump No. 3. The most significant effect of the dump and plume on metals concentrations was the observed increase in iron. Seven samples, all of which were associated with elevated turbidity, had concentrations over 1,000 µg/l.

Background manganese concentrations in the near bottom waters ranged from less than 10 (detection limit) to 44 µg/l. Only three samples from near bottom, all in the second plume, contained concentrations higher than 44 µg/l. These ranged from 60 to 93 µg/l manganese. Mercury concentrations increased in mid-depth and near bottom waters. In the mid-depth samples the concentrations ranged from less than 0.005 (detection limit) to 0.177 µg/l mercury. The bottom samples ranged from less than 0.005 to 0.144 µg/l mercury. Concentrations in the four surface samples ranged from less than 0.005 to 0.062 µg/l mercury.

Very few samples collected contained zinc or copper concentrations over the detection limit (1 µg/l). The highest zinc concentration was 25.9 µg/l, found at the near bottom 2.5 minutes after second dump. The other samples containing concentrations above detection limits (13 individual samples) ranged from 1.2 to 4.0 µg/l zinc. The highest copper concentration measured was 59 µg/l near the bottom at 1.75 min after the second dump. The other 11 concentrations above the detection limit ranged from 1.0 to 3.2 µg/l copper.

Table 496

Soluble Heavy Metal Concentrations: New York Bight
Dump No. 3, Dredged Material from Bay Ridge Channel

(Collected from the *Hatton*)

(µg/l)

Time (hr:min:sec)	Depth (m)	Mn	Cd	Cr	Zn	Ni	Pb	Cu	Fe	Hg	As
11:11:00	0.5	<10	<0.5	<2	<1	7.4	<1	<1	<5	<0.005	3.8
11:11:45	12	11	<0.5	2.3	<1	6.0	<1	<1	<5	<0.005	3.6
11:12:01	24	44	<0.5	<2	<1	5.0	<1	2.9	87	-	4.7
11:18:15	0.5	11	<0.5	<2	<1	8.4	<1	<1	10	0.014	3.6
11:18:45	12	28	<0.5	<2	<1	6.0	<1	<1	21	0.014	3.1
11:19:00	24	<10	<0.5	3.4	<1	7.4	1.1	<1	70	0.030	3.3
11:19:00 - Dump No. 3A occurred.											
11:21:30	24	<10	<0.5	<2	<1	2.2	<1	1.2	22	<0.005	3.8
11:22:30	0.5	<10	<0.5	3.4	<1	4.3	1.5	<1	7	0.014	3.6
11:22:45	12	<10	<0.5	<2	<1	7.9	3.7	<1	6	<0.005	4.0
11:23:00	24	<10	<0.5	3.4	<1	6.2	1.7	<1	180	0.014	6.6
11:23:30	12	44	<0.5	<2	<1	7.0	<1	<1	23	0.014	< 2
11:23:45	24	11	<0.5	3.4	<1	3.4	1.1	1.9	70	<0.005	< 2
11:24:00	24	<10	<0.5	<2	<1	4.8	1.1	1.3	23	<0.005	7.3
11:24:30	12	28	<0.5	3.9	<1	7.0	<1	<1	<5	<0.005	6.4
11:25:15	24	<10	<0.5	2.3	<1	< 2	2.3	2.6	128	0.014	3.6
11:25:15	24	44	0.6	2.9	<1	7.4	2.7	3.2	126	0.014	< 2
11:26:00	12	44	<0.5	<2	<1	< 2	1.7	<1	<5	<0.005	2.2
11:27:00	24	11	<0.5	2.3	<1	< 2	<1	2.5	1410	0.014	5.6
11:27:30	12	<10	<0.5	<2	<1	2.2	<1	<1	13	0.155	2.7
11:29:00	0.5	28	<0.5	<2	<1	< 2	5.8	<1	<5	0.062	10.7
11:29:30	12	33	<0.5	<2	1.2	4.2	1.2	<1	<5	<0.005	9.3
11:30:00	24	<10	<0.5	2.3	2.9	2.1	7.5	<1	1388	0.029	15.9
11:32:15 - Dump No. 3B occurred.											
11:32:30	0.5	<10	<0.5	<2	<1	< 2	<1	1.4	<5	<0.005	9.7
11:32:45	12	76	0.7	3.1	1.4	1.2	2.8	<1	<5	0.079	12.4
11:33:00	24	44	<0.5	<2	1.5	4.7	21.5	59.0	6969	0.062	14.8
11:33:45	12	<10	<0.5	<2	<1	4.3	<1	<1	20	<0.005	12.4

(Continued)

Table 496 (Concluded)

Time (hr:min:sec)	Depth (m)	Mn	Cd	Cr	Zn	Ni	Pb	Cu	Fe	Hg	As
11:34:00	24	< 10	< 0.5	< 2	< 1	3.5	1.5	< 1	32	< 0.005	14.8
11:34:20	12	< 10	< 0.5	< 2	4.0	6.7	3.1	1.9	92	< 0.005	9.7
11:34:40	24	< 10	< 0.5	< 2	25.9	< 2	3.8	1.0	114	0.144	10.3
11:35:00	12	< 10	< 0.5	< 2	< 1	< 2	6.2	< 1	25	0.177	10.7
11:35:30	24	< 10	< 0.5	< 2	1.8	< 2	< 1	< 1	51	< 0.005	-
11:36:00	12	60	< 0.5	< 2	2.8	< 2	3.8	< 1	< 5	< 0.005	12.1
11:36:15	24	< 10	< 0.5	2.3	< 1	5.8	< 1	< 1	39	0.029	10.0
11:36:45	12	33	< 0.5	< 2	< 1	< 2	6.0	< 1	< 5	< 0.005	9.3
11:37:00	24	< 10	< 0.5	2.5	< 1	4.5	< 1	< 1	2017	< 0.005	12.4
11:37:15	24	< 10	< 0.5	< 2	< 1	4.3	< 1	< 1	1600	0.013	9.7
11:37:45	24	60	< 0.5	< 2	< 1	3.5	< 1	< 1	1286	< 0.005	10.7
11:38:00	24	93	< 0.5	< 2	< 1	< 2	6.0	< 1	1293	< 0.005	14.5
11:41:15	0.5	< 10	< 0.5	< 2	< 1	< 2	1.2	< 1	< 5	0.062	9.3
11:41:30	12	11	< 0.5	2.5	2.5	< 2	7.9	< 1	53	0.062	13.1
11:41:45	24	400	< 0.5	< 2	< 1	< 2	8.6	< 1	93	0.029	12.8
11:46:00	24	< 10	< 0.5	3.1	4.0	2.5	< 1	< 1	63	< 0.005	8.3
11:50:45	0.5	< 10	< 0.5	< 2	< 1	4.5	< 1	< 1	< 5	0.029	7.9
11:51:30	12	< 10	< 0.5	< 2	< 1	5.6	4.9	< 1	128	< 0.005	8.3
11:52:00	24	< 10	< 0.5	< 2	2.1	7.6	< 1	< 1	55	0.013	11.0
12:03:15	24	< 10	< 0.5	3.1	2.0	< 2	7.9	< 1	104	0.011	12.8

Dash (-) indicates no analysis made.

Table 497

Soluble Heavy Metal Concentrations: New York Bight Dump No. 3, Dredged Material from Bay Ridge Channel (Collected from the Hudson)

(µg/l)

Time (hr:min:sec)	Depth (m)	Mn	Cd	Cr	Zn	Ni	Pb	Cu	Fe	Hg	As
11:19:00 - Dump											
11:19:30	1	158	<0.5	<2	<1	4.6	2.3	1.0	<5	0.020	21.5
11:19:35	12	93	<0.5	<2	1.2	5.7	4.0	1.3	<5	0.080	4.9
11:19:40	23	<10	<0.5	<2	<1	8.2	3.9	3.8	11	0.115	23.9
11:32:15 - Dump											
11:32:50	23	28	0.9	<2	3.8	2.1	5.2	<1	429		3.8
11:32:59	12	<10	<0.5	<2	18.9	3.8	3.9	<1	<5	0.077	22.4
11:33:15	23	55	1.1	<2	4.6	3.8	2.6	2.7	70	0.011	6.3
11:34:00	23	36	<0.5	<2	91.3	2.3	4.7	<1	52		
11:35:55	12	60	<0.5	<2	<1	5.1	3.4	1.1	15	0.100	21.5
11:35:55	23	22	0.9	<2	<1	4.0	4.1	1.8	38	0.024	5.0
11:36:00	1	28	<0.5	<2	<1	7.8	3.5	1.0	<5	0.020	3.4
11:37:00	23	22	0.9	<2	<1	4.9	3.7	1.2	67	0.024	5.0
11:37:10	12	<10	<0.5	<2	<1	4.8	3.5	1.5	11	0.090	24.4
11:37:40	49	49	1.0	<2	2.8	<2	8.4	<1	156	0.024	3.2
11:38:25	12	17	0.9	2.1	1.5	<2	2.1	1.2	63	0.024	3.8
11:39:05	23	100	<0.5	<2	4.8	<2	1.1	<1	34	0.014	
11:39:50	23	<10	1.0	<2	1.3	4.0	3.7	1.4	41	0.024	<2
11:40:30	1	28	<0.5	3.4	<1	4.9	4.4	<1	79	0.100	23.4
11:40:35	23	<10	<0.5	<2	121.3	6.3	2.4	2.6	41	0.020	27.3
11:41:20	12	60	<0.5	2.4	<1	3.4	2.7	<1	<5	0.090	2.9
11:41:25	23	60	<0.5	<2	<1	<2	5.1	3.5	50	0.010	3.9
11:42:20	23	<10	<0.5	2.2	<1	2.8	4.8	3.0	104	0.090	23.9
11:43:00	23	<10	0.7	3.1	7.0	3.2	2.4	<1	10	0.024	2.5
11:43:45	23	27	0.7	2.1	<1	2.7	2.4	<1	563	0.024	3.8
11:44:35	23	11	0.8	2.9	2.2	3.2	5.0	<1	702	0.207	9.2
11:45:15	23	<10	1.0	<2	<1	3.2	5.5	<1	154	0.063	3.8
11:46:00	23	<10	1.1	2.7	<1	4.3	6.0	1.3	147	0.011	6.9
11:47:00	23	17	0.9	2.1	<1	3.5	4.9	<1	195	0.077	5.6
11:47:35	23	11	0.9	4.0	<1	4.6	5.2	<1	140	0.037	3.2
11:48:20	23	16	0.9	<2	<1	4.9	6.2	<1	1476	0.026	3.2
11:49:05	23	130	<0.5	<2	<1	3.2	6.3	<1	1586	0.090	2.3

(Continued)

Table 497 (Concluded)

Time (hr:min:sec)	Depth (m)	Mn	Cd	Cr	Zn	Ni	Pb	Cu	Fe	Hg	As
11:49:50	23	17	<0.5	2.2	<1	3.2	7.3	<1	1403	0.090	3.2
11:50:45	23	<10	<0.5	2.2	1.8	2.3	7.1	1.9	1469	0.024	4.4
11:51:35	23	82	0.6	<2	1.0	5.0	53.9	71.0	1451	0.024	3.2
11:52:30	23	<10	<0.5	<2	2.7	<2	2.2	3.6	1498	0.063	5.7
11:53:30	23	49	<0.5	<2	<1	2.6	8.5	12.6	339	0.024	<2
11:54:25	12	<10	<0.5	<2	2.0	<2	<1	2.6	10	0.037	<2
11:54:32	1	60	<0.5	<2	<1	<2	<1	2.8	10	0.011	3.2
11:54:32	23	<10	0.7	<2	3.0	2.8	1.6	5.1	80	0.011	5.0
11:55:50	23	<10	<0.5	<2	<1	4.1	<1	4.5	52	0.037	<2
11:57:05	23	193	0.5	3.3	8.6	<2	<1	4.5	113	0.024	4.8
11:58:20	23	<10	0.5	2.6	7.1	<2	<1	5.7	80	0.011	5.0
12:04:05	12	17	<0.5	<2	2.7	<2	<1	3.0	15	0.024	45.6
12:04:10	23	147	<0.5	2.3	2.4	<2	<1	4.2	129	0.011	
12:04:40	1	17	<0.5	2.8	2.2	<2	<1	2.6	52	0.037	<2

Soluble lead and arsenic concentrations also showed moderate increases as a result of the dumping operation. The highest lead concentration was 21.5 μg/l in one near bottom sample. Others above the detection unit (1 μg/l) ranged from 1.1 to 8.6 μg/l. Background arsenic levels ranged from 3.1 to 4.7 μg/l. Maximum arsenic concentrations for near bottom, mid-depth, and surface samples were 14.8, 13.1, and 10.7 μg/l, respectively. There were no significant changes in cadmium, chromium, or nickel concentrations resulting from the third disposal.

Soluble heavy metals concentrations in the samples collected on the Hudson (Table 497) showed the same pattern seen in the samples collected on the Hatton. The Dump No. 3A plume reached the Hudson approximately 14 min after the dump. The second plume reached the Hudson approximately 10.75 min after Dump No. 3A. There were elevated iron concentrations associated with all bottom samples which had a high turbidity due to the plume passage. Concentrations in the first plume reached 429 μg/l iron and in the second plume reached 1586 μg/l.

Very few samples contained manganese, cadmium, arsenic, or mercury concentrations above background levels. Background concentrations of manganese ranged from less than 10 to 158 μg/l at surface, mid-depth, and bottom. Samples taken in the plumes near the bottom ranged from less than 10 to 147 μg/l manganese. Background cadmium levels were below the detection limit at all depths. Samples above the detection limit ranged from 0.5 to 1.1 μg/l. Background arsenic concentrations were 4.9 to 23.9 μg/l. Samples collected during plume passage ranged from less than 2 (detection limit) to 45.6 μg/l arsenic. Background mercury concentrations were unusually high. Surface, mid-depth, and bottom concentrations were 0.020, 0.080, and 0.115 μg/l mercury, respectively. One bottom sample collected approximately 10 minutes after the dump contained

0.207 μg/l mercury. The others contained from 0.010 to 0.100 μg/l mercury at all depths.

There was some release of chromium, zinc, lead, and copper. Background chromium concentrations were below the detection limit (2 μg/l). A number of samples from surface, mid-depth, and near bottom taken during the passage of the second turbid plume contained concentrations ranging from 2.1 to 4.0 μg/l chromium. Background zinc concentrations were below the detection limit of 1 μg/l at surface and near bottom and 1.2 μg/l zinc at mid-depth. Concentrations in a few near bottom and mid-depth samples in the first plume ranged from 3.8 to 121.3 μg/l zinc. Concentrations late in the second plume ranged from 1.0 to 8.6 μg/l zinc. Background lead concentrations ranged from 2.3 to 4.0 μg/l. Bottom concentrations in the first plume reached 8.4 μg/l. In the second plume, lead concentrations in near bottom water were generally 1.6 to 8.5 μg/l. One sample contained 53.9 μg/l lead. Copper concentrations prior to Dump No. 3B ranged from 1.0 to 3.8 μg/l. Many samples collected during passage of the plume had concentrations below the detection limit of 1 μg/l. Those above the detection limit in the first plume ranged from 1.0 to 3.5 μg/l copper. Those above the detection limit in the second plume generally ranged from 1.3 to 12.6 μg/l. One sample contained 71 μg/l soluble copper.

Nickel concentrations prior to the arrival of the plume from Dump No. 3B ranged from 4.6 to 8.2 μg/l. Concentrations in samples collected during Dump No. 3B plume passage ranged from less than 2 to 7.8 μg/l nickel. A slight trend of nickel decrease was indicated.

In summary, the most notable effect of these disposal operations on soluble heavy metals concentrations at the disposal site was release of iron associated with high turbidity. There was also some indication of release of mercury.

Nitrogen compounds. The ammonium and nitrate data for the water samples collected during Dump No. 3 from the Hatton are presented in Table 498. Even though few samples were collected, it appears that the Dumps Nos. 3A and 3B had no effect on the surface water ammonium concentrations at the Hatton. There was possible effect of Dump No. 3B on NH_4^+ in mid-depth water two minutes after the dump which persisted for less than one minute. Figure 176 presents ammonium concentrations in the near bottom waters at the Hatton. Ammonium showed two peaks following Dump No. 3A. However, much higher ammonium release was observed following Dump No. 3B. Concentrations showed some fluctuation and though at one point dropped to the ambient level, did not quite level off at this level during the span of the sampling period. The ammonium release (2.75 mg N/l) as a result of Dump No. 3B was higher than that observed during any other disposal operation in this area. There was no significant effect of Dumps Nos. 3A and 3B on the nitrate concentrations.

The results of the ammonium analyses for the water samples collected following Dumps Nos. 3A and 3B from the Hudson are presented in Table 499. Insufficient data limited any statement about the effect of Dump No. 3A on the water column. As a result of Dump No. 3B, ammonium in the mid-depth water increased six minutes after the dump and persisted for less than three minutes. The bottom water ammonium concentration (see Figure 177) which showed wide fluctuations, returned to values obtained for the single sample taken after Dump No. 3A occurred.

Phosphorus compounds. In the near bottom waters at the Hatton soluble ortho P concentrations increased coincident with increases in turbidity following Dumps Nos. 3A and 3B (Table 500). Pre-disposal concentrations in near bottom waters were about 0.04 mg P/l. The small peak at 11:23 hrs (to 01094 mg P/l)

Table 498

Ammonium Data: New York Bight Dump No. 3

Dredged Material from Bay Ridge Channel

(Collected from the Hatton)

(mg N/l)

Time (hr:min:sec)	Depth (m)	Ammonium (mg N/l)	Nitrate
11:11:00	0.05	0.07	0.04
11:11:45	12	0.09	0.04
11:12:15	24	0.33	0.04
11:18:15	0.5	0.14	0.04
11:19:00	24	0.15	0.04
11:19:00 Dump 3A occurred.			
11:21:30	24	0.28	0.04
11:22:30	0.5	0.12	0.04
11:22:45	12	0.06	0.04
11:23:00	24	0.69	0.04
11:23:30	12	0.05	0.04
11:23:45	24	0.51	0.04
11:24:00	24	0.33	0.04
11:24:30	12	0.09	0.04
11:25:15	24	0.29	0.04
11:25:15	24	0.31	0.04
11:26:00	12	0.09	0.04
11:27:00	24	0.26	0.04
11:27:30	12	0.06	0.04
11:29:00	0.5	0.08	0.04
11:29:30	12	0.05	0.04
11:30:00	24	0.78	0.04
11:32:15 Dump 3B occurred.			
11:32:30	0.5	0.05	0.06
11:32:45	12	0.05	0.04
11:33:00	24	0.42	0.15

Table 498 (Concluded)

Time (hr:min:sec)	Depth (m)	Ammonium (mg N/l)	Nitrate
11:33:45	12	0.05	0.05
11:34:00	24	0.41	0.06
11:34:20	12	0.31	0.05
11:34:40	24	0.25	0.04
11:35:00	12	0.05	0.04
11:35:30	24	0.18	0.04
11:36:00	12	0.05	0.05
11:36:15	24	2.75	0.04
11:36:45	12	0.05	0.06
11:37:00	24	1.71	0.05
11:37:15	24	1.40	0.04
11:37:45	24	1.33	0.04
11:38:00	24	0.98	0.05
11:41:15	0.5	-	0.04
11:41:30	12	0.05	0.06
11:41:45	24	0.64	0.04
11:46:00	24	0.66	0.04
11:50:45	0.5	0.05	0.04
11:51:30	12	0.05	0.04
11:52:00	24	0.18	0.04
12:03:15	24	0.50	0.04

Dash (-) indicates data not available.

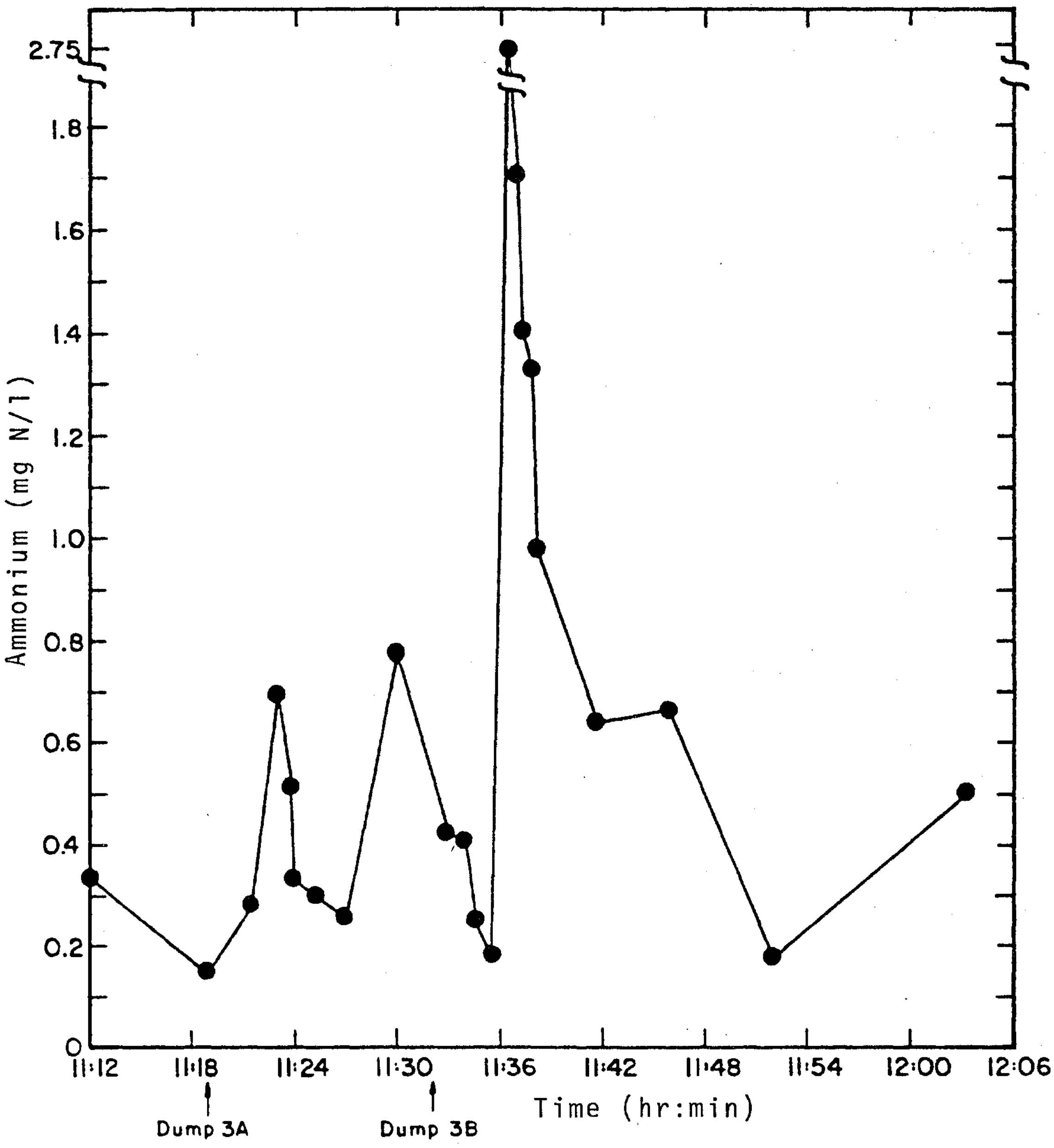


Figure 176
Ammonium Concentrations in Near Bottom Water as a Function of Time: New York Bight Dump Nos. 3A and 3B
Hatton

Table 499

Ammonium Data: New York Bight Dump No. 3
Material Dredged from Bay Ridge Channel

(Collected from the Hudson)

(mg N/1)

(mg N/1)

Time (hr:min:sec)	Depth (m)	Ammonium (mg N/1)	Nitrate
11:19:00 Dump 3A occurred.			
11:19:30	1	0.06	0.04
11:19:35	12	0.07	0.04
11:19:40	23	0.21	0.04
11:32:15 Dump 3B occurred.			
11:32:50	23	0.70	0.11
11:33:00	12	0.05	0.04
11:33:15	23	0.41	0.06
11:34:00	23	0.39	0.05
11:35:55	12	0.05	0.04
11:35:55	23	0.34	0.06
11:36:00	1	0.05	0.04
11:37:00	23	0.58	0.06
11:37:10	12	0.05	0.04
11:37:40	23	0.88	0.06
11:38:25	12	0.44	0.04
11:39:05	23	0.42	0.05
11:39:50	23	0.55	0.06
11:40:30	1	0.08	0.04
11:40:35	23	0.27	0.04
11:41:20	12	0.05	0.04
11:41:25	23	0.34	0.04
11:42:20	23	0.30	0.04
11:43:00	23	1.65	0.06
11:43:45	23	1.26	0.04

Table 499(Concluded)

Time (hr:min:sec)	Depth (m)	Ammonium (mg N/l)	Nitrate
11:44:35	23	0.90	0.05
11:45:15	23	0.81	0.05
11:46:00	23	0.72	0.05
11:47:00	23	0.69	0.05
11:47:35	23	0.98	0.06
11:48:20	23	0.72	0.06
11:49:05	23	0.48	0.06
11:49:50	23	0.54	0.05
11:50:45	23	0.20	0.05
11:51:35	23	0.44	0.05
11:52:30	23	0.32	0.04
11:53:30	23	0.37	0.05
11:54:25	12	0.05	0.06
11:54:32	1	0.05	0.09
11:54:32	23	0.44	0.06
11:55:30	23	0.30	0.06
11:57:05	23	0.50	0.05
11:58:20	23	0.44	0.05
12:04:05	12	0.05	0.06
12:04:10	23	0.58	0.06
12:04:40	1	0.05	0.06

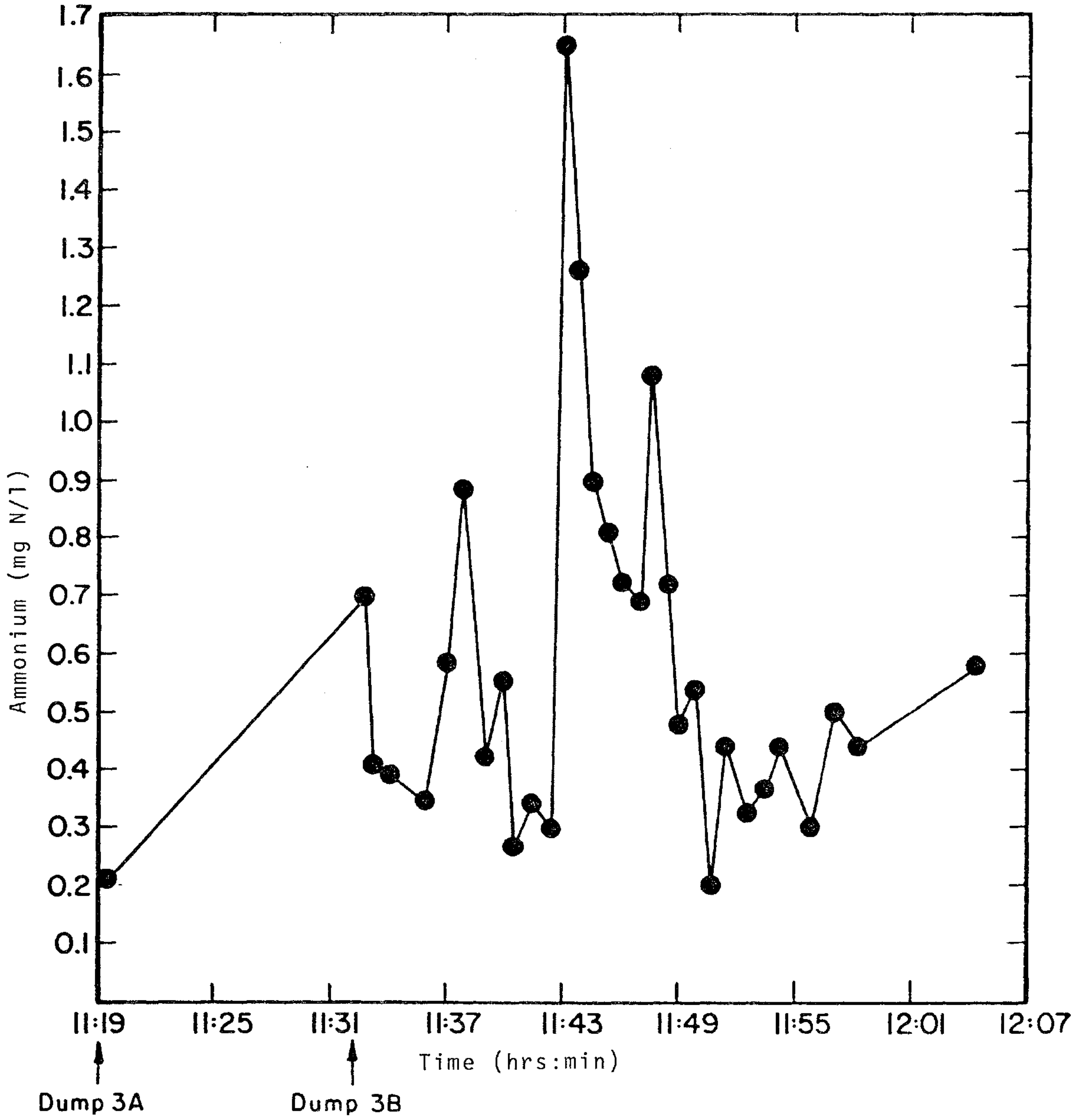


Figure 177
Ammonium Concentrations in Near Bottom Water as a
Function of Time: New York Bight
Dump Nos. 1, 3A & 3B-Hudson

Table 500

Soluble Orthophosphate Concentrations: New York Bight Dump No. 3, Dredged Material from Bay Ridge Channel

(Collected from the *Hatton*)

Time	Depth	Soluble Ortho P (mg P/1)	
hr:min:sec)	(m)	$\bar{X}$	SD
11:11:00	0.5	0.018	-
11:11:45	12	0.016	-
11:12:10	24	0.039	-
11:18:15	0.5	<0.01	-
11:18:45	12	0.016	-
11:19 - Dump No. 3A occurred.			
11:19:00	24	0.024	0.001
11:21:30	24	0.047	-
11:22:30	0.5	0.022	-
11:22:45	12	0.012	-
11:23:00	24	0.094	-
11:23:30	12	0.010	-
11:23:45	24	0.064	0
11:24:00	24	0.047	-
11:24:30	12	0.015	-
11:25:15	24	0.056	-
11:25:15	24	0.018	0.001
11:26:00	12	<0.01	-
11:27:00	24	0.058	-
11:27:30	12	0.01	-
11:29:00	0.5	0.27	-
11:29:30	12	0.28	-
11:30:00	24	0.16	-
11:32:15 - Dump No. 3B occurred.			
11:32:30	0.5	0.012	-
11:32:45	12	0.013	-
11:33:00	24	0.26 *	0.001
11:33:45	12	0.091	-
11:34:00	24	0.036	-
11:34:20	12	0.60	-
11:34:40	24	0.068	-
11:35:00	12	0.035	-
11:35:30	24	0.048	-
11:36:00	12	0.049	-
11:36:15	24	0.10	-
11:36:15	24	0.71	-
11:36:45	12	0.052	-
11:37:00	24	0.27	-

(Continued)

Table 500 (Concluded)

Time hr:min:sec)	Depth (m)	Soluble Ortho P (mg P/l) $\overline{X}$	 SD
11:37:15	24	0.21	-
11:37:45	24	0.18	-
11:38:00	24	0.22	-
11:41:15	0.5	0.10	-
11:41:30	12	0.011	-
11:41:45	24	0.19	-
11:46:00	24	0.19	-
11:50:45	0.5	0.055	-
11:51:30	12	0.043	-
11:52:00	24	0.040	-
12:03:15	24	0.081	-

Mean and standard deviation calculated from duplicate analyses of one sample.

