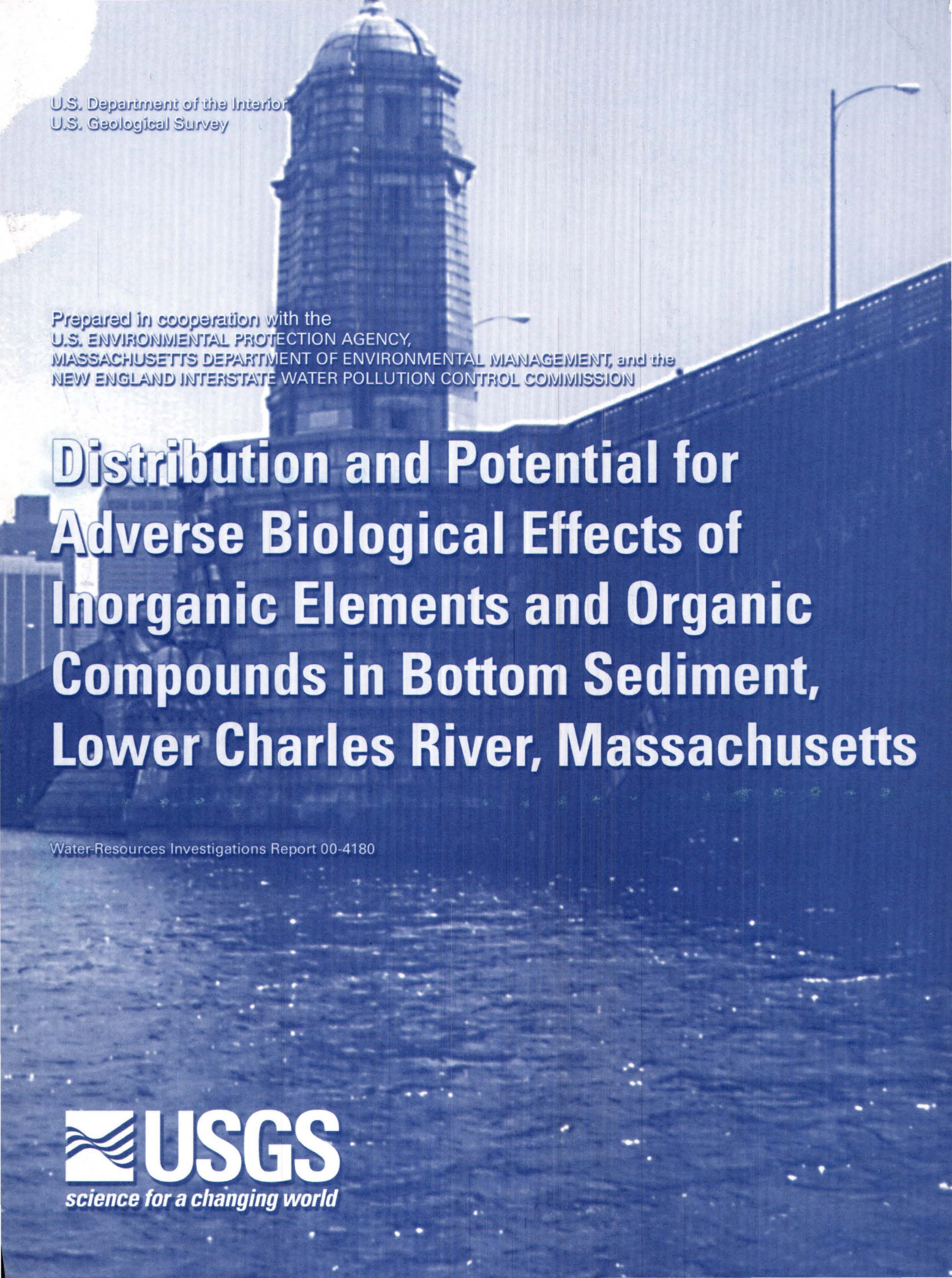

U.S. Department of the Interior
U.S. Geological Survey

Prepared in cooperation with the
U.S. ENVIRONMENTAL PROTECTION AGENCY,
MASSACHUSETTS DEPARTMENT OF ENVIRONMENTAL MANAGEMENT, and the
NEW ENGLAND INTERSTATE WATER POLLUTION CONTROL COMMISSION

Distribution and Potential for Adverse Biological Effects of Inorganic Elements and Organic Compounds in Bottom Sediment, Lower Charles River, Massachusetts

Water-Resources Investigations Report 00-4180

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U.S. Department of the Interior
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By ROBERT F. BREAULT, KEVIN R. REISIG, LORA K. BARLOW, and PETER K. WEISKEL

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Northborough, Massachusetts
2000

U.S. DEPARTMENT OF THE INTERIOR
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PLATE
(in back pocket)

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CONVERSION FACTORS, VERTICAL DATUM, AND SEDIMENT-QUALITY UNITS

CONVERSION FACTORS

Multiply	By	To obtain
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
cubic foot	0.02832	cubic meter
foot (ft)	0.3048	meter
inch (in.)	2.54	centimeter
inch (in.)	25.4	millimeter
inch (in.)	25,400	micron
mile (mi)	1.609	kilometer
square foot (ft^2)	0.0929	square meter

Temperature in degrees Fahrenheit (°F) can be converted to degrees Celsius (°C) as follows: °C = 5/9 (°F - 32).

VERTICAL DATUM

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)—a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

SEDIMENT-QUALITY UNITS

Concentrations of sediment-quality constituents are given in percent (%), parts per million (ppm), and parts per billion (ppb) by weight, and micromoles per gram (µm/g). Concentrations of water-quality constituents are given in parts per thousand (ppt) and milligrams per liter (mg/L).

Distribution and Potential for Adverse Biological Effects of Inorganic Elements and Organic Compounds in Bottom Sediment, Lower Charles River, Massachusetts

By Robert F. Breault, Kevin R. Reisig, Lora K. Barlow, *and* Peter K. Weiskel

Abstract

Surficial-sediment samples and cores collected from the lower Charles River Basin are generally enriched in inorganic elements and organic compounds, including polychlorinated byphenyls, total organochlorine pesticides, and polyaromatic hydrocarbons. Median concentrations of selected inorganic elements and organic compounds measured in surficial-sediment samples collected from the lower Charles River ranged from 1.3 to 35 times higher than median concentrations of these constituents measured in samples collected from urban rivers across the conterminous United States by the U.S. Geological Survey's National Water Quality Assessment Program (NAWQA).

The distribution of the inorganic elements in surficial sediment throughout the basin appears to be controlled primarily by in-stream processes associated with sediment transport and the presence of an anoxic zone within a non-tidal salt wedge in the basin. In contrast, the distribution of organic compounds appears to reflect local point and non-point sources.

Inorganic elements and organic compounds are present at sufficiently high concentrations at many surficial-sediment sampling sites to cause potentially severe biological effects to benthic organisms living in and on the bottom sediment. Ratios of acid volatile sulfide to simultaneously extracted metals, however, suggest that some inorganic elements would be toxic in fewer than 25 percent of the surficial-sediment samples. Many individual polyaromatic hydrocarbons, total petroleum hydrocarbons, and lead measured in cores exceeded exposure-based soil-concentration standards for direct contact and incident ingestion at areas where restoration of public wading and swimming beaches is being considered.

INTRODUCTION

The lower Charles River, known locally as the Charles River Basin or the basin, extends for about 8 mi from the Watertown Dam in Watertown, Mass., to the river's mouth at Boston Harbor. The basin is impounded at its mouth by the "New" Charles River Dam in Boston, Mass. (pl. 1). The basin was created by construction of the "Old" Charles River Dam in 1908, designed to be a solution to Boston's sanitary problems. Prior to 1908, the lower part of the Charles River was a tidal estuary; untreated sewage that was discharged directly into the river tended to accumulate on mud flats exposed at low tide (fig. 1). Exposed sewage created noxious odors, and the mud flats served as a breeding ground for mosquitoes thought to be responsible for disease (Jobin, 1998). Damming of the river interrupted the normal tidal cycle and flooded the mud flats, creating a freshwater pool with a constant water elevation of about 2.5 ft above mean sea level (fig. 2). Flooding of the estuary improved sanitary conditions, and the basin became a place of enjoyment and recreation for people (Jobin, 1998).

Figure 1. Lower Charles River Basin, Massachusetts, 1903; view is to the west-southwest.

During the past century, urban runoff, atmospheric deposition, inadvertent spills, combined sewer overflows, and illegal sewage connections have contributed fine-grained sediment, inorganic, and organic compounds to the basin. These contaminants have degraded the quality of the water, biota, and sediment. A previous investigation of sediment quality of the basin in 1997 indicated that the bottom sediment is contaminated with trace inorganic elements, polychlorinated byphenyls (PCBs), organochlorine pesticides, polyaromatic hydrocarbons (PAHs), and total petroleum hydrocarbons (TPHs) (Thomas Faber, U.S. Environmental Protection Agency, written commun., 1998).

Because of the long-standing sediment contamination problem that has been a major factor limiting public use (fishing and swimming) of the lower Charles River Basin, the U.S. Environmental Protection Agency (USEPA) Region I has designated the basin as a priority water body and the focus of the EPA Clean Charles 2005 Task Force. The goal of the Task Force is to improve the quality of the basin such that Federal, State, and local standards for fishing and swimming are consistently met in the Charles River by Earth Day, April 2005. More than 25 communities, environmental groups, citizen's groups, and many State and Federal agencies, including the USEPA, Massachusetts Department of Environmental Protection (MADEP), New England Interstate Water Pollution Control Commission (NEWIPCC), Massachusetts Water Resources Authority (MWRA), Massachusetts Executive Office of Environmental Affairs (EOEA), Massachusetts District Commission (MDC), U.S. Army Corps of Engineers (USACOE), and the U.S. Geological Survey (USGS) have joined together to pursue this common goal. One of several contributions made by the USGS toward achieving fishable and swimmable conditions is to provide detailed information concerning the geographic distribution and potential for adverse biological

