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Vertical Distirbution of Contaminant Metals in Disposal Sites of the New York Bight Apex and Spatial Distributions in Adjacent Areas, Summer 1983

by

Vincent S. Zdanowicz and Roger C. Kothe

Northeast Fisheries Center
Sandy Hook Laboratory
Environmental Chemistry Investigation

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Introduction

Since August 1980, annual surveys of the New York Bight (NYB) have been conducted to monitor sediment contaminant levels and observe changes in their distributions. The 1980 survey sought to establish a current baseline for metal levels in surface sediments in a standard grid of stations and in certain biota (Reid et al., 1982) and to compare these with data obtained in 1973-74. The 1981 survey obtained baseline measurements of metal levels in surface sediments throughout the Hudson Shelf Valley (HSV) and Hudson Canyon (HC), as well as data from the standard stations to compare with the previous year (Northeast Monitoring Program, 1982, in press). During the 1982 survey, in addition to the standard grid, two transects, lying between the sewage sludge and dredged spoil dumpsites in the Christiaensen Basin (CB) and traversing the upper HSV, were sampled to obtain vertical metal distributions, to see if the area influenced by sewage sludge disposal could be distinguished from that influenced by dredged spoil disposal. Results of the latest survey and comparison with prior results are presented here.

Methods

Samples were obtained during August 1982, NEMP survey DL8206. A Smith-McIntyre bottom grab was used to collect surface sediments for sampling using plastic cores, suitably cleaned for collection of trace metal samples. The grab was modified by mounting rubber flaps over the doors to the sample compartment to prevent disturbance of the sediment surface upon retrieval of the sampler. Cores were frozen immediately. In the laboratory, cores were extruded and layered before drying at 60°C. Analytical methodology, as described in Larsen et al. (1983), included leaching with concentrated nitric acid. NBS SRM 1645 was included in the analyses; average recoveries were 92% Cd, 85% Cr, 94% Cu, 88% Ni, 89% Pb and 92% Zn.

Results

Standard Monitoring Sites:

Highest mean concentrations (Table 1) of silver (5.4 ppm, dry weight), cadmium (5.2 ppm), copper (179 ppm), lead (168 ppm) and zinc (307 ppm) were found in surface (0-5 cm) sediment from station 6 (Figure 1), approximately 1 km west of the northwest corner of the designated sewage sludge disposal site. Maximum levels of chromium (110 ppm), nickel (33 ppm) and thallium (4.5 ppm) were found at station A56, approximately 10 km south of the CB in the upper HSV. Sediment at station 6 was comprised of black, oily fines mixed with fine to medium sand, while that at A56 was black, silty mud. Both were high in organic matter content. A gradient was observed down the HSV from maximal levels in the CB to minimal levels at the Hudson apron (station 14). Sandy sediments along the New Jersey (stations 23-28) and Long Island (stations 29-39) shelves showed the lowest concentrations.

Dumpsite Transects:

Highest mean concentrations (Table 2) of silver (18.7 ppm, dry weight), cadmium (16.2 ppm), chromium (393 ppm), copper (512 ppm) and lead (405 ppm) were found in the top centimeter layer of samples from station A44 in the sewage sludge dumpsite. The zinc maximum (1160 ppm) occurred in the top layer of samples from station A33, also in the sewage sludge dumpsite, northwest of the site of the other maxima. These samples were comprised of a black, thixotropic slurry over a find sand substrate. The slurry clearly was sewage sludge, as evidenced, after drying in the laboratory, by the presence of human artifacts (hair, vegetable seeds, etc.). In contrast, the nickel maximum (745 ppm) occurred in the top layer of sediments from station M109, west of the present dredged material dumpsite and south of the former site. Finally, the maximum thallium concentration (5.14 ppm) was in the 5-cm layer of sediments from station A38, due east of the present dredged spoil dumpsite. Samples exhibiting these maxima were high in silt/clay and organic matter content. Minimal levels (Ag, Cd <0.25; Cr, Cu <10; Pb, Zn <35; Ni <5 and Tl <0.50 ppm) were found in the bottom (5-cm) layer of samples from stations X and A32 for all eight metals, and A43 for all metals except Tl (0.77 ppm). These samples were comprised primarily of sands, low in silt/clay and organic matter. At some stations values were consistent throughout the five layers; those having low levels (same as minimal) were A43 (Cr, Pb, Ni), X (Cu, Ni) and A32 (Cu, Ni, Tl), while those showing maximal values (Ag, Cd >8; Ni >50; Cr >250; Cu, Pb >300; Zn >500 and Tl >4 ppm) were A25 (Cd, Ni), A34 (Cd, Cu, Zn), A36 (Cr, Cu, Ni, Pb) and A38 (Tl).

Distributions of the eight metals fell into three distinct patterns (Figures 3, 4 and 5). The copper distribution was representative of those of silver, cadmium, chromium, lead and zinc, with several minor exceptions, while the nickel and thallium distributions were unique. Overall, interelement correlation coefficients were high (n = 171; r >.860) between metals in the copper group, while nickel and thallium, as suggested by their distributions, did not correlate highly with any metal (Table 3). A noteworthy feature of the copper group distribution is the divergence of values in layers at stations in the immediate area of the sludge dumpsite.

The distribution of nickel differed in several important aspects. For example, mean values for individual layers at any station were generally grouped more tightly together than for the copper group, except at the dump impacted stations. Also, levels between stations did not fluctuate as widely, i.e. transect A gradients were much smoother than those of the Cu group, tending to be fairly constant across the middle of the CB (stations A27 to A31). The most striking feature of nickel's distribution was the amount present in the upper layer at stations M109 and A35, 10-20 times more than at the sewage dumpsite. Except for this enriched layer, however, nickel concentrations were roughly equivalent in sewage and dredged wastes. In contrast, thallium was consistently found in higher concentrations in samples from the dredged spoil dumpsite than in samples from the sewage sludge dumpsite, but only by a factor of ~2. Other important differences in the thallium distribution were a westward shift, from station A30 to A29 in transect A, in the location where high levels were found in all the layers and the occurrence of the maximum mean Tl concentration in the bottom (5 cm) layer at station A38 instead of in an upper layer at one of the dumpsite stations.

Discussion

Enrichment factors (EFs) were computed based on metal concentrations in a sample of preindustrial New York Harbor sediment from a 1977 Hudson River/New York Harbor geological survey obtained through Lamont-Doherty Geological Observatory (Table 5). An EF may be expressed as $(M/N)_A/(M/N)_B$, where $(M/N)_A$ is the ratio of some metal to a normalizing element in an ambient sediment and $(M/N)_B$ is the ratio of the same two metals in a background (reference) sediment; it is an expression of the degree of difference between the ambient and background sediments. In this study, since the ambient sediments are from ocean disposal sites and control areas, and the background sediment represents preindustrial levels in the area which serves as a source of materials for disposal, the EF expresses the degree of contamination of sediments in the disposal sites and adjacent areas. When used for this purpose, the most important requirement for any normalizing parameter is that its levels in sediment be unaffected by anthropogenic inputs, e.g. measured levels must be entirely natural levels. For metals, usually a major (% levels) sediment constituent, such as iron, aluminum or silicon, is used since, under normal conditions, pollutant (ppm levels) inputs may be neglected with respect to natural levels. Thallium, used here as the normalizing element, is a trace (ppm levels) constituent of sediments, so pollutant level inputs might be expected to substantially alter natural levels. In fact, there is a potential for substantial amounts of thallium to enter the environment (Midwest Research Institute, 1977), due largely to its presence in high sulfur coals and sulfide ores mined for zinc and lead (Robinson, 1973). Thus, power plants and lead and zinc smelters emit thallium as an airborne contaminant.

In ash, however, thallium is in the Tl_2O_3 form, which is readily soluble in water and, while mining and smelting operations are not carried on along the east coast (U.S. Bureau of Mines, 1981), coal combustion is widespread, suggesting that thallium should be entering coastal waters by an airborne route. Also, although its commercial use is so limited that it is no longer produced in the United States, (demand is easily met by imports, e.g. approximately one metric ton in 1982 (U. S. Bureau of Mines, 1981)), its presence in waste water effluents has been reported (Mueller et al., 1982; Young, 1978). However, due to its stability in solution (Shaw, 1952) and the fact that, unlike the other metals studied, it is not complexed by humic materials (O'Shea and Mancy, 1976), thallium does not accumulate in surface sediment in the same way many other metals do, in minute aggregates of organically complexed and adsorbed ions and clay particles. Its presence in surface sediments is due to weathering of source rock into fine particles susceptible to transport and eventual deposition. Thallium entering coastal waters from airborne and effluent sources remains in the dissolved state.

Partitioning of metals between dissolved and adsorbed phases occurs to varying degrees for all metals and is well known. The stability of dissolved thallium and its lack of affinity for humic materials, however, suggest that if thallium is not strongly bound when it enters the ecosystem, as in its parent material, it will exist in the dissolved state and not be deposited in sediments. Hence, it meets the criteria of a normalizing parameter for sediments.

Standard Monitoring Sites:

Metal levels in the top 5 cm of surface sediment at most stations in the sampling area (Figure 1) have not changed appreciably during the period August 1980 to August 1982. Along the New Jersey and Long Island shores there are minimal amounts of trace metals, as would be expected in areas of coarse sand. Concentrations of thallium were below the limits of detection at these stations so no EFs could be obtained, but little, if any, enrichment of sediment from anthropogenic sources would be expected there. Levels at the edge of the Hudson apron (station 14) also were consistently low, largely due to lower silt/clay content, and unenriched. In the "Mud Hole" (stations 13, 16 and 17), a depositional area, concentrations and EFs began to increase, EFs being 2-5. These increases are attributable to the presence of fine, enriched sediments mixing with clean sands.

In the apex, stations 19-22, 40-44 and 65, outside the CB, contained minimal or near minimal levels of all metals and EFs of 1-2 for Ni, Ag, Cd and Cu; however, EFs were 2-5 for Cr and Zn and 5-10 for Pb (Figure 6), indicating general, low-level contamination throughout the bight apex surrounding the CB. In comparison, highest EFs, similarly computed, found in a study of Chesapeake Bay (Cantillo, 1981), considered generally unpolluted, were ~7 for

Zn and Cu in sediments outside Baltimore Harbor. Cr and Ni EFs in the same samples were ~1 (unenriched). Thallium levels ranged from 0.1 to 0.9 ppm at stations 65, 21, 20 and 41, along the northern periphery of the CB, and from 1.4 to 2.0 ppm at stations 42, 19 and 44, west of the CB, indicating the presence of higher levels of estuarine silt/clay in these sediments, the sources of which are likely the dredged spoil deposit and the Hudson plume. The area west of the dredged spoil dumpsite has been shown to be a depositional site for fine particulate from dredged material lost either during disposal or due to scouring of the pile itself. Immediately west of the pile, near station M109, 60 cm/year of accumulation was reported between 1973 and 1978 (Dayal et al., 1981). This station, not sampled in prior years, showed the highest nickel concentrations (EF~13) for all three surveys. Nickel, which is not effectively removed from sewage effluents by treatment (Chen et al., 1974) might be expected to accumulate in estuarine sites, some of which would likely be dredged, so high levels are not unexpected. This partitioning is also consistent with the similarity generally observed between nickel levels at sewage sludge and dredged spoil stations.

