Analysis of Sediment Chemistry and Body Burden Data
Obtained at the Massachusetts Bay Disposal Site
October 1987

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The Massachusetts Bay Disposal Site (MBDS), referred to in previous studies as the Foul Area Disposal Site (FADS) is located at 42°25.7'N by 70°34.0'W.

Field operations were conducted at the site from 19 to 29 October 1987. The field operations included sediment sampling for both chemical and physical analysis and collection of the polychaete Nephtys incisa at several locations for body burden analysis of selected contaminants.

The results of the sediment chemistry analyses showed no statistically significant difference between the chemical concentrations in the top 2 cm sediment layer and the 10 cm layer of samples collected at the Mass Bay Disposal Site. The likelihood that a station had been affected by dredged material disposal as determined by each station's level of contaminant concentrations in the 2 cm sediment layer compared well with results from past REMOTS® surveys outlining the distribution of dredged material at MBDS. Stations 14-9, FG11, and 12-0 had significantly elevated concentrations of several chemical constituents associated with dredged material, while stations 18-17, FG23, and SE had concentrations assumed to be representative of natural sediment in the vicinity of MBDS. The results were less conclusive for stations FG9, 17-14, and 16-11 where concentrations did not consistently associate with either extreme.

No definite relationship was found between the chemical concentrations measured in the sediment and in tissue from Nephtys.

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ANALYSIS OF SEDIMENT CHEMISTRY AND BODY BURDEN DATA OBTAINED AT THE MASSACHUSETTS BAY DISPOSAL SITE, OCTOBER 1987

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ANALYSIS OF SEDIMENT CHEMISTRY AND BODY BURDEN DATA OBTAINED AT THE MASSACHUSETTS BAY DISPOSAL SITE OCTOBER 1987

1.0 INTRODUCTION

The Massachusetts Bay Disposal Site (MBDS) (formerly referred to as the Foul Area) is located approximately 18 nautical miles (nm) east-northeast of the entrance to Boston Harbor and 10 nm south-southeast of Gloucester, MA. This site, centered at 42°25.7'N by 70°34.0'W, was established in 1977 as a 2 nm diameter circle. The average volume of dredged material deposited annually at this site exceeds 300,000 cubic meters (400,000 yd^3).

Field operations were conducted at the site from 19 to 29 October 1987. The field operations included sediment sampling for both chemical and physical analysis and collection of the polychaete Nephtys incisa at several locations for body burden analysis of selected contaminants. The objectives of the sampling program were to:

- characterize the broad scale concentration of sediment contaminants,
- determine whether there was a significant difference between contaminant concentrations as measured in 10 cm sediment cores and in the top 2 cm sections of the cores,
- determine if a sufficient number of replicate sediment samples were collected to detect significant differences in contaminant concentrations among the stations,
- determine if there were significant differences in sediment contaminant concentrations among the stations sampled in and around the disposal site, and
- provide additional baseline information on contaminant body burden concentrations in the polychaete Nephtys incisa to evaluate the relationship between sediment contamination and biological uptake and to assess the potential value of this approach for monitoring in the future.

2.0 METHODS

The precise navigation required for all field operations was provided by the SAIC Integrated Navigation and Data Acquisition System (INDAS). A detailed description of INDAS and its operation can be found in Contribution #60 (SAIC, 1989). Positions were determined to an accuracy of 3 meters from ranges provided by a Del

Norte Trisponder System. Shore stations were established over known benchmarks at Marblehead Light and Eastern Point Light in Massachusetts.

Sediment samples were collected at nine stations in and around the disposal site (Figure 2-1) using a 0.1 m^2 Smith-McIntyre Grab Sampler. Ten replicate grabs were collected at stations 18-17, 16-11, and 17-14 while three grabs were collected at the remaining six stations (14-9, 12-0, FG9, FG11, FG23, and SE). Six polycarbonate plastic core liners (6.5 cm ID) were pushed into the sediment grab sample and extracted; one core was placed into a bag for subsequent chemical and physical analysis by the NED laboratory. The top 2 cm of the remaining five cores were bagged for separate analysis. The samples were kept cold and returned to the NED laboratory where they were stored at 4°C until analyzed. The 2 cm core sections from all nine stations were analyzed for metals (Pb, Zn, Hg, As, Cd, Cu, Cr, and Ni), total organic carbon (TOCs), petroleum hydrocarbons (PHCs), polychlorinated biphenyls (PCBs), and polycyclic aromatic hydrocarbons (PAHs). The 10 cm cores were analyzed for TOCs, PHCs, Pb, Zn, and Hg.

Sediment analyses were conducted using methods described by the U.S. Environmental Protection Agency (Plumb, 1981). Mercury analysis was performed using acid digestion and cold vapor atomic absorption spectrophotometry; arsenic analysis was accomplished using acid digestion and gaseous anhydride atomic absorption spectrophotometry. The other trace metals (Pb, Zn, Cr, Cu, Cd, and Ni) were analyzed using acid digestion and flame atomic absorption spectrophotometry. PCBs and PAHs were extracted with hexane and analyzed by electron capture gas chromatography.

The test organisms for body burden analysis were collected at five stations (18-17, 16-11, 12-0, 14-9, and FG23) in and around MBDS (Figure 2-1) with the Smith-McIntyre grab. Sediment was sieved through a 2 mm mesh and individuals of the polychaete Nephtys incisa were isolated and placed in seawater at ambient temperature. Sufficient biomass was collected for triplicate analyses. The polychaetes were maintained in seawater for a total of 24 hours for gut depuration before they were frozen and transported to the laboratory for analysis of Fe, Cd, Hg, Pb, Cu, total PCB and total PAH concentrations. These analyses were conducted by Environmental Monitoring Laboratory Inc., Wallingford CT. In preparing the samples, the contents of a single sample jar containing the total biomass of polychaetes from one station were first divided into three replicate sub-samples (each containing several individual polychaetes) prior to homogenization. The analytical methods used for the trace metals are described in US EPA (1983). The extraction methods for PCBs and PAHs were modified to reduce interferences and detect the low levels of these constituents normally found in the marine environment (Gardner and Pruell, 1988).