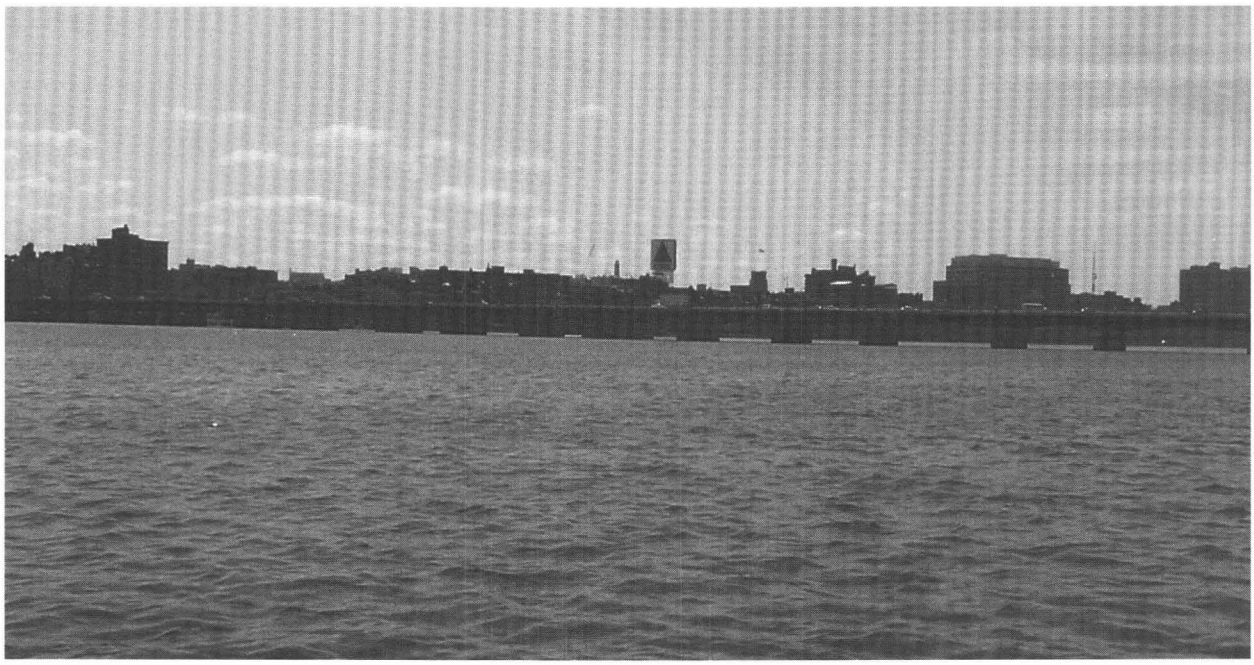

Figure 2. Lower Charles River Basin, Massachusetts, 1999; view is to the southwest.

effects of inorganic and organic compounds in bottom sediment. Sediment samples were collected in the summer of 1998 throughout the Charles River Basin and in more detail at areas where restoration of public wading and swimming beaches is being considered. Those data are presented and described here and will be used to assist current planning efforts of the MDC and the USACOE to restore the historical parklands and wildlife habitat, respectively, of the basin.

Channel Morphology and Thickness and Volume of Post-1908 Bottom Sediment

The present-day channel morphology of the basin is similar to that of the original tidal channel and associated mudflats, which was surveyed in detail prior to construction of the old dam (Pritchett and others, 1903). The bathymetry of the basin surveyed in 1901, however, has been modified slightly by sediment accumulation and by depressions excavated over the last 99 years. In one such depression, in front of Massachusetts Institute of Technology (MIT), the maximum water depth is about 40 ft. The total volume of water in the basin is estimated to be about 400 million cubic feet.

Construction of the Charles River Dam in 1908 reduced hydraulic gradients and eliminated tidal influence in the basin, thereby creating a "settling basin" for the Charles River Watershed. The creation of this basin, combined with large sediment loading as a consequence of the ever-increasing urbanization of the watershed, has resulted in deposition and entrapment of more than 53 million cubic feet of sediment since 1908. In other words, more than 11 percent of the capacity of the basin has been filled with sediment over the last 92 years. The thickness of this sediment ranges from less than 0.5 ft near the Watertown Dam and the river's edge to greater than 5 ft near the Museum of Science, and averages 1.3 ft (pl. 1).

Data-Collection, Sampling, and Sample Analysis Methods

Water depths and the thickness of post-1908 bottom sediment were measured at about 8,000 and 3,000 locations, respectively, in the basin. Both surficial and core samples were collected and analyzed for inorganic and organic contaminants. The collection of quality-assurance samples allowed determination of sample reproducibility and comparability between laboratories.

Water Depth and Sediment Thickness

An echo sounder unit (Furuno, Inc.) was used to measure water depths and sediment thickness. The unit emits sound waves through a transducer mounted on the stern of a small boat. This energy enters a medium and passes through it until it encounters an interface with a medium with different acoustic properties. At such interfaces, some of the energy is reflected and detected at the surface by the transducer. The first interface encountered between the water-column and post-1908 sediment (the river bottom) is displayed as a numerical value representing the depth of the water. The second interface between pre- (muddy) and post-1908 (clay) bottom sediment is displayed as a profile of different colors and various thicknesses. The color of this profile depends on the amplitude of the returning energy, which is a function of the acoustic properties of the medium and the thickness of the profile represents the thickness of the medium (in this study the medium is the post-1908 bottom sediment). A global positioning system (GPS; Trimble, Inc.) was used to locate each site precisely; GPS locations and echo-sounder measurements were recorded and cross-referenced by videotaping the data displays of the two instruments simultaneously.

Channel morphology and the thickness of river-bottom sediments were mapped from water-depth and sediment-thickness data using a combination of the triangular irregular network (TIN) data model and topogrid functions of ESRI's ARC/INFO geographic information system (GIS) software (Environmental Research Institute, Inc., Version 7.11; pl. 1). The total volume of water and bottom sediment in the basin was determined using the TIN data model of ARC/INFO.

Sample-Collection Design

Surficial-sediment samples (top 4.0 in) were collected in July and August 1998 (table 1 and pl. 1). Thirty-five sampling sites for surficial sediment were selected in consultation with USEPA Region I, according to a deterministic sampling design. The precise geographical coordinates of each sampling site in the field were determined using GPS. The samples were analyzed by the USEPA, Region I, Office of Environmental Measurement and Evaluation, Lexington, Mass., and by XRAL Laboratories, Ontario, Canada.

An additional 100 surficial samples were collected in July and August 1998 (table 1), according to a random sampling design. These 100 sampling sites were selected by dividing the basin into 323 ft^2 (30 m^2) cells and randomly choosing the cells within which samples were to be collected using a subroutine within the ARC/INFO GIS software (Scott, 1990). GPS was used to locate the boat within the cells in the field and to locate the sample sites precisely within those areas. These randomly chosen samples were analyzed by XRAL Laboratory.

Three sediment cores were collected at each of four areas where restoration of public wading and swimming beaches is being considered. The areas are Daly Field in Newton, Magazine Beach in Cambridge, Herter East Park in Brighton, and the Esplanade ponds in Boston (pl. 1). The cores extended to the interface between the post-1908 bottom-sediment and the natural tidal deposits of an earlier period (pre-1908); the vertical position of this interface was determined by manual probing with a plastic rod.

Sample-Collection Techniques

A stainless-steel Eckman dredge grab sampler (Wildco) was used to collect the surficial-sediment samples. The Eckman sampler can take a relatively undisturbed sample of sediment such as silt and sand (Mudroch and MacKnight, 1994). The sampler was deployed several times at slightly different locations at each sampling site to provide an adequate sample volume and to ensure the collection of a representative sample. In the field, water trapped in the dredge was decanted after ample time had been allowed for the settling of fine-grained sediment.

Table 1. Bottom-sediment sampling sites in the lower Charles River, Massachusetts, 1998

[Site locations shown in plate 1. Latitude and longitude are given in degrees, minutes, and seconds. **Station No.:** Bold, samples collected in consultation with U.S. Envirionmental Protection Agency according to a deterministic sampling design. No., number; USGS, U.S. Geological Survey]

Station No.	USGS identifier	Latitude ° ′ ″	Longitude ° ′ ″
Bottom-sediment surface samples			
1	BGY-015	42 22 09	71 03 48
2	CAY-068	42 22 07	71 04 00
3	BGY-016	42 22 06	71 04 03
4	CAY-069	42 22 07	71 04 13
5	BGY-022	42 21 58	71 04 15
6	BGY-023	42 21 59	71 04 15
7	CAY-016	42 22 08	71 04 34
8	CAY-015	42 21 59	71 04 21
9	CAY-070	42 22 02	71 04 23
10	CAY-017	42 22 01	71 04 24
11	BGY-024	42 21 55	71 04 15
12	BGY-025	42 21 52	71 04 25
13	BGY-070	42 21 49	71 04 23
14	BGY-071	42 21 50	71 04 27
15	CAY-071	42 21 53	71 04 33
16	BGY-026	42 21 48	71 04 25
17	CAY-018	42 21 50	71 04 35
18	BGY-027	42 21 41	71 04 24
19	CAY-019	42 21 41	71 04 41
20	BGY-072	42 21 39	71 04 24
21	BGY-030	42 21 34	71 04 32
22	CAY-073	42 21 40	71 04 41
23	BGY-028	42 21 31	71 04 27
24	BGY-029	42 21 30	71 04 29
25	CAY-020	42 21 36	71 04 41
26	CAY-022	42 21 37	71 04 43
27	CAY-021	42 21 34	71 04 48
28	BGY-031	42 21 29	71 04 34
29	BGY-017	42 21 26	71 04 33
30	BGY-032	42 21 30	71 04 35
31	BGY-033	42 21 27	71 04 49
32	BGY-034	42 21 19	71 04 41
33	CAY-023	42 21 29	71 04 50
34	CAY-024	42 21 26	71 04 57
35	CAY-026	42 21 33	71 05 00
36	BGY-036	42 21 19	71 04 54
37	BGY-035	42 21 24	71 04 52
38	CAY-025	42 21 30	71 04 59
39	BGY-037	42 21 24	71 04 58
40	CAY-074	42 21 32	71 05 07
Bottom-sediment surface samples—*Continued*			
41	BGY-018	42 21 14	71 04 59
42	BGY-073	42 21 18	71 04 59
43	BGY-074	42 21 24	71 05 04
44	CAY-027	42 21 26	71 05 06
45	BGY-038	42 21 17	71 05 03
46	CAY-028	42 21 24	71 05 10
47	CAY-029	42 21 25	71 05 12
48	CAY-031	42 21 28	71 05 16
49	CAY-030	42 21 25	71 05 15
50	CAY-032	42 21 30	71 05 19
51	BGY-039	42 21 11	71 05 19
52	BGY-040	42 21 14	71 05 22
53	CAY-033	42 21 24	71 05 24
54	BGY-041	42 21 13	71 05 21
55	CAY-034	42 21 27	71 05 26
56	CAY-035	42 21 26	71 05 28
57	BGY-042	42 21 16	71 05 27
58	CAY-037	42 21 24	71 05 30
59	CAY-036	42 21 22	71 05 29
60	BGY-043	42 21 13	71 05 28
61	BGY-045	42 21 12	71 05 29
62	CAY-039	42 21 17	71 05 33
63	CAY-038	42 21 23	71 05 35
64	BGY-044	42 21 11	71 05 28
65	BGY-046	42 21 13	71 05 33
66	BGY-020	42 21 08	71 05 31
67	BGY-019	42 21 16	71 05 31
68	CAY-014	42 21 24	71 05 34
69	BGY-075	42 21 07	71 05 34
70	CAY-040	42 21 16	71 05 37
71	CAY-041	42 21 17	71 05 40
72	BGY-076	42 21 06	71 05 48
73	CAY-042	42 21 19	71 05 47
74	BGY-077	42 21 10	71 05 52
75	CAY-043	42 21 14	71 05 45
76	BGY-047	42 21 09	71 05 43
77	BGY-048	42 21 11	71 05 42
78	CAY-075	42 21 17	71 05 54
79	BGY-049	42 21 05	71 05 53
80	BGY-021	42 21 08	71 06 28