Dash (-) indicates only one analysis made.

*Sample refiltered through 0.2 μ pore size membrane filter prior to analysis.

coincided with an increase in turbidity to 640 NTU (from 10 to 12 NTU ambient). An increase to 0.26 mg P/l occurred about a minute following Dump No. 3B. (This was one sample that had been refiltered through a 0.2 μ pore size membrane filter to remove fine material suspended in the filtered sample). Within one minute, concentrations were back to pre-disposal levels and then increased again with the increase in turbidity. The soluble ortho P concentration, and likewise the turbidity, remained elevated for at least five minutes following that peak. Twenty minutes after Dump No. 3B, near bottom water concentrations at the Hatton had returned to pre-disposal concentrations. As shown in Table 501, the near bottom water at the Hudson, which was located near down bottom current from the Hatton, the soluble ortho P concentration was 0.038 mg P/l 40 seconds after Dump No. 3A. This table also shows that near

Table 501

Soluble Orthophosphate Concentrations: New York Bight Dump No. 3, Dredged Material from Bay Ridge Channel (Collected from the Hudson)

Time hr:min:sec)	Depth (m)	Soluble Ortho P (mg P/l) $\overline{X}$	SD
11:19 - Dump No. 3A occurred.			
11:19:30	1	0.017	-
11:19:35	12	0.013	-
11:19:40	23	0.038	-
11:32:15 - Dump No. 3B occurred.			
11:32:50	23	0.10	-
11:32:59	12	0.01	0.001
11:33:15	23	0.066	-
11:34:00	23	0.13	0.001
11:35:55	12	<0.01	-
11:35:55	23	0.075	-
11:36:00	1	0.017	-
11:37:00	23	0.060	-
11:37:10	12	<0.01	-
11:37:40	23	0.096	-
11:38:25	12	0.081	-
11:39:05	23	0.066	0.001
11:39:50	23	0.18	-
11:40:30	1	0.019	-
11:40:35	23	0.047	0.001
11:41:20	12	<0.01	-
11:41:25	23	0.056	-
11:42:20	23	0.049	-
11:43:00	23	0.16	-
11:43:45	23	0.14	-
11:44:35	23	0.062	-
11:45:15	23	0.21	0.001
11:46:00	23	0.16	-
11:47:00	23	0.12	-
11:47:35	23	0.24	-
11:48:20	23	0.25	-
11:49:05	23	0.10	-
11:49:50	23	0.14	-
11:50:45	23	0.070	0.001
11:51:35	23	0.47	-
11:52:30	23	0.054	-
11:53:30	23	0.13	-
11:54:25	12	0.020	-
11:54:32	1	0.054	-
11:54:32	23	0.071	-

(Continued)

Table 501 (Concluded)

Time hr:min:sec)	Depth (m)	Soluble Ortho P (mg P/l) $\overline{X}$	 SD
11:55:50	23	0.058	-
11:57:05	23	0.11	-
11:58:20	23	0.074	-
12:04:05	12	0.052	0.001
12:04:10	23	0.091	-
12:04:40	1	0.024	-

Mean and standard deviation calculated from duplicate analyses of one sample.

Dash (-) indicates only one analysis made.

bottom concentrations after Dump No. 3B fluctuated between 0.047 and 0.47 mg P/l but without consistent relationship to the turbidity values. The data show an increase in soluble ortho P concentration above ambient in near bottom waters during the sampling period. The peaks and troughs, appearing to be highly erratic, could not be correlated with the two disposal events. The maximum concentrations found in the near bottom waters at both sampling locations were, in general, about the same but about 17 minutes apart.

At mid-depth at the Hatton, where the turbidity remained unchanged during monitoring, soluble ortho P concentrations, which were 0.016 mg P/l prior to disposal, showed an increase to 0.28 mg P/l ten minutes after Dump No. 3A and returned to ambient levels at the time of Dump No. 3B. This was followed by an increase to 0.60 mg P/l two minutes after Dump No. 3B. The level then decreased and fluctuated between 0.011 and 0.052 mg P/l for the duration of the sampling.

In the mid-depth waters near the Hudson, there was one increase in turbidity, four minutes after Dump No. 3B.

This coincided with the only increase in soluble ortho P concentration, from less than 0.01 to 0.013 mg P/l prior to Dump No. 3B to 0.081 mg P/l after it. The concentrations, thereafter, generally remained within ambient levels. Although the sampling boats were up surface current from the dumps, and there appeared to be no increased turbidity in the surface waters, soluble ortho P concentration increased in the surface water at the Hatton. One increase occurred at about the same time as an increase in mid-depth concentration (11:29 hrs). Near the Hudson, there appeared to be no change in concentration in the surface water during monitoring. The increase in the surface water concentration may have been due to contamination of the surface water samples by the near bottom pump discharge during sampling.

Both samples collected off the Hatton at 11:36:15 were filtered and analyzed. At this time the turbid water was coming in pulses, and the differences in concentrations between these two samples, 0.10 and 0.171 mg P/l, reflect this; the latter sample was very turbid, whereas the former was much clearer. These results show the high variability in the soluble orthophosphate concentration during this portion of the study.

Organic compounds. Two samples were taken before New York Bight Dump No. 3 at 12 and 24 m. Two more samples were taken at the same depths approximately six minutes after disposal was completed. The results of the organic analyses are presented in Table 502. Aldrin, lindane, and PCBs were detected in all the samples. In the 12 and 24 m pre-disposal samples, the concentrations were 1.0 and 1.2 ng/l of aldrin, 1.2 and 1.5 ng/l of lindane, and 4 and 10.0 ng/l of PCBs respectively. The 24 m turbid plume sample showed an aldrin concentration of 26.0 ng/l. The sample taken at 12 m one minute later contained 2.5 ng/l aldrin. Lindane was below the detection limit in the

Table 502

Data for Organic Compounds and Related Parameters: New York Bight Dump No. 3, Dredged Material from Bay Ridge Channel

	Pre-Disposal		During Bottom Turbid Plume Passage Post Disposal	
Time	11:14:00	11:15:00	11:30:30	11:31:30
Depth	12 m	24 m	24 m	12 m
Compound				
Chlorinated Hydrocarbons (ng/l)				
Aldrin	1.0	1.2	26.0	2.5
op'DDT	<3.0	<3.0	<3.0	<3.0
pp'DDT	<3.0	<3.0	<3.0	<3.0
op'DDD	<2.0	<2.0	<2.0	<2.0
pp'DDD	<2.0	<2.0	<2.0	<2.0
op'DDE	<2.0	<2.0	<2.0	<2.0
pp'DDE	<2.0	<2.0	<2.0	<2.0
Dieldrin	<1.2	<1.2	<1.2	<1.2
Endosulfan I	<1.2	<1.2	<1.2	<1.2
Endosulfan II	<4.4	<4.4	<4.4	<4.4
Endrin	<1.6	<1.6	<1.6	<1.6
Heptachlor	<0.4	<0.4	<0.4	<0.4
Lindane	1.2	1.5	<0.3*	2.8
PCBs	4	10	17	12
Other Organic Compounds (mg/l)				
Oil and Grease	2	0.5	1	0.5
TOC	5	3	18	2
Soluble TOC	3	3	4	2
TIC	23	29	29	24
Soluble TIC	23	29	28	24
Turbidity (NTU)	23	17	330	1

*Compound identified on both columns, but below detection limit.

24 m sample and 2.8 ng/l in the 12 m sample. The PCB concentrations were 17 and 12 ng/l in the 24 m and 12 m samples. respectively.

The oil and grease values ranged from 0.5 to 2.0 mg/l in all these samples. TOC ranged from 2 to 18 mg/l, with both figures observed in the turbid plume samples. The soluble TOC had a much narrower range of 2 mg/l (in the 12 m turbid plume sample) to 4 mg/l (in the 24 m turbid plume sample).

Sandy Hook Channel

The primary sources of contaminants for the New York Bight are the municipal and industrial wastewater discharges from New York and New Jersey to Raritan Bay. This bay is generally recognized as being highly polluted with large amounts of untreated or only partially treated municipal wastewaters being discharged to the bay primarily from New York City and other surrounding communities. While most of the industries discharging wastewaters to the bay or its tributaries are providing some type of waste treatment, because of the heavy concentration of industry in the area, the residual wasteloads are such that they cause the bay to be highly contaminated with various types of industrial wastes. While the objective of this particular study was not to determine the relative significance of contaminant release from dredged sediment and from municipal and industrial wastewater sources, it was felt that it would be of interest to take a set of water samples from the mouth of Raritan Bay in order to compare the concentration of contaminants present at the mouth of the bay to that which was found at the dredged material disposal site during the time of this study. A set of water samples was taken in Sandy Hook Channel (see Figure 143) near navigation Buoy 10 just off Sandy Hook. The data obtained from these samples are presented below.

The turbidity at this location in the Sandy Hook Channel ranged with depth from 3 NTU at the surface to 6 NTU near bottom (Table 503).

Dissolved oxygen, temperature, salinity, and pH. The D.O., temperature, salinity, and pH profiles were made near Buoy 10 in the Sandy Hook Channel during high tide. The data are presented in Table 504 and Figure 178. Neither the temperature nor D.O. data showed a distinct thermal stratification or thermocline like that noted in the mud dump site. The temperature ranged from 20°C at the surface to 17.5°C near the bottom. The surface D.O. was 6.8 mg/l. The salinity increased from 28.2 °/oo at the surface to 29.8 °/oo at the bottom. The pH was homogeneous throughout the system at 8.5.

Heavy metals. The five samples collected from the Sandy Hook Channel were analyzed for soluble heavy metals. Table 505 shows that there was no particular pattern to the concentration variations with depth except for iron. Manganese concentrations ranged from less than 10 to 36 μg/l. Iron concentrations ranged from less than 5 to 47 μg/l with the higher concentrations being found in the bottom waters. Zinc and nickel concentrations ranged from 2.0 to 3.4 μg/l and from 3.4 to 5.0 μg/l, respectively. Lead and arsenic ranged from less than 1 to 3.9 μg/l and from 6.8 to 9.2 μg/l, respectively.

Chromium and copper concentrations were below their detection limits of 2 μg/l and 1 μg/l, respectively, in all samples analyzed. Cadmium was below the detection limit of 0.5 μg/l in all samples except the one which contained 0.07 μg/l. Mercury concentrations ranged from less than 0.005 to 0.135 μg/l. Although at some depths at the sampling station in

Table 503

Turbidity in Sandy Hook Channel

(Collected from the Hatton)

Time (hr:min:sec)	Depth (m)	Turbidity (NTU)
14:04:00	0.5	3
14:06:00	3	4
14:09:30	6	4
14:12:00	9	4
14:14:30	12	6

Table 504

Water Column Profile: Sandy Hook Channel

September 1, 1976

Depth (m)	Temp (°C)	D.O. (mg/l)	Salinity ($^o/oo$)	pH
0.5	20	6.8	28.2	8.5
2	19.5	6.4	28.2	8.5
4	19	6.0	28.2	8.5
6.5	18.5	5.8	29.0	8.5
8.5	17.5	5.0	29.8	8.5
10	17.5	5.0	29.8	8.5

Time - 14:00 hrs.

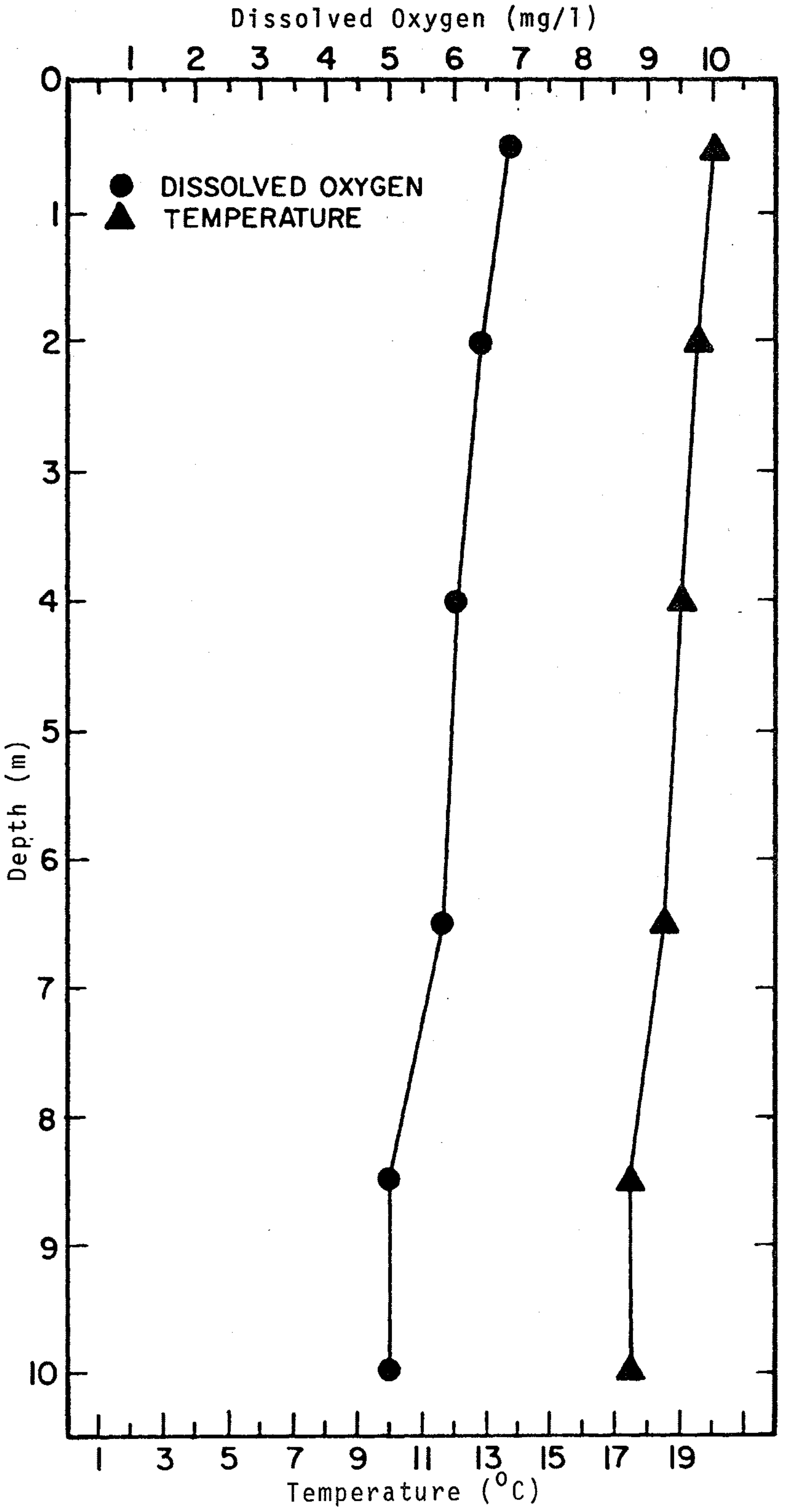


Figure 178

Water Column Temperature and Dissolved Oxygen Profile: Sandy Hook Channel - September 1, 1976

Table 505

Soluble Heavy Metal Concentrations: Sandy Hook Channel Water

(Collected from the Hudson on September 1, 1976)

(μg/l)

Time (hr:min:sec)	Depth (m)	Mn	Cd	Cr	Zn	Ni	Pb	Cu	Fe	Hg	As
14:04:00	0.5	<10	<0.5	<2	2.0	3.9	2.0	<1	<5	0.135	6.8
14:06:00	3	20	0.7	<2	2.7	4.2	< 1	<1	<5	<0.005	-
14:09:30	6	36	<0.5	<2	3.0	3.4	1.1	<1	<5	0.014	8.8
14:12:00	9	<10	<0.5	<2	3.4	3.7	3.9	<1	11	0.014	6.8
14:14:30	12	<10	<0.5	<2	2.2	5.0	2.8	<1	47	0.135	9.2

Dash (-) indicates not analyzed.

Sandy Hook Channel concentrations of mercury and arsenic appeared to have been slightly greater than ambient levels found at the mud dump site, in general, concentrations of heavy metals were about the same at both locations.

Nitrogen compounds. Table 506 presents ammonium and nitrate data for the samples collected near Buoy 10 in the Sandy Hook Channel. The ammonium content was on the order of 0.2 mg N/l to 0.05 mg N/l.

Phosphorus compounds. Concentrations in the water column at Buoy 10 varied from 0.041 to 0.38 mg P/l without apprent relationship with depth (Table 507). In general, these concentrations appeared somewhat higher than ambient concentrations found at the dump site.

Organic compounds. A set of samples were taken at the 3 m depth from Sandy Hook Channel for organic analyses. The data are shown in Table 508. Aldrin and PCBs were detected with values of 1.5 and 18 ng/l, respectively. Lindane was below the detection limit. The oil and grease concentration was 3 mg/l; TOC and soluble TOC were 5 mg/l.

Table 506

Ammonium and Nitrate Concentrations: Sandy Hook Channel

(mg N/l)

Time (hr:min:sec)	Depth (m)	Ammonium	Nitrate
14:04:00	0.5	0.20	0.05
14:06:00	3	0.25	0.05
14:09:30	6.0	0.20	0.05
14:12:00	9	0.16	0.05
14:14:30	12	0.07	0.05

Table 507

Soluble Orthophosphate Concentrations: Sandy Hook Channel Water Samples

Time	Depth	Soluble Ortho P (mg P/l)	
hr:min:sec)	(m)	$\overline{X}$	SD
14:04:00	0.5	0.12	0.001
14:06:00	3	0.14	0
14:09:30	6	0.38	-
14:12:00	9	0.041	-
14:14:30	12	0.074	-

Mean and standard deviation calculated from duplicate analyses of one sample.

Dash (-) indicates only one analysis made.

Table 508

Organic Compounds and Related Parameters:

Sandy Hook Channel

(14:06:00)

Compound	
Chlorinated Hydrocarbons (ng/l)	
Aldrin	1.5
op'DDT	<3.0
pp'DDT	<3.0
op'DDD	<2.0
pp'DDD	<2.0
op'DDE	<2.0
pp'DDE	<2.0
Dieldrin	<1.2
Endosulfan I	<1.2
Endosulfan II	<4.4
Endrin	<1.6
Heptachlor	<0.4
Lindane	<0.3*
PCBs	18
Other Organic Compounds (mg/l)	
Oil and grease	3
TOC	5
Soluble TOC	5
TIC	25
Soluble TIC	25
Turbidity (NTU)	14

Depth - 3 m.

* Compound identified on both columns, but below detection limit.

Mobile Bay, Alabama

Mobile, Alabama is a major port on the Gulf of Mexico. The Tombigbee, Tensaw, and Alabama Rivers converge there to empty into the Gulf. The Tennessee-Tombigbee Waterway, now under construction, will join a major section of the land-locked Southeast to the Gulf of Mexico through the port of Mobile. The Corps of Engineers currently maintains the channel through Mobile Bay to a depth of 42 feet and a width of 400 feet (see Figure 179).

The University of Texas at Dallas participated in a joint study to monitor the operations of a hydraulic pipeline dredge, the Paul F. Johncke, in the Mobile Bay Channel. Dr. Nichols and a sampling crew from the Virginia Institute of Marine Sciences (VIMS) conducted density current studies of the operation at the same time that the UTD staff was collecting samples. Field procedures and selection of sediment and water sampling sites were coordinated between the VIMS and UTD staff so as to provide data of maximum use to both studies.

Elutriate Tests

Characteristics of Sampling Sites

On June 2 and 3, 1976, UTD participated in this study. The sampling vessel used was the Mobile District's Gatlin, a 65-foot Corps of Engineers' survey vessel. On June 2, 1976, sediment and water samples were collected at two sites in Mobile Bay (Figure 180). Site 1 was near Buoys 21 and 22; Site 2, where duplicate water samples were taken, was at Buoy 19. These samples were taken approximately fifty feet in front of the operating dredge. It was close to where the dredge was scheduled to be operating on the following day. The sediments were taken with a Ponar grab sampler,

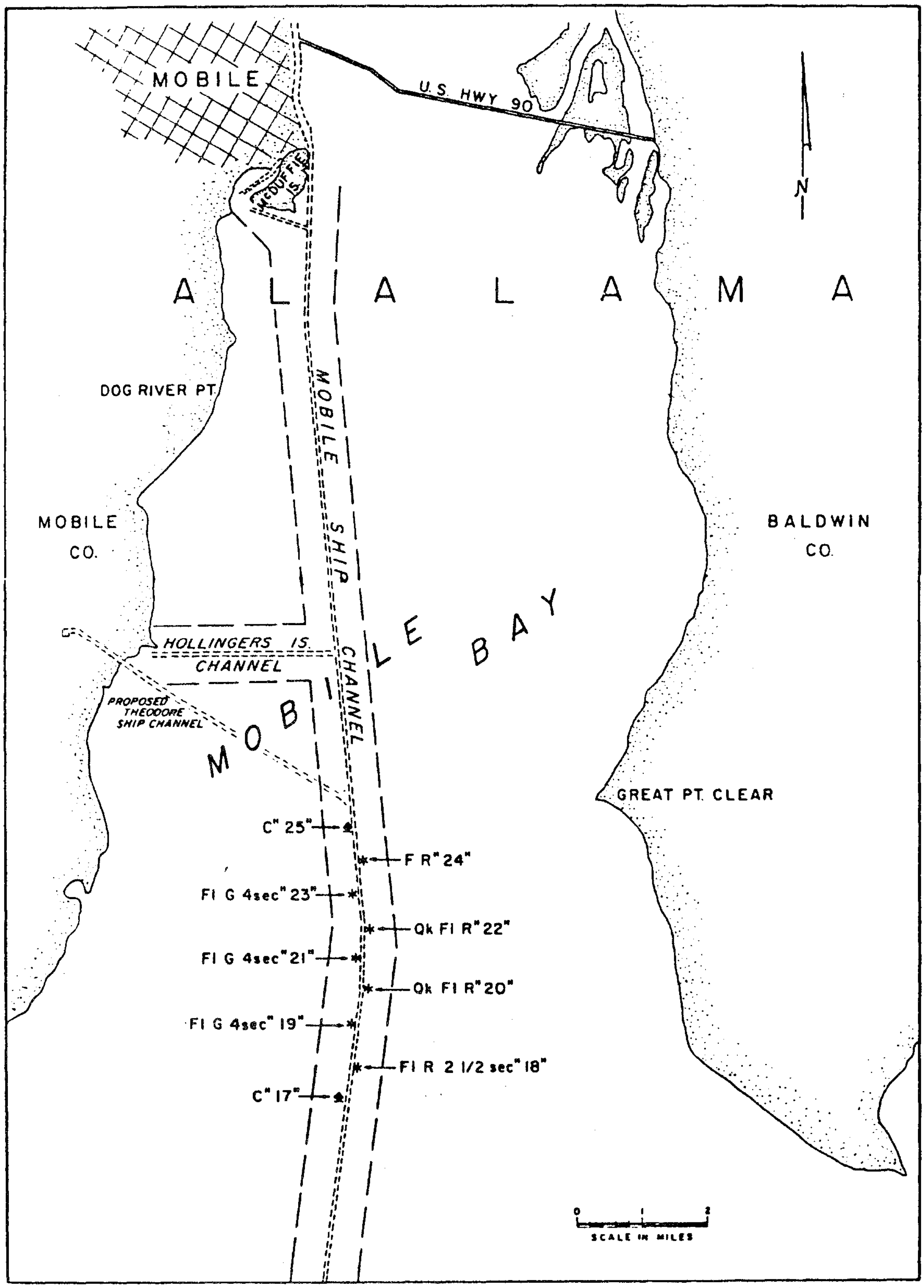


Figure 179

Map of Mobile Bay Study Area

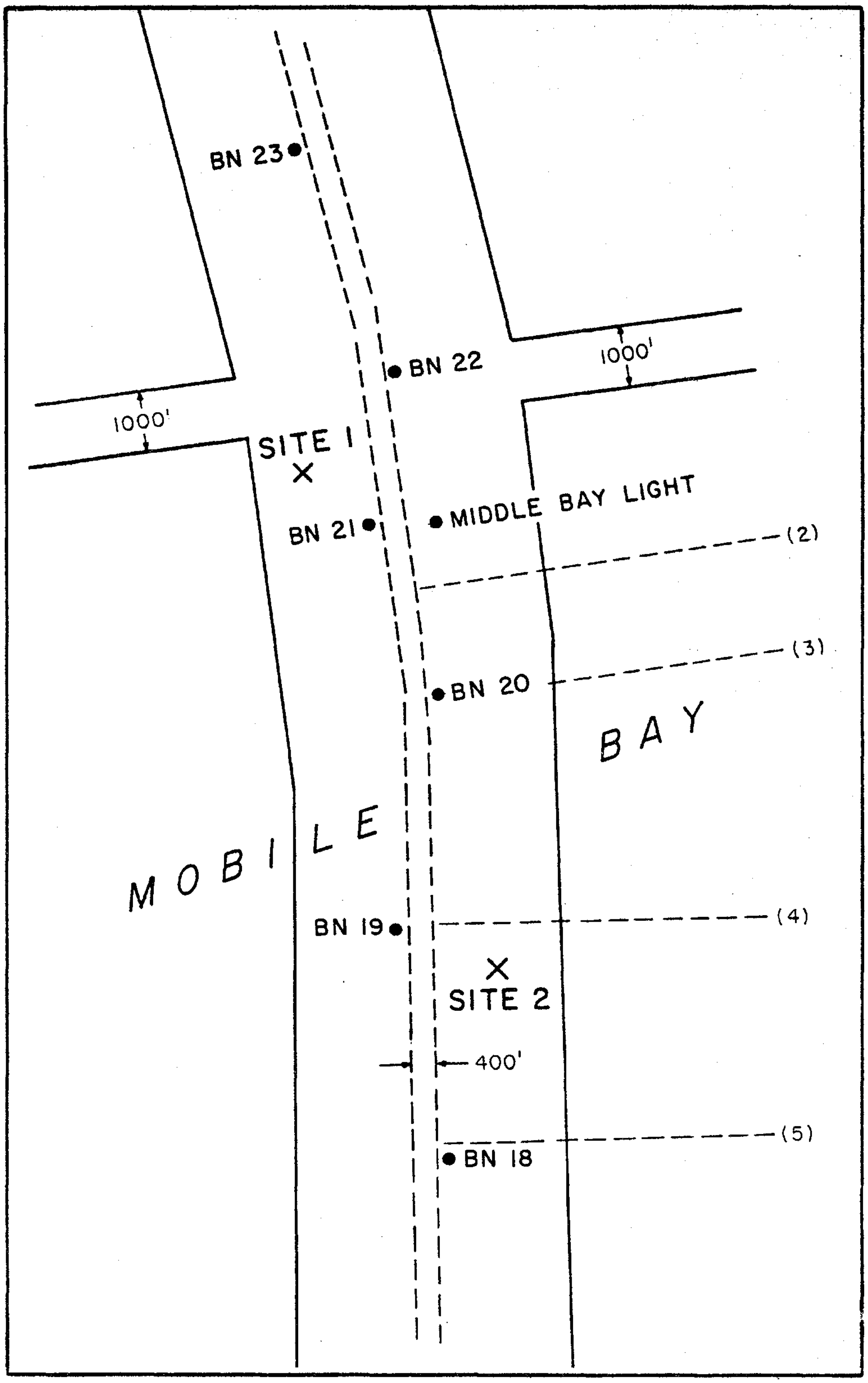


Figure 180
Mobile Bay Channel at Dredging Site

placed and sealed in five-gallon polyethylene buckets. Surface water samples were taken at the same sites as the sediment with a rope and bucket. Profiles of D.O., temperature, percent light transmission, and specific conductance were taken at one meter intervals at each of the two sampling sites. The Secchi depth at both stations was 0.4 meters. The sediment and samples were iced down and air freighted to Dallas that night. They were stored at 4°C until elutriation.