Highest enrichments were found associated with sites receiving inputs of sewage sludge. Generally, station 6 was the site of greatest concentrations (Table 4). Accumulation of dumped sludge occurs there, as can also be demonstrated by levels of coprostanol, a human fecal steroid (White, 1983). EFs of 40-50 were found at stations A44 and A33 within the dumpsite (Figure 6).

Examination of enrichment data for all the metals collectively supports the proposition of "boundaries" for the impacted section of the New York Bight. Sites east of station 65, south of station 44 and down-valley from station 14 show natural proportions of trace metals (enrichment factor <1) in sediment, suggesting that contamination is mostly confined to the CB/HSV, and not accumulating on the adjacent shelves.

Transects:

Data from previous years were not available for most stations on the transects, so no temporal trends could be discerned. Analysis of layered sediment cores, however (Figures 3, 4 and 5), revealed that stations in the dumpsites, as well as those between the dumpsites, showed different vertical distributions of metals, reflecting inputs of differing origin and nature.

Stations directly affected by sewage sludge were A16, 6, A19, 7, A33, A32, A31, A42 and A44. Distributions of the copper group metals showed that concentrations in the upper layer(s) of sediment at these stations were greater than in the lower layers by factors of 2-100. The material comprising the upper layer(s) was sludge with clean sand below. Enrichments factors in sludge layers also were much higher than in lower layers. Nickel and thallium showed this type of distribution for stations A19, 7, A33 and A44 only. Nickel values were elevated and enriched, but thallium values barely approached natural levels (Table 5). Stations X and A43, situated between two clearly impacted stations contained little or no sludge. Metal levels and % silt/clay were low, as would be expected in medium and fine sand, but the levels were enriched, suggesting the presence of a small amount of fine contaminated material mixed with the underlying sand.

Stations in the dredged spoil pile, A25, A34 and A36, contained high levels of copper group metals in all sediment layers, but in an irregular vertical pattern, i.e. levels in lower layers were sometimes higher than levels in the upper layer(s), while stations on the fringe of the pile, M109, A26 and A35, showed characteristics of both the dumpsites, a highly enriched upper layer, as in the sewage stations, and high concentrations in lower layers, distributed in an irregular pattern, as in the dredged spoil stations. Nickel concentrations were higher in the dredged spoil sites than in the sewage sludge sites and especially high and enriched in the upper layer of the fringe stations. Thallium concentrations, too, were higher in dredged material than in sewage sludge but were not elevated in the fringe of the pile. Its concentrations in dredged spoil samples were very similar to concentrations in sediments from the Hudson-Raritan estuary (Table 5), as would be expected since dredging projects in those areas are the source of the sediments found in the dredged spoil pile.

Between the two dumping sites deposition of fine sediments occurs. Resultant sediments are mixtures of materials from both dumpsites, the Hudson plume, the northern CB during periods of net southerly bottom water transport and the HSV during periods of net northerly bottom water transport. Littoral drift along New Jersey and Long Island provides coarser material and storm events can deliver large amounts of sand over short time periods to the area. The vertical distributions at these stations, A37, A38, A41, A27, A28, A29, A30 and 5, show that the material deposited there, although of mixed origin, is of fairly constant composition, since the EFs as well as the concentrations of each of the eight metals are almost constant, layer to layer; also, the levels and EFs are lower than in either dumpsite. Stations A27 and 5 had low concentrations, resulting from mixing of fine, contaminated sediment with coarse, clean sediment, or from scouring of fines by currents, preventing accumulation of large amounts of fine material, as suggested by its % silt/clay. Scouring is probably responsible for the low levels at A37 also. The area southeast of the former dredged spoil site has been shown to be erosional (Dayal et al., 1981).

Percent silt/clay at the depositional stations in the CB is intermediate between those found at the dumpsites. Values represent the entire top 5 cm portion of the sediment. High values at the dredged spoil stations are to be expected since dredging removes fine solids from depositional locations. When dumped, usually by barges, most of the spoils settle rapidly to the bottom as a single mass, losing some of the finer material to resuspension as it falls through the water column. Sewage sludge, in contrast, is only 5-10% solids. Generally, during disposal, it is released gradually into the wake of the sludge tanker in order to maximize dispersal in the water column. Coarse solids settle rapidly, but the plume of dissolved and particulate organic material may require one to two hours to become undetectable in the water column (Proni et al., 1976). Neither the disposal technique nor the nature of the waste itself favors accumulation of fine particulate in the disposal site. In addition, the dumpsite is located on a shallow bank, swept by predominantly southwest currents, where deposition does not naturally occur. Dredged spoils, then, would be expected to contain much higher levels of silt/clay and, indeed, a rough gradient exists, showing increasing silt/clay levels across the transects from east to west. Thallium would be expected to be associated with this fine silt/clay, based on prior discussion. A plot of the relationship is given in Figure 7. Thallium was the only metal that showed a linear relationship with silt/clay, suggesting silt/clay as its source. Clearly, sewage sludge shows anomalous behavior with respect to thallium and silt/clay.

In light of the above, it is probable that most of the mass of material settling in the upper HSV originates from the dredged spoil pile. Stations showing obvious impact by sludge, as identified by vertical distributions of metals, enrichments and silt/clay content, were found to the west of the sludge dumpsite and northwest, into the CB. Both waste materials appear to be transported toward the upper HSV from their respective disposal sites. Bottom currents in the head of the HSV moving in a northerly, clockwise motion (Freeland and Swift, 1978) aid in transporting lighter, smaller, highly organic sludge particles toward the CB, while heavier sludge particles and clay particles from dredged material are deposited directly into the HSV. A mixing zone must be present since it is known that sewage, as identified by coprostanol, is present in the HSV at station 10, south of the CB (White, 1983). The southern extent of this zone of mixing cannot be delineated from this study, since vertical distributions were not determined south of the CB. However, it appears that stations A16, A31 and A42, based on their compositions and enrichments, and possibly the adjacent stations, 5, A30 and A41, fall into this zone of mixing.

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Table 1. Mean concentrations of metals (μg/g, dry wt) in the top 5 cm of sediments.

Sta	Depth (m)	Ag			Cd			Cr			Cu			Ni			Zn			Tl			Pb		
		n	x	SD	n	x	SD	n	x	SD	n	x	SD	n	x	SD	n	x	SD	n	x	SD	n	x	SD
A16	21	2	7.56	.14	2	7.62	.49	2	153.	24.5	2	229.	2.97	2	29.6	1.51	2	400.	40.4	2	2.61	.21	2	233.	.28
A19	26	3	2.60	1.39	3	3.28	1.89	3	71.9	33.3	3	86.1	34.2	3	10.7	3.84	3	160.	135.	3	.83	.15	3	95.5	23.2
A25	19	3	6.17	1.85	3	9.43	1.09	3	238.	10.1	3	389.	16.7	3	60.2	22.3	3	553.	91.9	3	3.98	.60	3	298.	31.0
A26	27	3	6.78	3.51	3	7.36	4.94	3	195.	136.	3	334.	200.	3	42.6	17.5	3	436.	226.	3	3.01	1.17	3	239.	132.
A27	35	3	1.72	.66	3	1.02	.67	3	47.6	13.4	3	55.8	19.4	3	26.9	9.11	3	115.	39.4	3	2.21	.49	3	78.4	20.6
A28	37	3	3.09	.21	3	2.34	.31	3	76.1	8.00	3	90.8	12.5	3	21.3	1.70	3	161.	22.2	3	2.96	.14	3	112.	12.3
A29	38	3	4.97	.57	3	4.90	.42	3	113.	2.19	3	131.	7.18	3	26.4	1.93	3	240.	15.3	3	3.64	.37	3	158.	11.5
A30	37	3	7.76	2.19	3	7.06	1.17	3	142.	27.4	3	224.	62.4	3	28.1	4.45	3	366.	57.3	3	2.50	.65	3	210.	31.9
A31	34	3	5.05	2.36	3	5.08	1.77	3	89.7	37.1	3	140.	69.8	3	16.7	4.23	3	231.	95.3	3	.79	.18	3	139.	51.2
A32	28	3	.28	.21	3	.24	.11	3	11.8	3.36	3	9.67	4.96	3	2.56	.39	3	27.5	7.20	3	.35	.07	3	19.1	3.10
A33	25	3	.53	.16	3	3.33	1.87	3	59.2	37.7	3	81.1	51.1	3	9.48	4.94	3	292.	273.	3	.47	.28	3	67.4	28.8
A34	25	3	7.34	.71	3	9.65	2.05	3	267.	42.7	3	399.	43.7	3	51.2	8.40	3	550.	70.8	3	3.53	.54	3	277.	40.0
A35	24	3	8.11	1.16	3	5.89	.87	3	165.	32.1	3	254.	24.1	3	160.	96.4	3	383.	57.9	3	3.75	.38	3	270.	57.0
A36	23	3	8.00	1.71	3	9.45	.44	3	304.	7.94	3	317.	42.0	3	80.1	34.4	3	497.	12.6	3	3.94	.79	3	325.	7.41
A37	29	3	1.15	.22	3	.94	.33	3	34.4	5.94	3	55.5	12.8	3	15.7	3.45	3	140.	29.6	3	1.47	.09	3	65.2	14.7
A38	32	3	5.12	.91	3	4.30	.90	3	134.	10.8	3	177.	14.5	3	35.2	1.29	3	315.	26.7	3	4.67	.27	3	210.	13.3
A41	39	3	5.57	.87	3	7.25	1.28	3	137.	15.8	3	159.	15.5	3	37.2	2.50	3	342.	50.3	3	3.79	.94	3	215.	28.0
A42	34	3	4.10	2.12	3	4.00	1.28	3	84.3	37.7	3	133.	60.3	3	16.9	5.83	3	223.	90.6	3	.93	.21	3	129.	49.0
A43	28	3	.22	.06	3	.27	.23	3	8.99	.50	3	10.7	10.2	3	3.62	.20	3	32.5	1.62	3	.72	.02	3	32.	4.84
A44	25	3	8.25	12.7	3	7.31	9.84	3	162.	248.	3	209.	329.	3	20.6	27.4	3	405.	611.	3	1.19	1.43	3	180.	245.
A56	56	2	3.91	.69	2	3.53	.43	2	110.	12.0	2	123.	20.5	2	32.9	3.46	2	226.	25.4	2	4.51	.52	2	157.	16.9
A57	39	3	1.39	1.08	3	1.32	.42	3	49.6	15.8	3	55.6	21.7	3	17.3	5.60	3	106.	33.5	3	2.42	.41	3	76.8	25.3
M109	19	3	3.25	1.88	3	2.78	1.43	3	83.6	36.6	3	116.	64.9	3	213.	146.	3	193.	74.1	3	2.79	1.00	3	147.	55.2
M56	45	2	.52	.21	3	.72	.28	3	37.1	13.3	3	41.4	19.8	3	13.5	3.92	3	74.5	21.3	3	2.00	.44	3	46.9	14.0
M77	58	2	.17	.01	3	.72	.10	3	40.7	4.81	3	34.7	2.84	3	16.3	1.55	3	84.8	11.4	3	1.81	.41	3	59.2	6.44
M78	32	3	<.25	-	3	.05	.02	3	4.52	1.04	3	2.75	1.58	3	1.46	.36	3	9.07	2.03	3	.25	.06	3	6.62	1.80
NY1	30	3	2.72	1.23	3	3.14	.74	3	74.5	18.6	3	91.5	24.4	3	17.9	4.49	3	174.	47.5	3	2.39	.24	3	110.	31.1
NY10	39	6	.74	.11	6	1.14	.08	6	49.5	5.58	6	49.8	4.25	6	14.6	.80	6	90.7	7.15	6	1.46	.25	6	66.4	4.76
NY11	30	3	.35	.23	2	.27	.08	3	13.4	5.25	3	9.57	5.67	3	4.48	1.69	3	28.9	9.01	3	.52	.19	3	17.9	6.62
NY12	36	3	<.25	-	3	.11	.01	3	7.21	.12	3	2.12	.22	3	4.30	.03	3	18.7	1.67	3	.73	.06	3	9.92	1.82
NY13	62	7	.52	.17	7	.60	.15	7	28.8	4.13	7	19.2	3.20	7	11.1	1.72	7	67.3	7.03	7	2.47	.55	7	42.4	6.14
NY14	78	5	.12	.02	7	.17	.03	7	10.8	2.09	7	2.83	.46	7	8.37	.84	7	24.7	2.53	7	2.24	.42	7	11.9	1.81
NY16	69	3	.72	.27	3	.74	.15	3	29.8	7.78	3	18.2	7.07	3	13.0	3.06	3	69.8	15.2	3	1.34	.57	3	42.7	12.6
NY17	74	3	<.25	-	1	.62	-	3	11.3	5.26	3	5.40	3.47	3	7.19	2.29	3	32.4	14.1	1	1.50	-	3	14.5	10.1
NY18	23	3	1.12	.25	3	.81	.22	3	33.0	5.24	3	39.0	7.71	3	12.0	1.08	3	82.5	11.7	3	2.48	.75	3	56.9	4.17
NY19	14	3	.22	.03	3	.15	.01	3	32.2	1.18	3	2.23	.32	3	5.33	.27	3	40.0	1.68	3	2.00	.20	3	22.7	5.59