Table 1. Bottom-sediment sampling sites in the lower Charles River, Massachusetts, 1998—*Continued*

Station No.	USGS identifier	Latitude ° ′ ″	Longitude ° ′ ″
Bottom-sediment surface samples—*Continued*			
81	CAY-076	42 21 13	71 06 08
82	CAY-044	42 21 10	71 06 08
83	BGY-050	42 21 07	71 06 09
84	CAY-045	42 21 11	71 06 14
85	CAY-046	42 21 11	71 06 17
86	BGY-051	42 21 09	71 06 19
87	CAY-047	42 21 11	71 06 22
88	CAY-048	42 21 09	71 06 23
89	CAY-049	42 21 11	71 06 27
90	BGY-078	42 21 08	71 06 22
91	CAY-077	42 21 10	71 06 29
92	CAY-050	42 21 11	71 06 39
93	BGY-079	42 21 10	71 06 45
94	BGY-052	42 21 09	71 06 48
95	BGY-053	42 21 11	71 06 53
96	CAY-013	42 21 15	71 06 53
97	BGY-054	42 21 14	71 07 00
98	BGY-082	42 21 27	71 07 02
99	BGY-055	42 21 24	71 07 02
100	CAY-051	42 21 30	71 06 58
101	BGY-056	42 21 37	71 07 00
102	CAY-052	42 21 38	71 06 59
103	BGY-057	42 21 39	71 07 01
104	CAY-053	42 21 43	71 06 59
105	BGY-058	42 21 42	71 07 02
106	BGY-080	42 21 46	71 07 01
107	CAY-054	42 21 46	71 06 59
108	BGY-059	42 21 55	71 07 02
109	CAY-055	42 22 00	71 06 59
110	BGY-060	42 22 04	71 07 03
111	CAY-056	42 22 05	71 07 03
112	CAY-057	42 22 08	71 07 06
113	CAY-058	42 22 09	71 07 13
114	CAY-059	42 22 08	71 07 17
115	CAY-060	42 22 21	71 07 34
116	CAY-079	42 22 25	71 07 57
117	CAY-061	42 22 04	71 08 05
118	BGY-081	42 22 10	71 07 54
119	BGY-061	42 21 58	71 08 14
120	BGY-062	42 21 52	71 08 31
121	BGY-063	42 21 46	71 08 44
122	CAY-080	42 21 41	71 08 52
123	BGY-064	42 21 35	71 09 23
124	CAY-062	42 21 37	71 09 23
125	CAY-063	42 21 37	71 09 25
126	CAY-064	42 21 35	71 09 37
127	CAY-065	42 21 33	71 09 52
128	BGY-083	42 21 34	71 09 58
129	BGY-065	42 21 35	71 09 57
130	BGY-066	42 21 34	71 10 08
131	BGY-067	42 21 34	71 10 31
132	CAY-066	42 21 34	71 10 34
133	CAY-067	42 21 35	71 10 37
134	BGY-068	42 21 37	71 10 53
135	BGY-069	42 21 44	71 11 00
Bottom-sediment core samples			
136	BGY-089	42 21 34	71 10 05
137	BGY-090	42 21 33	71 10 07
138	BGY-091	42 21 33	71 10 10
139	BGY-092	42 22 12	71 07 52
140	BGY-088	42 22 10	71 07 53
141	BGY-087	42 22 09	71 07 53
142	BGY-086	42 21 15	71 04 57
143	BGY-085	42 21 14	71 04 59
144	BGY-084	42 21 14	71 05 02
145	CAY-083	42 21 14	71 06 48
146	CAY-082	42 21 15	71 06 52
147	CAY-081	42 21 17	71 06 54

The top 4.0 in. (if available) of sediment was removed from the dredge and placed in a pre-cleaned stainless-steel bowl and homogenized with a stainless-steel spatula. Sub-samples were collected, placed in pre-cleaned containers, and stored on ice for overnight delivery to the USEPA Region I and XRAL Laboratories for analysis. Sub-samples for analysis of the ratio of acid volatile sulfide to simultaneously extracted metals and total sulfide analysis were collected first from the homogenized samples to minimize the time that these samples were in contact with the atmosphere and were placed in wide-mouth glass containers purged with 90-percent-pure nitrogen gas to prevent changes in chemical oxidation state. The stainless-steel Eckman dredge, bowl, and spatula were decontaminated in the field between sample sites by rinsing with phosphate-free detergent, tap water, and deionized water, in that order.

Cores were collected using a piston corer with an 4-cm inside diameter acrylic-core barrel. The piston was fixed over the sediment by a cable attached to a boat. The core barrel was pushed past the piston using push rods from the surface. A slide hammer was used to drive the core barrel into the top 10 in. of the pre-1908 sediment. This clay-like sediment acted as a plug that effectively trapped the "soupy" post-1908 sediment in the core barrel. The post-1908 sediment was removed from the core barrel and placed in a pre-cleaned stainless-steel bowl and homogenized with a stainless-steel spatula. Subsamples were collected and placed in pre-cleaned containers, for delivery to the USEPA Region I and XRAL Laboratories for analysis, in a manner similar to that used for the surficial-sediment samples. The core barrel was cleaned in the field between sample sites by rinsing with phosphate-free detergent, tap water, and deionized water, in that order.

Laboratory Analysis

Thirty-five of the 135 surficial-sediment samples were analyzed at the USEPA laboratory for inorganic elements, PCBs, organochlorine pesticides, PAHs, TPHs, total organic carbon (TOC), total sulfides, total solids, and the ratio of acid volatile sulfide to simultaneously extracted metals (table 2). Cores were analyzed by USEPA for solid-phase concentrations of constituents that may potentially pose health risks for swimmers, including: inorganic elements, PCBs, organochlorine pesticides, PAHs, and TPHs (table 2). The USEPA laboratory also measured TOC, total sulfides, total solids, the ratio of acid volatile sulfide to simultaneously extracted metals, grain size, and metals concentrations derived from toxicity leaching characteristic procedure (TCLP) for each core. The 35 surficial-sediment samples and 12 cores analyzed by USEPA were subsampled in the field; these sub-samples, along with the remaining 100 surficial-sediment samples, were submitted to XRAL Laboratory for analysis of 32 inorganic elements and TOC (table 2).

Quality Assurance

The reliability of the data was ensured by preparation and analysis of duplicate field samples. Field duplicates were prepared during sampling at randomly-chosen sites to determine reproducibility. Field duplicates were subsamples of the homogenized sample. Field duplicate samples of all surficial-sediment and cores were also used to increase the number of constituents analyzed and as a direct

Table 2. Analytes, laboratories, and analytical techniques used in study

[AVS/SEM, Acid volatile sulfide to simultaneously extracted metals; ICP, inductively coupled plasma; PAH, Polyaromatic hydrocarbons; PCB, polychlorinated biphenyls; SOP, standard operating procedure; USEPA, U.S. Environmental Protection Agency]

Analyte	Laboratory	Analytical technique	USEPA Region 1 SOP, method, or reference
Inorganic elements (except mercury)	USEPA	ICP emission spectroscopy	ING ICP3.SOP
Mercury	USEPA	cold-vapor atomic absorption spectroscopy	INGMERC4.SOP
Inorganic elements	XRAL	ICP emission spectroscopy	XRAL Laboratory, written commun., 1998
Organochlorine pesticides and PCBs	USEPA	gas chromatography with election capture	PESTSOIL1.SOP
PAHs	USEPA	gas chromatography-mass spectrometry	PAH SOLL3.SOP
Total petroleum carbon	USEPA	infrared spectroscopy	USEPA Method 9071/418.1
Total organic carbon	USEPA and XRAL	infrared spectroscopy	EIA-MISTOCZ.SOP
Total sulfide	USEPA	ultraviolet-visible spectrophotometry	USEPA Method 9030
Total solids	USEPA	gravimetry	USEPA Method 160.3
AVS/SEM (except for mercury)	USEPA	ion specific electrode and ICP emission spectroscopy	EIA-INGAVSZ.SOP
Mercury (AVS/SEM)	USEPA	cold vapor absorption spectroscopy	INGMERC4.SOP
Metals derived from toxicity leaching procedure (TCLP)	USEPA	ICP emission spectroscopy	TCLP.SOP.292
Grain-size analysis	USEPA	sieving	GRSIZ.SOP

measure of comparability between results from the USEPA and XRAL laboratories. Field duplicates were analyzed by comparing the relative percent difference (RPD) of results. A RPD of less than 50 percent is considered to be within acceptable limits for field duplicates within (intralaboratory) and among laboratories (interlaboratory) (A. Beliveau, USEPA, written commun., 1998).

Analysis of field duplicate samples generated by subsampling in the field indicate that generally no observable sample contamination occurred during the collection, handling, and preparation of the samples. Intralaboratory comparisons show that the median RPDs for field duplicates were generally less than 10 percent for many of the constituents analyzed. Median RPDs for field duplicates analyzed by USEPA for TPH (90 percent), total sulfides (38 percent), fluorine (22 percent), beta-BHC (27 percent), 1,2,4,5,6,7,8, 8-octachloro-3a,4,7,7a-tetrahydro-4,7-methanoindan (commonly known as alpha-chlordane; 28 percent); 1,1-dichloro-2,2-*bis*(*p*-chlorophenyl)ethane (commonly known as DDD; 70 percent); and1,1,1-trichloro-2,2-*bis*(*p*-chlorophenyl)ethane (commonly known as DDT; 40 percent) were higher. Interlaboratory comparisons indicated that results that were equal to or greater than the minimum reporting limit (MRL) were generally in good agreement (in other words, the median RPD for all of the analyses done by both laboratories were less than 50 percent).

Although the median RPD for detected concentrations of mercury were less than 50 percent, there were many instances in which XRAL reported mercury values less than the MRL when the USEPA Laboratory reported values greater than the MRL for the same sample. This difference is likely due to the fact that the analytical method for mercury used by the USEPA is more sensitive than the method used by XRAL. Because of the good agreement in the concentrations of most inorganic elements and TOC reported by the two laboratories and the greater number of bottom sediment analyses done by XRAL compared to the USEPA, the following discussion of inorganic elements and TOC in bottom sediment is based on concentrations measured by XRAL. As a result of the discrepancy between mercury values reported by the two laboratories, and the lower MRL for mercury analyzed by USEPA, however, mercury results reported by USEPA will be used throughout the following discussion.

INORGANIC ELEMENTS AND ORGANIC COMPOUNDS IN BOTTOM SEDIMENT

The bottom sediment of the lower Charles River was found to be contaminated with a wide range of inorganic elements and organic compounds. Most trace elements were present at concentrations exceeding their average crustal abundances. Classes of organic compounds detected in the study area included PAHs, PCBs, and organochlorine pesticides.