3.0 RESULTS

Of the contaminants included in the New England River Basins Commission (NERBC) sediment classification, the sediment collected at MBDS contained "Low" concentrations of Hg, Cr, Cd, Zn, Ni, Cu, and PCBs (Table 3-1). The As concentrations at all stations were "Moderate." The Pb concentrations at station 14-9 were also "Moderate" while sediment collected at the other stations contained "Low" concentrations of Pb. Cadmium concentrations were below detection limits at all stations. The only PAH compounds that were above detection limits were at station 14-9 (Table 3-2).

Statistical tests using a Kruskal-Wallis ANOVA were performed on the chemical concentrations at stations 18-17, 16-11, and 17-14 to compare the values for the top 2 cm core sections versus the 10 cm cores (Table 3-3). The only significant difference ($p = 0.045$) occurred at station 16-11, where zinc levels were significantly higher in the 2 cm fractions.

Analysis of variance tests on arcsine transformed data were carried out with data from the top 2 cm core sections at all nine stations to determine if significant differences ($p<0.05$) existed among stations and, if so, which stations contributed to these differences. As confirmation of the results of the standard ANOVA significance testing on arcsine transformed data, additional tests using a non-parametric Kruskal-Wallis test on untransformed data as well as an ANOVA with the Box-Cox transformation (determines the appropriate power transformation to approach normality and homogeneity of variances) yielded identical results. Each test showed significant differences among the stations for all variables except arsenic. A Scheffé Test of means (Table 3-4; Scheffé, 1957) was then performed to determine the similarities or differences ($p<0.05$) among the stations sampled. For several of the variables measured (PHCs, Ni, Cu, and Pb), the concentrations at station 14-9 (on dredged material) were significantly different from the others. For PHCs, Pb, Zn, and Cu, a consistent pattern emerged where stations 16-11, 12-0, FG11, and 14-9 had the four highest mean concentrations, although they were not always significantly different from the other stations.

Additional calculations were made to determine the number of replicates required to be 80% certain of detecting a 50% difference between station means at a 5% level of significance. This procedure (Sokal and Rohlf, 1981) uses the formula:

$$n \geq 2(\sigma/\delta)^2 \{t_{\alpha[v]} + t_{2(1-P)[v]}\}^2$$

where n = number of replications,
σ = the true standard deviation (use coefficient of variation),
δ = the smallest true difference to be detected (50%),

v = degrees of freedom of the sample standard deviation,
α = significance level (0.05),
P = desired probability that a difference will be found to be significant (0.80), and
$t_{\alpha[v]}$ and $t_{2(1-P)[v]}\}$ = values from a two-tailed t-table.

The calculations were carried out on the stations having ten replicate grabs using the coefficient of variation determined for each station's concentration mean (Table 3-1). For Pb and Zn concentrations in the sediment, three replicates would have been sufficient to satisfy the above criteria. For PHCs and TOCs, seven of the twelve data sets tested would have required three or fewer replicates. The greater variability in the remaining data sets increased the number of replicates required.

Testing of the physical properties of the sediment at the nine sampling stations (Table 3-5) determined that dark brown/black organic silt occurred at all stations except 14-9 (on dredged material) where a larger component of fine sand was found. Lesser amounts of sand were also found at stations 12-0 and FG-11.

The samples of tissue from polychaete worms (Nephtys incisa) at five stations (18-17, 12-0, 16-11, 14-9, and FG23) were analyzed for concentrations of Cd, Pb, Cu, Fe, Hg, total PCBs, and total PAHs (Tables 3-6 and 3-7). ANOVAs were performed on the arcsine transformed data to test for significant differences in contaminant concentrations among the five stations; the only significant differences found were for Cu and PAHs. No significant differences were detected for Cd, Pb, Fe, and PCBs, and all Hg concentrations were below the detection limit. To determine which stations caused the significant differences for Cu and PAHs, the Scheffé Test of means was used (Table 3-8). The Cu concentrations at FG23 and 16-11 were found to be significantly greater than those at station 14-9 (on dredged material). PAH concentrations at stations 14-9 and 12-0 were significantly greater than at FG23 and 18-17. (Note: The Cu concentration in one replicate at station 16-11 was extremely high and was not used in any statistical calculations. During sample preparation, it was noted that gut contents were still present in a particularly large polychaete from this station and the sample became discolored during homogenization.)

4.0 DISCUSSION

Interpretation of the sediment chemistry and body burden results requires an understanding of each station's location in relation to the distribution of dredged material at MBDS (Figure 2-1). Station 14-9 is located on recently deposited dredged material near the location of the "FDA" disposal buoy. Station 12-0 and FG11 are most likely located on old dredged material deposited before the site boundaries were moved east in 1977. REMOTS® sediment profile surveys in 1985 and 1986 revealed the

presence of dredged material at these locations. Station 16-11 does not appear to be located on dredged material; however, its proximity to the area of recent disposal operations suggests that small patches of dredged material could occur there. Stations FG9 and 17-14 are located on the site boundary to the south and southeast, respectively, and should be beyond the influence of disposal operations; however, recent experience in documenting the actual positions of scow loads has demonstrated that scows do not always deposit the material precisely at the buoy, depending on weather conditions. In addition, these areas may have been affected by disposal operations conducted many years earlier, before adequate controls were established for disposing dredged material. Finally, stations 18-17, FG23, and SE are all located well outside the disposal site boundaries to the south or southeast and should not be affected by the disposal of dredged material.