On the following day the UTD crew collected 47 sets (two liters per set) of water samples at nine stations around the discharge of the Johncke's pipeline. (See Figure 183 which follows). Samples were collected with a submersible pump which could be lowered to a precisely known depth. Two 2.5-gallon cubitainers were collected at Station 2 for pesticide analysis. These samples were shipped back to UTD immediately and stored at 4°C until analyzed. Temperature, D.O., specific conductance, and percent light transmission profiles were run at one meter intervals.

The results of the dredging of Mobile Bay sediments are divided into two sections, elutriate test results and field studies. These are discussed in this order in this section of the report.

General Sediment Characteristics and Oxygen Demand

The sediments from Mobile Bay were analyzed for Eh, sulfide concentration, percent dry weight, and particle size distribution. The sample from Site 1 had an Eh of -51 mv, while Site 2 had an Eh of -9 mv. The mean sulfide concentrations were 327 mg/kg with a standard deviation of 25 for Site 1; Site 2 had a higher concentration, 577 mg/kg with a standard deviation of 20. The percent dry weights were found to be similar, 35 percent with a standard deviation of 1.6 for Site 1 and 31 percent with a standard deviation of 0.1 for Site 2. Differences were found between the two sites in reference to their particle size distribution. Site 1 was 0 percent clay, 64 percent silt, and 36 percent sand; in comparison, Site 2 was 10 percent clay, 73 percent silt, and 18 percent sand.

The oxygen demand test was performed on the two sediment samples from Mobile Bay, Alabama. Data are shown in Tables A40 and A41, Appendix A . The standard deviation ranges, 0 to 0.4 and 0 to 0.3 indicate good reproducibility between runs. The O_2 demand for a cubic meter and a gram dry weight were determined. The sediment from Site 2 exhibited a higher demand than Site 1. The demand for Site 1 was 5.1×10^2 g O_2 m^{-3} and 1.2 mg O_2 g^{-1} dry weight for the first hour, compared to the higher values of Site 2, 6.3×10^2 g O_2 m^{-3} and 1.6 mg O_2 g^{-1} dry weight. The plots of the data are presented in Figures 181 and 182 . The demand curve in both cases had two components. Site 1 had a fast component of -0.031 mg/l min^{-1}, while Site 2 was -0.041 mg/l min^{-1}. The slow components were -0.006 mg/l min^{-1} for Site 1 and -0.011 mg/l min^{-1} for Site 2. These slopes indicate the sediment from Site 2 has a higher demand than Site 1.

Elutriate Test General Parameters

On June 8, 1976, duplicate 5 percent oxic, 20 percent oxic, and 20 percent anoxic elutriate tests were run on the Site 1 sediment and water. Duplicate 20 percent oxic and duplicate 20 percent anoxic tests were run on the Site 2 sediment and one of the Site 2 water samples on June 9, 1976. On the same day, duplicate 5 percent oxic tests were run on Site 2 sediment using the second (replicate) site water sample.

Values of the general physical and chemical parameters measured during elutriate tests on Mobile Bay Site 1 samples are presented in Table 509. During the settling period of the 5 percent oxic tests the D.O. concentration decreased by 1.4 mg/l to about 5.5 mg/l. The D.O. after mixing of the

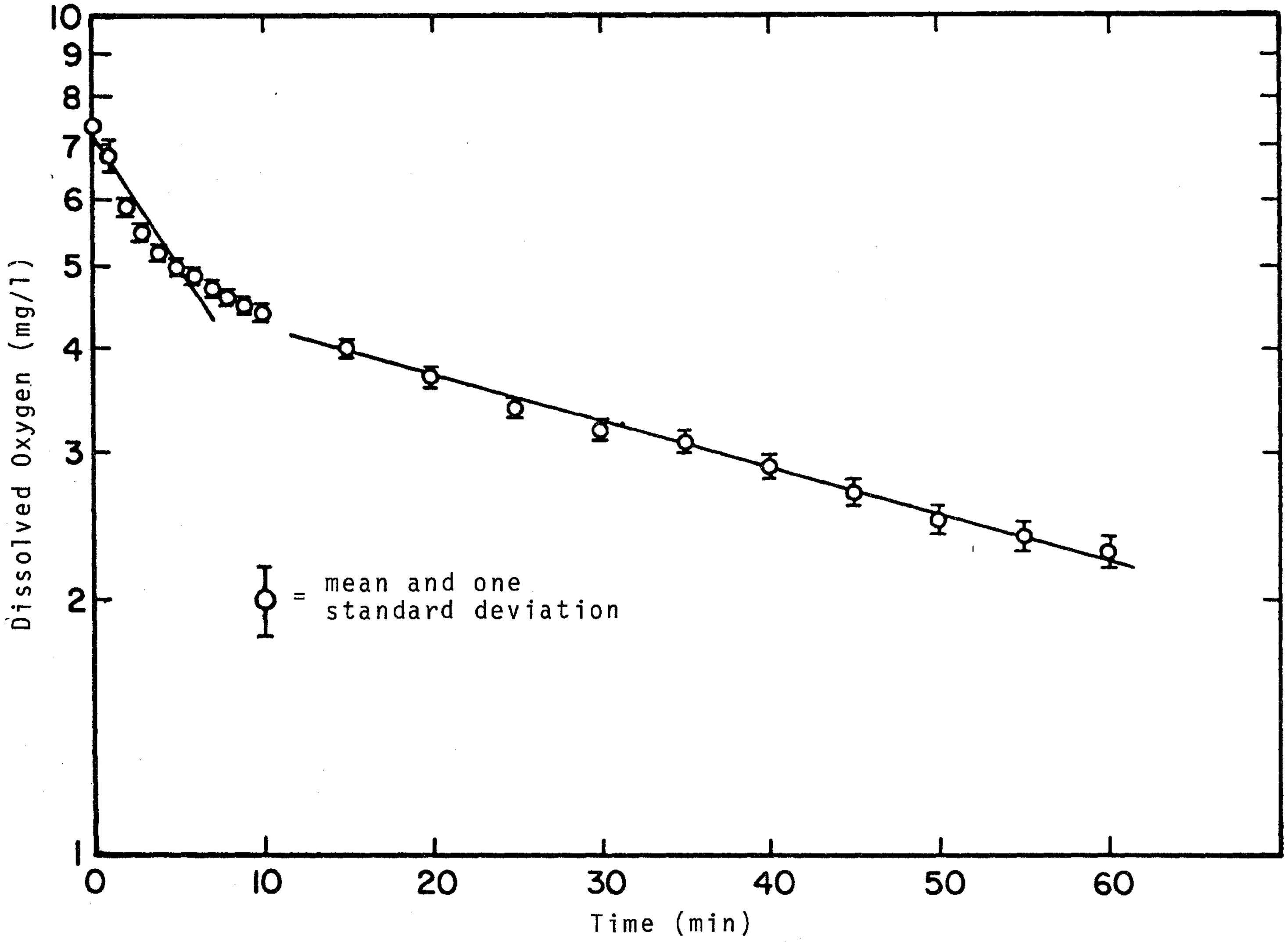


Figure 181

Oxygen Demand Test: Mobile Bay Site 1 Sediment

(Sample Size - 3 cc)

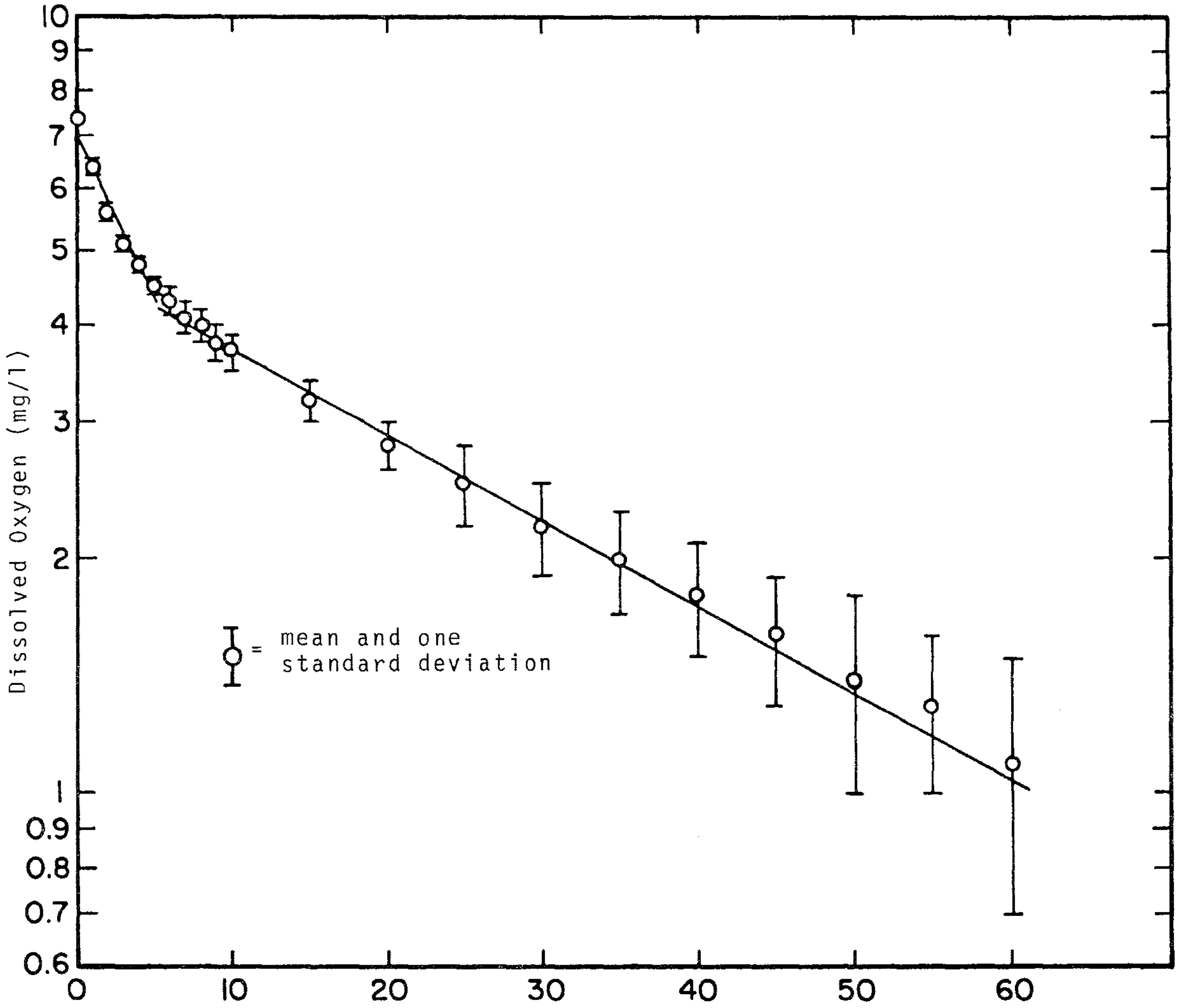


Figure 182

Oxygen Demand Test: Mobile Bay Site 2 Sediment

(Sample Size - 3 cc)

Table 509

General Physical and Chemical Parameters: Elutriate Tests on Mobile Bay Site 1 Sediment and Water

Sample Designation		D.O. (mg/l @ 20.8-21.0°C)			pH	Turbidity (NTU)	Specific Conductance (µmhos/cm @ 25°C)
		Initial	After Mixing	After Settling			
Site Water	A	6.9	-	-	7.7	25	2862
5% Oxic	A	2.2	6.9	5.5	7.9	170	4748
	B	2.6	6.8	5.4	7.7	250	4845
20% Oxic	A	0.8	4.6	1.6	7.7	90	8575
	B	<0.5	3.6	1.6	7.7	50	9968
20% Anoxic	A	0.5	<0.5	<0.5	7.8	145	7824
	B	<0.5	<0.5	0.9	7.8	155	8360

A and B are replicates.

Dash (-) indicates not applicable.

20 percent oxic tests was lower than that found after mixing of the 5 percent tests. The decrease during settling was also greater in the 20 percent tests, where D.O. decreased to 1.6 mg/l. This oxygen uptake was approximately twice that observed in the 5 percent test. The D.O. in the anoxic tests remained below or near the detection limit of 0.5 mg/l during settling.

The pH values of the elutriates ranged from 7.7 to 7.9, only slight changes from that of the site water (7.7). The turbidity increased as a result of elutriation to about the same degree (to 145-250 NTU) in the 5 percent oxic and 20 percent anoxic elutriates. The increase found as a result of 20 percent oxic elutriation was not as great. The specific conductance also increased upon elutriation. Values in the 20 percent oxic and anoxic elutriates were about the same, ranging from 7824 to 9968 μmhos/cm @ 25°C. The 5 percent elutriate showed less of an increase.

Presented in Table 510 are the values for the general physical and chemical parameters measured during the elutriate tests on Mobile Bay Site 2 sediment. The D.O. data indicate that the 5 percent tests with this sediment had a slightly higher oxygen demand and the 20 percent tests a slightly lower oxygen demand than the Site 1 sediment. The pH appeared to have increased upon elutriation. From site water pH of 7.0, values in the 20 percent elutriates increased to 7.8 and 8.0; in the 5 percent elutriates, the pH's were both 7.6. Turbidity increased upon elutriation, but the values in these elutriates appeared to be somewhat lower than those in corresponding Site 1 elutriates. The patterns of change, however, were the same. The 20 percent oxic elutriates had the lowest values (30 and 40 NTU), and the 5 percent oxic and 20 percent oxic elutriates had higher values (65-95 NTU). The specific conductance values increased as a result of elutriation. The greatest increase (to 9670 μmhos/cm

Table 510

General Physical and Chemical Parameters: Elutriate Tests on Mobile Bay Site 2 Sediment and Water

Sample Designation		D.O. (mg/1 @ 19.0-20.2°C)			pH	Turbidity (NTU)	Specific Conductance (µmhos/cm @ 25°C)
		Initial	After Mixing	After Settling			
Site Water	A	6.1	-	-	7.0	25	3580
20% Oxic	A	1.1	5.8	3.0	7.8	40	9670
	B	1.5	5.7	2.3	7.9	30	9670
20% Anoxic	A	1.4	<0.5	<0.5	7.9	65	7960
	B	1.4	<0.5	<0.5	8.0	70	7390
Site Water	B	5.9	-	-	7.0	20	3560
5% Oxic	A	5.5	6.6	6.2	7.6	80	5060
	B	5.5	6.7	6.2	7.6	95	4890

A and B are replicates.

[*] Site waters A and B were from the same location and collected at the same time; A was used for the 20 percent tests; B for the 5 percent tests.

Dash (-) indicates not applicable.

@ 25°C) was found in the 20 percent oxic elutriates; somewhat lower values were found in the anoxic elutriates. The least increase was seen in the 5 percent elutriates. The range of values in Site 2 duplicate elutriates was smaller than Site 1, but in general corresponding elutriates had similar values.

Heavy Metals

The sediment samples analyzed from the Mobile Bay Channel were analyzed for total content of selected heavy metals. The results of these analyses are shown in Table 511. Iron and manganese concentrations were high in both sediments. Mobile Site 1 contained 2530 mg/kg manganese; Site 2 had 64 g/kg iron. Zinc and nickel concentrations were also high. Zinc levels of 318 and 358 mg/kg were found in Mobile Sites 1 and 2, respectively. Cadmium, copper and chromium concentrations in Mobile Site 1 were 13, 30, and 31 mg/kg, respectively. In Mobile Site 2 they were 7, 14, and 34 mg/kg, respectively. Mercury concentrations were 0.06 and 0.09 mg/kg in Mobile Site 1 and Site 2, respectively. Lead concentrations were below the detection limit (0.5 mg/kg).

Table 512 presents the soluble heavy metals data in the site water and elutriates from standard tests run with site water and sediment from two dredging sites in the Mobile Bay Channel. The tests resulted in release of manganese and uptake of iron. Zinc was lost from solution in tests with Mobile Site 1 sediment and released in tests with Site 2 sediment.

The manganese release was greatest in tests with 20 percent sediment. Concentrations in the four 20 percent tests (oxic and anoxic) ranged from 2900 to 9050 μg/l in the tests with Mobile Site 1 and from 1019 to 4675 μg/l in tests with Mobile Site 2. Iron was lost from solution in all tests with both sediments. The site water concentration in the Site 1 tests was 60 μg/l iron. Concentrations in the 5 percent

Table 511

Total Concentrations of Selected Heavy Metals in Sediments Collected From Mobile Bay Channel, June 2, 1976

(mg/kg)

Sampling Location	Mn		Cd		Cr		Zn		Ni		Pb		Cu		Fe*		Hg	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Mobile Site 1	2530	85	13	6.6	31	2.0	318	11	1077	53	<0.5	0	30	0	49	2.3	0.06	0.021
Mobile Site 2	3305	64	7	1.9	34	0.5	358	18	950	0	<0.5	0	14	1.4	64	0	0.09	0.025

Mean and standard deviation calculated from duplicate analyses.

*g/kg

Table 512

Selected Soluble Heavy Metals in Samples From Elutriate Tests Run With Sediment and Water From the Mobile Bay Channel, Collected June 2, 1976

(μg/l)

Sampling Location	Mn		Cd		Cr		Zn		Ni		Pb		Cu		Fe		Hg		As	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Mobile Site 1																				
Site Water	88	0	1.4	0	<2	-	12	2.5	5.5	0	4.3	0	2.6	0	60	1	0.03	0	<2	-
5% Oxic A	138	0	1.0	0.2	<2	-	13	1.1	5.5	0	3.7	0.9	1.8	0.1	9	1	0.03	0	<2	-
B	75	0	1.1	0	<2	-	11	4.2	4.3	0.1	3.9	0	1.8	0.1	5	0	0.03	0	<2	-
20% Oxic A	2900	141	1.3	0	<2	-	24	11.4	4.7	0.2	5.2	0.1	2.0	0.1	16	0	0.03	0	<2	-
B	9000	0	1.4	0	<2	-	20	6.9	5.2	0.2	5.2	0.1	1.9	0	29	1	0.03	0	<2	-
20% Anoxic A	9025	35	1.3	0.1	<2	-	20	7.1	4.8	0.5	5.7	0.8	2.3	0.4	23	4	0.03	0	<2	-
B	9050	707	1.1	0.2	<2	-	32	17.9	3.2	0	5.1	0	2.0	0	22	0	0.12	0.014	<2	-
Mobile Site 2																				
Site Water	294	62	1.4	0	<2	-	182	6.0	6.8	0.2	6.4	0.9	3.2	0.5	44	6	0.05	0	<2	-
5% Oxic A	507	62	1.3	0.1	<2	-	149	22.0	6.4	0.7	6.0	0.4	2.9	0.8	18	1	0.03	0	<2	-
B	266	67	1.4	0	<2	-	176	7.9	6.1	0	6.0	0.4	3.6	0.1	16	1	0.03	0	<2	-
Site Water	182	9	1.3	0.4	<2		17	9.2	6.2	1.1	5.1	0	3.3	0.2	63	0	0.03	0	<2	-
20% Oxic A	1019	168	1.2	0.1	<2	-	15	0.4	7.7	0.5	4.8	1.3	2.4	0	25	8	0.03	0	<2	-
B	2688	354	1.4	0	<2	-	12	0.8	7.1	1.3	6.1	1.3	2.1	0.1	23	1	0.03	0	<2	-
20% Anoxic A	4675	354	1.3	0	<2	-	11	2.5	6.5	0.6	6.7	1.3	2.2	0.2	18	0	0.03	0	<2	-
B	2132	97	1.2	0	<2	-	38	7.6	7.3	0.5	5.7	0.8	2.4	0.1	18	0	0.03	0	<2	-

Dash (-) indicates data not applicable.

A and B are replicates.

Mean and standard deviation calculated from duplicate analyses.

oxic tests were 5 and 9 µg/l and in the 20 percent oxic and anoxic tests ranged from 16 to 29 µg/l. The site water for the 5 percent oxic tests with the Mobile Site 2 sediment contained 44 µg/l and the elutriates contained 18 and 16 µg/l iron. The site water used for the 20 percent tests contained 63 µg/l. The 20 percent oxic elutriates contained 25 and 23 µg/l iron. The 20 percent anoxic elutriates contained 18 µg/l. In the case of both of these metals the magnitude of increase or decrease was lesser in the 5 percent tests and greater in the 20 percent tests. There was no difference between the oxic and anoxic tests.

Zinc decreased slightly in one of the 5 percent tests with the Mobile Site 1 sediment, and in both 5 percent tests with the Mobile Site 2 sediment. There was increase in the four 20 percent tests with Mobile Site 1. The site water contained 12 µg/l and the elutriates contained 20 to 32 µg/l zinc. In the 20 percent tests with Mobile Site 2 the site water contained 17 µg/l and the elutriates contained 11 to 38 µg/l zinc. There was loss of zinc in three of the tests and release in one.

Concentrations of chromium and arsenic were below detection limits (2 µg/l) in all site waters and elutriates. There were no analytically significant changes in most of the other metals. Concentration ranges were 1.0 to 1.4 µg/l cadmium, 3.2 to 7.7 µg/l nickel, 3.7 to 6.7 µg/l lead, and 1.8 to 3.6 µg/l copper. Concentrations of mercury were 0.03 µg/l in all but two samples. One of the 20 percent anoxic elutriates contained 0.12 µg/l, indicating release of mercury was possible from Mobile Site 1 sediment. The site water used in the 5 percent tests with Mobile Site 2 contained 0.5 µg/l mercury, and the elutriates contained 0.03 µg/l mercury. There were no other changes. Despite the large concentrations of heavy metals in these sediments, manganese was the only soluble metal readily released in the elutriate tests of the sediments.

Nitrogen Compounds

The samples, designated Mobile Bay Sites 1 and 2, had organic N contents of 1169 and 953 mg N/kg and ammonium contents of 381 and 197 mg N/kg, respectively. The nitrogen compound concentrations for the Mobile Bay Site 1 elutriates are listed in Table 513 . The organic N concentrations for the duplicate oxic elutriates were highly variable. However, the organic N concentrations in the anoxic elutriates were higher than other elutriates. The ammonium release, particularly for the 5 percent tests, was relatively high considering the low ammonium concentration in the site water. Nitrate decreased in all the elutriates over that of the site water. An increase in the sediment percent led to a decrease in the nitrate concentration. However, as expected, the aeration condition did not seem to have any effect on the nitrate concentration in the 20 percent oxic and anoxic tests since the results were comparable.

Table 513

Nitrogen Compound Concentrations: Mobile Bay Site 1 Elutriate Test

(mg N/1)

Sample Designation		Organic N		Ammonium		Nitrate	
		$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Site Water		<0.05	∿ 0	0.05	0	0.25	0.02
5% Oxic	A	0.51	0.02	2.25	0	0.22	0.01
	B	0.60	0.03	2.38	0.02	0.24	0.01
20% Oxic	A	0.13	0.10	4.76	0.08	0.14	0.01
	B	0.94	0.21	6.13	0.06	0.08	0
20% Anoxic	A	1.14	0.08	4.61	0	0.10	0
	B	0.75	0.17	5.71	0.03	0.10	0

Mean and standard deviation calculated from duplicate analyses. A and B are replicates.

The nitrogen compound concentrations for the Mobile Bay Site 2 elutriate tests are presented in Table 514. Again organic N concentrations in the anoxic elutriates were higher than those under oxic conditions. The ammonium release from this sediment was lower than from Mobile Bay Site 1. For both Sites 1 and 2 sediments, ammonium release in the elutriates was higher under oxic conditions than under anoxic conditions and also increased using higher percent sediment volume. In all tests, nitrate decreased as a result of elutriation.

Phosphorus Compounds

Table 515 presents the total phosphorus concentrations in the Mobile Bay sediment samples on which elutriate tests were run. These two samples had about the same concentrations, which were in the order of 613 to 671 mg P/kg. Tabulated in Table 516 are the concentrations of soluble orthophosphate in the Mobile Bay elutriates. There did not appear to be much change in concentration as a result of either 5 percent of 20 percent elutriation of Site 1 samples. Concentrations in these elutriates ranged from 0.063 to 0.10 mg P/l compared to 0.061 mg P/l in the site water. There was, however, limited release under anoxic conditions (from 0.061 mg P/l in the site water to 0.17 and 0.25 mg P/l in the duplicate elutriates).

Soluble orthophosphate concentrations in elutriates from tests on Mobile Bay Site 2 sediment and water samples are also presented in Table 516. This site water had a lower concentration (0.02 mg P/l) than the Site 1 water. There appeared to be release of soluble ortho P as a result of each elutriation. Concentrations increased from 0.02 mg P/l in the site water to 0.031 mg P/l in the 5 percent oxic elutriates and to about 0.04 mg P/l in the 20 percent oxic elutriates. Greatest release was found as a result of anoxic elutriation. Those elutriates had concentrations of 0.086 and 0.11 mg P/l. Overall, the

Table 514

Nitrogen Compound Concentrations: Mobile Bay Site 2 Elutriate Tests

(mg N/1)

Sample Designation		Organic N		Ammonium		Nitrate	
		$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Site Water		<0.05	∿0	0.08	0.01	0.28	0.01
5% Oxic	A	<0.05	∿0	1.04	0.01	0.37	0
	B	<0.05	∿0	0.98	0.01	0.37	0.01
20% Oxic	A	0.44	0.09	3.42	0.04	0.27	0
	B	0.28	0.10	3.54	0.04	0.25	0.01
20% Anoxic	A	0.52	0.05	2.60	0	0.20	0.01
	B	0.71	0.03	2.28	0	0.24	0.01

Mean and standard deviation calculated from duplicate analyses of one sample.

A and B are replicates.

Table 515

Total Phosphorus Concentrations: Mobile Bay Sediment

Sample	Total P (mg P/kg dry weight)	
	$\bar{X}$	SD
Site 1	671	4
Site 2	613	4

Mean and standard deviation calculated from duplicate analyses of one digested sample.

Table 516

Soluble Orthophosphate Concentrations: Mobile Bay Elutriate Tests

Sample	Soluble Ortho P (mg P/1)	
	$\bar{X}$	SD
Mobile Bay Site 1		
Site Water	0.061	0.001
5% Oxic A	0.058	0
B	0.10	0.001
20% Oxic A	0.053	0
B	0.063	0
20% Anoxic A	0.17	0.001
B	0.25	0
Mobile Bay Site 2*		
Site Water A	0.02	0.001
20% Oxic A	0.040	0
B	0.043	0
20% Anoxic A	0.11	0.001
B	0.086	0.001
Site Water B	0.019	0
5% Oxic A	0.031	0
B	0.031	0.001

Mean and standard deviation calculated from triplicate analyses of one sample.

*Site water A and B were taken at the same time but were put in different containers. Site water A was used for the 20% oxic and 20% anoxic tests. Site water B was used for the 5% oxic tests.

Mobile elutriate tests showed good reproducibility with respect to soluble orthophosphate concentrations in the elutriates.

Bioassays

The results of the bioassay using Mobile Bay, Alabama sediments are presented in Table 517 . No toxicity was observed in either the 5 percent or 20 percent sediment tests. The chemical and physical characteristics of the bioassay elutriate waters are presented in Table 518 . The data show that the total ammonium nitrogen content for the 20 percent tests was approximately 3.5 mg N/l with 0.08 mg/l present as unionized ammonia. In addition, there were initial decreases in the D.O. concentrations and increased levels of turbidity. The initial decreases in D.O. concentration in both of the 20 percent sediment elutriates were severe enough to warrant a 15 minute aeration of the elutriate waters following the one-hour settling period. The 15 minute aeration period did not change significantly the level of ammonium nitrogen present in the bioassay elutriate waters.