Surficial Sediment

Of the 32 inorganic elements analyzed in surficial-sediment samples (excluding quality-assurance samples), 31 were present in concentrations greater than the analytical detection limits. Most inorganic elements were detected in every sample; 26 of the 32 inorganic elements analyzed were detected in at least 83 percent of the samples. In contrast, arsenic, beryllium, and tin were detected in 50-, 33-, and 38-percent of the surficial-sediment samples, respectively. Bismuth and tungsten were detected in fewer than one percent of the surficial-sediment samples. Antimony was not detected in any of the samples. Complete data on inorganic element concentrations and summary statistics are at the back of the report in tables 11 and 12, respectively.

Cadmium, chromium, copper, lead, mercury, nickel, silver, and zinc were selected for discussion because of their relatively high concentrations and toxicity. These inorganic elements are commonly considered trace elements because their concentrations are usually less than 1,000 ppm in uncontaminated natural sediment. Due to their toxicity, these elements are also classified as priority pollutants by the U.S. Environmental Protection Agency (1994). With the exception of cadmium, mercury, and silver, these inorganic elements were detected in every surficial-sediment sample; cadmium was detected at 126 surficial-sediment samples (93 percent); mercury was detected at 34 out of the 35 surficial-sediment samples analyzed by USEPA (97 percent); and silver was detected at 128 sites (95 percent). Chromium, copper, lead, mercury, nickel, silver, and zinc showed at least a twenty-fold range of concentrations between the minimum and maximum concentrations measured (table 12).

Inorganic elements in bottom sediment may be derived from the weathering of rocks or they may be introduced into the environment by human activities. Therefore, the proportion of these inorganic elements contributed by contaminant sources can be estimated by comparing sample concentrations to worldwide averages of elemental concentrations in the Earth's crust, or average crustal abundance (Lide and Frederikse, 1996). More than 90 percent of the measurements of cadmium, copper, lead, mercury, silver, and zinc detected in basin surficial-sediment samples exceeded their respective average crustal-abundance concentrations; such elevated concentrations potentially represent contamination by human activities. Chromium concentrations were greater than the average crustal abundance in 56 percent of the surficial-sediment samples. Concentrations of nickel were greater than the average crustal abundance in fewer than one percent of the surficial-sediment samples.

In contrast to the inorganic elements, most of which occur in nature, many organic compounds in bottom sediment can originate only as a result of human activities. Therefore, detection of organic compounds potentially represents contamination. In this report, concentrations of organic compounds greater than the MRL for each sample analysis were considered "detected." Concentrations of organic compounds less than the MRL were considered "undetected." It is necessary to make the distinction between "detected" and "undetected" because an undetectable concentration does not unequivocally demonstrate that a constituent is not present, but rather that the concentration of that constituent is such that it is below the MRL of the analytical method used for that sample. MRLs differ among some samples (even when the same method is used) for some of the organic compounds analyzed because of interferences from co-eluting compounds (compounds that are not separated from the analyte during the sample analysis). This artifact in the MRLs can create a situation in which a concentration is evaluated as "undetected" in one sample and "detected" in another. For example, all else being equal, the concentration of Aroclor-1254 (a PCB) measured at sample site 9 (90 ppb) would be considered "undetected" at sampling site 68 (MRL < 262 ppb) and "detected" at sampling site 42 (MRL < 36 ppb) because of the different physical and chemical characteristics of each sample that result in different MRLs (table 13, at the back of report).

With the above in mind, of the nine PCB Aroclors for which samples were analyzed, only two, Aroclor-1254 and -1260 were detected; these were detected at 33 and 21 surficial-sediment-sampling sites, respectively. Nine of the 22 organochlorine pesticides analyzed were detected in concentrations greater than the MRL. The most frequently detected organochlorine pesticides were chlordane, dieldrin, DDT, DDE, and DDD. Of the 16 PAHs for which samples were analyzed, all were detected in concentrations greater than the MRL at every site with the exception of indeno(1,2,3-cd)pyrene. Indeno(1,2,3-cd)pyrene was detected at all but one surficial-sediment-sampling site. Complete data on organic compound concentrations and summary statistics are at the back of the report in tables 13 and 12, respectively.

The 47 organic compounds for which samples collected in this study were analyzed fall into three major groups (PCBs, organochlorine pesticides, and PAHs). These groups of organic compounds contain constituents on the USEPA's priority pollutant list and have been given high priority in the Agency's water-quality and monitoring abatement programs (U.S. Environmental Protection Agency, 1994). Group concentrations are expressed as the sum of concentrations of several related compounds and breakdown products. Total PCBs were calculated as the sums of Aroclors-1254 and -1260 (table 13). Organochlorine pesticides can be further divided into two sub-groups based on similarity of chemical structure, total chlordane and total DDT. Total chlordane concentration is the sum of alpha-chlordane, gamma-chlordane, and chlordane-technical (table 13). Total DDT concentration is the sum of DDT, DDE, and DDD concentrations (table 13). Total PAH concentration is the sum of the concentrations of the 16 PAHs listed in table 13.

The four groups of organic compounds were detected at different frequencies and at different ranges of concentrations in the sediment samples. Total PCBs were detected in samples from 33 of the 35 sites (94 percent); at 75 percent of the sites, concentrations ranged from less than detection to 14,000 ppb. Total DDTs were detected in samples from 34 of the 35 sites (97 percent); at 75 percent of the sites, concentrations ranged from less than detection to 470 ppb. Total chlordane was detected in samples from 18 of the 35 sites (51 percent); at 75 percent of the sites, concentrations ranged from less than detection to 170 ppb. Total PAHs were detected at all sites,

concentrations ranged from 3,000 ppb to about 10 million parts per billion or about 1 percent by weight. Summary statistics for individual organic compounds are included in table 12 at the back of the report.

Cores at Proposed Public Beaches

Of the 32 inorganic elements analyzed in the cores, 28 were present in concentrations greater than the MRL (88 percent). Most inorganic elements were detected in nearly every sample; 26 of the 32 constituents were detected in at least 83 percent of the samples. In contrast, arsenic and tin were detected in 58 and 42 percent of the cores, respectively. Antimony, beryllium, bismuth, and tungsten were not detected in any of the cores. Complete data on inorganic element concentrations and summary statistics are at the back of the report in tables 11 and 12, respectively.

All of the high-priority inorganic elements (cadmium, chromium, copper, lead, mercury, nickel, silver, and zinc) were detected in every core and showed at least a five-fold range of concentrations between the minimum and maximum concentrations detected (table 12). As with the surficial-sediment samples, more than 80 percent of the cadmium, copper, lead, mercury, silver, and zinc concentrations measured in the cores were greater than their respective average crustal abundance. Chromium measurements were greater than the average crustal abundance for 67 percent of the samples. Nickel was not detected above the average crustal abundance in any of the cores.

Of the nine PCBs analyzed, only two were detected, Aroclors-1254 and -1260; these were detected in all of the cores. Five of the 22 organochlorine pesticides were detected at concentrations greater than the MRL. The most frequently detected organochlorine pesticides were chlordane (alpha and gamma), DDT, DDE, and DDD (table 13). Of the 16 PAHs analyzed, all were detected at concentrations greater than the MRL at every core with the exception of naphthalene, which was below the MRL in one core. Complete data on organic compound concentrations and summary statistics are at the back of the report in tables 13 and 12.

Total PCBs, total DDT, total chlordane, and total PAHs, were detected in all of the 12 cores. Total PCBs concentrations ranged from 260 to 7,900 ppb; concentrations were greater than 640 ppb for 75 percent of those sites. Total DDT concentrations ranged from 19 to 590 ppb; concentrations were greater than 65 ppb at 75 percent of those sites. Total chlordane concentrations ranged from 3.8 to 210 ppb; concentrations were greater than 9.5 for 75 percent of those sites. Total PAH concentrations ranged from 13,000 parts per billion (ppb) to 330,000 ppb, with 75 percent of the sites having concentrations greater than 23,000 ppb. Summary statistics for individual organic compounds are at the back of the report in table 12.

Comparison of Chemistry of Sediment in Lower Charles River to that in Other Urban Streams

Enrichment of inorganic elements and organic compounds is greater in surficial sediment collected from the lower Charles River than in sediment collected from other urbanized, free-flowing rivers. Concentrations of inorganic elements and organic compounds measured in surficial sediment from the basin were compared to concentrations of these constituents measured in surficial sediment collected from urban indicator sites across the conterminous United States as part of the National Water-Quality Assessment (NAWQA) Program of the U.S. Geological Survey (Breault and Harris, 1996; L. H. Nowell, U.S. Geological Survey, written commun., 1998; Lopes and Pritt, 1998; Karen Rice, U.S. Geological Survey, written commun., 1998). Median concentrations of chromium, cadmium, copper, lead, mercury, nickel, silver, zinc, total chlordane, total DDT, and total PAHs (total concentrations were calculated as the sum of the concentrations of related compounds and varied slightly between the two studies) measured in surficial-sediment samples collected in the basin were about 9.0, 1.3, 6.0, 11, 15, 1.3, 3.2, 3.2, 2.1, 35, and 9.5 times the median concentrations of these constituents from the NAWQA urban indicator sites (fig. 3*A*,*B*). The median concentration of total PCBs measured at the NAWQA sites was reported as less than the MRL. Given a MRL of 100 ppb for the laboratory used by NAWQA, the median total PCB concentration measured in basin surficial-sediment samples was at least 6.6 times greater than that of the NAWQA sites.