The results of the Scheffé Test suggest a relationship between chemical concentrations in the sediment and a station's proximity to dredged material. Examination of Table 3-4 reveals that stations 14-9, FG11, and 12-0 often occur as a common group in the statistical test results; these stations exhibited the highest concentrations for lead, zinc, copper, mercury, and petroleum hydrocarbon. These same stations also contained the highest percentage of fine sand (also indicative of dredged material). For these same variables, the minimum values were found at stations FG23, 18-17, and SE. These two groups of stations represented the two extremes, i.e., stations with the greatest and least likelihood, based on both their chemical concentrations and proximity to the "FDA" disposal buoy, of having been affected by the disposal of dredged material.

For determining Pb and Zn concentrations in the sediment, three replicate samples were found to be more than sufficient to be 80% certain of detecting a 50% difference between means at a 5% level of significance; given the low variance in these data, one sample would have satisfied the criteria. Of the six data sets used to calculate the number of replicates required for TOCs (Table 3-1), four required 3 or fewer replicates to meet the specified criteria. For PHCs, half of the data sets showed that only one sample was needed to have satisfied these same requirements, while one of the three remaining data sets showed as many as 28 replicate samples would have been needed to achieve the specified level of precision. Re-analysis of this particular data set after eliminating the one anomolously high PHC concentration resulted in a value of 5 being the required number of replicates, similar to the 2 cm sample. Assuming similar analytical extraction efficiencies in the laboratory, these results suggest that organic compounds may have been less evenly distributed in the sediment than the metals. All chemical concentrations at station 16-11 tended to be more variable, most likely due to the station being at the edge of the dredged material deposit where layering of material can be very patchy both vertically and horizontally.

The results of the sediment chemistry analyses (Table 3-4) were compared with body burden results (Table 3-8) to evaluate any relationship between the two. In both the sediment and tissue samples, Cd and Hg concentrations were below detection limits. Only Cu and PAH concentrations in the tissue had significant differences among the stations sampled. Cu concentrations in the tissue at station 14-9 were significantly less than at FG23 and 16-11; the opposite was true in the sediment. Even though PAH concentrations in the tissue of organisms collected at stations 14-9 and 12-0 were significantly greater than those from stations FG23 and 18-17, only sediment from station 14-9 had any detectable PAH concentrations. There is not sufficient evidence from this particular study to suggest a strong correlation between the sediment and tissue contaminant concentrations.

The ecological significance of PAH concentrations for invertebrate tissue has not been definitely established at this time (K.J. Scott, personal communication). While field data can demonstrate that organisms have been exposed to elevated levels of PAH, our current state of knowledge precludes knowing whether or not elevated tissue levels of certain PAH components are harmful to the organism.

5.0 CONCLUSIONS

The results of the sediment chemistry analyses showed no statistically significant difference between the chemical concentrations in the top 2 cm sediment layer and the 10 cm layer of samples collected at the Mass Bay Disposal Site. The likelihood that a station had been affected by dredged material disposal as determined by each station's level of contaminant concentrations in the 2 cm sediment layer compared well with results from past REMOTS® surveys outlining the distribution of dredged material at MBDS. Stations 14-9, FG11, and 12-0 had significantly elevated concentrations of several chemical constituents associated with dredged material, while stations 18-17, FG23, and SE had concentrations assumed to be representative of natural sediment in the vicinity of MBDS. The results were less conclusive for stations FG9, 17-14, and 16-11 where concentrations did not consistently associate with either extreme.

Within-station variability in the concentrations of the replicate 2 cm versus 10 cm sediment samples does not suggest that one type of sample should be collected in lieu of the other. For lead and zinc, the 2 cm layer was slightly more variable (comparing coefficients of variation) while, for TOCs and PHCs, the opposite was true. When considering the collection procedure onboard the research vessel, slightly more control can be exercised obtaining the 2 cm sample, suggesting it to be the sample of choice.

Calculations of the number of replicate sediment samples required to meet specified precision criteria determined that three replicates would have been more than sufficient to have measured accurately Pb and Zn concentrations; conversely, in approximately half of the data sets tested, more than three replicates would have been needed for PHC and TOC analyses. As typically the case when calculating the optimal number of replicates (n) to collect when measuring various parameters at a specified level of precision, the investigator often is faced with a series of conflicting values for n, one for each parameter. In the future, if the monitoring objectives for a particular task require more precise estimates of PHC and TOC, then additional replicate sediment samples would be required.

Finally, no definite relationship was found between the chemical concentrations measured in the sediment and in tissue from Nephtys. As more baseline body burden data are collected at MBDS and other dredged material disposal sites, a better evaluation of this relationship may be possible.

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Table 3-1

Results of the Analysis of the Top 2 cm and Total (10 cm) Sediment Cores Collected at MBDS, October 1987

Total Organic Carbon (%)