Table 1. (continued)

	Depth	Ag			Cd			Cr			Cu			Ni			Zn			Tl			Pb		
Sta	(m)	n	x	SD	n	x	SD	n	x	SD	n	x	SD	n	x	SD	n	x	SD	n	x	SD	n	x	SD
NY2	28	3	1.04	.36	3	1.40	.33	3	38.7	6.84	3	37.3	9.30	3	9.14	1.44	3	86.0	14.9	3	1.29	.12	3	51.9	8.92
NY20	13	3	.11	.04	3	.06	.01	3	5.37	.55	3	2.10	.50	3	2.85	.41	3	20.1	2.87	3	.32	.16	3	10.7	1.46
NY21	22	3	.22	.03	3	.23	.01	3	17.8	.47	3	4.53	.59	3	5.45	.51	3	49.3	3.82	3	.87	.36	3	24.6	2.14
NY22	24	2	.23	.05	3	.19	.02	3	10.4	1.49	3	5.54	1.32	3	2.41	.30	3	24.3	1.80	1	.33	-	3	15.5	1.55
NY23	18	3	<.25	-	3	<.25	-	3	3.93	.47	3	.57	.12	3	.95	.08	3	9.13	1.00	3	<.25	-	3	4.47	1.00
NY24	22	3	<.25	-	1	.09	-	3	2.03	.67	3	.37	.06	1	.15	-	3	3.20	.46	3	<.25	-	3	2.90	.85
NY25	20	3	<.25	-	1	.09	-	3	2.70	.79	3	.33	.06	3	.41	.16	3	4.83	1.23	3	<.25	-	3	2.77	1.25
NY26	26	1	.07	-	1	.08	-	6	4.03	.57	6	.39	.04	6	1.10	.13	6	6.17	.61	6	<.25	-	6	2.65	.22
NY27	25	2	<.25	-	2	<.25	-	2	3.05	.78	2	1.19	1.07	2	1.20	.06	2	5.15	.21	2	<.25	-	2	2.51	.04
NY28	39	3	<.25	-	1	.10	-	3	4.37	1.42	1	3.40	-	3	2.78	.65	3	10.7	5.69	3	<.25	-	3	4.67	4.04
NY29	39	1	.06	-	2	<.25	-	2	3.25	.49	2	.45	.07	2	.99	.15	2	5.30	.14	2	<.25	-	2	3.60	-
NY3	27	3	.85	.43	3	1.08	.43	3	33.0	10.7	3	29.3	12.3	3	8.01	1.92	3	71.3	20.3	3	1.10	.19	3	42.7	13.7
NY30	35	2	.08	.01	2	.09	.01	2	5.40	.14	2	1.08	.18	2	1.98	.04	2	10.9	.42	2	<.25	-	2	5.25	.35
NY31	33	5	<.25	-	5	<.25	-	5	2.56	.88	5	.50	.22	5	.52	.20	5	3.46	.87	5	<.25	-	5	2.72	.85
NY32	39	3	<.25	-	1	.07	-	3	3.03	.21	3	.61	.31	3	.94	.27	3	4.13	.42	3	<.25	-	3	2.90	.30
NY33	44	3	<.25	-	1	.08	-	3	4.20	1.93	3	1.64	1.08	3	2.37	.95	3	8.17	4.20	3	<.25	-	3	6.40	3.54
NY34	56	1	.07	-	1	.07	-	2	5.45	.07	2	.75	.07	2	2.26	.33	2	8.65	1.48	2	.48	.07	2	4.85	.92
NY35	57	1	.15	-	1	<.25	-	1	9.90	-	1	2.40	-	1	7.10	-	1	19.9	-	1	.48	-	1	8.40	-
NY36	51	2	.06	-	2	.12	-	2	6.75	.49	2	.71	.08	2	2.18	.18	2	8.05	.35	2	<.25	-	2	5.00	.99
NY37	52	2	<.25	-	2	<.25	-	2	4.75	.21	2	.35	.07	2	1.22	.10	2	4.85	.49	1	.16	-	2	3.05	.35
NY38	57	1	.06	-	1	.07	-	2	6.65	.07	2	1.05	.21	2	3.16	.24	2	10.7	.14	2	.24	.03	2	5.65	.35
NY39	46	2	<.25	-	2	.08	.01	2	3.90	.28	2	.53	.13	2	1.39	.13	2	5.65	1.34	2	<.25	-	2	3.30	1.41
NY4	19	4	.16	.21	6	.14	.05	6	5.65	1.69	6	9.91	7.87	6	13.0	19.7	6	25.0	7.85	6	.91	.25	6	20.3	15.9
NY40	30	2	.55	.03	2	.54	.06	2	15.9	4.88	2	16.2	1.48	2	9.87	1.32	2	53.9	25.8	2	1.98	.01	2	24.6	11.3
NY41	10	3	<.25	-	3	<.25	-	3	2.27	.31	3	.63	.06	3	.78	.11	3	6.23	.75	2	.11	.05	3	3.00	.46
NY42	16	3	.15	.03	3	.15	.01	3	18.4	2.15	3	2.83	.23	3	4.24	.17	3	48.3	1.46	3	1.77	.23	3	26.3	1.01
NY43	22	1	.08	-	3	.13	.02	3	21.6	2.88	3	3.73	2.07	3	5.52	3.93	3	32.0	3.46	3	.70	-	3	18.0	2.59
NY44	19	3	<.25	-	3	.21	.20	3	9.60	7.32	3	4.43	5.28	3	2.64	2.07	3	29.1	24.7	3	1.37	.29	3	14.6	13.3
NY5	35	3	2.96	1.32	3	2.75	.98	3	64.6	29.2	3	84.7	33.7	3	16.3	4.47	3	155.	58.2	3	1.99	.66	3	89.1	32.61
NY6	32	10	5.38	2.68	10	5.16	1.87	10	91.3	36.8	10	178.	71.5	10	16.3	4.00	10	307.	116.	10	1.15	.25	3	169.	36.8
NY65	13	3	<.25	-	3	<.25	-	3	1.83	.21	3	.67	.15	3	.71	.12	3	9.20	1.21	3	.57	.15	3	3.53	.49
NY7	24	6	2.80	1.60	6	4.12	2.98	6	90.6	63.1	6	117.	108.	6	11.5	7.69	6	195.	253.	6	.79	.37	3	94.5	75.45
NY8	25	1	.66	-	7	.33	.27	7	18.8	7.66	7	10.1	12.8	7	5.54	2.64	7	37.6	14.4	7	.76	.21	6	23.2	11.1
NY9	38	3	1.34	.12	3	1.18	.31	3	39.1	9.90	3	48.2	10.4	3	13.5	2.70	3	110.	37.9	3	2.19	.52	7	65.0	9.09
X	25	6	.40	.36	6	.34	.27	6	12.9	6.41	6	18.9	20.9	6	4.09	.88	6	41.7	18.7	6	.45	.26	6	34.7	8.60

Table 2. Mean concentrations (µg/g, dry wt) of metals in 1-cm layers of surface sediment.