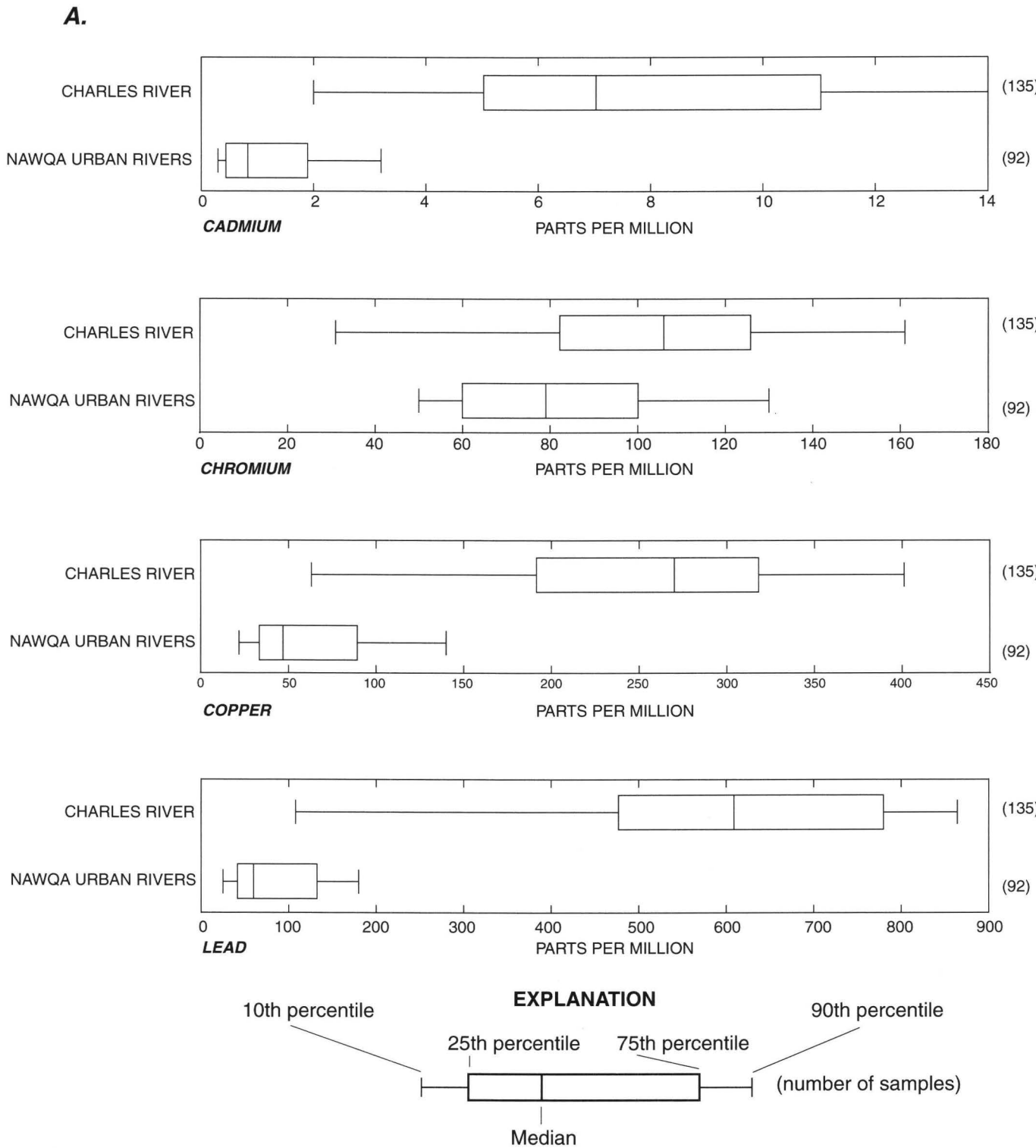

Figure 3. (*A*) Inorganic element and (*B*) organic compound concentrations in surficial sediment of the lower Charles River in comparison to other urban rivers.

A.—Continued

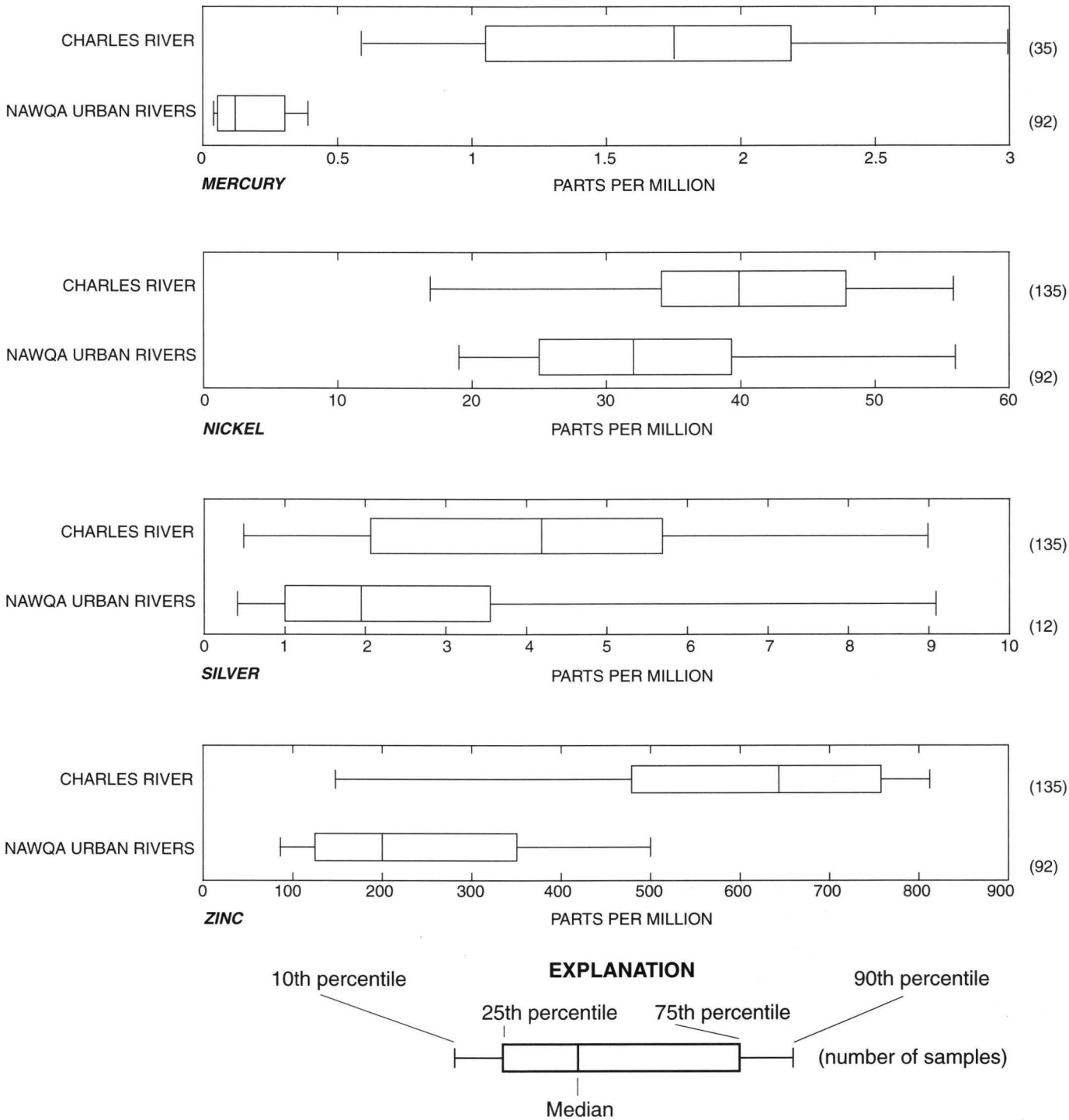

Figure 3. (*A*) Inorganic element and (*B*) organic compound concentrations in surficial sediment of the lower Charles River in comparison to other urban rivers—*Continued.*

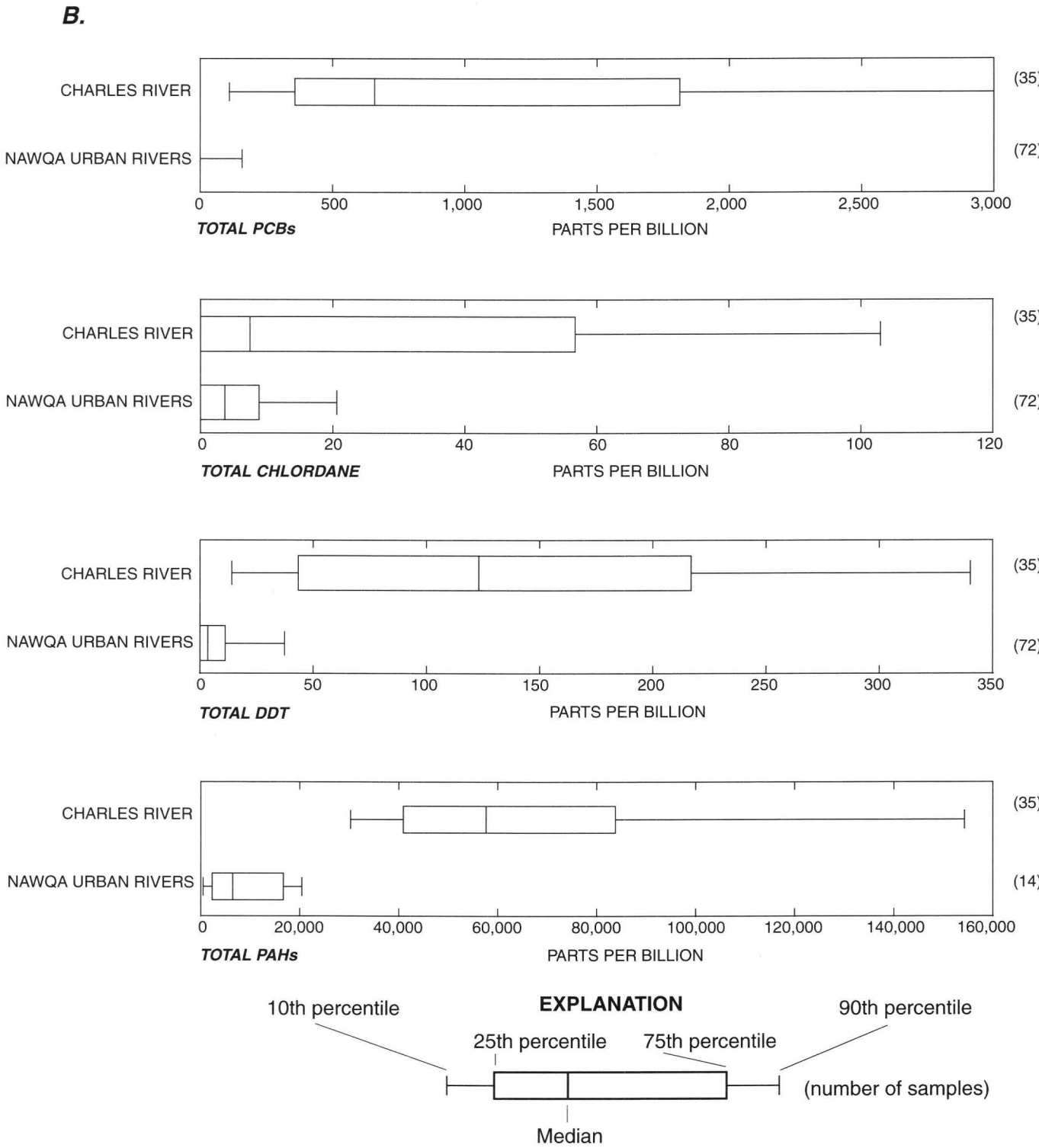

Figure 3. (*A*) Inorganic element and (*B*) organic compound concentrations in surficial sediment of the lower Charles River in comparison to other urban rivers—*Continued.*

Sample collection and preparation procedures differed between this study and the NAWQA program, but these differences were unlikely to be responsible for the large differences in median concentrations of surficial-sediment constituents. Surficial-sediment samples collected by the NAWQA program were sieved whereas those collected from the basin were not. Inorganic-element analysis of NAWQA samples was done on the silt and clay fractions (particles less than 63 microns in diameter), and organic analysis was performed on the fine to medium sand, silt, and clay fractions (particles less than 2 millimeters in diameter). The relatively "soupy" (or low concentration of total solids) nature (table 3) and fine texture of surficial sediment in the basin (table 4), however, indicates that the unsieved basin samples are comparable to the sieved NAWQA samples. Furthermore, although the samples collected in the NAWQA program were collected in free-flowing river reaches, their sieved fine fractions should be similar to those in sediment deposited in slack-water environments like the basin (Rice, 1999). In fact, because inorganic elements and organic compounds tend to be associated with fine-grained sediment, the concentrations of these constituents measured in unsieved samples collected from the basin could be expected to be slightly less than the corresponding sieved concentration (on a weight-percentage basis) due to dilution by larger particle-size material. Moreover, because the digestion method used in the NAWQA program ("total" digestion) is more robust than that used in this study ("total recoverable" digestion), "total recoverable" concentrations of some elements measured by this study would also be expected to be lower than corresponding "total" concentrations.