Replicate No.	18-17 (2cm)	18-17 (10cm)	16-11 (2cm)	16-11 (10cm)	17-14 (2cm)	17-14 (10cm)	FG23 (2cm)	FG9 (2cm)	FG11 (2cm)	12-0 (2cm)	14-9 (2cm)	SE (2cm)
	Stations											
1	1.64	1.35	--	1.09	1.37	1.17	1.45	1.35	1.39	0.44	0.45	1.05
2	1.61	1.60	0.75	0.80	0.61	1.30	1.34	1.23	1.42	1.16	0.65	1.13
3	1.27	1.77	1.26	3.03	1.28	1.07	1.21	1.36	0.51	1.01	0.61	1.21
4	1.76	1.37	1.45	1.10	1.16	0.97						
5	1.49	0.40	1.35	1.31	1.29	1.16						
6	1.38	1.42	1.29	1.36	1.00	0.98						
7	2.21	1.66	1.73	1.72	1.08	1.11						
8	1.90	1.75	1.54	1.81	1.11	1.12						
9	1.56	1.73	1.81	1.22	1.18	1.17						
10	1.29	1.47	1.56	0.63	0.94	0.50						
Mean	1.61	1.45	1.42	1.41	1.10	1.06	1.33	1.31	1.11	0.87	0.57	1.13
Std.	0.29	0.40	0.31	0.68	0.22	0.22	0.12	0.07	0.52	0.38	0.11	0.08
CV(%)	18.0	27.7	22.1	48.0	19.8	20.6	9.0	5.5	46.7	43.7	18.6	7.1
# Req.[1]	2	5	3	15	3	3						

Petroleum Hydrocarbon (ppm)

Replicate No.	18-17 (2cm)	18-17 (10cm)	16-11 (2cm)	16-11 (10cm)	17-14 (2cm)	17-14 (10cm)	FG23 (2cm)	FG9 (2cm)	FG11 (2cm)	12-0 (2cm)	14-9 (2cm)	SE (2cm)
	Stations											
1	300	310	430	380	330	230	210	360	530	460	720	260
2	300	350	700	610	290	340	270	370	590	450	2100	410
3	210	310	350	250	240	510	260	230	650	490	970	250
4	270	290	560	390	320	450						
5	350	230	650	440	300	320						
6	260	260	380	310	300	280						
7	270	270	290	260	240	300						
8	310	240	440	1300	310	270						
9	310	280	430	330	310	280						
10	330	310	390	400	340	390						
Mean	291	285	462	467	298	337	247	320	590	467	1263	307
Std.	39.8	36.6	132.6	310.3	33.9	87.9	32.1	78.1	60.0	20.8	735.3	89.6
CV(%)	13.7	12.8	28.7	66.4	11.4	26.1	13.0	24.4	10.2	4.5	58.2	29.2
# Req.	1	1	5	28	1	4						

[1]Number of replicates required to be 80% certain of detecting a 50% difference at a 5% level of significance. Only stations with 10 replicates were considered.

Note: Cadmium values were all below the detection limit of 2-3 ppm.

Table 3-1 (Continued)

Lead (ppm)

Replicate No.	Stations 18-17 (2cm)	18-17 (10cm)	16-11 (2cm)	16-11 (10cm)	17-14 (2cm)	17-14 (10cm)	FG23 (2cm)	FG9 (2cm)	FG11 (2cm)	12-0 (2cm)	14-9 (2cm)	SE (2cm)
1	50	49	59	53	47	50	45	43	59	66	112	48
2	50	50	81	69	50	49	37	54	66	59	103	43
3	44	46	59	58	46	47	38	43	89	74	119	48
4	46	47	73	58	48	47						
5	48	46	71	69	55	52						
6	46	48	56	51	50	47						
7	44	44	53	46	49	50						
8	44	43	56	56	54	52						
9	45	46	59	56	54	51						
10	45	46	57	54	65	51						
Mean	46.2	46.5	62.4	57.0	51.8	49.6	40.0	46.7	71.3	66.3	111.3	46.3
Std.	2.3	2.1	9.2	7.3	5.6	2.0	4.4	6.4	15.7	7.5	8.0	2.9
CV(%)	5.1	4.6	14.8	12.7	10.8	4.1	10.9	13.6	22.0	11.3	7.2	6.2
# Req.	1	1	1	1	1	1						

Zinc (ppm)

Replicate No.	Stations 18-17 (2cm)	18-17 (10cm)	16-11 (2cm)	16-11 (10cm)	17-14 (2cm)	17-14 (10cm)	FG23 (2cm)	FG9 (2cm)	FG11 (2cm)	12-0 (2cm)	14-9 (2cm)	SE (2cm)
1	94	94	103	96	93	94	99	93	108	112	125	87
2	97	96	125	113	93	91	95	95	113	112	114	81
3	92	92	97	94	92	91	91	95	126	120	141	86
4	96	98	116	101	90	85						
5	93	95	107	111	97	94						
6	93	93	102	95	90	89						
7	91	97	100	93	92	92						
8	94	93	102	98	96	98						
9	106	96	95	93	92	92						
10	93	91	99	93	97	85						
Mean	94.9	94.5	104.6	98.7	93.2	91.1	95.0	94.3	115.7	114.7	126.7	84.7
Std.	4.3	2.3	9.3	7.5	2.6	4.0	4.0	1.2	9.3	4.6	13.6	3.2
CV(%)	4.5	2.4	8.9	7.6	2.8	4.4	4.2	1.2	8.0	4.0	10.7	3.8
# Req.	1	1	1	1	1	1						

Table 3-1 (Continued)

Copper (ppm)

Replicate No.	Stations 18-17 (2cm)	16-11 (2cm)	17-14 (2cm)	FG23 (2cm)	FG9 (2cm)	FG11 (2cm)	12-0 (2cm)	14-9 (2cm)	SE (2cm)
1	22	27	22	19	24	39	34	78	20
2	21	28	21	19	25	46	35	70	18
3	22	32	28	18	21	62	37	71	19
Mean	21.7	29.0	23.7	18.7	23.3	49.0	35.3	73.0	19.0
Std.	0.6	2.6	3.8	0.6	2.1	11.8	1.5	4.4	1.0
CV(%)	2.7	9.1	16.0	3.1	8.9	24.1	4.3	6.0	5.3

Nickel (ppm)