Sta	Depth (m)	Depth in Sed (cm)	Ag			Cd			Cr			Cu			Ni			Pb			Zn			Tl		
			n	x	SD	n	x	SD	n	x	SD	n	x	SD	n	x	SD	n	x	SD	n	x	SD	n	x	SD
NY7	24	1	6	10.2	5.72	6	16.2	12.4	6	362.	270.	6	474.	433.	6	41.2	30.5	6	336.	309.	6	972.	1061.	6	1.39	1.34
		2	6	1.38	.86	6	2.40	1.69	6	43.0	31.2	6	57.5	61.0	6	6.32	4.07	6	51.3	41.2	6	126.	118.	6	.61	.18
		3	6	.66	.52	6	.96	.54	6	18.9	10.9	6	21.3	21.6	6	3.74	1.67	6	32.5	21.1	6	55.4	48.0	6	.52	.24
		4	6	.58	.67	6	.54	.44	6	13.6	6.32	6	14.2	11.2	6	2.84	.91	6	23.6	14.0	6	35.0	22.0	6	.40	.21
		5	6	.43	.48	6	.50	.52	6	15.5	14.0	6	19.8	28.6	6	3.64	3.18	6	29.3	22.5	6	44.6	46.9	6	.55	.20
A19	26	1	3	6.25	3.86	3	7.51	4.19	3	175.	92.4	3	207.	92.2	3	24.2	11.0	3	186.	95.8	3	388.	382.	3	1.33	.43
		2	3	.85	.21	3	1.59	1.50	3	23.6	5.00	3	31.5	10.3	3	4.26	.42	3	74.2	64.8	3	72.6	18.9	3	.68	.16
		3	2	.51	.08	2	.59	.04	2	15.3	1.27	2	18.1	.99	2	3.35	.76	2	29.4	3.96	2	41.7	5.30	2	.59	.13
		4	1	.58	-	1	1.50	-	1	26.0	-	1	31.5	-	1	5.71	-	1	50.8	-	1	72.8	-	1	.49	-
		5	1	.61	-	1	.49	-	1	13.1	-	1	23.9	-	1	3.07	-	1	29.9	-	1	40.4	-	1	.37	-
NY6	31	1	3	7.53	1.25	3	8.30	1.55	3	150.	17.1	3	269.	52.3	3	23.5	2.42	3	220.	32.9	3	493.	53.8	3	1.47	.51
		2	3	3.72	2.47	3	4.86	.88	3	80.4	11.3	3	144.	29.7	3	16.3	1.56	3	152.	12.2	3	277.	47.3	1	1.50	-
		3	2	.87	.42	3	3.01	1.45	3	46.8	14.6	3	70.5	25.2	3	10.8	2.39	3	132.	55.9	3	150.	37.0	1	1.50	-
		4	2	1.31	.22	3	3.32	.38	3	55.0	1.68	3	85.4	16.4	3	14.1	3.21	3	207.	95.6	3	199.	14.3	3	<.25	-
		5	3	1.16	.25	3	3.21	1.02	3	53.5	11.1	3	90.4	7.43	3	13.4	2.55	3	131.	22.2	3	171.	33.9	1	1.40	-
A16	21	1	2	9.09	.18	2	7.05	.42	2	160.	8.49	2	253.	16.2	2	31.8	-	2	223.	16.9	2	407.	36.7	2	2.69	.30
		2	2	9.77	1.32	2	9.19	2.42	2	202.	38.8	2	289.	40.3	2	34.4	4.24	2	270.	55.8	2	511.	87.6	2	3.03	.13
		3	2	8.47	1.05	2	9.43	1.80	2	185.	80.6	2	269.	38.8	2	32.9	5.30	2	287.	44.5	2	480.	135.	2	2.81	.14
		4	2	5.29	1.84	2	5.71	1.73	2	109.	28.2	2	176.	69.3	2	25.0	4.10	2	204.	102.	2	305.	81.3	2	2.28	.08
		5	2	5.18	.36	2	6.74	.46	2	109.	23.1	2	161.	11.3	2	24.1	2.12	2	182.	16.2	2	300.	24.0	2	2.23	.13
NY5	21	1	3	2.98	.81	3	2.52	.38	3	48.7	36.7	3	94.8	28.0	3	17.0	3.20	3	76.9	33.8	3	159.	30.5	3	2.00	.57
		2	3	2.91	1.07	3	2.50	.62	3	67.7	23.0	3	85.4	32.8	3	15.9	3.96	3	88.3	23.7	3	149.	44.8	3	2.08	.76
		3	3	2.87	1.14	3	2.87	.77	3	65.7	22.2	3	81.0	26.3	3	15.9	4.01	3	88.8	26.9	3	151.	52.9	3	2.12	.66
		4	3	3.59	2.79	3	3.28	2.24	3	80.0	54.3	3	95.3	65.5	3	17.7	7.63	3	109.	72.3	3	180.	116.	3	2.06	1.08
		5	3	2.44	1.10	3	2.57	1.13	3	61.0	29.2	3	67.3	26.5	3	15.0	4.29	3	81.9	29.0	3	138.	56.1	3	1.68	.63

Table 2. (continued)

Sta	Depth (m)	Depth in Sed (cm)	Ag			Cd			Cr			Cu			Ni			Pb			Zn			Tl		
			n	x	SD	n	x	SD	n	x	SD	n	x	SD	n	x	SD	n	x	SD	n	x	SD	n	x	SD
A44	25	1	3	18.7	29.8	3	16.2	26.1	3	392.	617.	3	511.	813.	3	42.2	63.0	3	405.	613.	3	1014.	1590.	2	2.77	2.94
		2	3	17.8	29.0	3	13.7	22.5	3	335.	543.	3	453.	733.	3	43.2	66.4	3	362.	559.	3	805.	1290.	2	2.69	2.84
		3	3	3.96	4.85	3	2.41	3.22	3	59.3	81.1	3	65.6	94.7	3	8.61	9.17	3	69.1	72.6	3	137.	167.	2	.92	.10
		4	3	.35	.15	3	3.12	4.75	3	13.0	2.00	3	11.0	4.26	3	3.84	.40	3	31.9	4.85	3	35.7	4.24	2	.75	.22
		5	3	.33	.17	3	1.12	1.48	3	10.5	3.61	3	7.77	2.17	3	5.15	3.67	3	33.3	23.6	3	33.8	4.85	1	.89	-
X	25	1	3	.41	.20	5	.26	.13	5	12.7	2.86	5	7.83	3.01	5	3.90	.26	5	42.1	16.9	5	35.5	4.71	3	.65	.28
		2	3	.18	.09	5	.52	.86	5	10.2	1.27	5	7.19	2.48	5	3.61	.44	5	30.9	9.50	5	34.7	5.05	4	.44	.16
		3	4	.19	.04	4	.21	.14	5	9.84	1.22	5	5.58	2.05	5	3.84	.58	5	29.4	6.63	5	33.6	3.60	3	.60	.26
		4	2	.20	.08	5	.12	.04	5	9.66	2.39	5	5.77	1.94	5	3.70	.41	5	29.8	9.67	5	32.6	3.25	3	.59	.17
		5	2	.20	.08	4	.16	.04	5	9.24	.69	4	6.25	3.48	5	3.74	.35	5	32.1	12.4	5	34.5	7.15	3	.33	.23
A43	28	1	3	.33	.13	3	.53	.70	3	9.87	.71	3	6.07	.47	3	4.16	.28	3	30.1	4.58	3	37.7	6.53	3	.74	.12
		2	2	.27	.09	1	.40	-	3	8.30	.82	3	6.10	3.64	3	3.49	.40	3	47.3	29.4	3	32.6	2.55	3	.55	.17
		3	2	.23	.13	2	.14	.08	3	9.37	.85	3	6.57	2.61	3	3.63	.01	3	32.1	8.23	3	32.9	6.44	2	.73	.07
		4	2	.13	.01	2	.29	.10	3	8.80	1.04	3	29.7	43.9	3	3.45	.48	3	28.4	10.4	3	29.4	4.71	2	.66	.12
		5	3	.16	.04	3	.23	.13	3	8.60	1.48	3	5.13	1.72	3	3.34	.23	3	24.4	3.03	3	30.2	2.11	3	.88	.17
A42	35	1	3	6.28	3.55	3	5.14	1.76	3	128.	51.1	3	216.	79.6	3	24.5	7.31	3	185.	59.9	3	315.	106.	2	1.28	.66
		2	3	4.27	3.04	3	5.28	.75	3	83.6	55.3	3	140.	95.1	3	18.1	11.1	3	128.	74.8	3	229.	138.	1	1.25	-
		3	3	4.11	1.42	3	3.59	1.59	3	76.9	28.3	3	121.	59.5	3	15.6	4.85	3	123.	44.6	3	209.	88.1	2	.83	.02
		4	3	3.88	1.95	3	3.91	1.95	3	80.8	36.2	3	118.	53.0	3	14.2	4.07	3	131.	43.2	3	224.	78.0	2	.90	.24
		5	3	1.92	1.39	3	2.09	.95	3	51.6	25.1	3	69.9	31.8	3	12.0	4.23	3	79.4	43.0	3	137.	70.0	2	.93	.04
A41	39	1	3	5.41	1.01	3	7.81	3.66	3	133.	18.3	3	151.	20.4	3	35.4	3.07	3	196.	15.0	3	306.	25.2	3	3.31	.45
		2	1	5.92	-	1	6.69	-	1	134.	-	1	160.	-	1	33.9	-	1	209.	-	1	307.	-	1	2.94	-
		3	3	4.89	1.35	3	6.46	.92	3	131.	32.4	3	148.	34.5	3	35.6	6.09	3	210.	44.5	3	327.	92.0	3	3.64	1.30
		4	3	5.59	1.07	3	6.90	.31	3	146.	24.1	3	164.	22.7	3	39.2	3.46	3	229.	34.4	3	363.	64.9	3	4.08	1.26
		5	2	6.59	2.54	2	7.38	.32	2	140.	28.9	2	178.	24.7	2	38.9	5.16	2	228.	51.6	2	383.	72.8	2	4.35	1.51

Table 2. (continued)

Sta	Depth (m)	Depth in Sed (cm)	Ag			Cd			Cr			Cu			Ni			Pb			Zn			Tl		
			n	x	SD	n	x	SD	n	x	SD	n	x	SD	n	x	SD	n	x	SD	n	x	SD	n	x	SD
A38	32	1	3	4.87	.92	3	3.74	1.03	3	129.	18.1	3	164.	30.5	3	33.4	2.81	3	187.	29.0	3	285.	53.1	3	4.87	.40
		2	3	5.47	.81	3	4.65	.68	3	141.	18.5	3	198.	16.5	3	37.8	3.81	3	214.	23.6	3	343.	64.0	3	4.50	.52
		3	3	5.36	2.68	3	4.66	2.22	3	131.	52.6	3	183.	58.5	3	33.8	7.34	3	203.	65.0	3	316.	86.9	3	4.07	.79
		4	3	4.70	.46	3	3.98	.97	3	126.	15.8	3	160.	14.0	3	34.6	2.77	3	209.	17.7	3	297.	10.9	3	4.76	.35
		5	3	5.18	.51	3	4.46	.29	3	144.	25.5	3	179.	19.5	3	36.3	3.32	3	237.	36.1	3	335.	54.9	3	5.14	.99
A37	29	1	3	1.62	.55	3	1.19	.40	3	48.4	12.4	3	78.8	15.2	3	19.5	2.78	3	81.0	6.25	3	145.	89.6	3	2.00	.35
		2	3	1.54	.47	3	1.04	.22	3	46.2	8.51	3	65.7	8.40	3	16.2	.42	3	72.0	6.85	3	173.	43.9	3	1.39	.16
		3	3	1.29	.33	3	.91	.22	3	36.0	8.22	3	55.3	3.92	3	17.4	2.31	3	69.6	11.4	3	173.	63.0	3	1.58	.09
		4	2	.52	.04	2	.40	.06	2	15.1	1.13	2	27.0	2.26	2	10.1	1.24	2	54.5	40.3	2	59.5	11.4	2	1.23	.60
		5	2	.28	.14	2	1.06	1.32	2	9.43	4.05	2	20.4	1.77	2	8.56	1.74	2	20.9	.71	2	89.4	9.40	2	.79	.20
A36	23	1	3	7.65	1.27	3	10.9	.96	3	327.	26.7	3	330.	45.9	3	68.6	9.46	3	349.	27.5	3	566.	36.8	3	3.56	1.60
		2	3	7.34	.67	3	10.4	.77	3	331.	19.2	3	318.	20.5	3	60.0	3.42	3	339.	14.0	3	557.	45.9	3	4.26	1.01
		3	3	7.37	1.46	3	9.33	1.15	3	308.	59.4	3	309.	45.5	3	71.8	29.0	3	310.	40.0	3	472.	109.	3	3.67	1.22
		4	3	9.26	4.00	3	8.67	.64	3	280.	16.1	3	326.	69.6	3	138.	139.	3	333.	28.0	3	458.	19.9	3	3.96	1.20
		5	3	8.41	3.96	3	7.91	2.02	3	276.	77.8	3	303.	113.	3	62.1	4.07	3	292.	83.6	3	434.	135.	3	4.26	.94
A35	24	1	3	9.12	1.78	3	7.75	2.78	3	211.	73.1	3	316.	93.8	3	498.	355.	3	431.	188.	3	527.	185.	3	4.23	1.25
		2	3	8.74	4.32	3	5.73	2.49	3	166.	72.1	3	240.	71.9	3	122.	86.01	3	244.	84.4	3	357.	109.	3	4.11	1.50
		3	3	8.66	1.24	3	5.28	.67	3	150.	14.1	3	245.	43.3	3	48.0	7.21	3	223.	20.5	3	347.	38.8	3	3.64	.34
		4	3	6.07	2.08	3	4.89	1.49	3	135.	58.1	3	216.	90.0	3	37.7	8.44	3	199.	74.2	3	308.	111.	3	2.99	1.02
		5	2	7.54	1.46	2	5.72	.54	2	166.	1.41	2	263.	11.3	2	41.6	4.67	2	245.	7.78	2	375.	6.36	2	3.93	1.07
M109	19	1	3	6.95	1.52	3	6.52	2.39	3	198.	56.5	3	270.	104.	3	744.	547.	3	369.	152.	3	421.	133.	3	3.60	1.44
		2	3	3.91	4.39	3	2.97	2.62	3	86.1	76.6	3	128.	128.	3	91.9	62.9	3	39.	111.	3	199.	130.	1	4.37	-
		3	3	1.39	1.47	3	1.04	.97	3	33.9	34.8	3	44.7	40.6	3	21.7	10.8	3	48.9	36.0	3	84.1	56.2	1	4.21	-
		4	3	1.50	1.70	3	1.19	1.16	3	34.8	34.3	3	51.4	54.6	3	29.6	17.8	3	59.4	50.5	3	102.	73.5	2	2.11	1.77
		5	1	3.13	-	1	2.60	-	1	68.2	-	1	98.3	-	1	36.6	-	1	112.	-	1	163.	-	1	2.89	-