Table 519 shows the concentrations of D.O. in the bioassay elutriate waters utilizing Mobile Bay, Alabama sediments. Minimal aeration was used to maintain a D.O. concentration of greater than 2 mg/l. Examination of Table 520 shows release of manganese and iron to the bioassay elutriate waters. Both nickel and copper were removed from the waters while no significant change from the control waters occurred for cadmium, chromium, zinc and lead.

Total ammonium nitrogen concentrations in the bioassay elutriate waters at the end of the 96-hour test period are presented in Table 521. A comparison of Tables 518 and 521 shows a slight decrease in concentration for the controls and a slight increase in both the 5 and 20 percent sediment tests.

Table 517

Number of Organisms Alive During the 96-Hour Bioassay:
Mobile Bay, Alabama Site 2 Sediment

Time (hrs)	Percent Sediment of Total Elutriate Volume					
	Controls		5%		20%	
	A	B	A	B	A	B
0	10	10	10	10	10	10
2	10	10	10	10	10	10
12	10	10	10	10	10	10
24	10	10	10	10	10	10
36	10	10	10	10	10	10
48	10	10	10	10	10	10
60	10	10	10	10	10	10
72	10	10	10	10	10	10
84	10	10	10	10	10	10
96	10	10	10	10	10	10

A and B are replicate bioassay tests.

Table 518

Chemical and Physical Parameters of Bioassay Elutriate Water After the One Hour Settling Period: Mobile Bay, Alabama

Site 2 Sediment

Sample Designation		pH	D.O. (mg/l @ 21°C)	Specific Conductance (μmhos/cm)	Total Ammonium (mg N/l)	Unionized Ammonia (mg N/l)	Turbidity (NTU)	Salinity (°/oo)
Control	A	8.0	7.2	39,800	0.025	<0.01	<1	20
Control	B	8.0	7.3	39,800	0.023	<0.01	<1	29
5%	A	7.9	4.0	40,500	1.16	0.03	86	30
	B	8.0	4.3	40,500	1.23	0.03	81	30
20%	A	7.9	1.6	39,700	3.57	0.08	13	29
	B	7.9	1.2	39,800	3.51	0.08	28	29
20%	A*	7.9	4.3		3.50	0.08		
	B*	7.9	3.8		3.41	0.08		

A and B are replicate bioassay tests.

*Data after 15 minute aeration following one hour settling period.

**For bioassay elutriates, unionized ammonia calculated from Skarheim's tables for fractions of ammonia in undissociated form.

Table 519

Dissolved Oxygen Concentrations in Bioassay Elutriate Waters: Mobile Bay, Alabama Site 2 Sediment

Time (hr)	Dissolved Oxygen (mg/l @ 21.0°C)					
	Control		5%		20%	
	A	B	A	B	A	B
0	7.3	7.3	4.0	4.3	1.6	1.2
After 15 min aeration	-	-	-	-	4.3	3.8
24	6.0	6.5	3.7	4.0	3.3	3.8
48	4.9	5.3	3.6	3.8	3.0	3.7
72	4.8	5.2	3.6	3.8	3.8	3.9
96	4.8	5.1	3.5	3.6	3.7	3.9

A and B are replicate bioassay tests.

Dash (-) indicates no aeration.

Table 520

Release of Heavy Metals to Bioassay Elutriate Waters: Mobile Bay, Alabama Site 2 Sediment

(μg/l)

Sample Designation		Mn	Cd	Cr	Zn	Ni	Pb	Cu	Fe
Control	A	114	1.8	2	10.0	18.5	5.7	13.4	14
	B	160	1.5	2	10.0	17.5	7.0	13.1	12
5%	A	251	2.6	2	30.7	8.7	7.0	4.4	2400
	B	327	1.9	2	14.4	8.7	6.3	4.4	2023
20%	A	6138	1.3	2	7.7	5.8	5.7	2.5	874
	B	6282	1.5	2	37.7	6.9	8.3	3.0	1241

A and B are replicates.

Table 521

Ammonium Content of Bioassay Elutriate Water At the End of the 96-hour Bioassay: Mobile Bay, Alabama Site 2 Sediment @ 21°C

Sample		pH	Total Ammonium (mg N/l)	Unionized Ammonia (mg N/l)
Control	A	8.0	0.14	0.01
	B	8.0	0.15	0.01
5%	A	7.9	1.19	0.03
	B	8.0	1.30	0.03
20%	A	7.9	3.72	0.08
	B	7.9	3.74	0.08

A and B are replicates.

Field Studies

Characteristics of Study Site

Much of the eastern gulf coast of the United States is paralleled by a set of barrier islands located a few miles off the coast. Generally between the barrier islands and the coast are shallow bays and, in many areas, salt marshes. Many of the metropolitan centers are generally located somewhat inland on the coastal rivers. In many areas, located between the barrier islands and the coast is the intercoastal waterway. For many parts of the coast, this waterway consists of a dredged channel. Also, at many parts of the coast, dredged channels are present between the open ocean and the coastal metropolitan centers. The shallow nature and physical characteristics of the sediments of the coastal bays and nearshore open ocean waters through which these channels are dredged necessitates frequent dredging. In many instances, this dredging is done hydraulically with pipeline discharge of the dredged sediments a few hundred yards from the side of the channel. In order to evaluate the reliability of the elutriate test as a method for estimating the release of contaminants for open water disposal of dredged sediments arising from hydraulic dredging and pipeline disposal of sediments found along the gulf coast, field studies were conducted near Mobile Bay, Alabama, and Apalachicola, Florida. This section of the report presents the results of the Mobile Bay studies. The next section presents the results of the Apalachicola studies.

Dissolved Oxygen, Temperature, and Salinity

A pipeline dredging operation was monitored on June 3, 1976, at Mobile Bay, Alabama. The D.O. content of the water column was measured. Sampling stations 1 through 8 were arranged along three transects. One of these was along the center line of the dredged sediment discharge plume. This was determined by a drogue which was released at the point of discharge which was designed to move with the currents of about 0.5 to 1 m depth. The other two followed a path approximately 45° either side of the center line of the discharge plume (Figure 183). Station 9 was a "reference" station located upcurrent from the discharge point.

The D.O., temperature, and salinity profiles of the water column 15 meters in front of the dredge were taken on June 2, 1976. These data are presented in Figures 184 and 185. In Figure 184 there is noted a gradual decrease in D.O. with depth, 7.9 mg/l at the surface and 3.7 mg/l one meter off the bottom. Temperatures ranged from 24.5°C at the surface to 22.9°C at the bottom. Salinity profiles for the same water showed 2 °/oo at the surface, with slightly greater than 22 °/oo at the bottom. The data presented in Figure 184

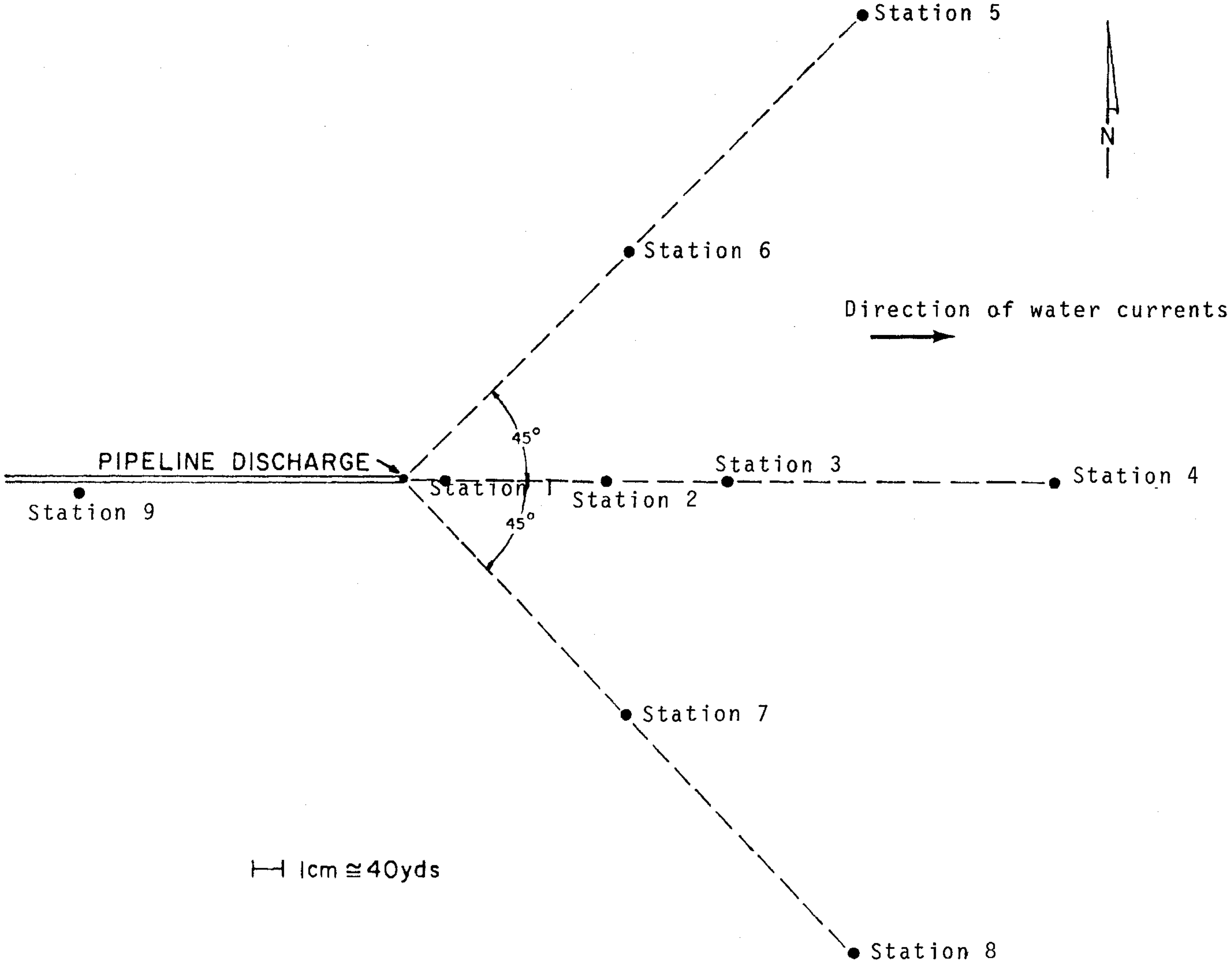


Figure 183
UTD Sampling Stations: Mobile Bay, Alabama

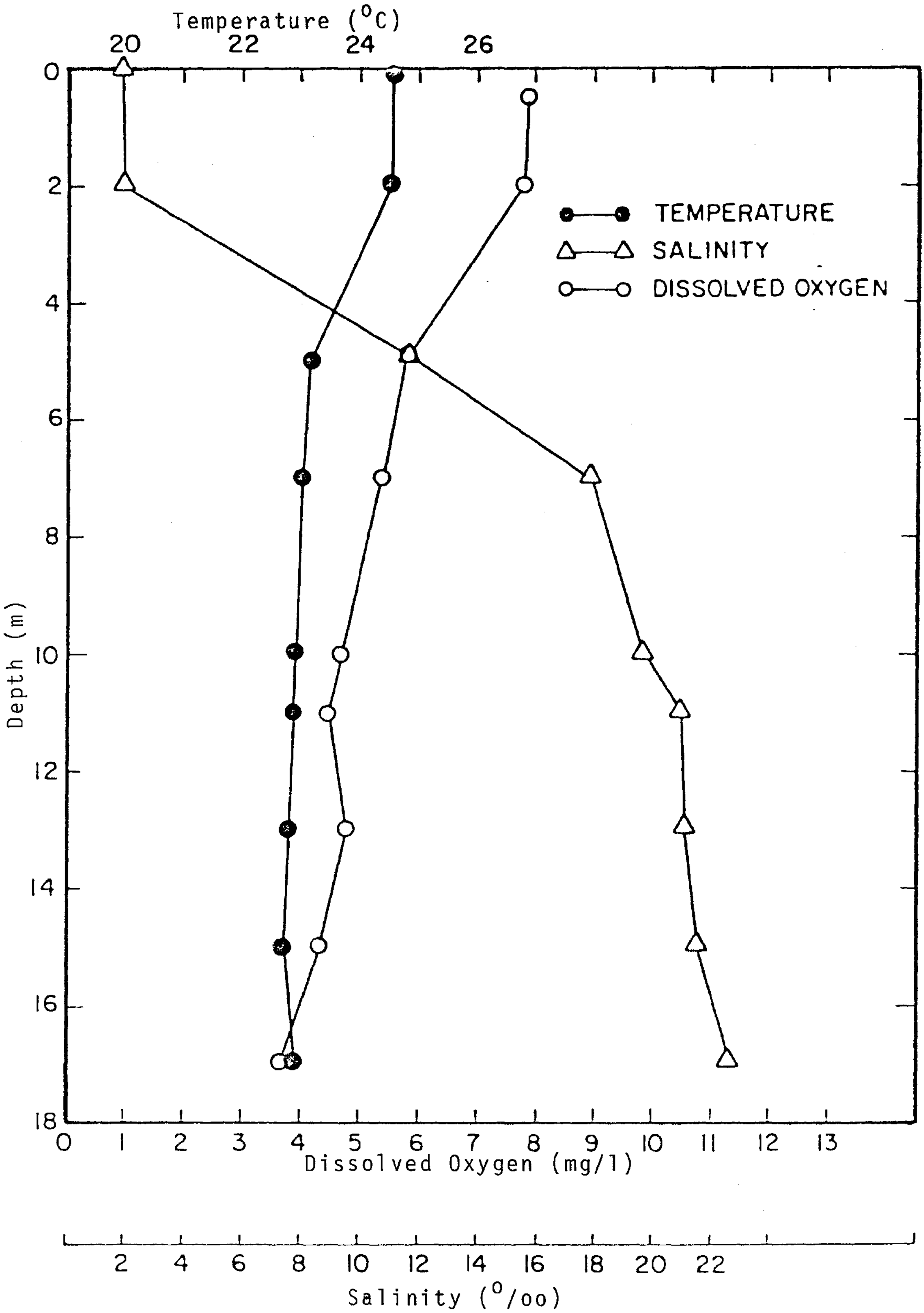


Figure 184

Temperature, Dissolved Oxygen, Salinity Profiles:
Mobile Bay, Alabama 15 m in front of dredge
June 2, 1976

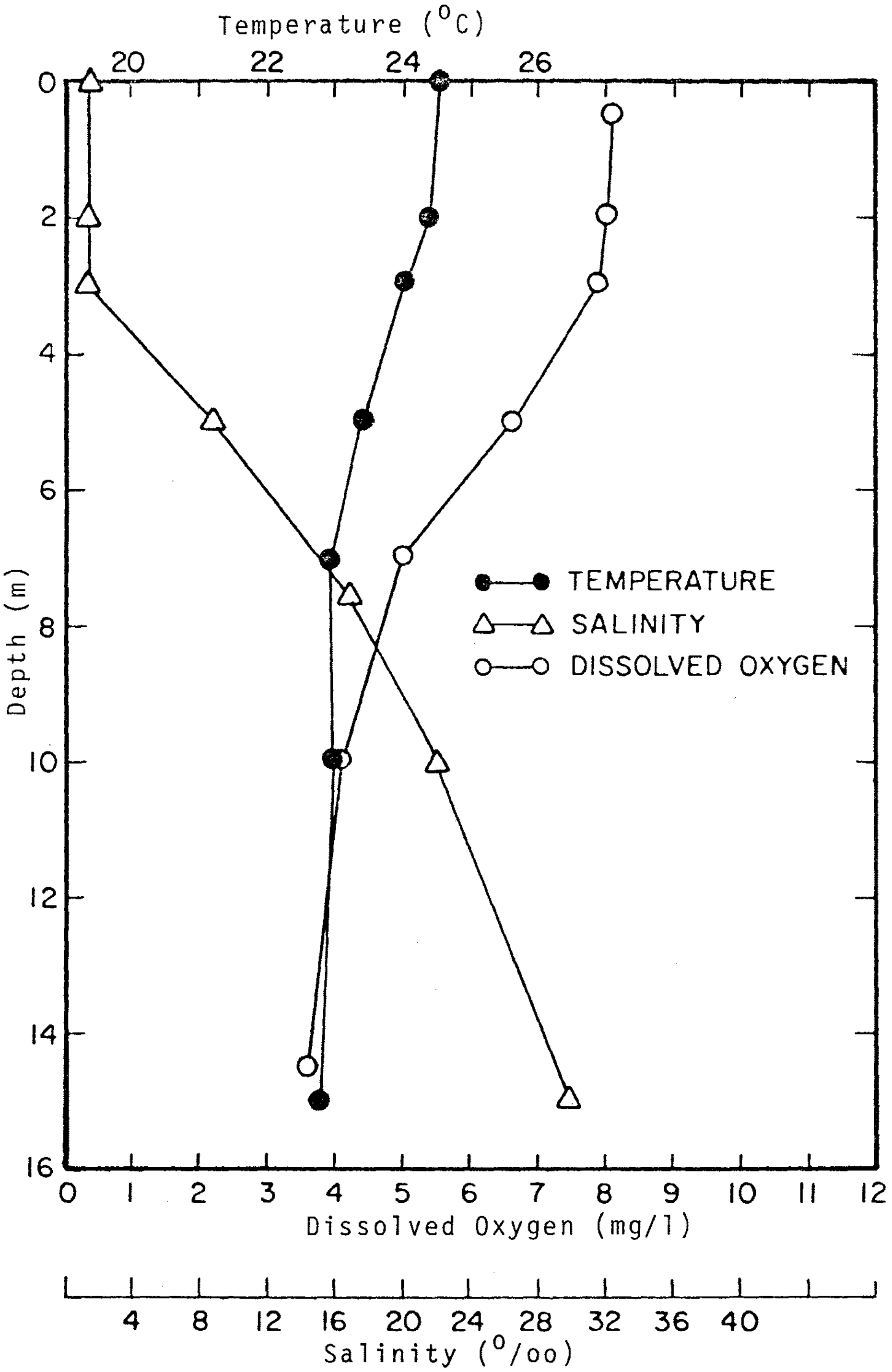


Figure 185
Temperature, Salinity, Dissolved Oxygen Profiles:
Mobile Bay, Alabama near Buoys 21-22
June 3, 1976

show that on June 2, 1976, the channel had a relatively fresh water layer of approximately 2 to 6 m thickness overlying more saline water. The less saline water is approximately 2°C warmer than the waters at the bottom of the channel. A similar profile was taken at Buoys 21 and 22. The results, presented in Figure 185, show a comparable range of readings, with 8.1 mg/l at the surface and 3.6 mg/l near the bottom. Essentially the same vertical distributions of temperature and salinity were found on June 3 as on the previous day.

The monitoring of the dredge disposal area during disposal began on June 3, 1976. The D.O. of the water column at the depth of 3 and 4 meters was monitored over a period of 25 minutes; the data are presented in Figure 186. The extreme variability of the system 40 meters from the discharge was evident in this graph. The D.O. at 4 meters ranged from 0.5 mg/l to 6.0 mg/l, while at 3 meters the D.O. ranged from 3.2 mg/l to 6.2 mg/l. Because of this variability, it was decided to do a study of D.O. variability in the discharge plume. These studies were conducted at Stations 2 and 3.

At Station 2, the water column's D.O. content was monitored for approximately 60 minutes at five different depths: 0.5, 1.0, 2.0, 3.0, and 3.5 meters. The data are plotted in Figure 187. The upper two meters of the water column exhibited little fluctuation over the sampling period. The upper meter of water appeared to be little affected by the disposal operation. The D.O. content of these waters is near the saturation value for this temperature and salinity. At the 2 m depth during the early part of the measuring period, the D.O. content of the water was depressed about 1 mg/l. At 3.0 meters fluctuations of the D.O. levels were observed, ranging from 1.2 mg/l to 6.6 mg/l. The water near the bottom exhibited D.O. depletion throughout the sampling period. During this period of time the surface salinity

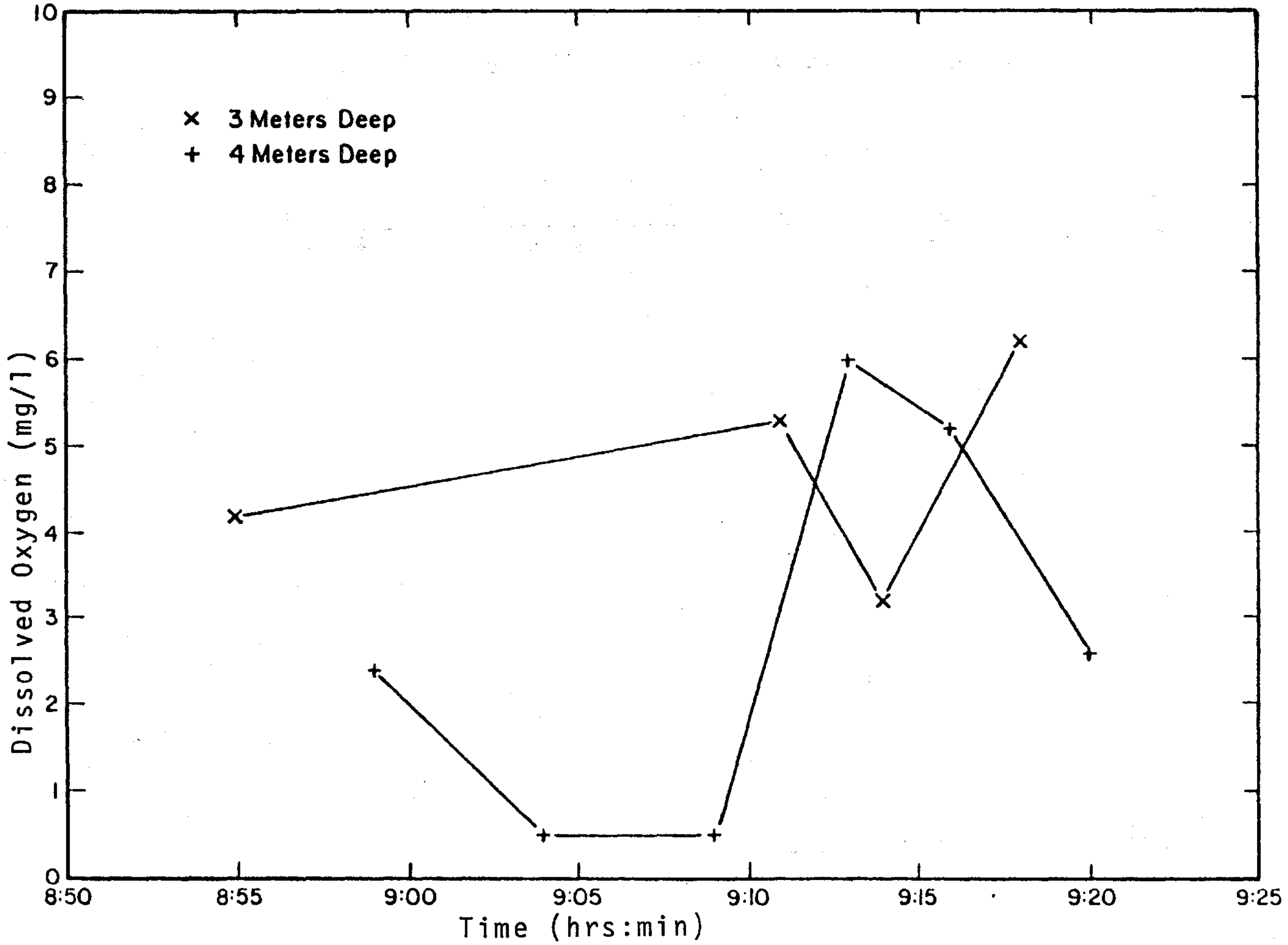


Figure 186

Dissolved Oxygen: Mobile Bay, Alabama

Station 1 June 3, 1976

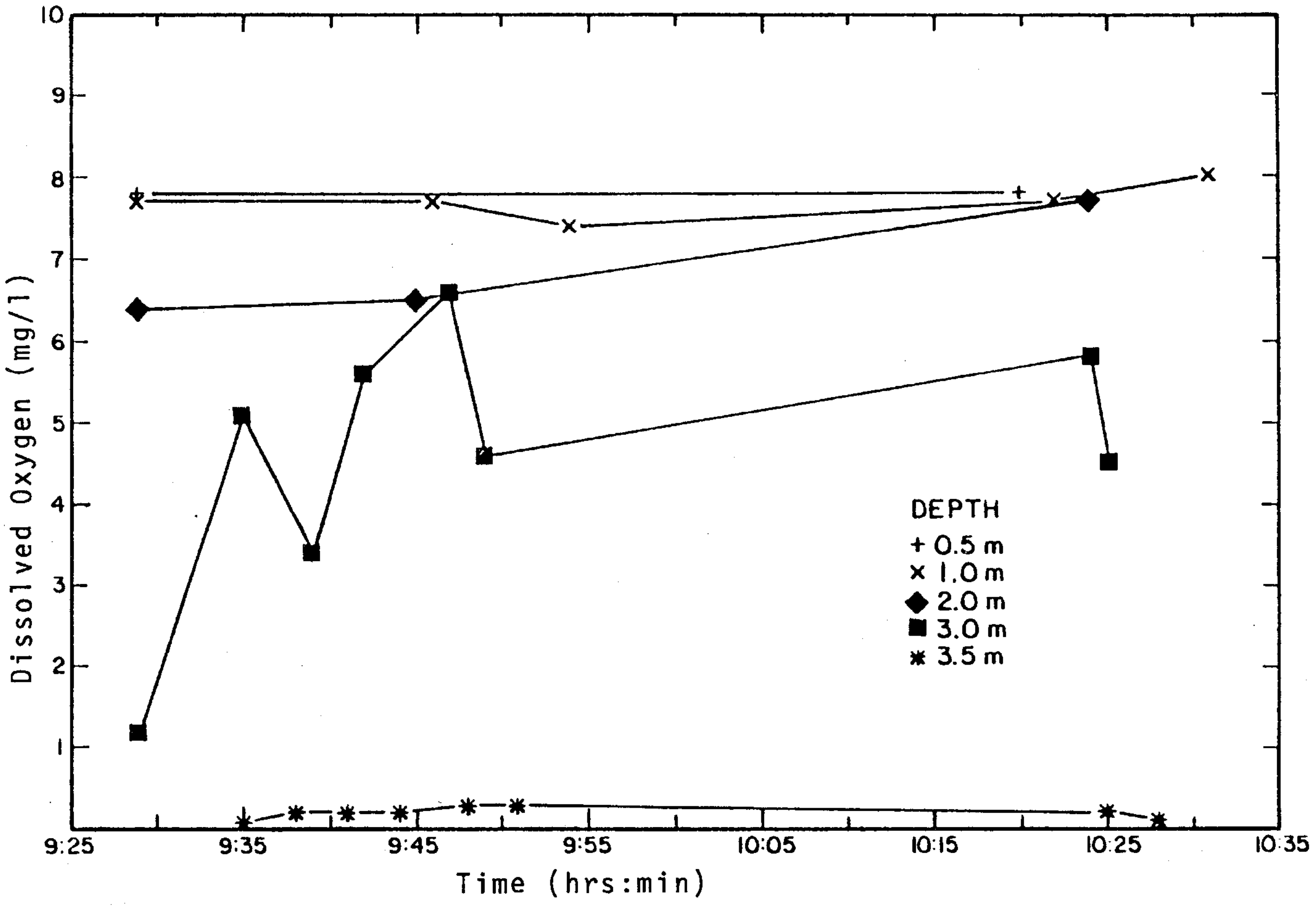


Figure 187

Dissolved Oxygen: Mobile Bay, Alabama

Station 2   June 3, 1976

ranged from 1.5 to 2 ^{o}/oo. At a depth of 3.5 m, just above the bottom, the salinity during the one-hour study period ranged from 3.5 to 4.8 ^{o}/oo. The temperature values for all measurements ranged from 24.2 to 25.1°C. The data indicate the formation of a density current of high oxygen demanding materials. The fluctuations in the D.O. levels at 3.0 meters were most likely caused by fluctuations in the thickness of the density current.

The same sampling technique was used at Station 3 for approximately 55 minutes (Figure 188). The water of the upper 2 meters was little affected by the disposal operations. At 3 m depth the D.O. was depressed to 2 to 3 mg/l during the study period. The bottom waters, 3.5 meters, showed fluctuations from 0.6 mg/l to 5.6 mg/l. At this station the density current appeared to be diluted slightly based on the fact that the salinities were, in general, 3.5 ^{o}/oo compared to those at Station 2, which were generally above 4 ^{o}/oo.