Replicate No.	Stations 18-17 (2cm)	16-11 (2cm)	17-14 (2cm)	FG23 (2cm)	FG9 (2cm)	FG11 (2cm)	12-0 (2cm)	14-9 (2cm)	SE (2cm)
1	34	30	31	33	29	32	31	23	32
2	32	32	30	32	30	31	32	21	30
3	32	31	31	33	30	31	31	24	32
Mean	32.7	31.0	30.7	32.7	29.7	31.3	31.3	22.7	31.3
Std.	1.2	1.0	0.6	0.6	0.6	0.6	0.6	1.5	1.2
CV(%)	3.5	3.2	1.9	1.8	2.0	1.8	1.8	6.7	3.7

PCB's (ppm)

Replicate No.	Stations 18-17 (2cm)	16-11 (2cm)	17-14 (2cm)	FG23 (2cm)	FG9 (2cm)	FG11 (2cm)	12-0 (2cm)	14-9 (2cm)	SE (2cm)
1	0.05	0.22	0.06	0.04	0.08	0.10	0.21	0.43	0.04

Table 3-1 (Continued)

Mercury (ppm)

Replicate No.	18-17 (2cm)	18-17 (10cm)	16-11 (2cm)	16-11 (10cm)	17-14 (2cm)	17-14 (10cm)	FG23 (2cm)	FG9 (2cm)	FG11 (2cm)	12-0 (2cm)	14-9 (2cm)	SE (2cm)
	Stations											
1	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	0.22	0.08	0.26	-0.05
2	-0.05	-0.05	0.06	0.11	-0.05	-0.05	-0.05	-0.05	0.44	-0.05	0.35	-0.05
3	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	0.22*	-0.05	0.15	0.07	0.32	-0.05
4	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05						
5	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05						
6	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05						
7	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05						
8	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05						
9	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05						
10	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05						
Mean									0.27		0.31	
Std.									0.15		0.05	
CV(%)									55.6		14.8	

Arsenic (ppm)

Replicate No.	18-17 (2cm)	16-11 (2cm)	17-14 (2cm)	FG23 (2cm)	FG9 (2cm)	FG11 (2cm)	12-0 (2cm)	14-9 (2cm)	SE (2cm)
	Stations								
1	16	13	19	13	18	17	15	12	14
2	18	12	12	14	15	19	14	15	11
3	16	15	14	12	16	18	18	10	18
Mean	16.7	13.3	15.0	13.0	16.3	18.0	15.7	12.3	14.3
Std.	1.2	1.5	3.6	1.0	1.5	1.0	2.1	2.5	3.5
CV(%)	6.9	11.5	24.0	7.7	9.4	5.6	13.3	20.4	24.5

Chromium (ppm)

Replicate No.	18-17 (2cm)	16-11 (2cm)	17-14 (2cm)	FG23 (2cm)	FG9 (2cm)	FG11 (2cm)	12-0 (2cm)	14-9 (2cm)	SE (2cm)
	Stations								
1	-8	19	-8	-8	-8	15	-8	9	-7
2	-8	15	10	-8	-8	19	10	-7	-7
3	-8	16	12	-8	-8	31	-8	-7	-7
Mean		16.7				21.7			
Std.		2.1				8.3			
CV(%)		12.5				38.4			

* Questionable value due to other replicates being below detection limit.

Note: Negative values indicate that the concentration was below the specified detection limit.

Table 3-2

PAH's in Sediment Collected at MBDS, October 1987.
Concentrations are based on dry weight.

Parameter	Detection Limits (ug/Kg)	FG23	FG9	12-0	FG11	18-17	17-14	SE	14-9	16-11
Phenol	330	-	-	-	-	-	-	-	-	-
Bis(2-chloroethyl)ethyl	330	-	-	-	-	-	-	-	-	-
2-Chlorophenol	330	-	-	-	-	-	-	-	-	-
1,3-Dichlorobenzene	330	-	-	-	-	-	-	-	-	-
1,4-Dichlorobenzene	330	-	-	-	-	-	-	-	-	-
Benzyl alcohol	330	-	-	-	-	-	-	-	-	-
1,2-Dichlorobenzene	330	-	-	-	-	-	-	-	-	-
2-Methylphenol	330	-	-	-	-	-	-	-	-	-
Bis(2-chloroisopropyl)ethyl	330	-	-	-	-	-	-	-	-	-
4-Methylphenol	330	-	-	-	-	-	-	-	-	-
N-Nitroso-di-n-propylamine	330	-	-	-	-	-	-	-	-	-
Hexachloroethane	330	-	-	-	-	-	-	-	-	-
Nitrobenzene	330	-	-	-	-	-	-	-	-	-
Isophrone	330	-	-	-	-	-	-	-	-	-
2-Nitrophenol	330	-	-	-	-	-	-	-	-	-
2,4-Dimethylphenol	330	-	-	-	-	-	-	-	-	-
Benzoic acid	1600	-	-	-	-	-	-	-	-	-
Bis(2-chloroethoxy)methane	330	-	-	-	-	-	-	-	-	-
2,4-Dichlorophenol	330	-	-	-	-	-	-	-	-	-
1,2,4-Trichlorobenzene	330	-	-	-	-	-	-	-	-	-
Aniline	330	-	-	-	-	-	-	-	-	-
Napthalene	330	-	-	-	-	-	-	-	-	-
4-Chlorosailine	330	-	-	-	-	-	-	-	-	-
Hexachlorobutadiene	330	-	-	-	-	-	-	-	-	-
4-Chloro-3-methylphenol	330	-	-	-	-	-	-	-	-	-
2-Methylnapthalene	330	-	-	-	-	-	-	-	-	-
Hexachlorocyclopentadiene	330	-	-	-	-	-	-	-	-	-
2,4,6-Trichlorophenol	330	-	-	-	-	-	-	-	-	-
2,4,5-Trichlorophenol	1600	-	-	-	-	-	-	-	-	-
2-Chloronaphthalene	330	-	-	-	-	-	-	-	-	-
2-Nitroanilene	1600	-	-	-	-	-	-	-	-	-
Dimethyl phthalate	330	-	-	-	-	-	-	-	-	-
Acenaphthylene	330	-	-	-	-	-	-	-	-	-
3-Nitroaniline	1600	-	-	-	-	-	-	-	-	-
Acenaphthene	330	-	-	-	-	-	-	-	-	-

- not detected.