Table 2. (continued)

Sta	Depth (m)	Depth in Sed (cm)	Ag			Cd			Cr			Cu			Ni			Pb			Zn			Tl		
			n	x	SD	n	x	SD	n	x	SD	n	x	SD	n	x	SD	n	x	SD	n	x	SD	n	x	SD
A33	25	1	3	.78	.40	3	11.6	6.87	3	203.	178.	3	290.	237.	3	28.2	22.0	3	173.	127.	3	1161.	1313.	3	1.21	1.01
		2	3	.50	.44	3	2.74	2.09	3	41.1	10.8	3	53.1	18.1	3	7.17	1.33	3	61.1	15.3	3	140.	43.8	3	.42	.14
		3	3	.53	.28	3	1.02	.32	3	21.2	.72	3	28.4	2.08	3	4.35	.57	3	36.1	4.22	3	69.9	8.97	3	.31	.13
		4	3	.46	.17	3	.54	.23	3	16.7	3.77	3	19.5	4.68	3	3.99	.60	3	37.0	7.03	3	54.6	11.3	3	.22	.02
		5	3	.37	.11	3	.71	.37	3	13.6	3.15	3	14.5	1.14	3	3.65	1.55	3	30.0	5.03	3	38.6	8.84	3	.18	.09
A32	28	1	3	.87	.96	3	.46	.50	3	21.0	14.7	3	22.7	25.3	3	3.39	1.59	3	25.7	15.3	3	47.5	36.7	3	.44	.13
		2	3	.12	.04	3	.19	.11	3	9.09	.54	3	6.13	1.64	3	2.17	.12	3	13.2	.92	3	21.7	2.40	3	.25	-
		3	3	.09	-	3	.13	.04	3	10.0	1.95	3	6.47	2.87	3	2.10	.12	3	13.3	1.00	3	21.0	4.04	3	.29	.08
		4	3	.18	.09	3	.15	.04	3	9.17	.37	3	7.45	4.12	3	2.45	.13	3	18.9	8.90	3	23.1	5.00	2	.46	.05
		5	3	.13	.05	3	.26	.09	3	9.66	.33	3	5.55	.10	3	2.72	.29	3	24.7	8.53	3	24.2	1.31	2	.44	.01
A31	34	1	3	8.85	7.41	3	6.90	4.94	3	146.	109.	3	242.	219.	3	24.0	15.0	3	207.	162.	3	361.	297.	3	1.14	.67
		2	3	3.23	1.43	3	3.65	.77	3	67.9	15.2	3	104.	25.5	3	14.5	2.02	3	102.	19.0	3	175.	43.4	3	.47	.09
		3	3	4.04	.30	3	4.15	.16	3	70.3	7.46	3	107.	7.51	3	13.9	1.11	3	122.	5.77	3	192.	6.93	3	.66	.06
		4	3	2.78	.38	3	4.83	2.11	3	59.1	4.02	3	81.6	6.53	3	13.2	1.00	3	99.1	12.0	3	152.	20.9	3	.73	.15
		5	3	6.34	3.40	3	5.85	2.34	3	105.	56.6	3	168.	101.	3	18.1	6.73	3	167.	76.2	3	278.	139.	3	.98	.41
A30	37	1	3	7.38	2.51	3	6.68	.59	3	147.	17.4	3	230.	71.3	3	28.5	3.75	3	206.	28.0	3	359.	58.9	3	2.80	.20
		2	3	9.80	5.17	3	8.23	1.33	3	166.	64.3	3	281.	141.	3	33.7	10.9	3	252.	75.0	3	429.	132.	3	2.69	.76
		3	3	7.73	4.76	3	6.43	2.18	3	131.	61.1	3	218.	135.	3	29.4	9.85	3	198.	82.0	3	346.	138.	3	2.33	.95
		4	3	6.77	2.32	3	6.61	1.02	3	123.	28.5	3	196.	73.4	3	24.8	6.41	3	191.	48.8	3	337.	75.2	3	2.34	.77
		5	3	7.12	5.84	3	7.34	6.34	3	142.	122.	3	196.	154.	3	24.4	14.1	3	204.	161.	3	359.	304.	3	2.36	1.49
A29	38	1	3	5.31	.35	3	4.69	.27	3	117.	4.04	3	142.	4.62	3	26.5	1.95	3	154.	9.07	3	244.	14.5	3	3.97	.83
		2	2	4.74	1.18	2	3.81	.40	2	103.	2.12	2	123.	19.0	2	23.7	2.62	2	139.	14.8	2	222.	40.3	2	4.10	1.40
		3	3	5.24	.55	3	4.92	.14	3	118.	4.16	3	139.	9.54	3	27.4	1.02	3	171.	4.73	3	255.	17.7	3	3.69	.66
		4	2	4.48	.08	2	6.60	2.00	2	112.	6.36	2	124.	9.19	2	26.4	.28	2	159.	4.95	2	236.	13.4	2	3.31	.94
		5	2	4.14	.76	2	4.66	.46	2	108.	23.1	2	113.	14.1	2	25.8	6.15	2	150.	29.7	2	222.	40.3	2	3.36	.25

Table 2. (continued)

Sta	Depth (m)	Depth in Sed (cm)	Ag			Cd			Cr			Cu			Ni			Pb			Zn			Tl		
			n	x	SD	n	x	SD	n	x	SD	n	x	SD	n	x	SD	n	x	SD	n	x	SD	n	x	SD
A28	37	1	3	3.39	.39	3	2.36	.43	3	81.5	7.69	3	99.5	16.5	3	22.3	1.60	3	115.	15.7	3	171.	26.9	3	2.96	.24
		2	3	3.28	.14	3	2.22	.32	3	76.8	13.6	3	91.8	12.6	3	21.8	2.66	3	109.	14.5	3	160.	24.3	3	3.10	.17
		3	3	2.59	.30	3	2.02	.34	3	64.6	11.1	3	78.5	17.3	3	18.6	2.15	3	98.8	16.2	3	141.	26.9	3	2.71	.13
		4	3	3.10	.62	3	2.54	.68	3	81.2	17.6	3	93.7	24.4	3	22.0	3.69	3	121.	26.4	3	169.	42.1	3	3.03	.45
		5	3	3.12	.27	3	2.55	.15	3	76.5	8.28	3	90.4	6.66	3	21.8	1.20	3	115.	8.08	3	163.	8.19	3	3.00	.25
A27	35	1	3	2.00	.96	3	1.15	.80	3	54.9	23.1	3	69.9	37.4	3	28.7	9.51	3	82.6	33.8	3	129.	54.9	3	2.36	.64
		2	3	1.99	1.52	3	1.08	.94	3	52.1	28.9	3	60.4	39.9	3	26.0	4.25	3	75.7	43.9	3	121.	70.6	3	2.26	.62
		3	3	1.51	.42	3	.91	.49	3	43.1	4.24	3	49.4	10.5	3	25.6	6.96	3	93.4	32.4	3	111.	28.9	3	2.09	.40
		4	3	1.70	.26	3	1.01	.48	3	46.2	6.94	3	53.5	9.71	3	28.0	12.1	3	71.8	13.9	3	112.	18.1	3	2.09	.18
		5	3	1.42	.46	3	.97	.77	3	41.6	9.65	3	45.8	10.8	3	26.0	13.4	3	68.8	16.8	3	104.	32.7	3	2.25	.86
A26	27	1	3	8.67	3.00	3	10.9	5.12	3	271.	134.	3	475.	206.	3	53.8	14.7	3	315.	115.	3	569.	236.	3	3.40	.97
		2	3	7.12	3.40	3	7.58	5.25	3	207.	156.	3	359.	212.	3	45.0	15.3	3	250.	128.	3	469.	205.4	3	3.08	1.19
		3	3	6.83	4.16	3	7.02	6.20	3	191.	172.	3	317.	253.	3	43.0	20.2	3	238.	166.	3	413.	259.	3	2.84	1.26
		4	3	4.76	2.87	3	3.99	2.86	3	111.	79.9	3	203.	134.	3	31.7	16.5	3	157.	102.	3	301.	176.	3	2.67	1.03
		5	3	6.52	4.84	3	7.23	6.09	3	193.	157.	3	318.	250.	3	39.6	24.5	3	236.	174.	3	429.	308.	3	3.05	1.51
A25	19	1	3	5.61	3.52	3	8.67	3.12	3	254.	67.5	3	449.	59.6	3	57.4	11.8	3	313.	91.7	3	587.	56.2	3	3.57	2.14
		2	3	6.16	4.54	3	9.50	1.75	3	259.	43.5	3	478.	41.5	3	54.1	3.20	3	319.	48.6	3	538.	152.	3	4.76	.78
		3	3	7.33	1.31	3	9.58	.81	3	250.	31.5	3	374.	66.0	3	52.7	11.5	3	290.	28.3	3	561.	52.7	3	4.13	.57
		4	3	7.54	1.89	3	11.1	3.15	3	277.	56.3	3	428.	130.	3	73.6	23.7	3	400.	173.	3	615.	136.	3	4.33	.99
		5	3	4.22	1.92	3	8.26	3.08	3	149.	51.7	3	217.	52.1	3	63.0	64.1	3	170.	68.1	3	463.	186.	3	3.14	.40
A34	25	1	3	6.49	1.72	3	8.13	3.81	3	218.	81.9	3	374.	117.	3	42.0	12.3	3	244.	81.6	3	494.	158.	3	3.33	1.50
		2	3	7.80	1.06	3	10.5	.90	3	288.	26.9	3	427.	84.8	3	52.6	6.32	3	303.	7.55	3	602.	36.5	3	3.40	.42
		3	3	7.16	.97	3	9.49	1.01	3	261.	17.3	3	394.	52.8	3	51.7	7.84	3	275.	32.5	3	542.	48.2	3	3.62	.40
		4	3	7.67	1.62	3	9.93	3.82	3	276.	82.0	3	404.	102.	3	53.5	14.4	3	276.	52.0	3	550.	109.	3	3.51	.66
		5	3	7.57	1.94	3	10.1	3.67	3	294.	88.3	3	394.	127.	3	56.4	19.5	3	288.	78.2	3	562.	142.	3	3.79	.98

Table 3. Coefficients of correlation among metals. N = 171.