The variable D.O. found near the bottom is likely due to two causes. It is primarily due to the nature of the dredging operation in which the oxygen demand of the dredged sediment slurry is highly variable as a result of the variability of the amount of sediment in the slurry. The operation of the dredge involves sucking a sediment-water mixture from the bottom of the channel. While the dredging operators like to achieve a 20 percent sediment in this slurry, since this is optimum pumping efficiency, this is rarely achieved for any extended period of time. The suction head on the dredge swings through an arc back and forth in front of the dredge as it slowly walks forward. This results in a highly variable percent sediment in the dredge discharge pipe, ranging from essentially clear water to sediment percentages similar to that originally present in the undredged sediment. In addition to a variable oxygen demand in the slurry, the variable percent sediment in the slurry leads to an unstable

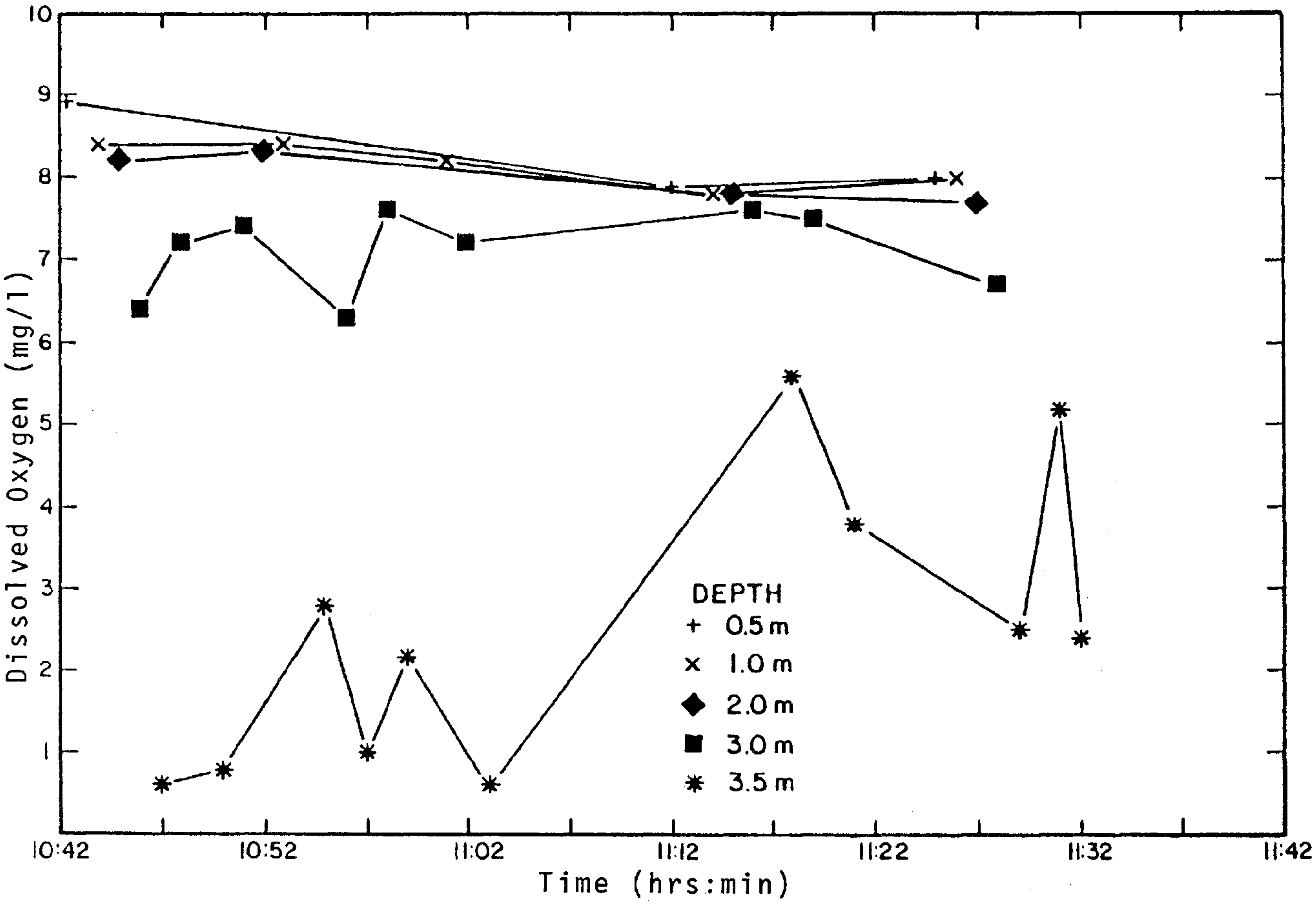


Figure 188
Dissolved Oxygen: Mobile Bay, Alabama
Station 3 June 3, 1976

density current which would tend to promote mixing between the oxygen deficient waters and the density current and the overlying waters.

Water column D.O. profiles were taken at each station. The plots of the data obtained are presented in Figure 189. The data from Stations 1 through 4 indicate the extent of the D.O. depletion as a function of depth as one moves away from the discharge point. As seen in Figures 186, 187 and 188, as one moves away from the discharge point, the height of the water mass affected decreases. The changes in D.O. at Stations 1 through 4 (Figure 189) indicate that the density current was from 1 to 1.5 meters thick at the time of sampling. The profile data from Stations 5, 7, 8 and 9 (Figure 189) indicate similar profiles. The profiles are somewhat different from Stations 1 through 4 in that the D.O. never falls below 4.5 mg/l. These stations are less affected by the dredged material disposal oepration discharge. The Station 6 profile (Figure 189), however, resembled those taken at Stations 1, 2 and 3. It can be concluded that this area was affected by the disposal operations. This indicates that part of the discharge plume was moving in a more northerly direction.

The turbidity of the water in the disposal site was monitored using a transmissometer with a 10 cm light path. The water in the area was quite turbid at all times. Station 9, the reference station, had a maximum transmissivity of 27.3 percent. The changes in transmissivity over a period of time were monitored at Stations 2 and 3 (Figures 190 and 191). The data from Station 2 showed little noticeable difference between 1.0 and 2.5 meter depths. All of the values for all depths fell within the range of the readings from 2.5 meters, 10.2 percent to 15.9 percent. The same thing was true at Station 3 for the readings at 3.5 meters depth; they ranged from 4.3 percent to 16.9 percent.

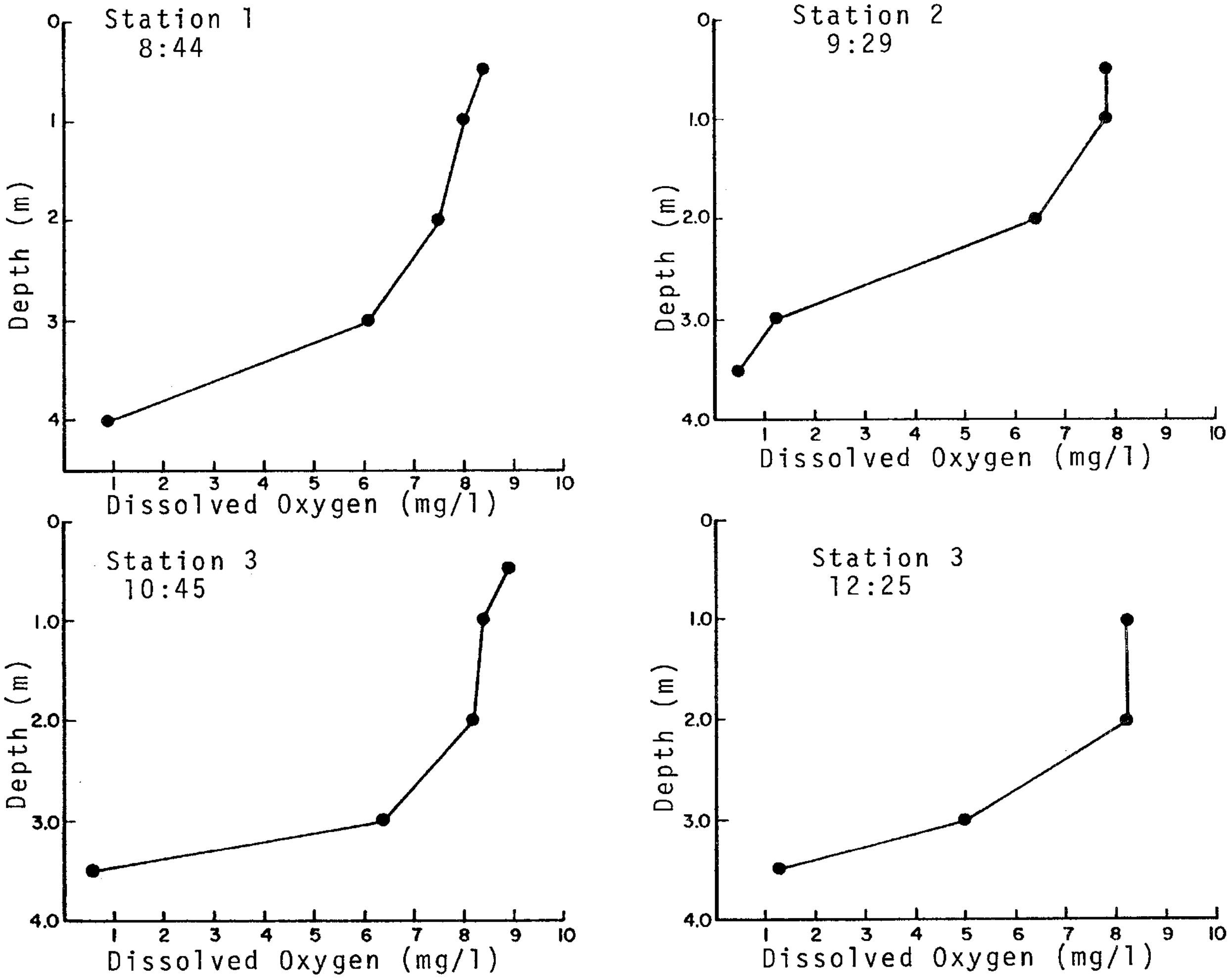
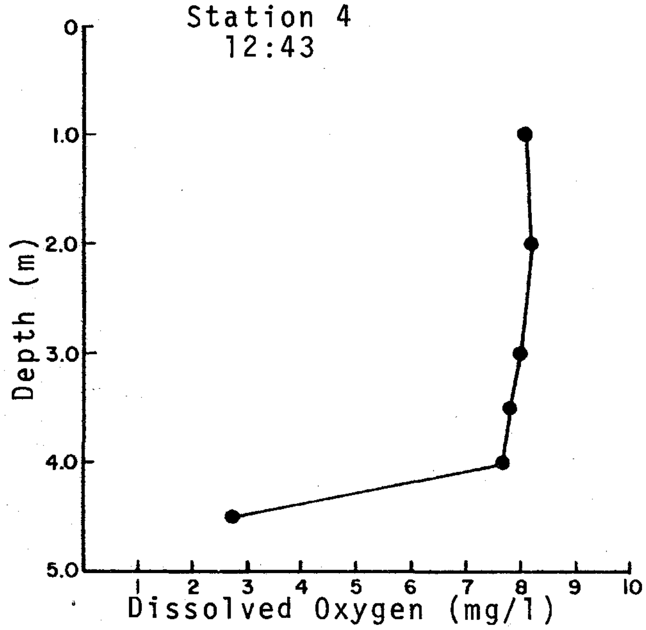


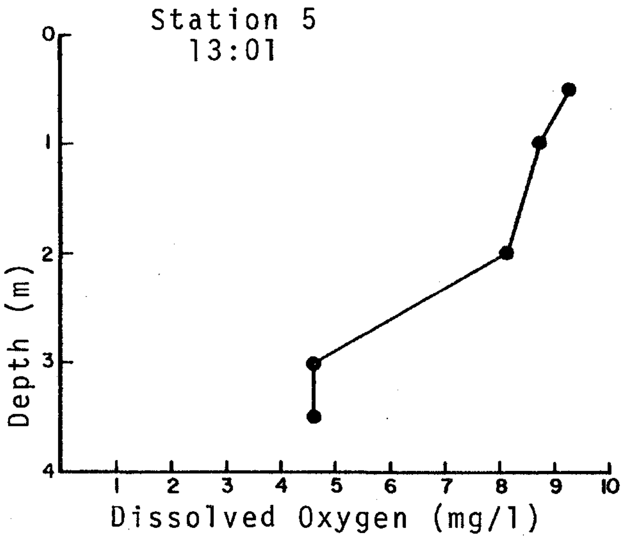
Figure 189

Dissolved Oxygen Profiles:

Mobile Bay, Alabama

June 3, 1976





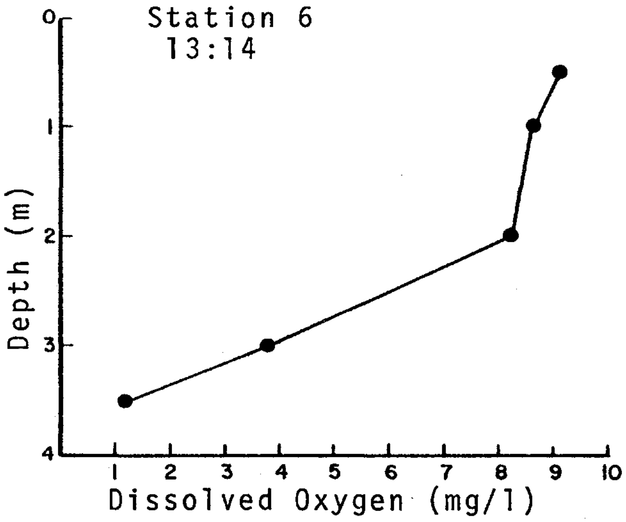


Figure 189 (continued)

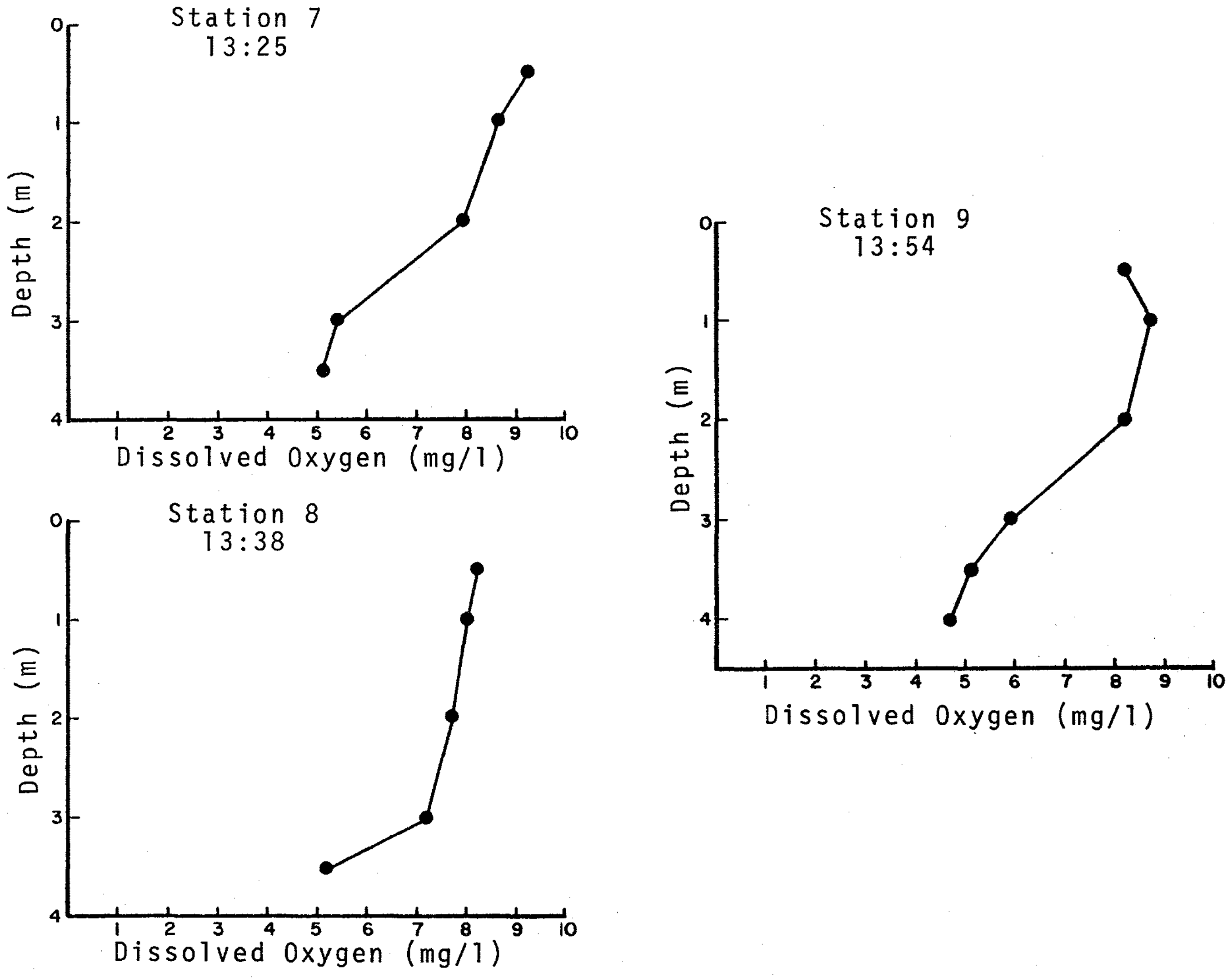


Figure 189 (continued)

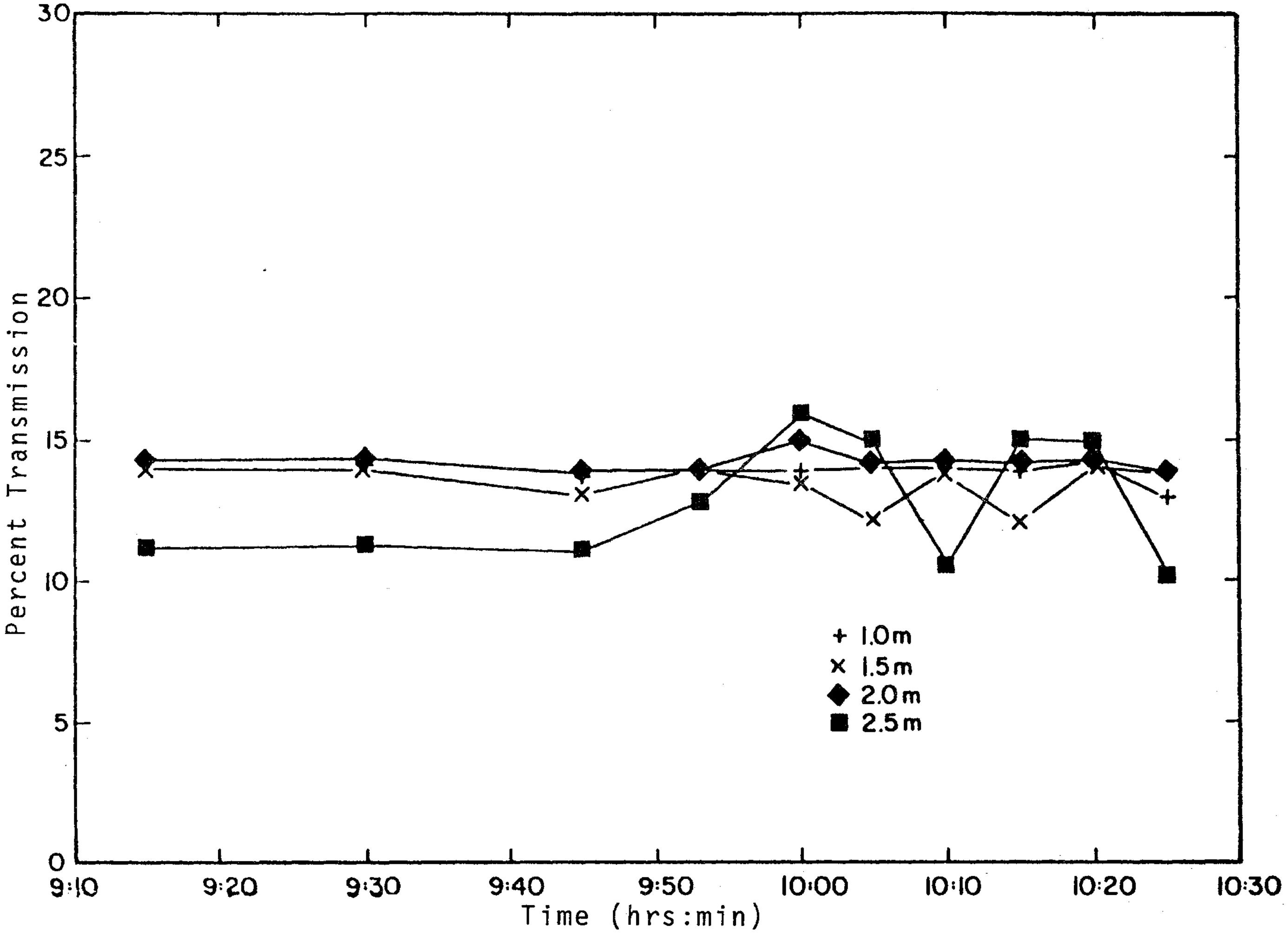


Figure 190
Changes in Percent Light Transmission:
Mobile Bay, Alabama Station 2
June 3, 1976

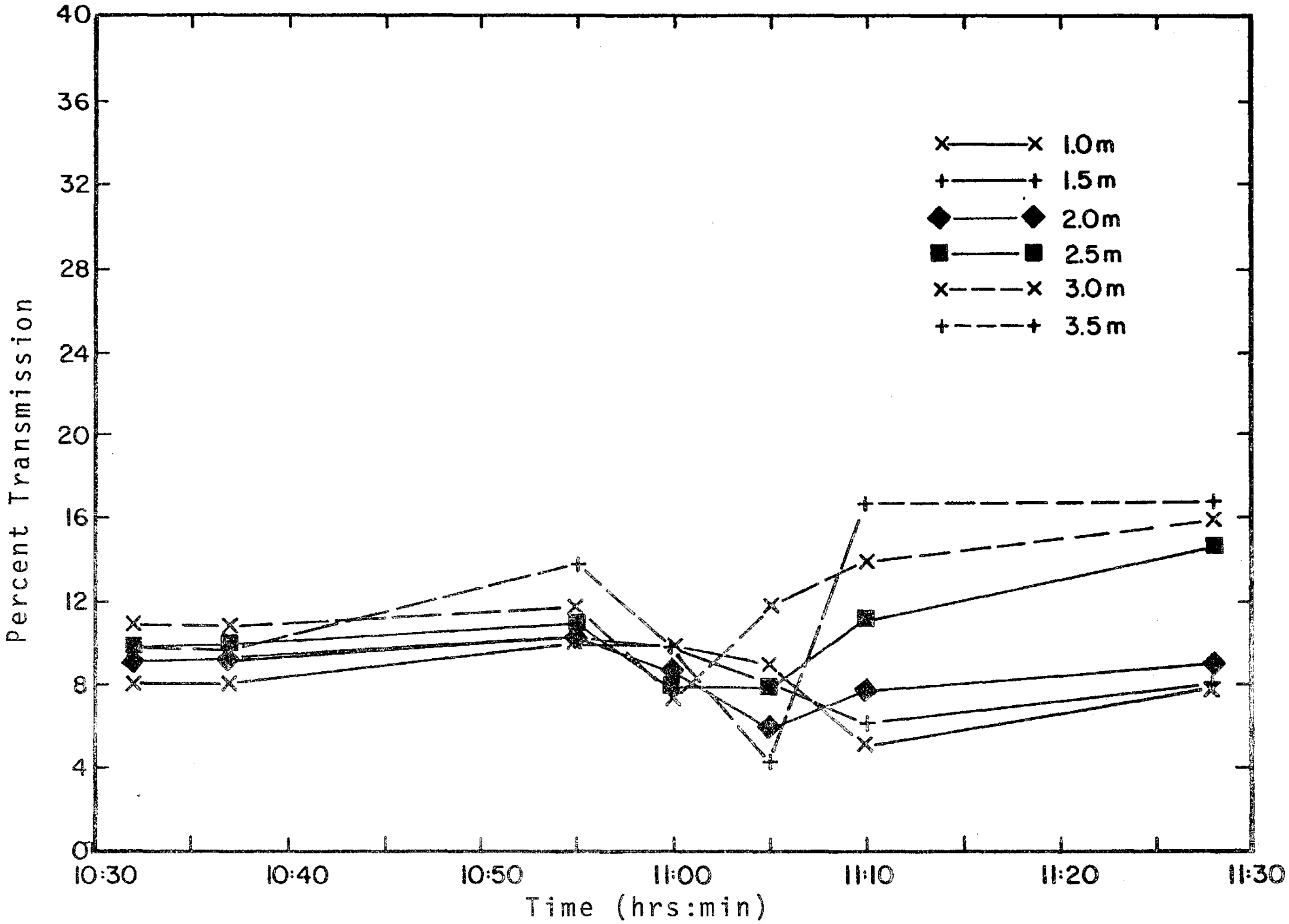


Figure 191
Changes in Percent Light Transmission:
Mobile Bay, Alabama Station 3
June 3, 1976

Water column profiles were taken at all the stations using the transmissometer (Figure 192). Due to the already high turbidity of the water, there are only a few profiles that correlate well with the D.O. profiles in Figure 188. Station 4 is one of these. The sharp decrease in percent transmission occurred at the same depth where a sharp decrease in D.O. was observed. At Station 1 the high turbidity was seen at the surface; Station 2, surface and bottom; Station 3, a uniform profile; and Station 4, only at the bottom. These profiles point to a movement and concentration of particles at the bottom of the water column with increasing distance from the discharge point, or a formation of density current. The remaining stations showed relatively uniform plots with a slight decrease near the bottom. These were what one would expect and were similar to the reference Station 9.

Heavy Metals

The concentrations for selected soluble heavy metals collected from Mobile Bay are shown in Table 522 . At Stations 1, 2, and 3 (see Figure 183 for station locations) where the density current from the discharge was most evident, elevated concentrations of iron, and occasionally of arsenic and cadmium were detected. Zinc concentrations were lower in the samples taken at these stations than at other stations that were affected to a lesser extent by the dredged material discharge. There were no changes in concentrations of manganese, chromium, lead, or copper as a result of the disposal.