Table 3-2 (Continued)

Parameter	Detection Limits (ug/Kg)	FG23	FG9	12-0	FG11	18-17	17-14	SE	14-9	16-11
2,4-Dinitrophenol	1600	-	-	-	-	-	-	-	-	-
4-Nitrophenol	330	-	-	-	-	-	-	-	-	-
Dibenzofuran	330	-	-	-	-	-	-	-	-	-
2,4-Dinitrotoluene	330	-	-	-	-	-	-	-	-	-
2,6-Dinitrotoluene	330	-	-	-	-	-	-	-	-	-
Diethylphthalate	330	-	-	-	-	-	-	-	-	-
4-Chlorophenyl-phenylether	330	-	-	-	-	-	-	-	-	-
Fluorene	330	-	-	-	-	-	-	-	-	-
4-Nitroaniline	1600	-	-	-	-	-	-	-	-	-
4,6-Dinitro-2-methylphenol	1600	-	-	-	-	-	-	-	-	-
N-Nitrosodiphenylamine[1]	330	-	-	-	-	-	-	-	-	-
4-Bromophenyl-phenylether	330	-	-	-	-	-	-	-	-	-
Hexachlorobenzene	330	-	-	-	-	-	-	-	-	-
Pentachlorophenol	1600	-	-	-	-	-	-	-	-	-
Phenanthrene	330	-	-	-	-	-	-	-	-	-
Anthracene	330	-	-	-	-	-	-	-	-	-
Di-n-butylphthalate	330	-	-	-	-	-	-	-	440	-
Fluoranthene	330	-	-	-	-	-	-	-	510	-
N-Nitrosodimethylamine	330	-	-	-	-	-	-	-	-	-
Pyrene	330	-	-	-	-	-	-	-	-	-
Butylbenzylphthalate	330	-	-	-	-	-	-	-	-	-
3,3-Dichlorobenzidine	660	-	-	-	-	-	-	-	-	-
Benzo(a)anthracene	330	-	-	-	-	-	-	-	-	-
Bis(2ethylhexyl)phthalate	330	-	-	-	-	-	-	-	7200	-
Chrysene	330	-	-	-	-	-	-	-	-	-
Di-n-octyl phthalate	330	-	-	-	-	-	-	-	-	-
Benzo(b)fluoranthene	330	-	-	-	-	-	-	-	-	-
Benzo(k)fluoranthene	330	-	-	-	-	-	-	-	-	-
Benzo(a)pyrene	330	-	-	-	-	-	-	-	-	-
Indeno(1,2,3-cd)pyrene	330	-	-	-	-	-	-	-	-	-
Dibenzo(a,h)anthracene	330	-	-	-	-	-	-	-	-	-
Benzo(g,h,i)perylene	330	-	-	-	-	-	-	-	-	-

[1]Cannot be separated from diphenylamine.
- not detected.

Table 3-3

Comparison of Chemical Concentrations of the Top 2cm Versus the Total (10cm) Length of Sediment Cores Collected at MBDS, October 1987

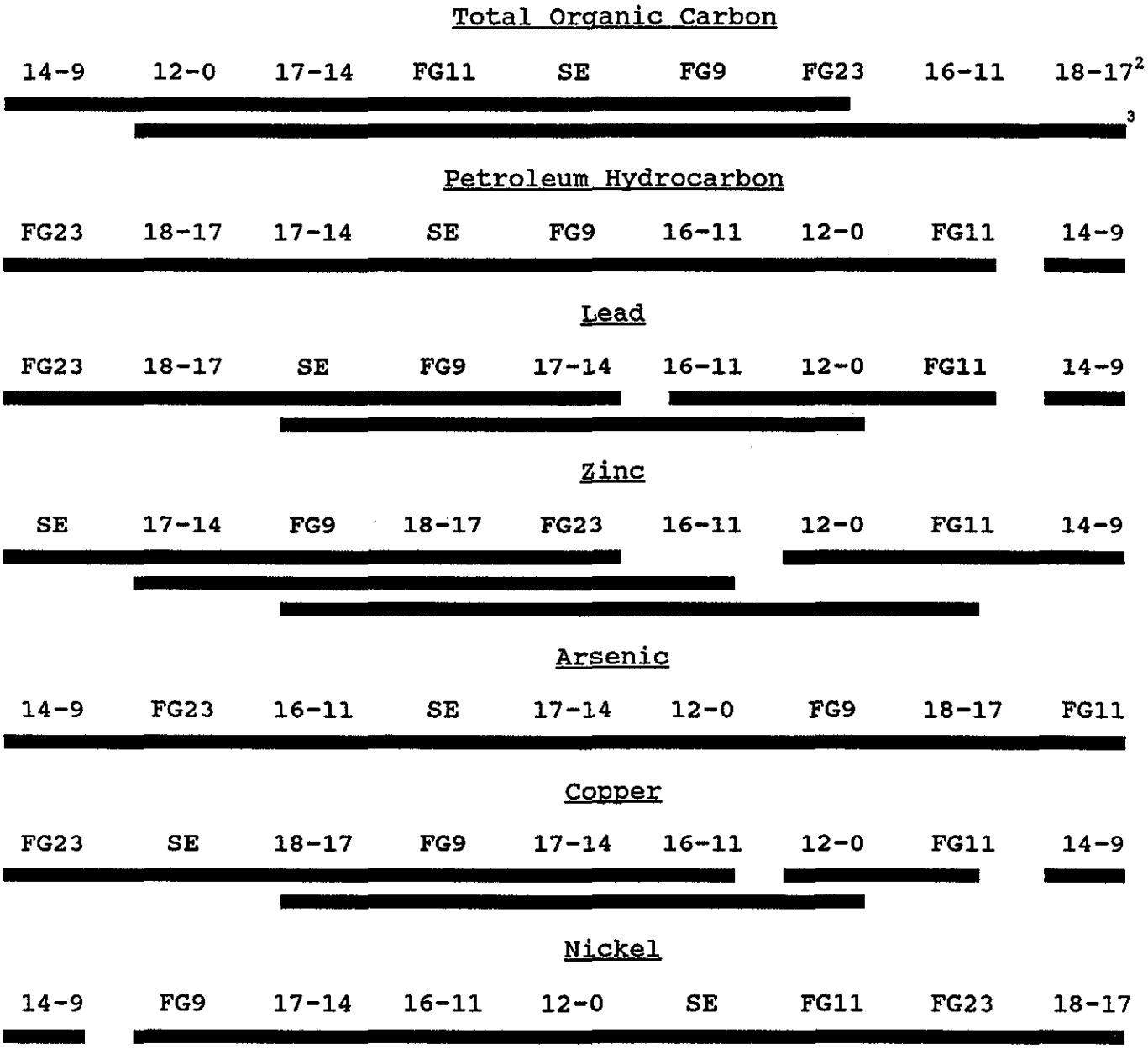
Variable	18-17	17-14	16-11
TOC's	ns[1]	ns	ns
PHC's	ns	ns	ns
Lead	ns	ns	ns
Zinc	ns	ns	+[2]