	Ag	Cd	Cr	Cu	Ni	Pb	Zn	Tl
Ag								
Cd	0.908							
Cr	0.902	0.959						
Cu	0.900	0.953	0.971					
Ni	0.354	0.317	0.373	0.365				
Pb	0.921	0.937	0.957	0.952	0.502			
Zn	0.860	0.964	0.940	0.941	0.336	0.907		
Tl	0.638	0.602	0.690	0.657	0.374	0.739	0.579	

Table 4. Stations exhibiting maximum concentrations (ppm, dry wt).

	Ag*	Cd	Cr	Cu	Ni	Pb	Zn	Tl*
1980	-	6 (3.7)	5 (75)	6 (121)	40 (18)	6 (135)	6 (229)	-
1981	9 (4.0)	6 (4.1)	9 (125)	18 (125)	9 (35)	9 (237)	9 (258)	-
1982	6 (5.4)	6 (5.2)	A56* (110)	6 (179)	A56* (33)	6 (168)	6 (307)	A56* (4.5)

*Not monitored in prior years.

Table 5. Trace metal concentrations in Hudson-Raritan sediments, ppm dry wt. ( ) show ratios of metal concentrations to the thallium concentration in the same samples. [ ] are enrichment factors.*

Sample	Ag	Cd	Cr	Cu	Ni	Pb	Zn	Tl
LD 1 (Preindustrial[a] Hudson River)	<.20 (-)	0.36 (0.17)	14.0 (6.7)	10.9 (5.1)	20.0 (9.4)	9.7 (4.6)	55.0 (26.7)	2.1
LD 3 (Preindustrial[a] NY Harbor)	<.20 (-)	0.70 (0.15)	24.2 (5.1)	17.7 (3.8)	27.6 (5.9)	17.4 (3.7)	65.3 (13.9)	4.7
LD 2 (Contaminated[a] NY Harbor)	1.64 (0.68) [4.5]**	1.98 (0.82) [5.5]	60.1 (25.1) [4.9]	71.1 (29.6) [7.8]	22.7 (9.6) [1.6]	81.2 (33.7) [9.1]	135 (56.1) [4.0]	2.4
RB (Contaminated)	5.7 (1.2) [8.0]**	3.1 (0.7) [4.7]	140 (30) [5.9]	150 (33) [8.7]	38.0 (8.4) [1.4]	180 (40) [10.8]	280 (66) [4.7]	4.7

Sample LD 1 is from 50-55 cm below the sediment surface in the Hudson River, approximately 50 miles north of the southern tip of Manhattan Island.

Sample LD 3 is from NY Harbor at the Battery, 60-65 cm below sediment surface.

Sample LD 2 is from the same core as LD 3, but 50-55 cm below surface.

Sample RB is from Raritan Bay, ~5 n mi south of the Narrows, 0-5 cm (surface).

* Enrichment factors: $(M^+/Tl)/(M^+/Tl)_{LD\ 3}$

**Using Cd/Tl reference value from LD3.

[a] Personal communication, Dr. B. Deck, Lamont-Doherty Geological Observatory.

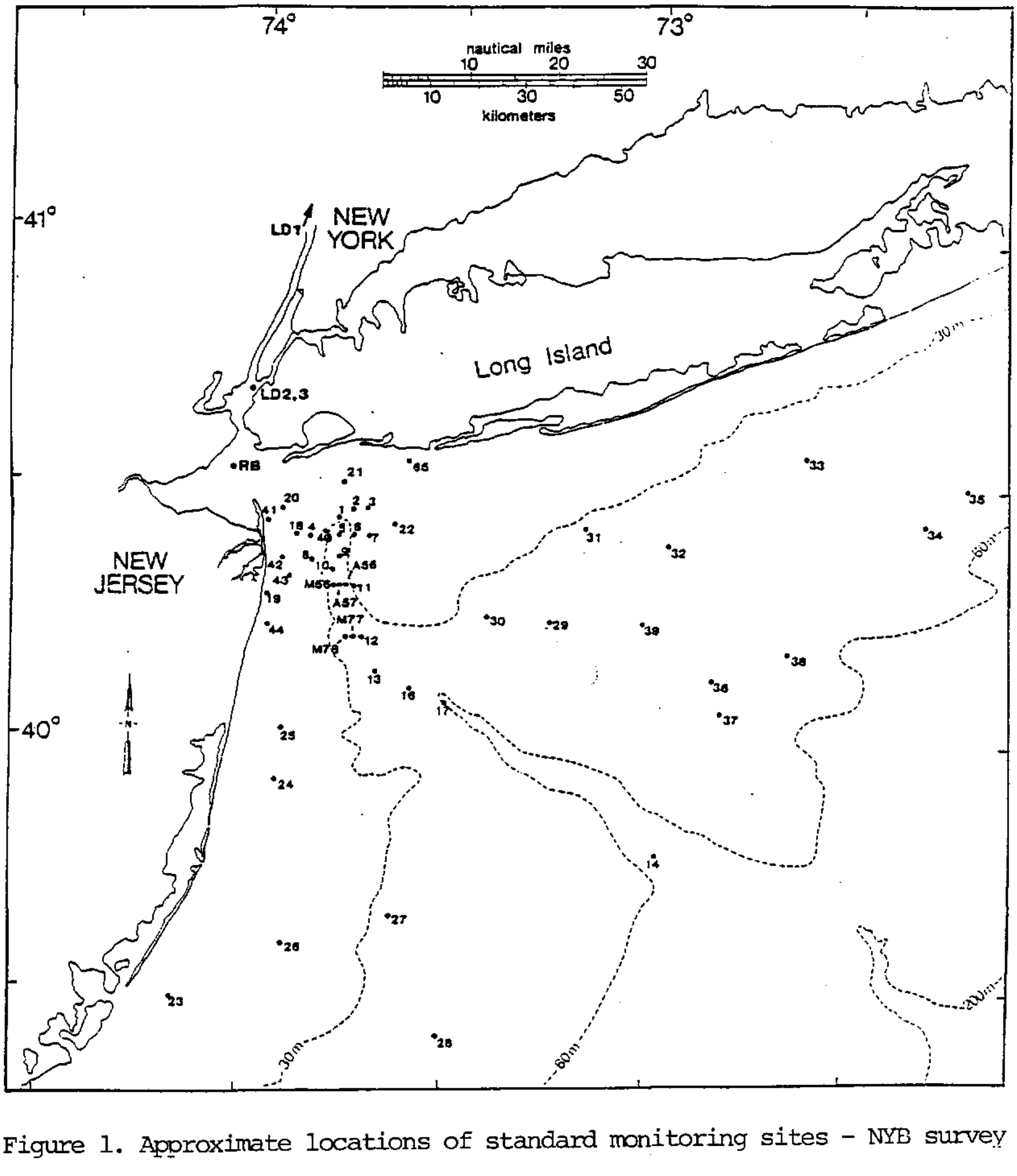


Figure 1. Approximate locations of standard monitoring sites - NYB survey DL8206.

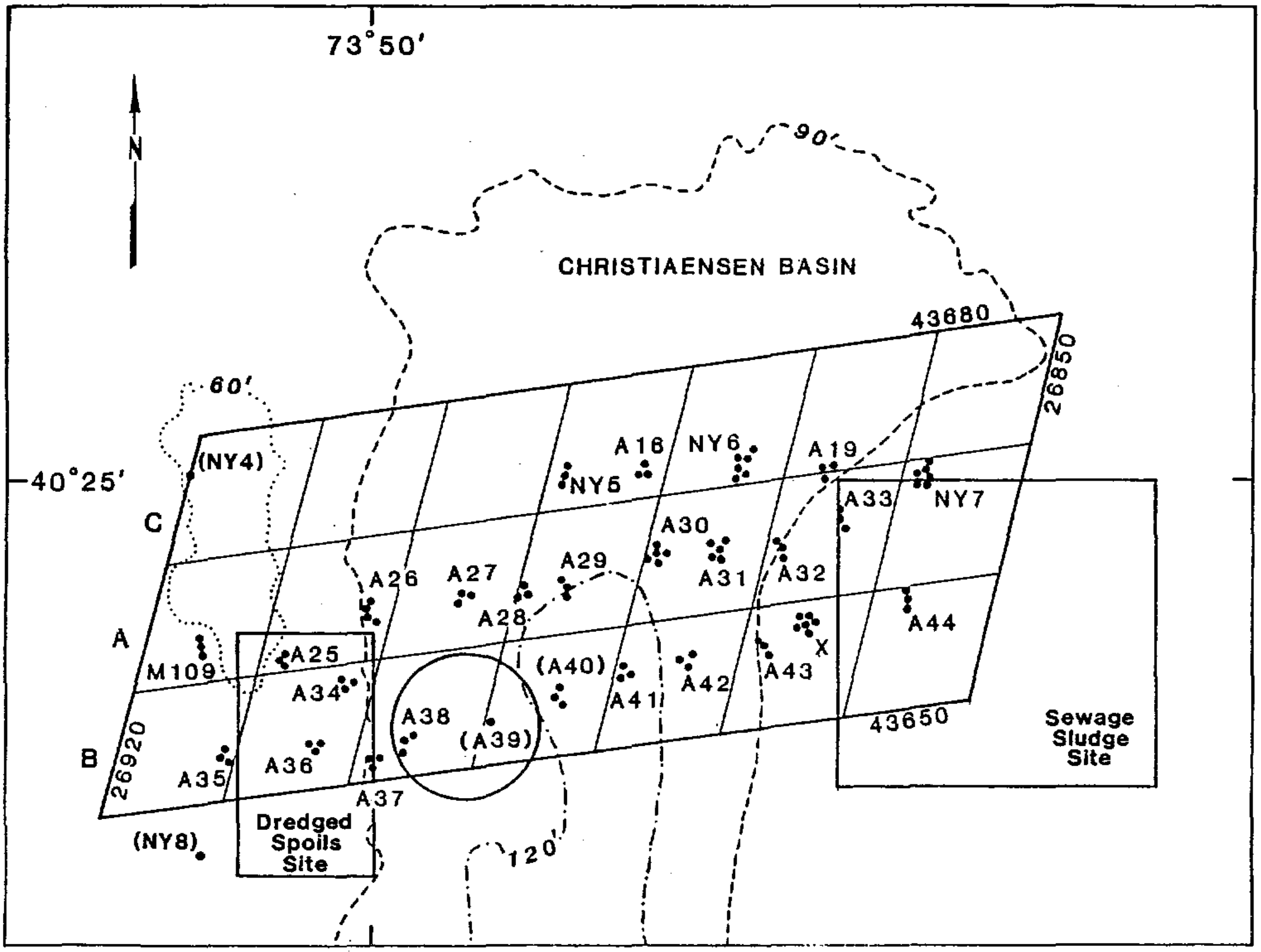


Figure 2. Approximate locations of individual bottom samples at stations comprising the dumpsite transects.