Several characteristics of the basin may explain the high concentrations of contaminant in sediment, relative to those in other urbanized, but free-flowing rivers. The basin is characterized by low hydraulic gradients, a lack of flushing, and a lack of natural uncontaminated sediment—from erosion of upstream uncontaminated soils—that typically dilute contaminated urban sediments. The presence of an anoxic, sulfide-rich zone within a salt wedge that forms as a result of present-day dam operations also may be a

Table 3. Distribution of total solids in bottom-sediment samples, lower Charles River, Massachusetts, 1998

[D, field duplicate; No., number]

Station No.	Total solids (percent)	Station No.	Total solids (percent)	Station No.	Total solids (percent)
1	30.2	68	13.7	118-D	15.0
2	45.5	69	31.8	122	30.6
3	28.9	72	33.9	128	29.4
4	12.5	74	14.7	136	36.7
8	9.6	78	13.7	137	32.3
9	10.3	80	24.6	138	34.6
13	21.4	81	23.9	139	22.4
14	8.1	90	23.1	140	22.7
15	18.9	91	26.9	141	38.3
20	42.2	93	55.6	141-D	40.3
22	61.7	96	19.7	142	37.7
29	52.7	98	23.7	142-D	33.7
40	12.5	98-D	40.3	143	34.0
41	25.6	106	20.4	144	36.9
42	69.9	106-D	18.2	145	52.5
43	10.4	116	65.2	146	58.2
66	47.1	118	12.6	147	31.2
67	20.3				

Table 4. Grain-size distribution in cores, lower Charles River, Massachusetts, 1998

[Grain-size distribution given as percent retained. **Gravel:** Sieve number 4, greater then 4.75 millimeters. **Coarse sand:** Sieve number 10, less than 4.75 millimeters, greater than 2 millimeters. **Medium sand:** Sieve number 40, less than 2 millimeters, greater than 0.425 millimeters. **Fine sand:** Sieve number 200, less than 0.425 millimeters, greater than 0.075 millimeters. **Silt and clay:** Less than 0.075 millimeters. No., number]

Station No.	Gravel	Sand			Silt and clay
		Coarse	Medium	Fine	
136	0	5.6	0	58.4	36
137	0	1	1.8	18.7	78.5
138	0	0	1	20	79
139	0	.5	3.3	26	70.2
140	0	1.6	3.5	31	64.2
141	0	5.1	0	64.2	30.7
142	0	.6	0	28.6	70.8
143	0	.8	17.3	31.5	50.4
144	0	2.5	15.6	46.9	35
145	.4	5	6.5	49.5	38.6
146	0	1.1	11.6	44	42.9
147	.3	2.8	24.4	44.5	28

factor. Large volumes of salt water from Boston Harbor enter the basin when the gates of the locks at the new dam are opened frequently to allow boats into or out of the basin. Harbor water that enters the basin sinks to the bottom because its density is greater than that of fresh water, creating a non-tidal salt wedge. Anoxic conditions develop in the salt wedge due to oxygen uptake by heterotrophic bacteria in the sediment and the slow transfer of oxygen from the overlying freshwater to the salt wedge. Anoxia in the salt wedge causes naturally occurring sulfate in the harbor water to be converted to sulfide. Inorganic elements may be immobilized in the sediment by sequestration by this sulfide. Under the same anoxic conditions, a sulfide-poor system would lack the ability to sequester inorganic elements; as a result, inorganic elements would be more mobile and likely to be transported out of the system.

The effects of the salt wedge, however, may be altogether variable because temporal changes in the spatial extent and chemistry (for example, oxygen concentration) of the salt wedge depend strongly upon anthropogenic and natural influences acting on that flow and the natural flow of water through the basin. Anthropogenic influences include operation of the dam at the mouth of the basin. Natural processes include river flow and stormwater discharges to the basin. For example, the spatial extent of the salt wedge in the basin at the time of sediment sampling in June 1998 was considerably less than the spatial extent measured in 1999, likely because the salt wedge had been recently flushed out of the basin by a large storm (Breault and others, 2000).

DISTRIBUTION OF INORGANIC ELEMENTS AND ORGANIC COMPOUNDS IN BOTTOM SEDIMENT

The geographical distribution of a contaminant in bottom sediment is controlled primarily by the geographic distribution of its sources. Once a contaminant is discharged into a river, however, it can readily be sorbed onto the surface of fine-grained sediment or colloidal material (particulate phases) that are suspended in the water column and (or) be bound by complexing agents dissolved in the water column (dissolved phases) (Horowitz, 1991). Therefore, the distribution of contaminants within bottom sediment depends partly on chemical processes and partly on physical processes that control the transport of these particulate and dissolved phases. Chemically, under changing geochemical conditions (for example, pH, redox, dissolved oxygen, ionic strength, and bacterial action); contaminants can remain suspended or dissolved in the water column; settle to the river bottom; be re-mobilized from sediments; or enter the food chain (Aston and Chester, 1976). Physically, under changing hydraulic conditions, contaminants can be dispersed over a wide geographical area. For example, during high flows, water velocities may be sufficient to transport contaminants in the water column and (or) resuspend and mobilize sediment-associated contaminants, move them downstream, and redeposit them in another part of the river characterized by a low-energy environment (Horowitz, 1991), such as on the inside of a meander, and in reaches where the river channel widens abruptly. Fine-grained sediment and elevated concentrations of TOC also are generally found in these low-energy environments, whereas coarse-grained sediment and lower concentrations of TOC generally are found in higher-energy environments (or non-depositional and erosional areas). In addition, elevated concentrations of iron also are generally found in low-energy environments

because fine-grained bottom sediment surfaces are often coated with iron-oxides. Consequently, fine-grained sediment (table 4), and elevated iron (table 11), and TOC concentrations (table 5) may be used as an empirical proxy for elevated concentrations of contaminants in bottom sediment (Horowitz, 1991).

Surficial Sediment Throughout the Lower Charles River

The distribution of the inorganic elements in surficial sediment throughout the basin appears to be controlled primarily by in-stream processes associated with sediment transport and the presence of an anoxic zone within a non-tidal salt wedge in the basin. In contrast, the distribution of organic compounds appears to reflect local point and non-point sources. In order to better understand the relative importance of in-stream processes on the geographical distribution of inorganic elements and organic compounds, the relation between contaminant enrichment and iron and TOC concentrations in the surficial-sediment samples were investigated using linear correlation coefficients or Pearson's *r*-values (positive Pearson's *r*-value indicates a direct relation between the two variables; a negative value indicates an inverse relation).

In general, the inorganic elements—cadmium, chromium, copper, lead, mercury, nickel, silver, and zinc—measured in surficial-sediment samples (n=135 for each element except mercury, for which n=35) showed moderate correlations with TOC (Pearson's *r*-values 0.3, 0.3, 0.3, 0.2, 0.3, 0.6, 0.5, and 0.7, respectively) and iron (0.3, 0.3, 0.2, 0.7, 0.4, 0.4, 0.4, and 0.6, respectively). In contrast, the organic compounds—total PCBs, total DDT, total chlordane, and total PAHs—measured in surficial-sediment samples (n=35) showed little to no correlation with TOC (0.3, 0.1,-0.1, 0.1, respectively) and iron (0.1, 0.03, 0.1, -0.2, respectively). The lack of a moderate relation between concentrations of the selected organic compounds and TOC and iron concentrations in surficial-sediment samples may indicate that the geographical distribution of the organic compounds is not greatly affected by in-stream processes, but rather may reflect the presence of local point and non-point sources. In contrast, enrichment of the inorganic elements appears to be related to the concentration of TOC and iron, and thus, abundant fine-grained sediment as a result of sediment deposition in low-energy environments.

The presence of an anoxic, sulfide-rich zone within the non-tidal salt wedge may also be an important factor in determining the geographical distribution of inorganic elements in the basin. Inorganic elements that exist in the water column as particulate and(or) dissolved phases which are transported into areas of the basin affected by the salt wedge can undergo chemical and physical changes that favor deposition and cause sediments in those areas to become enriched in those inorganic elements. These physical and chemical changes can differ for each phase and associated inorganic element and may include the following:

- Flocculation (as a result of the balancing of negative charges because of increased ionic strength) of the particulate phase (mostly clays) into "coacervates" (or thermodynamically unstable assemblages) that settle to the river bottom forming a solid-rich liquid layer at the sediment-water interface commonly referred to as "fluid mud" (Aston and Chester, 1976). Fluid mud has been observed by a number of divers working in the basin;
- Release of inorganic elements by ion exchange reactions involving sodium and magnesium, and subsequent incorporation by biota (namely phytoplankton) and (or) re-adsorption by inorganic and organic detritus that also may eventually settle to the river bottom; and,
- Release of sorbed inorganic elements (also due to ion exchange reactions) and the subsequent formation and settling of insoluble sulfide solids (amorphous or mineral). This potential removal mechanism is supported by the fact that the basin surficial-sediment is enriched in molybdenum. Molybdenum enrichment is often thought to involve coprecipitation with iron sulfides (Aston and Chester, 1976); almost 60 percent of the molybdenum concentrations measured in basin surficial sediment were greater than its average crustal abundance.