Soluble iron concentrations at Stations 5 through 9 ranged from 68 to 265 μg/l. There was no particular pattern discernible with variation in depth. At Station 1, directly in front of the pipeline discharge, the concentrations of iron ranged from 184 to 709 μg/l. Higher concentrations were found in the samples taken at 3.5 and 4 meters where the density current was thickest. Concentrations were high above

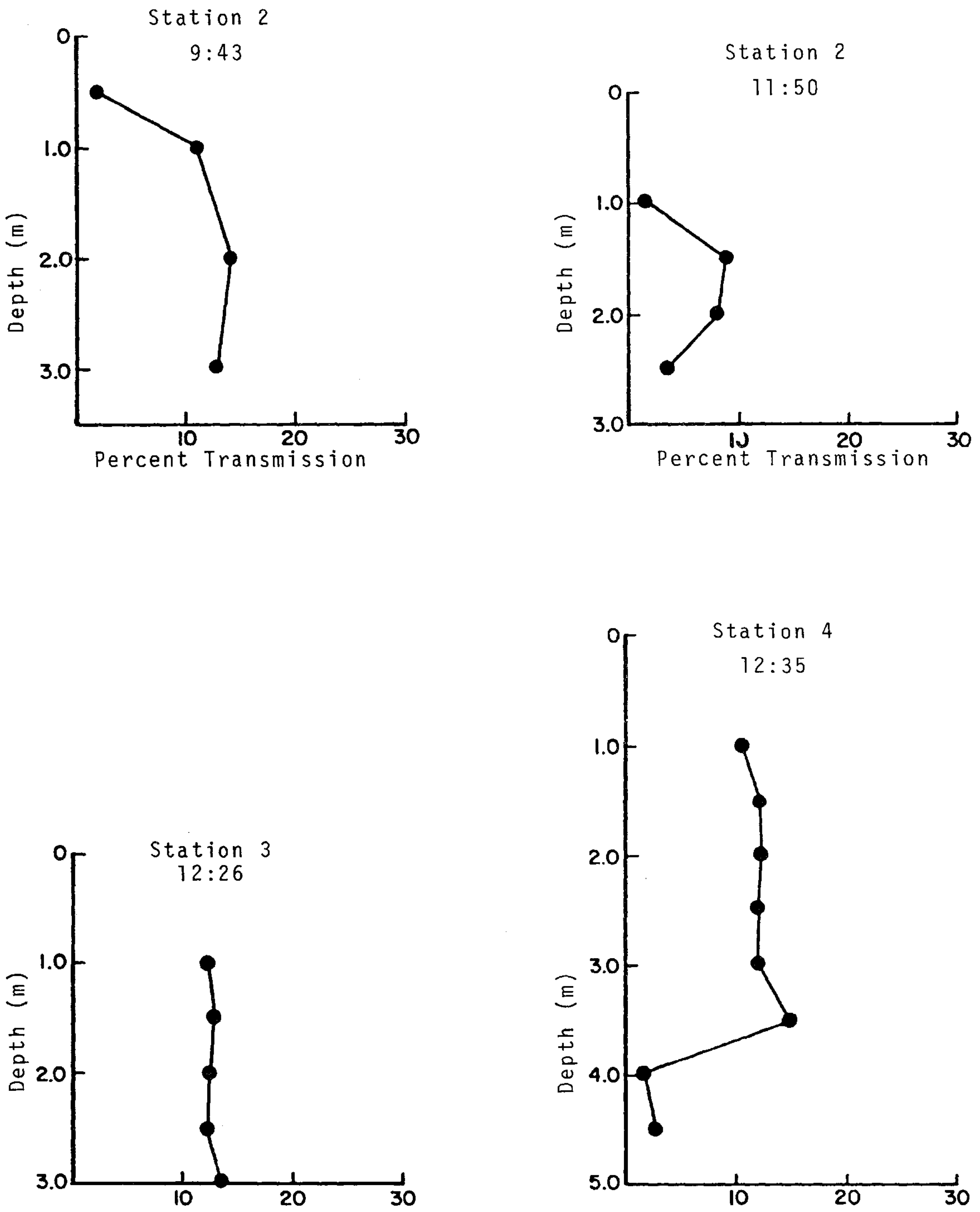


Figure 192
Water Column Profiles Transmissometer Data:
Mobile Bay, Alabama - June 3, 1976

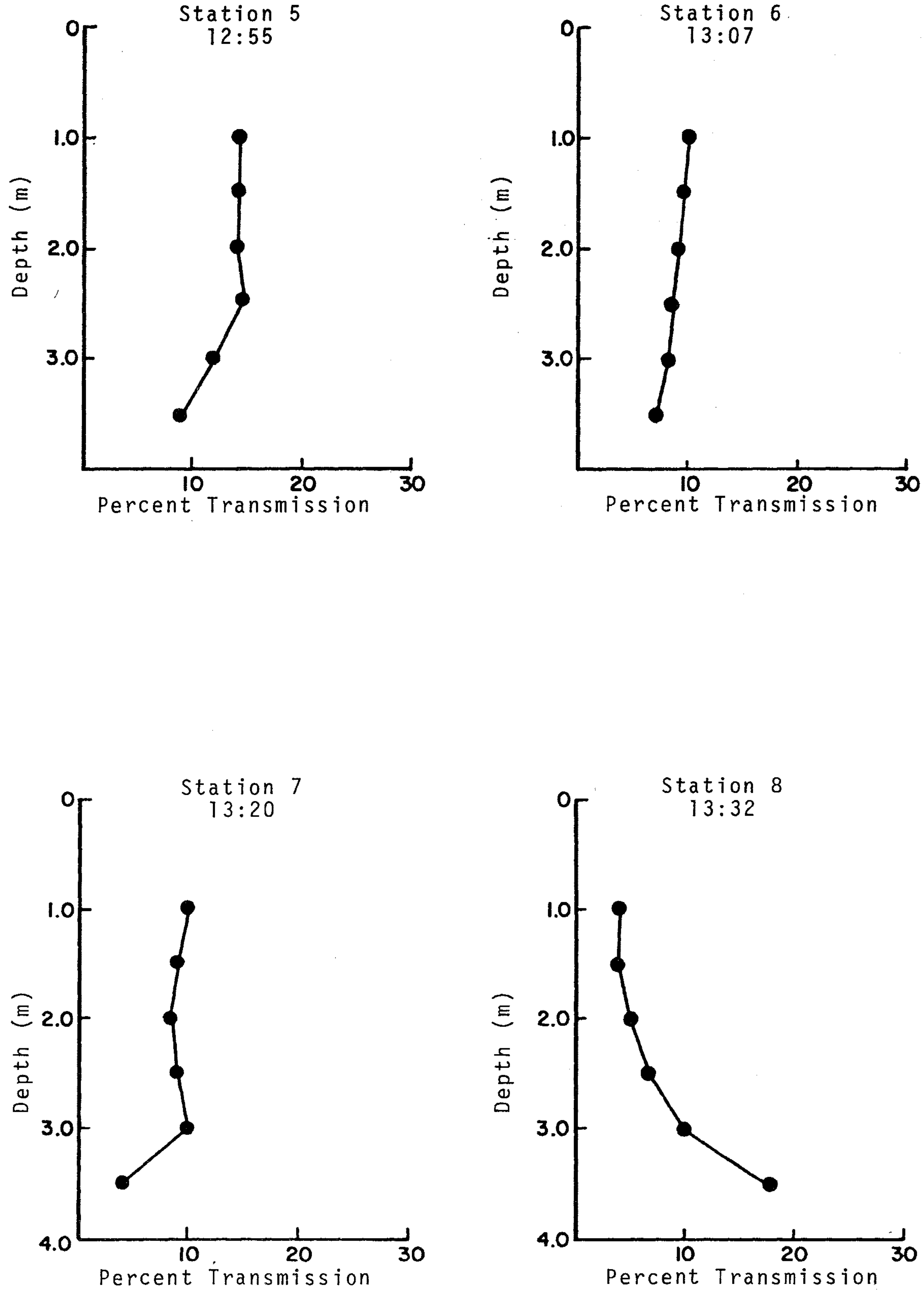


Figure 192 (continued)

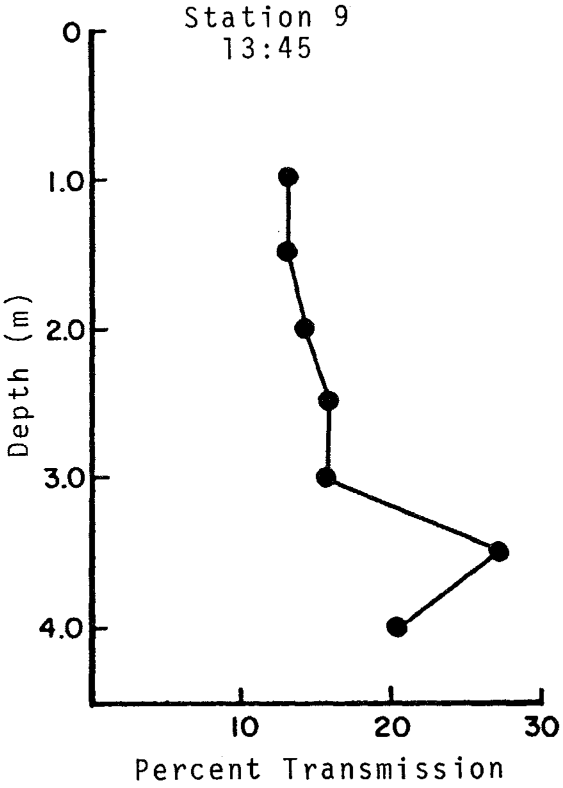


Figure 192 (continued)

Table 522

Selected Soluble Heavy Metals:

Mobile Bay Samples

(μg/1)

Time (hr:min)	Depth (m)	Mn	Cd	Cr	Zn	Ni	Pb	Cu	Fe	Hg	As
Station 1:											
9:00	0.5	129	2.1	<2	27.5	5.1	5.5	2.8	337	0.015	3.1
9:01	3.0	99	2.5	<2	13.5	5.5	6.2	2.1	302	<0.005	4.4
9:02	3.5	129	2.6	<2	14.8	4.9	6.9	2.5	682	<0.005	10.0
9:03	4.0	114	2.7	<2	11.4	5.1	5.5	2.5	317	0.065	3.1
9:05	2.0	114	2.0	<2	10.7	4.9	5.5	2.0	184	0.065	4.4
9:14	3.0	129	2.7	<2	9.8	4.6	7.6	1.7	615	<0.005	7.5
9:15	4.0	160	2.4	<2	8.6	4.0	5.5	2.4	709	<0.005	9.4
Station 2:											
9:40	0.5	84	2.4	<2	24.6	4.6	6.2	2.8	265	<0.005	4.4
9:41	1.5	53	2.4	<2	21.3	4.0	6.2	2.5	171	0.085	2.5
9:42	2.0	84	2.1	<2	14.9	4.0	6.2	2.3	262	<0.005	<2
9:43	3.5	145	2.1	<2	9.1	4.6	6.2	5.4	566	0.015	11.3
9:44	3.0	84	2.2	<2	11.1	4.6	5.5	2.5	129	0.100	6.9
10:20	0.5	114	1.8	<2	21.1	4.2	7.6	2.4	151	0.135	<2
10:21	1.5	68	2.4	<2	27.4	6.2	6.2	3.3	190	0.100	3.8
10:23	2.5	99	1.8	<2	23.2	4.2	6.2	2.5	286	0.015	2.5
10:25	3.5	99	2.4	<2	11.1	5.1	7.6	2.0	503	0.135	5.0
10:26	3.0	99	2.2	<2	11.9	5.3	6.9	2.1	199	0.085	2.5

(Continued)

Table 522 (Continued)

Time (hr:min)	Depth (m)	Mn	Cd	Cr	Zn	Ni	Pb	Cu	Fe	Hg	As
Station 3:											
10:52	3.0	84	2.5	<2	12.4	4.9	6.2	1.8	166	0.115	5.0
10:55:30	2.0	68	1.9	<2	21.3	4.2	4.8	2.5	245	0.150	<2
10:58:30	0.5	114	2.2	<2	27.0	3.8	6.2	2.1	151	0.085	<2
11:01	1.0	99	1.6	<2	17.8	4.7	4.9	2.4	324	0.050	2.5
Station 2:											
12:01	0.5	114	1.4	<2	18.6	5.0	5.5	2.5	285	0.050	<2
12:02:30	1.5	84	1.5	<2	16.5	4.4	5.5	3.2	240	0.050	<2
12:05	2.5	114	1.5	<2	17.1	5.3	6.7	2.8	379	0.050	5.0
12:06	3.5	129	1.3	<2	21.1	5.0	7.9	2.0	423	0.050	9.4
Station 3:											
12:19:30	3.5	175	1.7	<2	9.2	5.3	6.7	1.9	650	0.050	<2
12:23	3.0	114	1.6	<2	27.5	5.6	6.1	3.3	333	0.075	6.3
12:25	2.0	145	1.6	<2	28.7	5.3	6.7	3.1	340	0.050	<2
12:26:30	1.0	84	1.4	<2	24.6	5.6	6.1	2.9	333	0.050	<2
Station 4:											
12:41	4.0	99	1.5	<2	22.4	5.0	5.5	3.3	323	0.050	2.5
12:44	1.5	114	1.3	<2	20.3	5.0	5.5	2.5	297	0.050	<2
12:46	3.5	114	1.1	<2	17.5	4.4	6.1	2.9	172	0.050	7.5

(Continued)

Table 522 (Continued)

Time (hr:min)	Depth (m)	Mn	Cd	Cr	Zn	Ni	Pb	Cu	Fe	Hg	As
Station 5:											
13:01	1.0	114	1.6	<2	17.8	4.7	6.1	2.5	144	0.120	<2
13:02:30	3.0	145	1.1	<2	17.5	4.4	6.1	3.1	241	0.050	3.8
13:04	3.5	114	1.6	<2	22.8	5.3	6.7	3.1	280	0.050	<2
Station 6:											
13:14:30	3.5	129	1.5	<2	12.1	5.0	5.5	2.3	190	0.050	<2
13:15:30	3.0	129	1.4	<2	24.0	5.3	6.1	2.7	198	0.050	4.4
13:17	1.0	129	1.3	<2	16.9	4.7	4.9	2.8	142	0.050	7.5
Station 7:											
13:24:30	1.0	129	1.6	<2	19.4	5.0	5.5	3.3	254	0.050	<2
13:25:30	3.0	145	2.2	<2	24.5	8.6	6.9	3.8	68	0.141	<2
13:26:30	3.5	145	1.7	<2	31.0	7.9	5.5	2.9	116	0.067	<2
Station 8:											
13:36:30	1.0	160	2.2	<2	21.5	7.9	4.8	2.1	237	0.067	3.4
13:37:30	3.0	129	2.4	<2	40.5	9.0	6.9	3.8	43	0.127	<2
13:39:30	3.5	145	2.4	<2	33.7	7.9	5.5	3.1	116	0.067	<2

(Continued)

Table 522 (Concluded)

Time (hr:min)	Depth (m)	Mn	Cd	Cr	Zn	Ni	Pb	Cu	Fe	Hg	As
Station 9:											
13:51	1.0	114	2.4	<2	19.3	8.6	6.2	2.4	122	0.127	<2
13:52	3.0	114	2.1	<2	33.5	8.3	5.5	2.8	163	0.114	<2
13:53	3.5	190	2.2	<2	31.7	7.9	5.5	3.4	107	0.067	<2

this depth because the water was still mixed and turbid from the discharge. Stations 2 and 3 had concentrations from 0.5 to 3.0 meters ranging from 129 to 379 µg/l iron. In the bottom meter of the water column, where the density current existed, iron concentrations ranged from 423 to 650 µg/l. Station 4 was in the same line as Stations 1 through 3, but the density current had dissipated somewhat by the time that it reached this distance. The concentrations at 1.5 and 3.5 meters were 297 and 172 µg/l iron, respectively, but at 4.0 meters, it was still elevated, 323 µg/l.

Arsenic concentrations at Station 3 through 9 ranged from below the detection limit (2 µg/l) to 7.5 µg/l. There were a few samples taken at Stations 1 and 2 which exceeded this range. Two samples taken at 3.5 and 4.0 meters at Station 1 contained 10.0 and 9.4 µg/l arsenic, respectively. Two samples, both taken at 3.5 meters at Station 2, contained 11.3 and 9.4 µg/l arsenic. All other samples taken at these two stations had arsenic concentrations in the range of less than 2 to 7.5 µg/l.

Cadmium concentrations at Station 4 through 6 ranged from 1.1 to 1.6 µg/l. At Stations 1 through 3 the range was 1.4 to 2.7 µg/l, with the higher concentrations being found at Station 1 (2.0 to 2.7 µg/l). Cadmium levels at Stations 7, 8, and 9 were slightly higher than background and ranged from 1.6 to 2.4 µg/l. The elevated Station 9 levels are due to the close proximity of the dredging operation.

The lowest zinc concentrations (8.6 to 14.9 µg/l) were found in the highly turbid samples from Stations 1, 2 and 3, indicating sorption. Concentrations in other samples at these stations ranged from 16.5 to 28.7 µg/l. Concentrations at Stations 4, 5 and 6 also fell in this range. Slightly higher concentrations, ranging from 19.3 to 40.5 µg/l, were seen at Stations 7, 8 and 9.

Mercury concentrations varied widely. At Stations

1 through 3 the range was from less than 0.005 µg/l (detection limit) to 0.150 µg/l. At Stations 4, 5, and 6 all samples but one contained 0.05 µg/l mercury. At Stations 7, 8 and 9, the range was wide, 0.05 to 0.141 µg/l mercury. The variation in mercury concentrations at the first three stations was likely due to the influence of the density current.

There were no patterns of change in concentrations of manganese, lead, or copper. The ranges of these metals were 53 to 190 µg/l manganese, 4.8 to 7.9 µg/l lead, and 1.7 to 5.4 µg/l copper. Chromium concentrations in all samples were below the detection limit of 2 µg/l.

Nitrogen Compounds

The ammonium and nitrate data for the water samples collected are presented in Table 523. Water samples from Station 1, which is 50 meters away from the end of the pipe, showed a pattern of increasing ammonium concentration with depth which was correlated with increases in turbidity. The difference in ammonium concentrations in the two samples collected at 3 meters depth appeared to have occurred as a result of variation in the density current which is evident from the turbidity and other data. Water samples collected from Station 2, at a distance of 250 meters from the pipe, also showed the same pattern of increasing ammonium concentrations with depth. The density current was much thinner at this station and the ammonium concentrations higher at the bottom than those at Station 1. Samples collected one and a half hours later from this station showed much higher ammonium concentrations at surface and bottom than the earlier samples, but the concentrations decreased in mid-depth water.

At a distance of 400 meters from the discharge pipe at Station 3 the ammonium concentrations in the bottom water were slightly less than those observed at Station 2. At Station 4, at a distance of 800 meters from the pipe,

Table 523

Ammonium and Nitrate Data: Mobile Bay, Alabama

(Water Samples)

June 3, 1976
(mg N/1)

Sampling Location	Time	Depth	Ammonium		Nitrate	
	(hr:min:sec)	(m)	$\bar{X}$	SD	$\bar{X}$	SD
Station 1						
	09:00:00	0.5	<0.05	∿0	<0.04	∿0
	09:01:00	3.0	0.58	0	0.04	0
	09:02:00	3.5	5.11	0.08	<0.04	∿0
	09:03:00	4.0	6.14	0.11	0.16	0.01
	09:05:00	2.0	0.10	0.01	0.17	0
	09:14:00	3.0	3.04	0.04	<0.04	∿0
	09:15:00	4.0	6.10	0	0.04	0
Station 2						
	09:40:00	0.5	<0.05	∿0	0.16	0.01
	09:41:00	1.5	<0.05	∿0	0.05	0.01
	09:42:00	2.5	0.32	0.01	0.06	0.01
	09:43:00	3.5	6.58	0.06	<0.04	∿0
	09:44:00	3.0	0.42	0	0.06	0
	10:20:00	0.5	<0.05	∿0	0.08	0.01
	10:21:00	1.5	<0.05	∿0	0.06	0
	10:23:00	2.5	0.06	0.01	0.10	0.01
	10:25:00	3.5	6.93	0	<0.04	∿0
	10:26:00	3.0	0.18	0.01	0.16	0.01
	12:01:00	0.5	0.12	0.01	0.18	0.01
	12:02:30	1.5	<0.05	∿0	0.16	0.01
	12:05:00	2.5	<0.05	∿0	0.10	0.01
	12:06:00	3.5	8.28	0.08	-	-

(Continued)

Table 523 (Concluded)

Sampling Location	Time (hr:min:sec)	Depth (m)	Ammonium		Nitrate	
			X̄	SD	X̄	SD
Station 3	10:52:00	3.0	1.60	0.03	0.04	0.01
	10:55:30	2.0	0.06	0	0.06	0
	10:58:30	0.5	0.09	0	0.08	0.03
	11:01:00	1.0	<0.05	∿0	-	-
	12:19:30	3.5	5.70	0.01	0.07	0
	12:23:00	3.0	0.29	-	0.23	0.01
	12:25:00	2.0	<0.05	∿0	0.22	0.01
	12:26:30	1.0	<0.05	∿0	0.12	0.01
Station 4	12:41:00	4.0	1.62	0	0.12	0.01
	12:44:00	1.5	<0.05	∿0	-	-
	12:46:00	3.5	0.86	0.02	0.21	0
Station 5	13:01:00	1.0	<0.05	∿0	0.16	0
	13:02:30	3.0	0.49	0.01	-	-
	13:04:00	3.5	0.68	0.01	-	-
Station 6	13:14:30	3.5	1.59	0.03	0.10	0
	13:15:30	3.0	0.59	0.07	0.14	0.01
	13:17:00	1.0	0.07	0.01	0.23	0.01
Station 7	13:24:30	1.0	0.07	0	-	-
	13:25:30	3.0	0.08	0.01	0.28	0.01
	13:26:30	3.5	0.18	0.01	0.13	0.01
Station 8	13:36:30	1.0	0.30	0.01	0.20	0.01
	13:37:30	3.0	0.12	0.01	0.16	0
	13:39:30	3.5	0.13	0.01	0.14	0.01
Station 9	13:51:00	1.0	0.05	0	0.22	0.01
	13:52:00	3.0	0.73	0.04	0.20	0
	13:53:00	3.5	0.14	0	0.14	0.01

Mean and standard deviation calculated from duplicate analyses.
Dash (-) means data not available.

ammonium concentrations, which increased with depth, were much lower in comparison to those observed at Stations 1, 2, and 3. This is expected because of dilution and also some of the material might have settled to the bottom and moved very slowly. At Stations 5 and 6, at an angle of 45° toward north from the discharge line and at 400 to 800 meters, respectively, concentrations decreased from those observed in the samples from the actual discharge line. Also, as the distance from the end of the discharge pipe increased, ammonium concentrations decreased at all depths. At Stations 7 and 8, which are at 45° angles from the discharge line toward south, concentrations were much lower than those observed at other sampling locations. At Station 8, ammonium concentrations and turbidity were much higher in the surface water than in the bottom waters. At Station 9, which is back along the discharge pipe toward the dredge, ammonium increased at 3 meters over the 1 meter value but at 3.5 meters, it was much lower than the 3 meter value.

No discernible pattern of nitrate concentrations could be observed with respect to depth at Stations 1, 2, 3, and 4. At other stations, nitrate concentrations decreased with depth. No clear pattern of nitrate concentrations with distance could be observed, though Stations 1 and 2 had lower concentrations than other stations. At distances of 400 and 800 meters from the discharge point, nitrate concentrations were higher at both surface and bottom waters at 45° angles toward south from the discharge line as compared to those at 45° angles toward north.

Organic N data for some selected water samples are presented in Table 524. A high organic N concentration was found in the bottom water at Station 3. Measurable concentrations were observed in the bottom waters at Stations 1 and 2. For all other samples analyzed, organic N concentrations were below the detection limit.

Table 524

Organic N Data for Selected Water Samples
Collected from Mobile Bay
(mg N/1)

Sampling Location	Time (hr:min:sec)	Depth (m)	Organic N
Station 1	09:01:00	3.0	0.15
	09:05:00	2.0	<0.05
Station 2	09:41:00	1.5	<0.05
	09:43:00	3.5	1.53
Station 3	12:19:30	3.5	5.40
	12:25:00	2.0	<0.05
Station 5	13:01:00	1.0	<0.05
	13:04:00	3.5	<0.05
Station 8	13:36:30	1.0	<0.05
	13:39:30	3.5	<0.05

Phosphorus Compounds

Table 525 presents the soluble orthophosphate and total phosphorus concentrations in samples collected during dredged material disposal in Mobile Bay. During the first profile sampling at Station 1, soluble orthophosphate concentrations were at or below 0.016 mg P/1 down to about 3.5 m. There the concentration was 0.31 mg P/1. The concentration was lower (0.037 mg P/1) at the 4 m depth. When the 3 and 4 meter depths were subsequently resampled, concentrations were 0.10 and 0.35 mg P/1, respectively. These values correspond to high turbidity values (reported elsewhere) and indicate the presence of a density current of dredged material flowing in a thin layer between 3 and 4 meters' depth. This density current was also seen at Station 2, approximately 84 m downcurrent from the discharge. During the first two profile samplings, concentrations down to 3 m were 0.018 mg P/1 or less where

Table 525

Soluble Ortho P and Total P Concentrations: Mobile Bay Disposal Operation June 3, 1976

Time (hr:min:sec)	Depth (m)	Soluble Ortho P (mg P/l)		Total P (mg P/l)	
		$\bar{X}$	SD	$\bar{X}$	SD
Station 1					
9:00:00	0.5	<0.01	0	-	
9:01:00	3	0.014	0	-	
9:02:00	3.5	0.31	0	-	
9:03:00	4	0.037	0	-	
9:05:00	2	0.016	0	-	
9:14:00	3	0.10	0.001	-	
9:15:00	4	0.35	0.002	-	
Station 2					
9:40:00	0.5	0.011	0	-	
9:41:00	1.5	<0.01	0.001	0.13	0.004
9:42:00	2.5	0.01	0.001	-	
9:43:00	3.5	0.22	0.006	-	
9:44:00	3	0.018	0.001	-	
10:20:00	0.5	0.013	0	-	
10:21:00	1.5	0.010	0	-	
10:23:00	2.5	0.010	0.001	-	
10:25:00	3.5	0.12	0.001	-	
10:26:00	3	0.018	0	-	
12:01:00	0.5	0.040	0	-	
12:02:30	1.5	0.027	0	-	
12:05:00	2.5	0.020	0	-	
12:06:00	3.5	0.44	0	-	

(Continued)

Table 525 (Continued)

Time (hr:min:sec)	Depth (m)	Soluble Ortho P (mg P/l)		Total P (mg P/l)	
		X̄	SD	X̄	SD
Station 3					
10:52:00	3	0.027	0	-	
10:55:30	2	0.019	0	-	
10:58:30	0.5	0.018	0.001	-	
11:01:00	1	0.054	0.001	-	
12:19:30	3.5	0.070	0.001	-	
12:23:00	3	0.027	0	-	
12:25:00	2	0.022	0	0.14	0.06
12:26:30	1	0.041	0	-	
Station 4					
12:41:00	4	0.024	0	-	
12:44:00	1.5	0.023	0	-	
12:46:00	3.5	0.017	0	-	
Station 5					
13:01:00	1	0.065	0	0.10	0.03
13:02:30	3	0.023	0	-	
13:04:00	3.5	0.026	0	0.20	0.016
Station 6					
13:14:30	3.5	0.058	0	-	
13:15:30	3	0.040	0.001	-	
13:17:00	1	0.054	0	-	
Station 7					
13:24:30	1	0.044	0.001	-	
13:25:30	3	0.043	0	-	
13:26:30	3.5	0.016	0.001	-	

(Continued)

Table 525 (Concluded)

Time (hr:min:sec)	Depth (m)	Soluble Ortho P (mg P/l)		Total P (mg P/l)	
		$\bar{X}$	SD	$\bar{X}$	SD
Station 8					
13:36:30	1	0.033	0	0.17	0.06
13:37:30	3	0.023	0	-	
13:39:30	3.5	0.026	0.001	0.092	0.016
Station 9					
13:51:00	1	0.031	0	-	
13:52:00	3	0.030	0	-	
13:53:00	3.5	0.013	0	-	

Mean and standard deviation calculated from duplicate analyses of one sample.

Dash (-) indicates no analysis made.

turbidity values were about 3000 NTU. At 3.5 m they were 0.22 and 0.12 mg P/l. During the third profile sampling at Station 2, concentrations at all depths were higher, but the concentration at the 3.5 m depth (0.44 mg P/l) was substantially greater than in the upper waters, and also corresponded to a higher level of turbidity.

At Station 3, nearly 400 m downcurrent from the discharge, there was less evidence of a density current with respect to soluble orthophosphate levels. Concentrations ranged from 0.018 to 0.054 mg P/l in the first three meters. At 3.5 m, the concentration was 0.070 mg P/l. At Station 4, about 800 m downcurrent from the discharge, soluble ortho P concentrations (and turbidity) appeared fairly uniform with depth, ranging from 0.017 to 0.024 mg P/l. The total phosphorus concentrations at 1.5 and 2 m at Stations 2 and 3, respectively, were both about 0.13 mg P/l.

Soluble orthophosphate concentrations at Stations 5 and 8 (about 800 m from the discharge at 45° angles above and below current direction) ranged from 0.023 to 0.065 mg P/l, and 0.023 to 0.033 mg P/l, respectively. The highest soluble ortho P concentrations at these stations were in the surface waters. Although this was also the pattern of total P concentrations at Station 8, at Station 5, the higher total phosphorus concentration was in the near bottom water. The lower phosphorus concentrations found in the near bottom water at Station 8 may have been related to what appeared to be a salt wedge entering the disposal area with a rising tide. The salinity in the near bottom waters was 11 °/oo whereas in the surface waters, it was 1 °/oo.

The only other station that appeared to have such a salinity variation was Station 7 (located about 400 m from the discharge, 45° below the current direction). There the 1 and 3 m soluble orthophosphate concentrations were both about 0.044 mg P/l. However, at 3.5 m, it was 0.016 mg P/l.

Concentrations of soluble orthophosphate at Station 6, (about 400 m from the discharge 45° above the direction of current) ranged from 0.040 to 0.058 mg P/l. There did not appear to be a particular pattern with depth. At Station 8 slightly lower total P and soluble ortho P concentrations were found in deeper waters.

Samples collected at Station 9, about 400 m up-current from the discharge, had soluble orthophosphate concentrations ranging from 0.013 to 0.031 mg P/l. The lowest concentration was found at 3.5 m, but these values did not appear to be related to salinity differences.

Organic Compounds

Table 526 presents the results of the pesticide and PCB analyses as well as the characteristics of the samples in terms of pH, specific conductance, turbidity,

Table 526

Mobile Bay Dredged Sediment Discharge Plume Water Samples-Station 2

Compound	2 Meter Samples	3.5 Meter Samples
	(ng/l)	
Aldrin	1.1	19.7
op'DDT	< 3.0*	3.6
pp'DDT	< 3.0	71.9
op'DDD	< 2.0	< 2.0
pp'DDD	< 2.0	< 2.0
op'DDE	< 2.0	< 2.0
pp'DDE	11.6	10.7
Dieldrin	< 1.2	< 1.2
Endosulfan I	< 1.2	< 1.2
Endosulfan II	< 2.2	< 2.2
Endrin	< 1.6	< 1.6
Heptachlor	< 0.4	< 0.4
Lindane	7.8	3.3
PCBs	231	273
<u>Other Parameters</u>		
Oil and Grease (mg/l)	< 0.5	1.5
TOC (mg/l)	19	504
Soluble TOC (mg/l)	16	10
pH @ 25°C	7.6	7.5
Specific Conductance (μmhos/cm @ 25°C)	3.03×10^3	7.6×10^3
Turbidity (NTU)	37	240
% Settleable Solids (v/v) (24 hours settling)	< 1	22

*Compound present in quantities below detection limit.

percent settleable solids, oil and grease, TOC, and soluble TOC. The table shows that the turbidity of the 2 meter sample (37 NTU) is much less than that of the 3.5 meter sample (240 NTU). Percent settleable solids in the 2 meter sample was less than one percent while the 3.5 meter sample had 22 percent. Oil and grease in the 2 meter sample was below the detection limit (0.5 mg/l) and 1.5 mg/l was found in the 3.5 meter sample. The TOC and soluble TOC in the 2 meter sample were 19 and 16 mg/l, respectively. These results indicate that TOC content is mainly present in the soluble form and only 2.2 mg/l is attributed to the particulate matter. The TOC and soluble TOC in the 3.5 meter sample were 504 and 10 mg/l, respectively. Apparently in the 3.5 meter sample most of the TOC was associated with particulate matter.