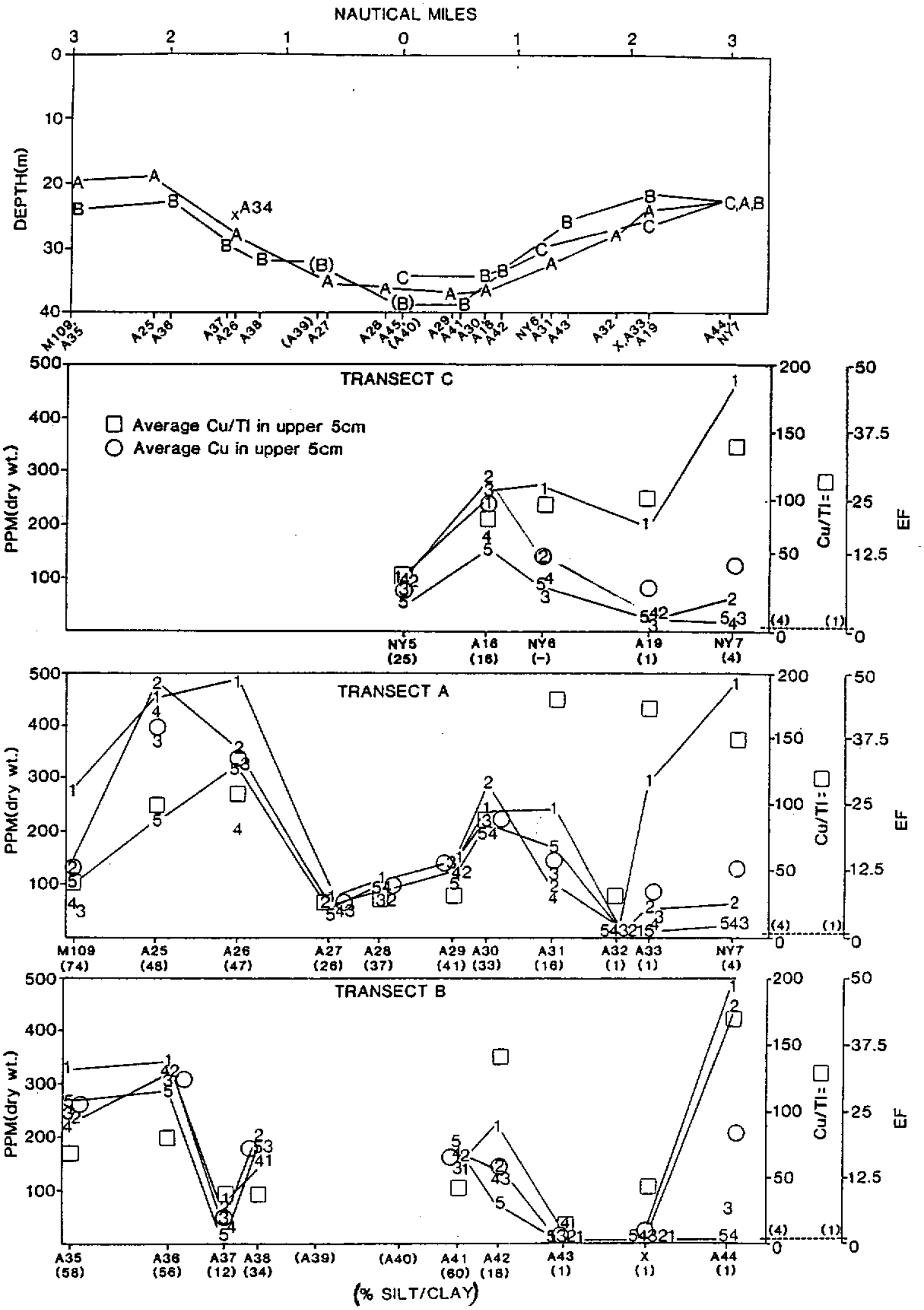


Figure 3. Vertical distribution of copper in sediments from the dumpsite transects.

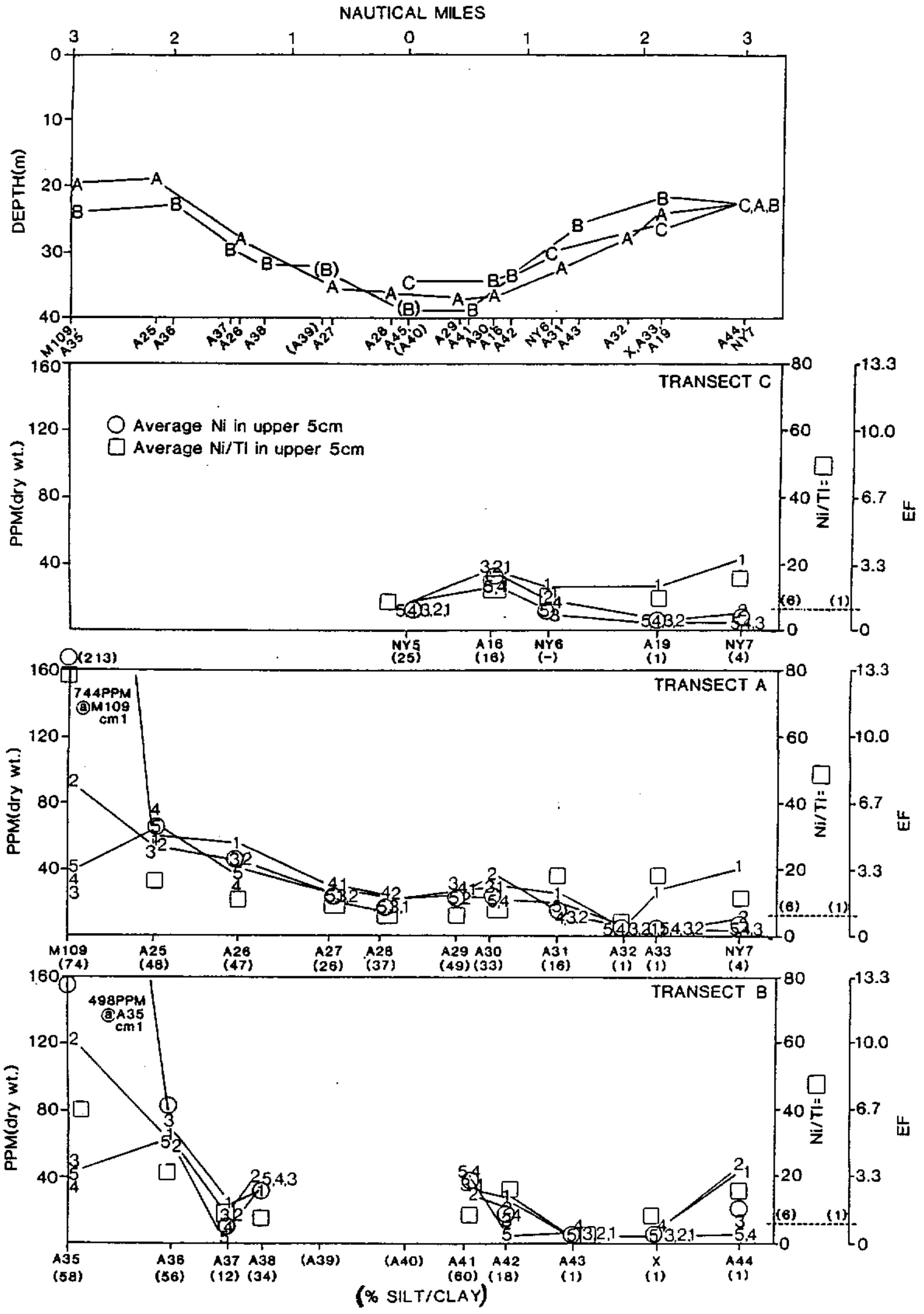


Figure 4. Vertical distribution of nickel in sediments from the dumpsite transects.