Table 5. Distribution of total organic carbon in bottom-sediment samples, lower Charles River, Massachusetts, 1998

[D, field duplicate; LD, lab duplicate; No. number; USEPA, U.S. Environmental Protection Agency laboratory; XRAL, XRAL Laboratories (Ontario, Canada); --, not analyzed]

Station No.	Total organic carbon		Station No.	Total organic carbon		Station No.	Total organic carbon	
	XRAL (percent)	USEPA (percent)		XRAL (percent)	USEPA (percent)		XRAL (percent)	USEPA (percent)
1	5.7	6.4	33	0.2	--	67	11.6	11.6
2	4.7	4.6	33-LD	.24	--	68	12.7	13.3
2-D	4.6	--	34	1.8	--	69	9.4	9.4
3	21.6	21.7	35	3.9	--	69-LD	9.4	--
4	11.6	13.0	36	8.5	--	70	12.9	--
5	10.8	--	37	10.4	--	71	13.0	--
5-D	10.3	--	38	2.2	--	72	8.1	8.6
6	11.5	--	39	11.5	--	73	12.7	--
6-D	12.3	--	40	12.1	13.5	74	13.5	14.2
7	11.0	--	41	10.0	7.9	75	14.3	--
8	9.9	11.1	42	.6	.6	75-D	13	--
9	11.1	12.4	43	11.9	13.1	76	5.6	--
10	10.7	--	44	11.9	--	77	4.4	--
11	11.5	--	45	2.1	--	78	13.6	12.3
11-LD	11.6	--	45-LD	2.2	--	79	13.7	--
12	11.7	--	46	12.0	--	80	11.4	10.4
13	10.8	10.1	47	12.0	--	81	8.6	9.1
14	11.8	10.4	48	12.6	--	82	12.5	--
15	11.5	15.1	49	13.0	--	83	11.0	--
16	10.9	--	50	21.9	--	84	8.5	--
17	13.4	--	51	12.2	--	85	11.4	--
18	3.2	--	52	12.9	--	86	11.3	--
19	1.1	--	52-D	12.9	--	87	10.9	--
20	9.3	9.1	53	12.6	--	88	11.6	--
21	7.7	--	54	12.2	--	89	10.6	--
21-D	7.0	--	54-LD	12.6	--	90	12.6	13.4
22	6.8	7.3	54-LD	12.7	--	91	11.6	9.4
23	12.6	--	55	13.5	--	92	2.6	--
24	12.6	--	55-D	13.5	--	93	10.1	5.3
24-LD	12.5	--	56	13.3	--	94	11.2	--
24-LD	12.6	--	57	14.4	--	95	9.6	--
25	11.2	--	58	12.8	--	96	12.0	12.3
26	9.5	--	59	11.9	--	96-LD	12.2	--
27	9.0	--	60	11.6	--	97	11.2	--
27-D	9.1	--	61	11.8	--	97-D	11.8	--
28	10.9	--	62	16.4	--	98	13.5	9.6
29	3.6	3.5	63	13.3	--	98-D	--	8.8
30	10.7	--	64	12.2	--	99	10.6	--
31	1.4	--	64-LD	12	--	99-LD	11.2	--
32	3.0	--	65	14.1	--	99-LD	10.9	--
32-LD	3.0	--	66	9.5	8.6	100	11.0	--

Table 5. Distribution of total organic carbon in bottom-sediment samples, lower Charles River, Massachusetts, 1998—*Continued*

Station No.	Total organic carbon		Station No.	Total organic carbon		Station No.	Total organic carbon	
	XRAL (percent)	USEPA (percent)		XRAL (percent)	USEPA (percent)		XRAL (percent)	USEPA (percent)
101	10.3	--	116	3.3	1.2	133	0.8	--
101-D	11.2	--	117	9.6	--	134	.6	--
102	10.7	--	118	17.2	17.5	135	.5	--
102-LD	10.9	--	118-D	--	17.5	136	9.0	6.4
103	9.3	--	119	10.0	--	137	11.8	10.5
104	11.4	--	120	9.2	--	138	12.6	11.6
105	9.9	--	121	11.6	--	138-LD	12.5	--
106	10.5	10.3	122	11.5	8.6	139	15.6	12.0
106-D	--	8.9	122-LD	11.9	--	140	12.9	10.9
107	18.2	--	123	8.5	--	141	7.3	4.6
108	7.8	--	124	8.1	--	141-D	--	5.0
109	10.9	--	125	10.5	--	142	6.5	4.9
110	7.6	--	126	9.0	--	143	6.6	4.8
110-LD	7.6	--	127	3.1	--	144	5.8	5.0
111	11.4	--	127-D	3.08	--	145	5.1	6.8
112	7.2	--	128	11.9	10.4	146	2.9	2.5
113	11.1	--	129	8.9	--	146-D	--	2.4
114	10.4	--	130	2.0	--	147	12.0	8.0
114-D	11.1	--	131	.5	--			
115	4.5	--	132	.5	--			

To demonstrate the relative importance of the salt wedge on the geographical distribution of inorganic elements, the relation between contaminant enrichment and total sulfides (table 6) in the surficial-sediment samples were also investigated using Pearson's *r*-values. Pearson's *r*-values between cadmium, chromium, copper, lead, mercury, nickel, silver, and zinc and total sulfides (n=35) showed moderate correlations (0.2, 0.3, 0.4, 0.4, 0.2, 0.4, 0.3, and 0.3, respectively).

An alternative hypothesis, which would also explain the moderate relations that exists among the inorganic elements, total sulfides, TOC, iron, and abundant fine-grained sediment, is that the salt wedge has no real effect on the distribution of inorganic elements. Rather, sediment deposition is greater in the areas affected by the salt wedge because the salt wedge forms in the deepest parts of the basin where fine-grained sediment and associated inorganic elements likely accumulate. Whatever the case may be, it appears that surficial sediment in the downstream part of the basin is somewhat enriched in inorganic elements compared to sediment upstream. Furthermore, these elements appear to be mostly associated with sulfide solids (discussed below).

Cores at Proposed Public Beaches

Inorganic elements and organic compounds in cores collected from the four proposed public beaches generally were found in the highest concentrations in depositional areas—Daly Field and Herter East Park. Median percent silt and clay (table 4) and TOC (table 5) concentrations were also generally higher in cores collected from Daly Field and Herder East Park compared to those in cores from the other proposed beaches. Concentrations of the inorganic elements, organic compounds, and TOC, and percent silt and clay were generally lowest in cores collected from Magazine Beach and the Esplanade Ponds. In these areas of low deposition, the fine-grained sediment that contains contaminants apparently is re-suspended and transported downstream or unable to be deposited due to physical barriers and the flow regime.

Table 6. Distribution of total sulfides in bottom-sediment samples, lower Charles River, Massachusetts, 1998

[D, field duplicate; No., number; ppm, parts per million; USEPA, U.S. Environmental Protection Agency]

Station No.	Total sulfides (ppm)	Station No.	Total sulfides (ppm)	Station No.	Total sulfides (ppm)
1	8,210	67	3,430	118	582
2	1,500	68	7,670	118-D	870
3	6,550	69	644	122	105
4	14,200	72	467	128	452
8	21,000	74	5,100	136	1,120
9	20,800	78	2,390	137	590
13	3,640	80	1,180	138	1,370
14	27,000	81	484	139	4,120
15	4,790	90	1,190	140	1,920
20	537	91	1,510	141	534
22	10	93	398	141-D	474
29	156	96	226	142	1,560
40	842	98	407	143	1,710
41	570	98-D	283	144	732
42	2	106	977	145	505
43	12,200	106-D	491	146	204
66	496	116	358	147	1,540

As with the surficial sediment, the inorganic elements—cadmium, chromium, copper, lead, mercury, nickel, silver, and zinc—measured in cores (n=12) generally showed moderate correlations with TOC (Pearson's r-values 0.8, 0.7, 0.7, 0.8, 0.8, 0.2, 0.9 and 0.7, respectively) and iron (0.2, 0.6, 0.4, 0.3, 0.4, 0.9, 0.2, and 0.4, respectively). In addition, these constituents also showed moderate correlations with abundant fine-grained sediment (0.5, 0.8, 0.5, 0.7, 0.8, 0.3, 0.6 and 0.8, respectively) as would be expected.

The lack of any significant relation between concentrations of total PCBs, total chlordane, total DDT, and total PAHs and TOC concentrations in surficial-sediment samples contrasts with their significant correlation in the core samples. The organic compounds—total PCBs, total DDT, total chlordane, and total PAHs—measured in cores (n=12) showed moderate correlations with TOC (Pearson's r-values 0.8, 0.9, 0.8, and 0.5, respectively). This difference may be due to the fact that core samples represent a much longer depositional period (about 92 years) than do surficial-sediment samples (about 25 years). Historically, the use and nearly continuous disposal of many organic compounds including PCBs, chlordane, DDT, and PAHs was likely more prevalent than in recent years. Currently, it is likely that these contaminants are discontinuously discharged to the basin and at much lower concentration. Therefore, correlations would be expected in sediments deposited at an earlier time when these organic compounds were ubiquitous and equally affected by sediment transport processes whereas these correlations may be obscured in sediments deposited more recently because of source loading effects. Alternatively, diagenesis of more labile TOC in cores also would reinforce correlations among TOC and enrichment of refractory organic compounds such as PCBs, DDT, chlordane, and PAHs that may otherwise obscure correlations between these organic compounds and TOC in surficial sediments.

POTENTIAL FOR ADVERSE BIOLOGICAL EFFECTS

The chemistry of bottom sediment influences the biotic quality of a river, as aquatic organisms ingest particulate matter and accumulate inorganic elements and organic compounds in their tissues (Forstner and Wittmann, 1979). The accumulation of inorganic elements and organic compounds in aquatic organisms can cause physiological problems and even death. Subsequent ingestion of contaminated aquatic organisms by higher-level organisms transfers the accumulated contaminants upward through the food chain.

Concentrations of some contaminants increase with upward movement through the food chain. This biomagnification process can directly affect humans, who are generally near the top of the food chain. The effects of ingestion of contaminated aquatic organisms on human health were not measured directly as part of this investigation. The presence of inorganic elements and organic compounds in bottom sediment, however, can be related to their adverse effects on benthic organisms (for example, amphipod crustaceans, gastropod molluscs, and oligochaetes).

Benthic Organisms

The potential for adverse biological effects of contaminated sediment was assessed using sediment-quality guidelines (threshold-effects level or TEL, and probable-effects level or PEL; table 7 Ecosystem Conservation Directorate Evaluation and Interpretation Branch, 1995). Samples collected where the salinity ranges from 1 to 20 ppt were assessed using interim quality guidelines for marine sediment. Samples collected outside the influence of the salt wedge during the sampling period were assessed using interim quality guidelines for freshwater sediment (figs. 4 and 5). TELs and PELs define concentration ranges that are rarely, occasionally, or frequently associated with adverse effects (also referred to as the minimal, possible, and probable effect ranges, respectively). The TEL defines the concentration below which effects rarely occur. The PEL defines the concentration above which effects frequently occur. Adverse effects include decreased numbers of species, increased number of diseased fish, or mortality of sensitive species.

As with detection limits, constituents whose concentrations were less than the MRL were considered to be undetected and therefore rarely associated with adverse effects (below the TEL) even though, in some cases, the MRL was greater than the TEL and sometimes the PEL. Therefore, in these instances, the assessment that a particular constituent is rarely associated with adverse effects at a particular location does not unequivocally demonstrate that the constituent will not bring about adverse biological effects occasionally or even frequently.

Generally, however, MRLs greater than sediment-quality guidelines (TELs and PELs) were the result of interferences from high concentrations of co-eluting chemicals of similar structure. Because chemicals were grouped on the basis of structural similarities to assess biological affects, surficial sediment at many sampling sites was shown to be a potential cause of adverse biological effects (occasionally or frequently) even though many chemicals had MRLs greater than the TELs and PELs.