Lindane, aldrin, pp'DDE, op'DDT and PCBs were found in the 2 meter sample. The same compounds and pp'DDT were found in the 3.5 meter sample. Concentrations of aldrin, pp'DDE, lindane and PCBs in the 2 meter sample were 1.1, 11.6, 7.8, and 231 ng/l, respectively. The 3.5 meter sample contained aldrin, op'DDT, pp'DDT, pp'DDE, lindane and PCBs in concentrations of 19.7, 3.5, 71.9, 10.7, 313, and 273 ng/l, respectively. Except for lindane and pp'DDE, concentrations of the other measurable compounds were higher in the 3.5 meter sample than in the 2 meter sample. It could be reasonably concluded that a considerable fraction of these compounds are associated with the particulate matter in the 3.5 meter sample. The most obvious is pp'DDT which was not detected in the 2 meter sample while the 3.5 meter sample contained 7.19 ng/l. The low solubility of pp'DDT supports this conclusion.

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PART V: APPENDIX A

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Table A1

Sediment Oxygen Demand: Los Angeles Site 1 Sediment

(mg/l @ 20°C)

Time (Min)	Dissolved Oxygen				
	Run 1	Run 2	Run 3	$\overline{X}$	SD
0	7.6	7.4	7.4	7.5	0.1
1	6.9	7.2	7.0	7.0	0.2
2	6.3	6.8	6.5	6.5	0.3
3	5.7	6.3	6.0	6.0	0.3
4	5.2	5.8	5.7	5.7	0.3
5	4.9	5.5	5.3	5.2	0.3
6	4.6	5.2	5.0	4.9	0.3
7	4.3	5.0	4.9	4.7	0.4
8	4.1	4.9	4.7	4.6	0.4
9	4.0	4.7	4.5	4.4	0.4
10	3.9	4.5	4.4	4.3	0.3
15	3.2	4.0	3.8	3.7	0.4
20	2.7	3.5	3.2	3.1	3.1
25	2.3	3.2	2.8	2.8	0.4
30	2.0	2.8	2.3	2.4	0.4
35	1.6	2.4	2.1	2.0	0.4
40	1.4	2.1	1.7	1.7	0.4
45	1.1	1.7	1.4	1.4	0.3
50	0.9	1.4	1.2	1.2	0.3
55	0.7	1.2	1.0	1.0	0.3
60	0.5	1.0	0.8	0.8	0.3

Sample size - 3 cc.

Table A2

Sediment Oxygen Demand: Los Angeles Site 2 Sediment

(mg/l @ 20°C)

Time (Min)	Dissolved Oxygen				
	Run 1	Run 2	Run 3	$\overline{X}$	SD
0	7.4	7.4	7.4	7.4	0.0
1	6.8	6.8	6.8	6.8	0.0
2	6.5	6.6	6.5	6.5	0.1
3	6.4	6.5	6.4	6.4	0.1
4	6.3	6.4	6.2	6.3	0.1
5	6.2	6.3	6.1	6.2	0.1
6	6.1	6.3	6.1	6.2	0.1
7	6.1	6.7	6.0	6.1	0.1
8	6.0	6.1	5.9	6.0	0.1
9	5.9	6.1	5.9	6.0	0.1
10	5.9	6.0	5.8	5.9	0.1
15	5.7	5.8	5.6	5.7	0.1
20	5.4	5.5	5.4	5.4	0.1
25	5.2	5.3	5.2	5.2	0.1
30	5.0	5.0	5.0	5.0	0.0
35	4.9	4.9	4.9	4.9	0.0
40	4.7	4.7	4.7	4.7	0.0
45	4.6	4.6	4.6	4.6	0.0
50	4.4	4.5	4.4	4.4	0.1
55	4.3	4.4	4.3	4.3	0.1
60	4.2	4.2	4.1	4.2	0.1

Sample size - 3 cc.

Table A3

Sediment Oxygen Demand: Newport Subsample A

(mg/l @ 19°C)

Time (Min)	Dissolved Oxygen				
	Run 1	Run 2	Run 3	$\overline{X}$	SD
0	7.5	7.2	7.3	7.3	0.2
1	7.2	6.8	6.8	6.9	0.2
2	6.7	6.3	6.1	6.4	0.3
3	6.4	6.0	5.9	6.1	0.3
4	6.2	5.9	5.8	6.0	0.2
5	6.0	5.7	5.6	5.8	0.2
6	5.9	5.5	5.4	5.6	0.3
7	5.7	5.3	5.3	5.4	0.2
8	5.6	5.2	5.1	5.3	0.3
9	5.4	5.0	5.0	5.1	0.2
10	5.3	4.9	4.9	5.0	0.2
15	4.6	4.2	4.3	4.4	0.2
20	4.0	3.7	3.7	3.8	0.2
25	3.5	3.2	3.2	3.3	0.2
30	3.1	2.8	2.8	2.9	0.2
35	2.6	2.4	2.3	2.4	0.2
40	2.2	2.1	2.0	2.1	0.1
45	2.0	1.7	1.6	1.8	0.2
50	1.6	1.4	1.3	1.4	0.2
55	1.4	1.2	1.1	1.2	0.2
60	1.2	1.1	0.9	1.1	0.2

Sample size - 3cc.

Table A4

Sediment Oxygen Demand: Newport Subsample B

(mg/1 @ 19°C)

Time (Min)	Dissolved Oxygen				
	Run 1	Run 2	Run 3	$\overline{X}$	SD
0	7.5	7.5	7.5	7.5	0.0
1	7.3	7.3	7.4	7.3	0.1
2	7.1	7.1	7.2	7.1	0.1
3	7.0	7.0	7.1	7.0	0.1
4	6.9	6.9	7.0	6.9	0.1
5	6.9	6.8	6.9	6.9	0.1
6	6.8	6.8	6.8	6.8	0.0
7	6.8	6.7	6.8	6.8	0.1
8	6.7	6.7	6.7	6.7	0.0
9	6.7	6.6	6.6	6.6	0.1
10	6.6	6.6	6.6	6.6	0.0
15	6.4	6.4	6.3	6.4	0.1
20	6.3	6.3	6.2	6.3	0.1
25	6.1	6.1	6.0	6.1	0.1
30	6.0	5.9	5.8	5.9	0.1
35	5.9	5.8	5.7	5.8	0.1
40	5.8	5.7	5.6	5.7	0.1
45	5.7	5.6	5.5	5.6	0.1
50	5.6	5.5	5.4	5.5	0.1
55	5.5	5.4	5.2	5.4	0.2
60	5.4	5.3	5.1	5.3	0.2

Sample size - 3 cc.

Table A5

Sediment Oxygen Demand: Stamford Sediment

(mg/l @ 20°C)

Time (min)	Dissolved Oxygen				
	Run 1	Run 2	Run 3	$\bar{X}$	SD
0	7.4	7.4	7.4	7.4	0.0
1	7.0	7.3	7.2	7.2	0.1
2	6.7	6.8	6.8	6.8	0.1
3	6.4	6.6	6.7	6.6	0.1
4	6.3	6.4	6.5	6.4	0.1
5	6.1	6.2	6.3	6.2	0.1
6	5.9	6.0	6.1	6.0	0.1
7	5.8	5.9	6.0	5.9	0.1
8	5.7	5.8	5.8	5.8	0.1
9	5.5	5.6	5.6	5.6	0.1
10	5.4	5.5	5.6	5.5	0.1
15	4.9	4.9	5.0	4.9	0.1
20	4.3	4.4	4.4	4.4	0.1
25	3.9	4.1	4.0	4.0	0.1
30	3.5	3.6	3.6	3.6	0.1
35	3.2	3.2	3.3	3.2	0.1
40	2.9	2.9	3.0	2.9	0.1
45	2.6	2.6	2.7	2.6	0.1
50	2.3	2.3	2.4	2.3	0.1
55	2.1	2.1	2.2	2.1	0.1
60	1.8	1.8	1.9	1.8	0.1

Sample size - 3 cc.

Table A6

Sediment Oxygen Demand: Norwalk Site 1 Sediment

(mg/l @ 19°C)

Time (min)	Dissolved Oxygen				
	Run 1	Run 2	Run 3	$\bar{X}$	SD
0	7.5	7.5	7.5	7.5	0.0
1	7.1	7.0	7.4	7.2	0.2
2	6.8	6.7	7.0	6.8	0.2
3	6.6	6.5	6.8	6.6	0.2
4	6.5	6.3	6.7	6.5	0.2
5	6.3	6.2	6.5	6.3	0.2
6	6.2	6.1	6.4	6.2	0.2
7	6.1	5.9	6.2	6.1	0.2
8	5.9	5.8	6.1	5.9	0.2
9	5.8	5.7	6.0	5.8	0.2
10	5.7	5.6	5.9	5.7	0.2
15	5.2	5.1	5.4	5.2	0.2
20	4.8	4.6	5.0	4.8	0.2
25	4.3	4.2	4.5	4.3	0.2
30	4.0	3.8	4.0	3.9	0.1
35	3.6	3.5	3.7	3.6	0.1
40	3.2	3.1	3.4	3.2	0.2
45	2.9	2.9	3.0	2.9	0.1
50	2.6	2.6	2.6	2.6	0.0
55	2.4	2.3	2.3	2.3	0.1
60	2.2	2.2	2.1	2.2	0.1

Sample size - 3 cc.

Table A7

Sediment Oxygen Demand: Norwalk Site 2 Sediment

(mg/l @ 19°C)

Time (min)	Dissolved Oxygen			
	Run 1	Run 2	$\bar{X}$	SD
0	7.5	7.3	7.4	0.1
1	7.1	7.1	7.1	0.0
2	6.7	6.7	6.7	0.0
3	6.5	6.5	6.5	0.0
4	6.3	6.3	6.3	0.1
5	6.1	6.2	6.2	0.1
6	6.0	6.1	6.1	0.0
7	5.9	5.9	5.9	0.0
8	5.8	5.8	5.8	0.1
9	5.6	5.7	5.7	0.1
10	5.5	5.6	5.6	0.1
15	5.0	5.1	5.0	0.1
20	4.5	4.6	4.6	0.1
25	4.0	4.2	4.1	0.1
30	3.6	3.8	3.7	0.1
35	3.3	3.4	3.4	0.1
40	3.0	3.1	3.0	0.1
45	2.6	2.8	2.7	0.1
50	2.4	2.5	2.4	0.1
55	2.1	2.3	2.2	0.1
60	1.9	2.1	2.0	0.1

Sample size - 3 cc.

Table A8

Sediment Oxygen Demand: Foundry Cove, New York

(mg/l @ 20°C)

Time	Dissolved Oxygen				
	Run 1	Run 2	Run 3	$\bar{X}$	SD
0	7.5	7.5	7.5	7.5	0
1	7.3	7.2	7.2	7.2	0.1
2	6.6	6.5	6.4	6.5	0.1
3	6.3	6.2	6.1	6.2	0.1
4	6.0	5.9	5.9	5.9	0.1
5	5.9	5.8	5.7	5.8	0.1
6	5.8	5.7	5.5	5.7	0.2
7	5.7	5.6	5.4	5.6	0.2
8	5.6	5.4	5.2	5.4	0.2
9	5.5	5.3	5.1	5.3	0.2
10	5.4	5.3	5.0	5.2	0.2
15	5.1	5.0	4.8	5.0	0.2
20	4.8	4.8	4.6	4.8	0.2
25	4.7	4.7	4.5	4.7	0.2
30	4.6	4.5	4.3	4.5	0.2
35	4.5	4.4	4.2	4.4	0.2
40	4.4	4.3	4.2	4.3	0.2
45	4.3	4.2	4.1	4.2	0.2
50	4.2	4.1	4.0	4.2	0.2
55	4.1	4.0	4.0	4.1	0.2
60	4.1	3.9	3.9	4.0	0.2

Sample size - 2 cc.

Table A9

Sediment Oxygen Demand: Menominee, Michigan, Site 1

(mg/l @ 21°C)

Time (min)	Dissolved Oxygen				
	Run 1	Run 2	Run 3	$\bar{X}$	SD
0	8.7	8.7	8.8	8.7	0.1
1	7.6	7.8	7.7	7.7	0.1
2	6.8	7.1	7.0	7.0	0.2
3	6.4	6.7	6.6	6.6	0.2
4	6.0	6.3	6.3	6.2	0.2
5	5.8	6.1	6.1	6.0	0.2
6	5.6	5.9	5.9	5.8	0.2
7	5.4	5.7	5.8	5.6	0.2
8	5.3	5.6	5.6	5.5	0.2
9	5.2	5.5	5.5	5.4	0.2
10	5.1	5.4	5.4	5.3	0.2
15	4.7	5.0	5.0	4.9	0.2
20	4.4	4.7	4.8	4.6	0.2
25	4.2	4.5	4.6	4.4	0.2
30	4.0	4.3	4.4	4.2	0.2
35	3.9	4.2	4.3	4.1	0.2
40	3.8	4.1	4.2	4.0	0.2
45	3.7	4.0	4.1	3.9	0.2
50	3.6	3.9	4.0	3.8	0.2
55	3.5	3.8	3.9	3.7	0.2
60	3.4	3.7	3.9	3.7	0.3

Sample size - 3 cc.

Table A10

Sediment Oxygen Demand: Menominee Michigan, Site 2

(mg/1 @ 20°C)

Time	Dissolved Oxygen				
(min)	Run 1	Run 2	Run 3	$\bar{X}$	SD
0	8.7	8.8	8.7	8.7	0.1
1	7.9	8.1	7.8	7.9	0.2
2	7.3	7.5	7.3	7.4	0.1
3	6.9	7.2	7.0	7.0	0.2
4	6.7	6.9	6.8	6.8	0.1
5	6.4	6.8	6.7	6.6	0.2
6	6.3	6.6	6.4	6.4	0.2
7	6.1	6.5	6.2	6.3	0.2
8	5.9	6.4	6.1	6.1	0.3
9	5.8	6.2	5.9	6.0	0.2
10	5.7	6.1	5.8	5.9	0.2
15	5.3	5.7	5.4	5.5	0.2
20	4.9	5.3	5.0	4.9	0.2
25	4.5	5.0	4.7	4.7	0.3
30	4.2	4.7	4.4	4.4	0.3
35	4.0	4.5	4.1	4.2	0.3
40	3.7	4.3	3.9	4.0	0.3
45	3.5	4.0	3.6	3.7	0.3
50	3.3	3.9	3.5	3.6	0.3
55	3.2	3.7	3.3	3.4	0.3
60	3.0	3.6	3.2	3.3	0.3

Sample size - 3 cc.

Table A11

Sediment Oxygen Demand: Wilmington, North Carolina

Time (min)	D.O. (mg/l @ 20°C)				
	Run 1	Run 2	Run 3	$\overline{X}$	SD
0	7.3	7.3	7.2	7.3	0.1
1	7.0	7.2	6.8	7.2	0.2
2	7.0	7.1	6.7	6.9	0.2
3	6.9	7.0	6.7	6.9	0.2
4	6.9	7.0	6.6	6.8	0.2
5	6.8	7.0	6.5	6.8	0.3
6	6.8	6.9	6.5	6.7	0.2
7	6.8	6.9	6.5	6.7	0.2
8	6.7	6.9	6.4	6.7	0.3
9	6.7	6.8	6.4	6.6	0.2
10	6.7	6.8	6.3	6.6	0.3
15	6.6	6.7	6.2	6.5	0.3
20	6.4	6.6	6.1	6.4	0.3
25	6.3	6.5	6.0	6.3	0.3
30	6.2	6.5	5.9	6.2	0.3
35	6.1	6.4	5.8	6.1	0.3
40	6.1	6.3	5.8	6.0	0.3
45	6.0	6.3	5.7	6.0	0.3
50	5.9	6.2	5.6	5.9	0.3
55	5.8	6.2	5.6	5.9	0.3
60	5.8	6.1	5.5	5.8	0.3

Sample size - 3 cc.

Table A12

Sediment Oxygen Demand: WES Lake, Vicksburg, Mississippi Sediment

(mg/l @ 20°C)

Time	Dissolved Oxygen				
(min)	Run 1	Run 2	Run 3	$\bar{X}$	SD
0	9.0	9.0	9.0	9.0	0
1	8.5	8.3	8.4	8.4	0.1
2	7.9	7.7	7.6	7.7	0.2
3	6.4	6.1	6.0	6.2	0.2
4	6.0	5.7	5.6	5.8	0.2
5	5.6	5.4	5.2	5.4	0.2
6	5.4	5.2	5.0	5.2	0.2
7	5.2	5.0	4.9	5.0	0.2
8	5.1	4.9	4.8	4.9	0.2
9	5.0	4.8	4.7	4.8	0.2
10	4.9	4.7	4.6	4.7	0.2
15	4.5	4.5	4.3	4.4	0.1
20	4.2	4.3	4.1	4.2	0.1
25	4.1	4.2	4.0	4.1	0.1
30	4.0	4.1	3.9	4.0	0.1
35	3.9	4.0	3.8	3.9	0.1
40	3.8	4.0	3.8	3.9	0.1
45	3.7	3.9	3.7	3.8	0.1
50	3.6	3.9	3.7	3.7	0.2
55	3.5	3.8	3.6	3.6	0.2
60	3.4	3.8	3.6	3.6	0.2

Sample size - 2 cc.

Table A13

Sediment Oxygen Demand: Apalachicola

Sites 3, 4 and 5 Sediments

Time (min)	Dissolved Oxygen (mg/l @ 21°C) Site 3	Site 4	Site 5
0	9.0	9.0	9.0
1	7.6	8.1	7.1
2	6.8	7.2	6.3
3	6.5	6.3	5.7
4	6.2	5.5	5.3
5	6.0	5.0	5.0
6	5.9	4.6	4.8
7	5.8	4.2	4.5
8	5.7	3.9	4.3
9	5.5	3.6	4.1
10	5.4	3.4	4.0
15	5.0	2.4	3.2
20	4.7	1.8	2.8
25	4.4	1.4	2.3
30	4.1	0.9	2.0

Sample size - 5 cc.

Table A14

Sediment Oxygen Demand: Apalachicola Site 3 Sediment

Time (min)	Dissolved Oxygen (mg/l @ 20°C)				
	Run 1	Run 2	Run 3	$\bar{X}$	SD
0	7.5	7.4	7.5	7.5	0.1
1	6.4	6.7	6.7	6.6	0.2
2	5.6	5.6	5.7	5.6	0.1
3	5.0	5.2	5.1	5.1	0.1
4	4.8	5.0	4.9	4.9	0.1
5	4.5	4.8	4.6	4.6	0.1
6	4.3	4.6	4.4	4.4	0.2
7	4.2	4.4	4.2	4.3	0.2
8	4.0	4.3	4.1	4.1	0.2
9	4.0	4.2	4.0	4.1	0.2
10	3.9	4.0	3.8	3.9	0.1
15	3.4	3.6	3.3	3.4	0.1
20	3.1	3.3	3.1	3.2	0.2
25	2.8	3.1	2.8	2.9	0.1
30	2.6	2.9	2.6	2.7	0.2
35	2.4	2.7	2.4	2.5	0.2
40	2.2	2.5	2.2	2.3	0.2
45	2.1	2.4	2.1	2.2	0.2
50	2.0	2.2	2.0	2.1	0.1
55	1.9	2.2	1.8	2.0	0.2
60	1.8	2.1	1.7	1.9	0.2

Sample size - 3 cc.

Table A15

Sediment Oxygen Demand: Apalachicola Site 4 Sediment

Time (min)	Dissolved Oxygen (mg/l @ 20°C)				
	Run 1	Run 2	Run 3	$\bar{X}$	SD
0	7.5	7.5	7.5	7.5	0.0
1	6.8	6.9	6.8	6.8	0.1
2	6.3	6.4	6.4	6.4	0.1
3	6.0	6.1	6.1	6.1	0.1
4	5.8	5.8	5.9	5.8	0.1
5	5.5	5.5	5.5	5.5	0.0
6	5.3	5.4	5.3	5.3	0.1
7	5.3	5.3	5.2	5.2	0.1
8	5.1	5.2	5.1	5.1	0.1
9	5.0	5.0	5.0	5.0	0.0
10	4.9	4.9	5.0	4.9	0.1
15	4.4	4.5	4.6	4.5	0.1
20	4.0	4.1	4.2	4.1	0.1
25	3.6	3.8	3.8	3.7	0.2
30	3.4	3.5	3.6	3.5	0.1
35	3.0	3.2	3.3	3.2	0.2
40	2.9	3.1	3.2	3.1	0.2
45	2.7	2.9	3.0	2.9	0.2
50	2.6	2.7	2.9	2.7	0.2
55	2.4	2.6	2.8	2.6	0.2
60	2.3	2.5	2.7	2.5	0.2

Sample size - 2 cc.

Table A16

Sediment Oxygen Demand: Apalachicola Site 5 Sediment

Time (min)	Dissolved Oxygen (mg/l @ 20°C)				
	Run 1	Run 2	Run 3	$\bar{X}$	SD
0	7.3	7.3	7.3	7.3	0.0
1	6.6	6.6	6.5	6.6	0.1
2	5.9	5.8	5.7	5.8	0.1
3	5.4	5.4	5.3	5.4	0.1
4	5.1	5.0	5.0	5.0	0.1
5	4.9	4.9	4.9	4.9	0.0
6	4.8	4.7	4.7	4.7	0.1
7	4.6	4.6	4.6	4.6	0.0
8	4.5	4.5	4.4	4.5	0.1
9	4.4	4.4	4.3	4.4	0.1
10	4.3	4.3	4.2	4.3	0.1
15	4.0	4.0	3.8	3.9	0.1
20	3.6	3.7	3.6	3.6	0.1
25	3.4	3.4	3.3	3.4	0.1
30	3.2	3.2	3.2	3.2	0.0
35	3.1	3.0	3.0	3.0	0.1
40	3.0	2.9	2.9	2.9	0.1
45	2.8	2.8	2.7	2.8	0.1
50	2.7	2.7	2.6	2.7	0.1
55	2.6	2.6	2.5	2.6	0.1
60	2.5	2.5	2.3	2.5	0.1

Sample size - 3 cc.

Table A17

Sediment Oxygen Demand: Mississippi River Sediment Test No. 1

(mg/l @ 21°C)

Time (min)	Dissolved Oxygen				
	Run 1	Run 2	Run 3	$\bar{X}$	SD
0	8.8	8.8	8.8	8.8	0.0
1	8.6	8.6	8.6	8.6	0.0
2	8.6	8.5	8.6	8.6	0.1
3	8.5	8.5	8.5	8.5	0.0
4	8.5	8.4	8.5	8.5	0.1
5	8.5	8.4	8.5	8.5	0.1
6	8.5	8.4	8.5	8.5	0.1
7	8.5	8.4	8.4	8.4	0.1
8	8.5	8.3	8.4	8.4	0.1
9	8.5	8.3	8.4	8.4	0.1
10	8.4	8.3	8.4	8.4	0.1
15	8.4	8.2	8.3	8.3	0.1
20	8.3	8.1	8.2	8.2	0.1
25	8.2	8.1	8.1	8.1	0.1
30	8.2	8.0	8.0	8.1	0.1
35	8.1	7.9	8.0	8.0	0.1
40	8.1	7.8	7.9	7.9	0.1
45	8.0	7.7	7.8	7.8	0.2
50	7.9	7.7	7.7	7.8	0.1
55	7.9	7.6	7.7	7.7	0.2
60	7.8	7.6	7.6	7.7	0.1

Sample size 3 cc.

Table A18

Sediment Oxygen Demand: Mississippi River Sediment Test No. 2

(mg/l @ 21°C)

Time (min)	Dissolved Oxygen Run 1	Run 2	Run 3	$\overline{X}$	SD
0	9.0	8.8	8.8	8.9	0.1
1	8.8	8.7	8.7	8.7	0.1
2	8.7	8.6	8.6	8.6	0.1
3	8.6	8.6	8.6	8.6	0.0
4	8.6	8.6	8.6	8.6	0.0
5	8.6	8.6	8.5	8.5	0.1
6	8.5	8.5	8.5	8.5	0.0
7	8.5	8.5	8.5	8.5	0.0
8	8.4	8.5	8.4	8.4	0.1
9	8.4	8.4	8.4	8.4	0.0
10	8.4	8.4	8.4	8.4	0.0
15	8.2	8.3	8.2	8.2	0.1
20	8.1	8.1	8.1	8.1	0.0
25	8.0	8.0	8.0	8.0	0.0
30	7.8	7.9	7.8	7.8	0.1
35	7.7	7.8	7.7	7.7	0.1
40	7.6	7.7	7.6	7.6	0.1
45	7.5	7.6	7.5	7.5	0.1
50	7.4	7.4	7.4	7.4	0.0
55	7.3	7.3	7.3	7.3	0.0
60	7.2	7.2	7.2	7.2	0.0

Sample size 3 cc.

Table A19

Sediment Oxygen Demand: James River Sediment No. 1

Time	Dissolved Oxygen (mg/l @ 21°C)				
(min)	Run 1	Run 2	Run 3	$\bar{X}$	SD
0	9.0	9.0	9.0	9.0	0.0
1	7.5	8.2	7.3	7.7	0.5
2	6.4	7.2	6.1	6.6	0.6
3	5.9	6.7	5.6	6.1	0.6
4	5.5	6.3	5.3	5.7	0.5
5	5.4	6.0	5.0	5.5	0.5
6	5.2	5.8	4.9	5.3	0.5
7	5.0	5.6	4.8	5.1	0.4
8	4.9	5.4	4.6	5.0	0.4
9	4.8	5.3	4.5	4.9	0.4
10	4.6	5.2	4.4	4.7	0.4
15	4.3	4.9	4.0	4.4	0.5
20	4.0	4.6	3.7	4.1	0.5
25	3.7	4.4	3.4	3.8	0.5
30	3.6	4.2	3.2	3.7	0.5
35	3.4	4.0	3.0	3.5	0.5
40	3.2	3.9	2.8	3.3	0.6
45	3.0	3.8	2.6	3.1	0.6
50	2.8	3.7	2.5	3.0	0.6
55	2.7	3.6	2.4	2.9	0.6
60	2.6	3.4	2.3	2.8	0.6

Sample size - 3 cc.

Table A20

Sediment Oxygen Demand: James River Sediment No.2

Time	Dissolved Oxygen (mg/l @ 21°C)				
(min)	Run 1	Run 2	Run 3	$\bar{X}$	SD
0	8.8	8.8	8.8	8.8	0.0
1	7.0	6.8	7.0	6.9	0.1
2	5.8	5.7	5.8	5.8	0.1
3	5.1	5.2	5.2	5.2	0.1
4	4.8	4.9	4.9	4.9	0.1
5	4.5	4.7	4.6	4.6	0.1
6	4.2	4.5	4.4	4.4	0.2
7	4.0	4.4	4.3	4.2	0.2
8	3.9	4.2	4.1	4.1	0.2
9	3.8	4.1	4.0	4.0	0.2
10	3.7	4.0	3.9	3.9	0.2
15	3.2	3.6	3.4	3.4	0.2
20	2.9	3.2	3.1	3.1	0.2
25	2.6	3.0	2.8	2.8	0.2
30	2.3	2.7	2.5	2.5	0.2
35	2.1	2.5	2.3	2.3	0.2
40	1.9	2.3	2.2	2.1	0.2
45	1.7	2.2	1.9	1.9	0.3
50	1.6	2.0	1.8	1.8	0.2
55	1.4	1.8	1.6	1.6	0.2
60	1.3	1.7	1.4	1.5	0.3

Sample size - 3 cc.

Table A21

Sediment Oxygen Demand: Bailey Creek Sediment

Time (min)	Dissolved Oxygen (mg/l @ 21°C) Run 1	Run 2	Run 3	$\bar{X}$	SD
0	8.8	8.8	8.8	8.8	0.0
1	8.4	8.3	8.3	8.3	0.1
2	8.2	8.1	8.2	8.2	0.1
3	8.1	8.0	8.0	8.0	0.1
4	8.0	7.8	7.8	7.9	0.1
5	7.9	7.7	7.6	7.7	0.2
6	7.8	7.6	7.5	7.6	0.2
7	7.7	7.5	7.4	7.5	0.2
8	7.6	7.4	7.3	7.4	0.2
9	7.5	7.3	7.2	7.3	0.2
10	7.5	7.2	7.1	7.3	0.2
15	7.1	6.8	6.8	6.9	0.2
20	6.8	6.5	6.4	6.6	0.2
25	6.5	6.2	6.1	6.3	0.2
30	6.3	6.0	5.9	6.1	0.2
35	6.0	5.8	5.7	5.8	0.2
40	5.8	5.6	5.5	5.6	0.2
45	5.6	5.3	5.4	5.4	0.2
50	5.4	5.1	5.2	5.2	0.2
55	5.2	4.9	5.0	5.0	0.2
60	5.0	4.7	4.8	4.8	0.2

Sample size - 3 cc.