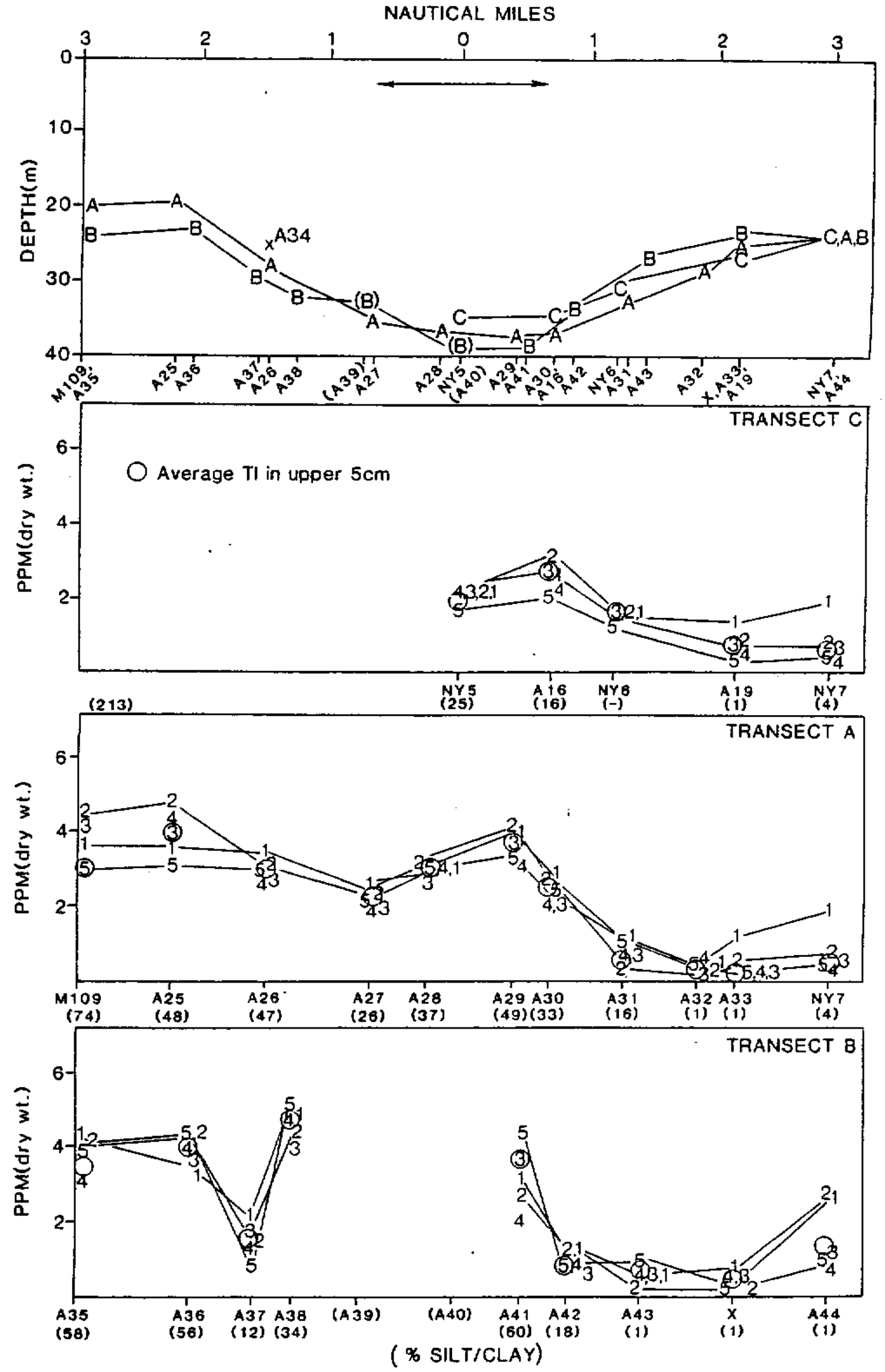
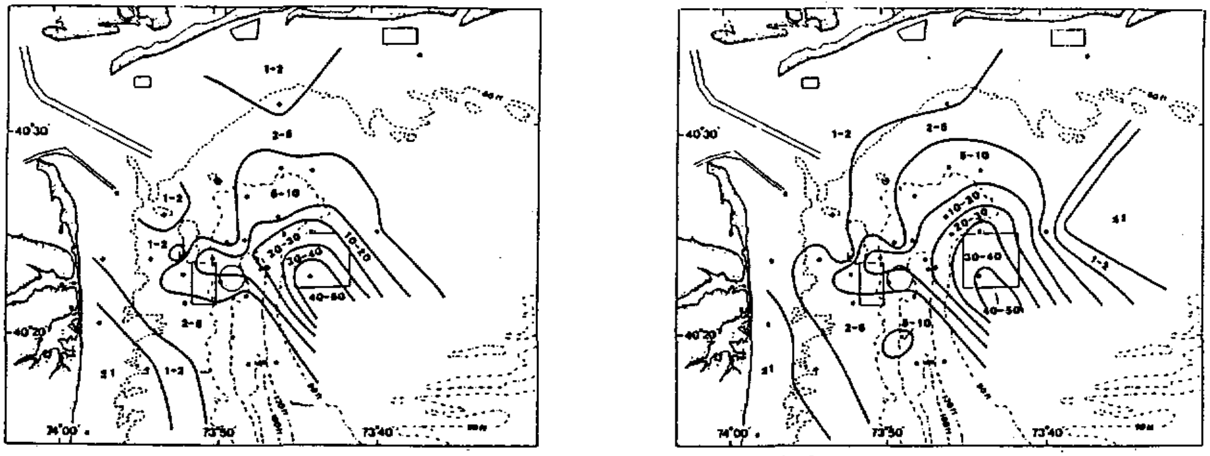
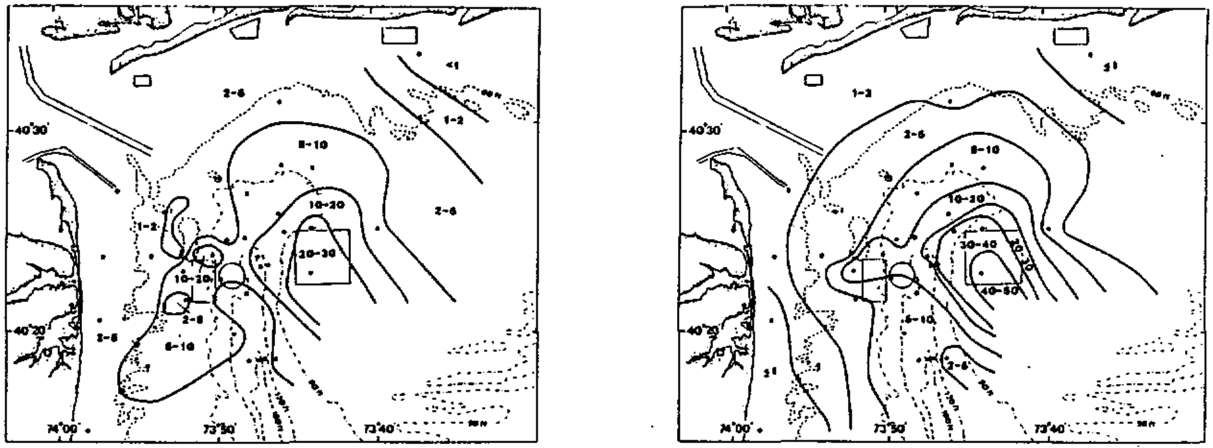


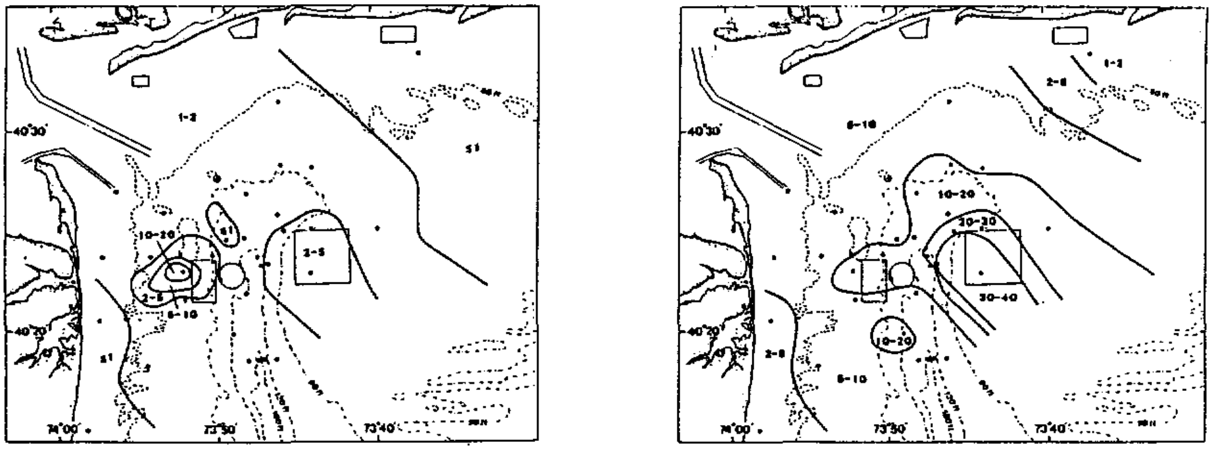
Figure 5. Vertical distribution of thallium in sediments from the dumpsite transects.



a) Silver b) Cadmium



c) Chromium d) Copper



e) Nickel f) Lead

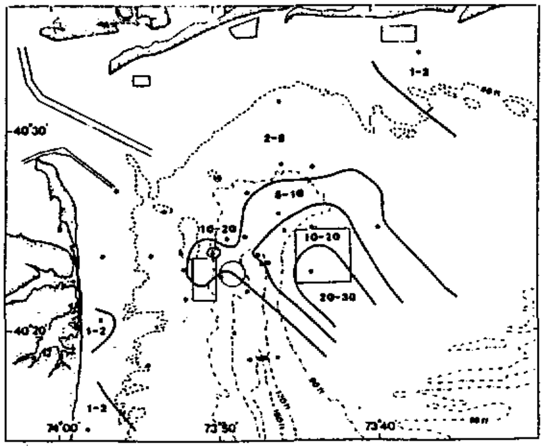


Figure 6. Enrichment profiles of sediments in the NYB apex.

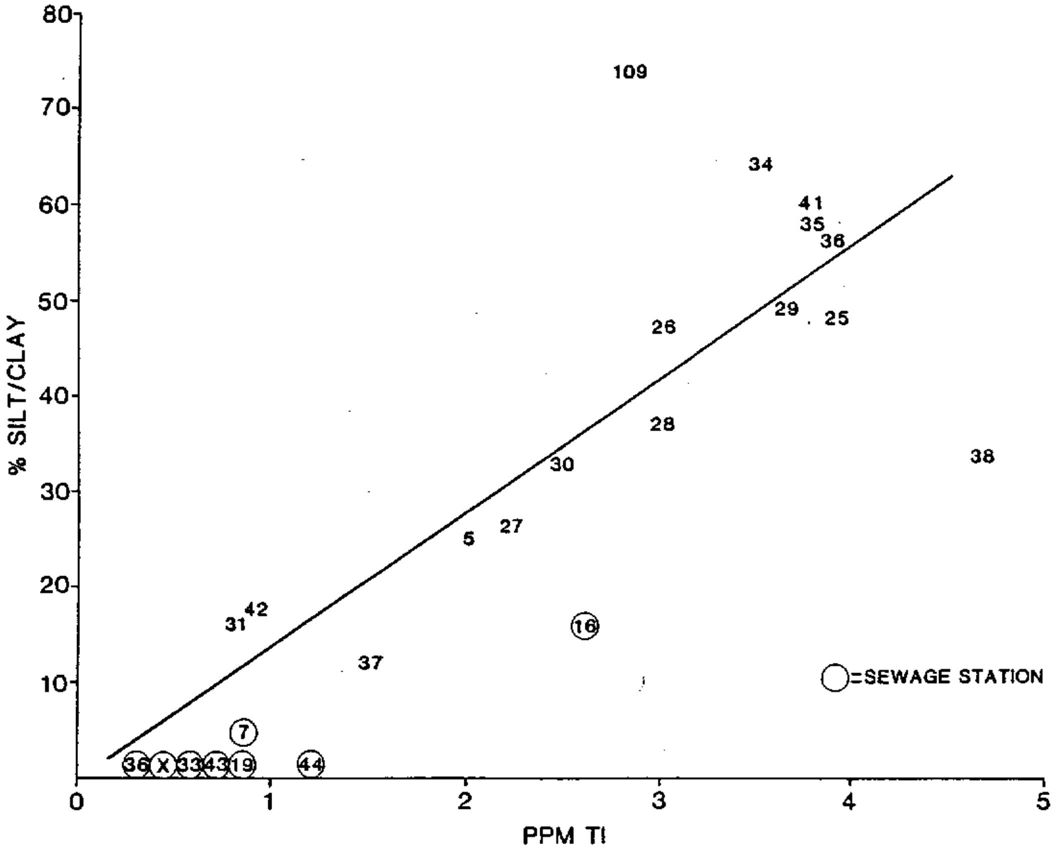


Figure 7. % silt/clay vs. thallium concentration in sediments from the dumpsite transects.