[1] ns - indicates that there was no significant difference in concentrations of the 2cm versus the 10 cm samples; Kruskal-Wallis ANOVA at $p \leq 0.05$.

[2] + - indicates that the concentrations in the 2cm samples were significantly greater than the 10cm samples, ($p=0.045$).

Table 3-4

Results of Scheffé[1] Test of Means at 5% Level of Significance for Chemical Constituents in the Sediment



[1] Scheffé test performed on arcsine transformed data.
[2] Stations are arranged from minimum to maximum mean concentration.
[3] Bars indicate stations with means not significantly different.

Note: Detectable concentrations of mercury were only found at 14-9, 12-0, and FG11.

Table 3-5

Results of Physical Testing of Sediment Collected at MBDS
October 1987

Station	Visual Classification	% Coarse Material	% Medium Sand	% Fine Sand	% Fines
FG-23	dark brown to black organic silt	<1	<1	2	98
FG-9	dark brown to black organic silt	<1	<1	8	92
12-0	dark brown to black organic silt	<1	2	12	86
FG-11	dark brown organic silt with sand	<1	4	13	83
18-17	dark brown to black organic silt	<1	<1	1	99
17-14	dark brown to black organic silt	<1	<1	1	99
SE	dark brown to black organic silt	<1	<1	1	99
14-9	sandy organic silt	9	7	18	66
16-11	dark brown to black organic silt	<1	<1	1	99

Table 3-6

Trace Metals in Body Tissues in Nephtys
Collected at MBDS, October 1987

	Concentration in ug/g dry weight				
Station/Replicate	Cd	Pb	Cu	Fe	Hg
18-17/1	0.6	4.1	9.7	1710	<0.03
18-17/2	0.7	5.6	8.5	566	<0.03
18-17/3	0.8	4.1	11.0	1199	<0.03
Mean	0.7	4.6	9.7	1158	-
±Std. Dev.	0.1	0.9	1.2	573	-
16-11/1	0.7	8.4	15.4	681	<0.03
16-11/2	0.7	12.7	12.7	1289	<0.04
16-11/3	0.6	7.7	958*	2053	<0.03
Mean	0.7	9.6	14.0	1341	-
±Std. Dev.	0.1	2.7	1.9	687	-
12-0/1	0.4	1.8	11.0	989	<0.02
12-0/2	0.8	7.8	14.3	1407	<0.03
12-0/3	0.6	8.2	10.4	1129	<0.02
Mean	0.6	5.9	11.9	1175	-
±Std. Dev.	0.2	3.6	2.1	213	-
14-9/1	0.5	9.5	8.7	769	<0.02
14-9/2	0.5	8.4	6.1	705	<0.02
14-9/3	0.6	2.9	7.2	915	<0.01
Mean	0.5	6.9	7.3	796	-
±Std. Dev.	0.1	3.5	1.3	108	-
FG-23/1	0.6	5.6	11.2	915	<0.02
FG-23/2	0.9	8.1	12.7	1501	<0.02
FG-23/3	0.9	5.0	16.2	1278	<0.03
Mean	0.8	6.2	13.4	1231	-
±Std. Dev.	0.2	1.6	2.6	296	-

* This value was assumed to be an outlier and was not used to calculate the mean and standard deviation. See text for detail.