Table A22

Sediment Oxygen Demand: Galveston Bay Entrance Channel Buoy 1 Sediment

Time	Dissolved Oxygen (mg/l @ 20°C)				
(min)	Run 1	Run 2	Run 3	$\bar{X}$	SD
0	8.1	8.4	8.3	8.3	0.2
1	7.5	7.6	7.7	7.6	0.1
2	6.8	6.8	6.9	6.8	0.1
3	6.3	6.3	6.3	6.3	0.0
4	5.9	5.8	5.9	5.9	0.1
5	5.7	5.6	5.6	5.6	0.1
6	5.4	5.3	5.3	5.3	0.1
7	5.2	5.1	5.1	5.1	0.1
8	4.9	4.9	4.9	4.9	0.0
9	4.8	4.7	4.7	4.7	0.1
10	4.7	4.6	4.5	4.6	0.1
15	4.0	4.1	4.0	4.0	0.1
20	3.6	3.6	3.6	3.6	0.0
25	3.3	3.2	3.2	3.2	0.1
30	3.0	3.0	3.0	3.0	0.1
35	2.8	2.7	2.7	2.7	0.1
40	2.5	2.5	2.6	2.5	0.1
45	2.3	2.3	2.4	2.3	0.1
50	2.2	2.2	2.3	2.2	0.1
55	2.1	2.0	2.2	2.1	0.1
60	2.0	1.9	2.1	2.0	0.1

Sample size - 5 cc.

Table A23

Percent Settleable Solids: Galveston Hopper Dredge Samples**

Dredging Location and Date (1975)	Time (hr:min)	Sample Source*	Percent Settleable Solids
August 25:			
Run 1 (Buoys 9-11)	12:55	D	7.5
	13:00	D	10
	13:05	D	22
	13:10	D	8
	13:20	D	10
	13:35	D	5
	13:50	D	5
	13:55	S	5
Run 2 (Buoys 7A-11)	14:45	D	1.
	14:50	D	9
	14:55	D	5
	15:00	D	13
	15:05	D	10
	15:10	D	13
August 28:			
Run 1 (Buoys 6-8) (Galv. Dump No. 2)	12:08	D	89
	12:18	D	15
	12:28	D	13
	12:38	S	1
	12:48	S	5
Run 2 (Buoys 6-8) (Galv. Dump No. 3)	13:15	D	89
	13:25	D	6
	13:35	D	13
	13:45	D	3
	14:05	S	3
	14:25	S	15
August 29:			
Run 1 (Buoys 4-8)	10:06	D	35
	10:16	D	9
	10:36	S	7
	10:46	S	6
	10:56	S	11
	11:06	S	15

(Continued)

Table A23(Concluded)

Dredging Location and Date (1975)	Time (hr:min)	Sample Source*	Percent Settleable Solids
August 29:			
Run 2 (Buoys 1-3)	12:03	D	100
(Galv. Dump No. 4)	12:13	D	97
	12:23	D	36
	12:33	S	10
	12:53	S	
Run 3 (Buoys 1-3)			
(Galv. Dump No. 5)	13:30	D	88
	13:40	D	54
	13:55	D	53
	14:05	S	39
	14:15	S	45

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*Sample source: D = Dredging pump discharge, S = Supernatant.
**Sample source and percent settleable solids data in this table correspond to hopper samples concentrations data in other Galveston Hopper Dredge tables, and are not repeated in those tables.

Table A24

Sediment Oxygen Demand: Texas City Channel Site 1

Time	Dissolved Oxygen (mg/l@20°C)				
(min)	Run 1	Run 2	Run 3	$\overline{X}$	SD
0	8.7	8.7	8.8	8.7	0.1
1	8.4	8.2	8.5	8.4	0.2
2	7.7	7.6	7.9	7.7	0.2
3	7.4	7.0	7.5	7.3	0.3
4	7.0	6.6	7.1	6.9	0.3
5	6.8	6.2	6.8	6.6	0.3
6	6.4	5.8	6.4	6.2	0.3
7	6.2	5.6	6.1	6.0	0.3
8	5.9	5.2	5.8	5.6	0.4
9	5.7	5.0	5.6	5.4	0.4
10	5.5	4.8	5.4	5.3	0.3
15	4.5	3.7	4.3	4.2	0.4
20	3.7	2.9	3.5	3.4	0.4
25	3.1	2.2	2.8	2.7	0.5
30	2.5	1.6	2.2	2.1	0.5
35	2.1	1.2	1.7	1.7	0.4
40	1.6	0.8	1.4	1.3	0.4
45	1.3	0.5	1.0	0.9	0.4
50	1.0	0.3	0.8	0.7	0.3
55	0.7	0.2	0.5	0.5	0.2
60	0.5	0.1	0.3	0.3	0.3

Sample size - 5 cc.

Table A25

Sediment Oxygen Demand: Texas City Channel

Site 2

Time (min)	Dissolved Oxygen (mg/l@20°c)				
	Run 1	Run 2	Run 3	$\bar{X}$	SD
0	8.6	8.5	8.5	8.5	0.1
1	7.9	7.6	7.9	7.8	0.2
2	7.5	7.1	7.4	7.3	0.2
3	7.1	6.7	6.8	6.9	0.2
4	6.8	6.3	6.5	6.5	0.2
5	6.5	6.0	6.1	6.2	0.3
6	6.2	5.8	5.8	5.9	0.2
7	6.0	5.6	5.5	5.7	0.3
8	5.8	5.3	5.2	5.4	0.3
9	5.6	5.1	5.0	5.2	0.3
10	5.4	4.9	4.8	5.0	0.3
15	4.6	4.0	3.9	4.2	0.4
20	3.8	3.4	2.8	3.3	0.5
25	3.3	2.9	2.5	2.9	0.4
30	2.8	2.3	2.0	2.4	0.4
35	2.3	1.9	1.6	1.9	0.4
40	2.0	1.6	1.2	1.6	0.4
45	1.6	1.2	0.9	1.2	0.4
50	1.3	0.9	0.6	0.9	0.4
55	1.0	0.7	0.4	0.7	0.3
60	0.8	0.5	0.3	0.5	0.2

Sample size - 5 cc.

Table A26

Sediment Oxygen Demand: Texas City Channel

Site 4

Time (min)	Dissolved Oxygen (mg/1@21°C)				
	Run 1	Run 2	Run 3	$\bar{X}$	SD
0	7.4	7.4	7.5	7.4	0.1
1	6.9	6.8	7.2	7.0	0.2
2	6.4	6.4	6.6	6.5	0.1
3	6.0	6.1	6.1	6.1	0.1
4	5.8	5.8	5.9	5.8	0.1
5	5.6	5.7	5.6	5.6	0.1
6	5.4	5.5	5.4	5.4	0.1
7	5.2	5.3	5.2	5.2	0.1
8	5.1	5.2	5.0	5.1	0.1
9	5.0	5.0	4.9	5.0	0.1
10	4.9	4.9	4.8	4.9	0.1
15	4.3	4.4	4.1	4.3	0.2
20	3.8	4.0	3.6	4.0	0.3
25	3.3	3.6	3.2	3.4	0.2
30	3.0	3.2	2.8	3.0	0.2
35	2.6	2.9	2.4	2.6	0.3
40	2.3	2.6	2.1	2.3	0.3
45	2.0	2.3	1.8	2.0	0.3
50	1.8	2.1	1.5	1.8	0.3
55	1.5	1.9	1.4	1.6	0.3
60	1.4	1.6	1.1	1.4	0.4

Sample size - 3 cc.

Table A27

Sediment Oxygen Demand: Texas City Channel

Site 5

Time (min)	Dissolved Oxygen (mg/l@21°C)				
	Run 1	Run 2	Run 3	$\bar{X}$	SD
0	7.6	7.4	7.5	7.5	0.1
1	6.8	6.8	7.0	6.9	0.1
2	6.1	6.3	6.5	6.3	0.2
3	5.8	6.0	6.1	6.0	0.2
4	5.5	5.7	6.0	5.7	0.3
5	5.2	5.5	5.7	5.5	0.3
6	5.1	5.3	5.6	5.3	0.3
7	5.0	5.1	5.5	5.2	0.3
8	4.8	5.0	5.4	5.1	0.3
9	4.7	4.9	5.3	5.0	0.3
10	4.6	4.8	5.2	4.9	0.3
15	4.2	4.4	5.0	4.4	0.3
20	4.0	4.0	4.7	4.2	0.4
25	3.7	3.8	4.5	4.0	0.4
30	3.5	3.6	4.3	3.8	0.4
35	3.3	3.5	4.1	3.6	0.4
40	3.2	3.3	4.0	3.5	0.4
45	3.0	3.1	3.9	3.3	0.5
50	2.9	3.0	3.8	3.2	0.5
55	2.7	3.0	3.7	3.1	0.5
60	2.6	2.9	3.6	3.0	0.5

Sample size - 3 cc.

Table A28

Sediment Oxygen Demand: Texas City Channel

Site 6

Time (min)	Dissolved Oxygen (mg/1@21°C)				
	Run 1	Run 2	Run 3	$\overline{X}$	SD
0	8.0	7.4	7.4	7.6	0.3
1	7.2	6.3	6.9	6.8	0.5
2	6.7	5.8	6.6	6.3	0.5
3	6.2	5.4	6.2	5.9	0.5
4	5.9	5.1	5.8	5.6	0.4
5	5.7	4.9	5.7	5.4	0.5
6	5.6	4.7	5.5	5.3	0.5
7	5.4	4.5	5.2	5.0	0.5
8	5.2	4.4	5.1	4.9	0.4
9	5.1	4.2	4.9	4.7	0.5
10	5.0	4.1	4.8	4.6	0.5
15	4.2	3.5	4.3	4.0	0.4
20	3.8	3.1	3.9	3.6	0.4
25	3.2	2.7	3.6	3.2	0.4
30	2.9	2.3	3.2	2.8	0.5
35	2.5	2.1	3.0	2.5	0.4
40	2.3	1.8	2.8	2.3	0.5
45	2.0	1.6	2.5	2.0	0.4
50	1.7	1.4	2.3	1.8	0.5
55	1.5	1.3	2.1	1.6	0.4
60	1.4	1.1	2.0	1.5	0.5

Sample size - 3 cc.

Table A29

Sediment Oxygen Demand: Galveston Channel Sediment

Time (min)	Dissolved Oxygen (mg/l @ 20°C) Run 1 (5 cc)	Run 2 (3 cc)	Run 3 (2 cc)
0	8.6	8.5	8.6
1	8.0	7.7	8.1
2	6.2	7.1	7.6
3	5.6	6.8	7.4
4	5.2	6.5	7.1
5	4.9	6.2	6.9
6	4.5	6.0	6.8
7	4.3	5.9	6.7
8	4.0	5.8	6.6
9	3.8	5.6	6.5
10	3.6	5.5	6.4
15	2.7	4.9	6.0
20	2.1	4.5	5.7
25	1.4	4.1	5.5
30	1.0	3.8	5.2
35		3.5	5.0
40		3.3	4.9
45		3.1	4.7
50		2.9	4.6
55		2.8	4.5
60		2.6	4.4

Table A30

Sediment Oxygen Demand: Houston Ship Channel

Site 1 Sediment

Time	Dissolved Oxygen (mg/l @ 20°C)					
(min)	Run 1	Run 2	Run 3	Run 4	$\bar{X}$	SD
0	7.3	7.2	7.2	7.3	7.2	0.1
1	7.2	6.9	6.9	7.3	7.0	0.2
2	6.8	6.5	6.5	6.8	6.6	0.2
3	6.7	6.3	6.3	6.5	6.4	0.2
4	6.5	6.1	6.2	6.4	6.3	0.2
5	6.4	6.0	6.1	6.2	6.2	0.2
6	6.4	5.9	6.0	6.1	6.1	0.2
7	6.3	5.8	5.9	6.0	6.0	0.2
8	6.2	5.7	5.8	5.9	5.9	0.2
9	6.2	5.6	5.7	5.8	5.8	0.3
10	6.1	5.6	5.7	5.8	5.8	0.2
15	5.8	5.2	5.3	5.4	5.4	0.3
20	5.5	5.0	5.0	5.1	5.2	0.2
25	5.2	4.7	4.6	4.9	4.8	0.3
30	5.0	4.4	4.3	4.6	4.6	0.3
35	4.7	4.2	4.0	4.3	4.3	0.3
40	4.5	4.0	3.8	4.1	4.1	0.3
45	4.3	3.8	3.6	3.9	3.9	0.3
50	4.1	3.6	3.4	3.7	3.7	0.3
55	3.9	3.4	3.2	3.5	3.5	0.3
60	3.7	3.2	3.0	3.3	3.2	0.3

Sample size - 2 cc.

Table A31

Sediment Oxygen Demand: Houston Ship Channel

Site 2 Sediment

Time (min)	Dissolved Oxygen (mg/l @ 20°C)				
	Run 1	Run 2	Run 3	$\bar{X}$	SD
0	7.4	7.4	7.4	7.4	0.0
1	7.1	6.9	7.0	7.0	0.1
2	6.8	6.6	6.7	6.7	0.1
3	6.6	6.4	6.5	6.5	0.1
4	6.4	6.2	6.3	6.3	0.1
5	6.3	6.1	6.2	6.2	0.1
6	6.2	6.0	6.1	6.1	0.1
7	6.1	5.9	6.0	6.0	0.1
8	6.0	5.8	5.9	5.9	0.1
9	6.0	5.8	5.8	5.9	0.1
10	5.9	5.7	5.8	5.8	0.1
15	5.6	5.4	5.4	5.5	0.1
20	5.3	5.1	5.0	5.1	0.2
25	5.0	4.9	4.7	4.9	0.2
30	4.9	4.7	4.5	4.7	0.2
35	4.6	4.4	4.2	4.4	0.2
40	4.4	4.2	4.0	4.2	0.2
45	4.2	4.0	3.7	4.0	0.2
50	4.0	3.9	3.5	3.8	0.3
55	3.9	3.7	3.3	3.6	0.3
60	3.7	3.5	3.1	3.4	0.3

Sample size - 2 cc.

Table A32

Sediment Oxygen Demand: Houston Ship Channel

Site 3 Sediment

Time	Dissolved Oxygen (mg/l @ 20°C)				
(min)	Run 1	Run 2	Run 3	$\bar{X}$	SD
0	7.2	7.2	7.2	7.2	0.0
1	6.3	6.7	6.4	6.5	0.2
2	5.7	5.9	5.8	5.8	0.1
3	5.3	5.5	5.4	5.4	0.1
4	5.1	5.3	5.1	5.2	0.1
5	5.0	5.1	4.9	5.0	0.1
6	4.8	4.9	4.7	4.8	0.1
7	4.7	4.8	4.6	4.7	0.1
8	4.5	4.6	4.5	4.5	0.1
9	4.4	4.5	4.3	4.4	0.1
10	4.3	4.4	4.2	4.3	0.1
15	3.9	4.0	3.8	3.9	0.1
20	3.6	3.6	3.4	3.5	0.1
25	3.3	3.3	3.1	3.2	0.1
30	3.1	3.1	2.9	3.0	0.1
35	2.8	2.8	2.7	2.8	0.1
40	2.6	2.6	2.5	2.6	0.1
45	2.4	2.4	2.3	2.4	0.1
50	2.3	2.3	2.2	2.3	0.1
55	2.2	2.1	2.0	2.1	0.1
60	2.0	2.0	1.9	2.0	0.1

Sample size - 3 cc.

Table A33

Sediment Oxygen Demand: Port Lavaca Sediment Sample

Time (Min)	Dissolved Oxygen				
	Run 1	Run 2	Run 3	$\overline{X}$	SD
0	7.6	7.5	7.5	7.5	0.1
1	6.9	6.7	6.6	6.7	0.2
2	6.5	6.1	6.0	6.2	0.3
3	6.2	5.8	5.7	5.9	0.3
4	5.9	5.5	5.5	5.6	0.2
5	5.8	5.4	5.3	5.5	0.3
6	5.6	5.3	5.2	5.4	0.2
7	5.5	5.1	5.1	5.2	0.2
8	5.4	5.0	5.0	5.1	0.2
9	5.3	4.9	4.9	5.0	0.2
10	5.2	4.9	4.8	5.0	0.3
15	5.0	4.5	4.4	4.6	0.3
20	4.7	4.2	4.1	4.3	0.3
25	4.4	4.0	3.9	4.1	0.3
30	4.3	3.8	3.7	3.9	0.3
35	4.1	3.7	3.6	3.8	0.3
40	4.0	3.6	3.5	3.7	0.3
45	3.9	3.4	3.3	3.5	0.3
50	3.8	3.3	3.2	3.4	0.3
55	3.7	3.3	3.2	3.4	0.3
60	3.6	3.2	3.1	3.3	0.3

Sample size - 5 cc.

Table A34

Sediment Oxygen Demand: Duwamish River Site 1 Sediment

Time	Dissolved Oxygen				
(min)	Run 1	Run 2	Run 3	$\bar{X}$	SD
0	7.9	8.0	8.0	8.0	0.1
1	7.9	7.7	7.9	7.8	0.1
2	7.9	7.7	7.8	7.8	0.1
3	7.9	7.7	7.8	7.8	0.1
4	7.9	7.7	7.8	7.8	0.1
5	7.9	7.7	7.8	7.8	0.1
6	7.8	7.7	7.8	7.8	0.1
7	7.8	7.7	7.8	7.8	0.1
8	7.8	7.7	7.8	7.8	0.1
9	7.8	7.6	7.8	7.7	0.1
10	7.8	7.6	7.8	7.7	0.1
15	7.8	7.5	7.8	7.7	0.2
20	7.8	7.5	7.7	7.7	0.2
25	7.7	7.4	7.7	7.6	0.2
30	7.7	7.3	7.6	7.5	0.2
35	7.7	7.3	7.6	7.5	0.2
40	7.6	7.2	7.6	7.5	0.2
45	7.6	7.2	7.6	7.5	0.2
50	7.6	7.2	7.5	7.4	0.2
55	7.6	7.1	7.5	7.4	0.3
60	7.5	7.1	7.4	7.3	0.2

Sample size - 5 cc.

Table A35

Sediment Oxygen Demand: Duwamish River Site 2 Sediment

Time (min)	Dissolved Oxygen				
	Run 1	Run 2	Run 3	$\bar{X}$	SD
0	8.0	8.0	8.0	8.0	0.0
1	7.3	7.2	7.2	7.2	0.1
2	6.4	6.4	6.4	6.4	0.0
3	5.9	5.9	5.9	5.9	0.0
4	5.6	5.7	5.7	5.7	0.1
5	5.4	5.5	5.5	5.5	0.1
6	5.2	5.3	5.3	5.3	0.1
7	5.0	5.2	5.2	5.1	0.1
8	5.0	5.0	5.1	5.0	0.1
9	4.8	5.0	5.0	4.9	0.1
10	4.7	4.9	4.9	4.8	0.1
15	4.2	4.5	4.5	4.4	0.2
20	3.9	4.2	4.2	4.1	0.2
25	3.6	4.0	4.0	3.9	0.2
30	3.4	3.8	3.8	3.7	0.2
35	3.2	3.6	3.6	3.5	0.2
40	3.1	3.4	3.4	3.3	0.2
45	3.9	3.3	3.3	3.2	0.2
50	2.7	3.2	3.2	3.0	0.3
55	2.6	3.0	3.1	2.9	0.3
60	2.5	2.9	3.0	2.8	0.3

Sample size - 5 cc.

Table A36

Sediment Oxygen Demand: Duwamish River Site 3 Sediment

Time	Dissolved Oxygen				
(min)	Run 1	Run 2	Run 3	X	SD
0	8.0	8.0	8.0	8.0	0.0
1	7.2	7.2	7.0	7.1	0.1
2	6.1	6.4	6.1	6.2	0.2
3	5.7	6.0	5.8	5.8	0.2
4	5.3	5.8	5.5	5.5	0.3
5	5.1	5.5	5.2	5.3	0.2
6	4.9	5.4	5.1	5.1	0.3
7	4.7	5.2	4.9	4.9	0.3
8	4.5	5.1	4.8	4.8	0.3
9	4.4	5.0	4.6	4.7	0.3
10	4.3	4.9	4.5	4.6	0.3
15	3.8	4.5	4.0	4.1	0.4
20	3.4	4.1	3.7	3.7	0.4
25	3.2	3.9	3.4	3.5	0.4
30	2.9	3.7	3.2	3.3	0.4
35	2.7	3.5	3.0	3.1	0.4
40	2.5	3.3	2.8	2.9	0.4
45	2.3	3.2	2.6	2.7	0.5
50	2.2	3.0	2.5	2.6	0.4
55	2.0	2.9	2.3	2.4	0.5
60	1.9	2.7	2.2	2.3	0.4

Sample size - 3 cc.

Table A37

Sediment Oxygen Demand :

Perth Amboy Channel Sediment

Time	Dissolved Oxygen (mg/l @ 22°C)				
(min)	Run	Run 2	Run 3	$\overline{X}$	SD
0	7.4	7.4	7.4	7.4	0.0
1	7.3	7.1	7.1	7.2	0.1
2	6.8	6.5	6.8	6.7	0.2
3	6.5	6.1	6.4	6.3	0.2
4	6.3	5.8	6.1	6.1	0.2
5	6.1	5.7	5.9	5.9	0.2
6	5.9	5.5	5.7	5.7	0.2
7	5.8	5.3	5.6	5.6	0.2
8	5.6	5.1	5.4	5.4	0.3
9	5.5	5.0	5.2	5.2	0.3
10	5.3	4.9	5.1	5.1	0.2
15	4.8	4.3	4.6	4.6	0.3
20	4.3	3.8	4.0	4.0	0.3
25	3.9	3.4	3.6	3.6	0.3
30	3.6	3.1	3.2	3.3	0.3
35	3.2	2.7	2.9	2.9	0.3
40	3.0	2.4	2.6	2.7	0.3
45	2.7	2.2	2.3	2.4	0.3
50	2.4	2.0	2.1	2.2	0.2
55	2.2	1.8	1.9	2.0	0.2
60	2.1	1.6	1.7	1.8	0.3

Sample size - 2 cc.

Table A38

Sediment Oxygen Demand: Perth Amboy Anchorage Sediment

Time	Dissolved Oxygen (mg/l @ 22°C)				
(min)	Run	Run 2	Run 3	$\overline{X}$	SD
0	7.4	7.4	7.4	7.4	0.0
1	6.9	6.8	7.1	6.9	0.2
2	6.5	6.5	6.7	6.6	0.1
3	6.2	6.2	6.4	6.3	0.1
4	6.0	5.9	6.2	6.0	0.2
5	5.8	5.8	6.0	5.9	0.1
6	5.7	5.6	5.8	5.7	0.1
7	5.5	5.4	5.7	5.5	0.2
8	5.3	5.3	5.6	5.4	0.2
9	5.2	5.1	5.5	5.3	0.2
10	5.0	5.0	5.4	5.1	0.2
15	4.4	4.3	4.9	4.5	0.3
20	3.8	3.8	4.3	4.0	0.3
25	3.3	3.3	3.9	3.5	0.3
30	2.9	2.9	3.4	3.1	0.3
35	2.4	2.6	3.0	2.7	0.3
40	2.1	2.3	2.6	2.3	0.3
45	1.8	2.0	2.2	2.0	0.2
50	1.5	1.7	2.0	1.7	0.3
55	1.3	1.5	1.7	1.5	0.2
60	1.0	1.3	1.4	1.2	0.2

Sample size - 2 cc.

Table A39

Sediment Oxygen Demand: Bay Ridge Channel Sediment

Time (min)	Dissolved Oxygen (mg/l @ 22°C) Run	 Run 2	 Run 3	 $\overline{X}$	 SD
0	7.4	7.4	7.4	7.4	0.1
1	7.0	7.0	6.9	7.0	0.1
2	6.7	6.8	6.6	6.7	0.1
3	6.6	6.6	6.4	6.5	0.1
4	6.4	6.4	6.3	6.4	0.1
5	6.3	6.3	6.1	6.2	0.1
6	6.2	6.2	6.0	6.1	0.1
7	6.1	6.1	5.9	6.0	0.1
8	6.0	6.0	5.8	5.9	0.1
9	5.9	5.9	5.7	5.8	0.1
10	5.8	5.8	5.7	5.8	0.1
15	5.4	5.4	5.2	5.3	0.1
20	5.1	5.0	4.9	5.0	0.1
25	4.8	4.7	4.5	4.7	0.2
30	4.5	4.4	4.2	4.4	0.2
35	4.2	4.1	4.0	4.1	0.1
40	4.0	3.9	3.7	3.9	0.2
45	3.7	3.6	3.4	3.6	0.2
50	3.5	3.4	3.2	3.4	0.2
55	3.3	3.2	3.0	3.2	0.2
60	3.1	3.0	2.9	3.0	0.1

Sample size - 2 cc.

Table A40

Sediment Oxygen Demand: Mobile Bay, Alabama, Site 1

Time (min)	Dissolved Oxygen (mg/l)				
	Run 1	Run 2	Run 3	$\bar{X}$	SD
0	7.4	7.4	7.4	7.4	0.0
1	6.5	6.3	6.3	6.4	0.1
2	5.7	5.5	5.6	5.6	0.1
3	5.2	5.0	5.1	5.1	0.1
4	4.9	4.7	4.8	4.8	0.1
5	4.6	4.4	4.5	4.5	0.1
6	4.5	4.1	4.3	4.3	0.2
7	4.3	4.0	4.1	4.1	0.2
8	4.1	3.8	4.0	4.0	0.2
9	4.0	3.6	3.8	3.8	0.2
10	3.9	3.5	3.7	3.7	0.2
15	3.4	3.0	3.2	3.2	0.2
20	3.0	2.6	2.8	2.8	0.2
25	2.7	2.2	2.5	2.5	0.3
30	2.5	2.0	2.2	2.2	0.3
35	2.2	1.7	2.0	2.0	0.3
40	2.1	1.5	1.7	1.8	0.3
45	1.9	1.4	1.5	1.6	0.3
50	1.8	1.1	1.3	1.4	0.4
55	1.6	1.0	1.2	1.3	0.3
60	1.5	0.8	1.1	1.1	0.4

Sample size - 3 cc.

Table A41

Sediment Oxygen Demand: Mobile Bay, Alabama, Site 2

Time (min)	Dissolved Oxygen (mg/l)				
	Run 1	Run 2	Run 3	$\bar{X}$	SD
0	7.4	7.4	7.4	7.4	0.0
1	7.0	6.5	6.8	6.8	0.3
2	6.0	5.8	6.0	5.9	0.1
3	5.5	5.4	5.5	5.5	0.1
4	5.2	5.2	5.2	5.2	0.0
5	5.0	5.0	5.0	5.0	0.0
6	4.8	4.9	4.9	4.9	0.1
7	4.7	4.8	4.7	4.7	0.1
8	4.5	4.6	4.6	4.6	0.1
9	4.4	4.5	4.5	4.5	0.1
10	4.3	4.4	4.4	4.4	0.1
15	4.0	4.0	4.0	4.0	0.0
20	3.6	3.8	3.7	3.7	0.1
25	3.3	3.5	3.4	3.4	0.1
30	3.2	3.3	3.2	3.2	0.1
35	3.0	3.2	3.0	3.1	0.1
40	2.8	3.0	2.9	2.9	0.1
45	2.6	2.8	2.7	2.7	0.1
50	2.5	2.6	2.5	2.5	0.1
55	2.3	2.5	2.4	2.4	0.1
60	2.2	2.4	2.3	2.3	0.1

Sample size - 3 cc.

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

Lee, G Fred
Evaluation of the elutriate test as a method of predicting contaminant release during open-water disposal of dredged sediments and environmental impact of open-water dredged material disposal; Vol. II: Data report / by G. Fred Lee ... [et al.], Environmental Chemistry, University of Texas at Dallas, Richardson, Tex. Vicksburg, Miss. : U. S. Waterways Experiment Station ; Springfield, Va. : available from National Technical Information Service, 1978.
1 v. in 2 : ill. ; 27 cm. (Technical report - U. S. Army Engineer Waterways Experiment Station ; D-78-45, v.2)
Prepared for Office, Chief of Engineers, U. S. Army, Washington, D. C., under Contract Nos. DACW39-75-C-0102 and DACW39-76-C-0117 (DMRP Work Unit No. 1E03A/B)
References: p. 1183-1186.

1. Contaminants. 2. Dredged material. 3. Dredged material disposal. 4. Elutriate tests. 5. Environmental effects. 6. Open-water disposal. 7. Sediment sampling. 8. Waste

(Continued on next card)

Lee, G Fred
Evaluation of the elutriate test as a method of predicting contaminant release during open-water disposal of dredged sediments and environmental impact of open-water dredged material disposal; Vol. II: Data report ... 1978. (Card 2)

disposal sites. I. Texas. University at Dallas. Environmental Chemistry. II. United States. Army. Corps of Engineers. III. Series: United States. Waterways Experiment Station, Vicksburg, Miss. Technical report ; D-78-45, v.2.
TA7.W34 no.D-78-45 v.2