Table 3-7

Total PCBs and Total PAHs in Body Tissues in *Nephtys* Collected at MBDS, October 1987

Station/Replicate	PCBs (as Aroclor 1254)	Total PAHs*
	Concentration in ng/g dry weight	
18-17/1	112	381
18-17/2	286	216
18-17/3	477	472
Mean ± Std.Dev.	292 ± 183	356 ± 130
16-11/1	357	1820
16-11/2	595	374
16-11/3	1051	128
Mean ± Std.Dev.	668 ± 353	774 ± 914
12-0/1	1568	1993
12-0/2	107	1538
12-0/3	680	3057
Mean ± Std.Dev.	785 ± 736	2196 ± 780
14-9/1	690	2778
14-9/2	300	2146
14-9/3	56	2571
Mean ± Std.Dev.	349 ± 320	2498 ± 322
FG-23/1	158	213
FG-23/2	146	122
FG-23/3	140	189
Mean ± Std.Dev.	148 ± 9.3	175 ± 47

* Total PAHs include: Fluorene, Phenanthrene, Anthracene, Fluoranthene, Pyrene, Benzo(a)anthracene, Chrysene, Benzo(b)fluoranthene, Benzo(a)pyrene, Indeno(1,2,3-cd)pyrene, Dibenzo(a,h)anthracene, Benzo(g,h,i)perylene.

Table 3-8

Results of Scheffé Test[1] of Means at 5% Level of Significance for Body Burden Concentrations in Nephtys

Cadmium

14-9	12-0	16-11	18-17	FG23[2]
═══	═══	═══	═══	═══

[3]

Lead

18-17	12-0	FG23	14-9	16-11
═══	═══	═══	═══	═══

Copper

14-9	18-17	12-0	FG23	16-11
═══	═══	═══		
	═══	═══	═══	═══

Iron

14-9	18-17	12-0	FG23	16-11
═══	═══	═══	═══	═══

PCBs

FG23	18-17	14-9	16-11	12-0
═══	═══	═══	═══	═══

PAHs

FG23	18-17	16-11	12-0	14-9
═══	═══	═══		
		═══	═══	═══

[1] Scheffé test performed on arcsine transformed data.
[2] Stations are arranged from minimum to maximum mean concentration.
[3] Bars indicate stations with means not significantly different.

Note: No detectable Hg concentrations were measured.

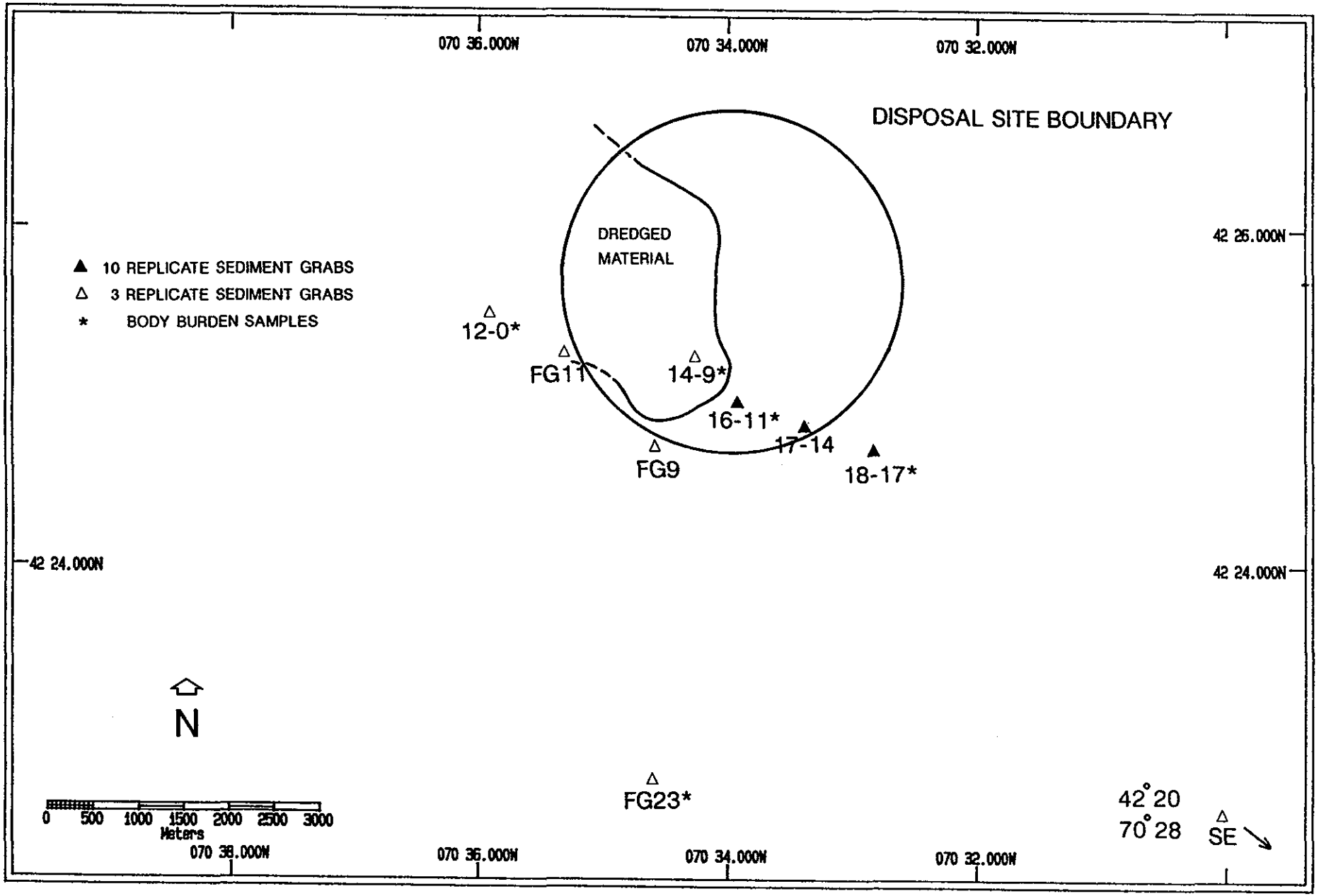


Figure 2-1. Sediment sampling stations at MBDS, October 1987. Outlined area indicates the presence of dredged material in 1986 REMOTS survey.