The National Status and Trends Program (NSTP) approach (Long and Morgan, 1990) with modifications was used to derive the TEL and PEL values. This approach involves the evaluation and compilation of chemical and biological data from numerous studies (including models of equilibrium partitioning in sediment, sediment-quality assessment values, spiked sediment toxicity tests, and field studies) conducted throughout North America. The available data covered a large and varied geographical area and included many different species.

The following evaluation of the extent and frequency of exceedences of these sediment-quality guidelines (PELs and TELs) in the lower Charles River should be considered an informal screening to distinguish the chemicals and sites that are likely to be associated with adverse biological effects. These conservative numerical guidelines were developed in order to "sustain and protect aquatic life" (Ecosystem Conservation Directorate Evaluation and Interpretation Branch, 1995); they are not intended to preclude the use of site-specific biological assessments and other measures of biological effects. Therefore, the PELs and TELs should be used in conjunction with other information to support practical and informed decisionmaking regarding sediment quality.

Although some inorganic elements are essential for life, most inorganic elements are toxic to living organisms at sufficiently high concentrations. The potential for adverse effects on benthic organisms at the surficial-sediment sampling sites (concentrations above PEL) in the basin is estimated to be frequent for about 77 percent of the inorganic elements tested; occasional (concentrations above TEL but below PEL) for about 15 percent; and rare (concentrations below PEL) for about 8 percent. The element with the largest percentage of PEL exceedences in the basin is mercury, in 33 of 35 samples (94 percent); followed by lead, in 123 (91 percent); cadmium, in 113 (84 percent); zinc, in 112 (83 percent); silver, in 101 (75 percent); copper, in 99 (73 percent); nickel, in 85 (63 percent); and chromium, in 72 of 135 samples (53 percent) (fig. 4).

Chlordane, DDT, PCBs, and high concentrations of PAHs are found in bottom sediment only as a result of human activities. Because many biological systems are not well adapted to the effects of these compounds, they may be toxic at very low concentrations (table 7). The potential for adverse effects on benthic organisms in the basin was frequent for 63 percent of the organic compounds measured, occasional for about 22 percent; and rare for 15 percent. The PEL for PAHs were exceeded in the largest number of samples of PEL exceedences with 35 (100 percent) followed by total PCBs, with 31 (89 percent); total chlordane, with 17 (49 percent); and total DDT, with 5 (14 percent) (fig. 5).

This approach of assessing potential adverse biological effects has both advantages and disadvantages. In particular, these guidelines are developed on a chemical-by-chemical basis, and do not account for the effects of multiple contaminants. At many sampling sites, more than one compound is present at an elevated concentration.

Table 7. Bottom-sediment-quality guidelines and their relation to the potential frequency of adverse effects on benthic organisms

[**Threshold effect levels (TELs):** Concentrations below which adverse biological effects rarely are observed. **Probable effect levels (PELs):** Concentrations above which adverse biological effects frequently are observed. ppb, parts per billion; ppm, parts per million; --, no TEL or PEL exists]

Constituent	Freshwater		Saltwater	
	TELs	PELs	TELs	PELs
Inorganic elements (ppm)				
Arsenic	5.9	17	7.24	41.6
Cadmium	.60	3.53	.68	4.21
Chromium	37.3	90	52.3	160
Copper	35.7	197	18.7	108
Lead	35	91.3	30.2	112
Mercury	.17	.49	.13	.7
Nickel	18	35.9	15.9	42.8
Silver	--	--	.73	1.77
Zinc	123	315	124	271
Polychlorinated biphenyls (ppb)				
Aroclor-1221	--	--	21.6	189
Aroclor-1232	--	--	21.6	189
Aroclor-1242	--	--	21.6	189
Aroclor-1248	--	--	21.6	189
Aroclor-1254	--	--	21.6	189
Aroclor-1260	--	--	21.6	189
Total	34.1	277	21.5	189
Organochlorine pesticides (ppb)				
alpha-BHC	--	--	.32	.99
beta-BHC	--	--	.32	.99
delta-BHC	--	--	.32	.99
gamma-BHC	--	--	.32	.99
Alpha Chlordane	--	--	2.26	4.79
gamma Chlordane	--	--	2.26	4.79
Chlordane (technical)	--	--	2.26	4.79
Total Chlordane	4.5	8.9	2.26	4.79
Organochlorine pesticides (ppb)—*Continued*				
4,4'-DDD	3.54	8.51	1.22	7.81
4,4'-DDE	1.42	6.75	2.07	3.74
4,4'-DDT	--	--	1.19	4.77
Total DDT	6.98	4,450	3.89	51.7
Dieldrin	2.85	6.67	.71	4.3
Endrin	2.67	62.4	--	--
Heptachlor epoxide	.6	2.74	--	--
Polyaromatic hydrocarbons (ppb)				
Acenaphthene	--	--	6.71	88.9
Acenaphthylene			5.87	128
Anthracene			46.9	245
Benzo(a)-anthracene	31.7	385	74.8	693
Benzo(a)pyrene	31.9	782	88.8	763
Chrysene	57.1	862	108	846
Dibenzo(a,h)-anthracene			6.22	135
Floranthene	111	2,355	113	1,494
Florene			21.2	144
Naphthalene			34.6	391
Phenanthrene	41.9	515	86.7	544
Pyrene	53	875	153	1,398
Total[1]	--	--	3.12	1,442
Total[2]	--	--	655	6,676

[1]Low molecular weight polyaromatic hydrocarbons.
[2]High molecular weight polyaromatic hydrocarbons.

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Arsenic	5.9	17	7.24	41.6
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Chromium	37.3	90	52.3	160
Copper	35.7	197	18.7	108
Lead	35	91.3	30.2	112
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Nickel	18	35.9	15.9	42.8
Silver	--	--	.73	1.77
Zinc	123	315	124	271
Polychlorinated biphenyls (ppb)				
Aroclor-1221	--	--	21.6	189
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Aroclor-1242	--	--	21.6	189
Aroclor-1248	--	--	21.6	189
Aroclor-1254	--	--	21.6	189
Aroclor-1260	--	--	21.6	189
Total	34.1	277	21.5	189
Organochlorine pesticides (ppb)				
alpha-BHC	--	--	.32	.99
beta-BHC	--	--	.32	.99
delta-BHC	--	--	.32	.99
gamma-BHC	--	--	.32	.99
Alpha Chlordane	--	--	2.26	4.79
gamma Chlordane	--	--	2.26	4.79
Chlordane (technical)	--	--	2.26	4.79
Total Chlordane	4.5	8.9	2.26	4.79
Organochlorine pesticides (ppb)—*Continued*				
4,4'-DDD	3.54	8.51	1.22	7.81
4,4'-DDE	1.42	6.75	2.07	3.74
4,4'-DDT	--	--	1.19	4.77
Total DDT	6.98	4,450	3.89	51.7
Dieldrin	2.85	6.67	.71	4.3
Endrin	2.67	62.4	--	--
Heptachlor epoxide	.6	2.74	--	--
Polyaromatic hydrocarbons (ppb)				
Acenaphthene	--	--	6.71	88.9
Acenaphthylene			5.87	128
Anthracene			46.9	245
Benzo(a)-anthracene	31.7	385	74.8	693
Benzo(a)pyrene	31.9	782	88.8	763
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Pyrene	53	875	153	1,398
Total[1]	--	--	3.12	1,442
Total[2]	--	--	655	6,676

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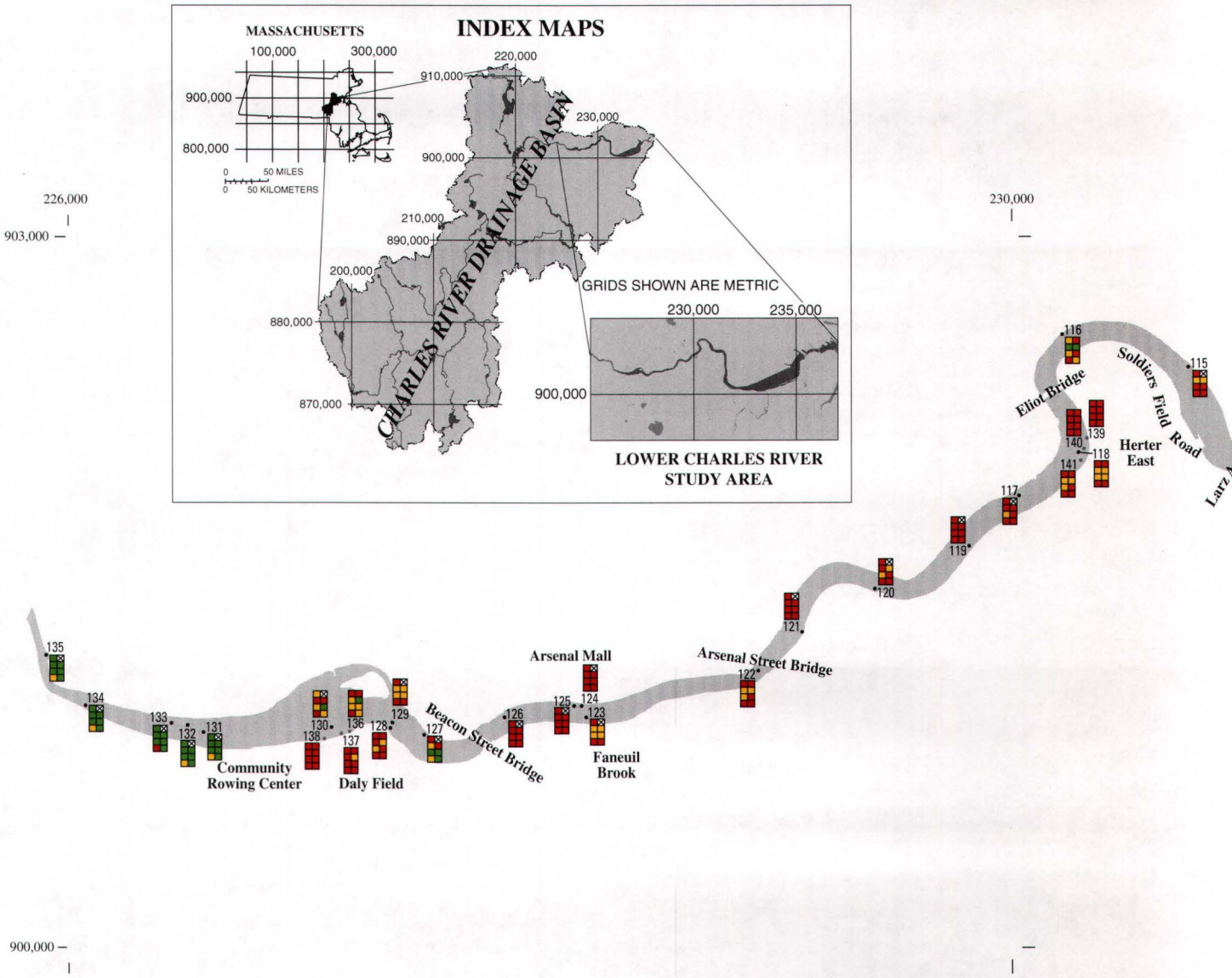
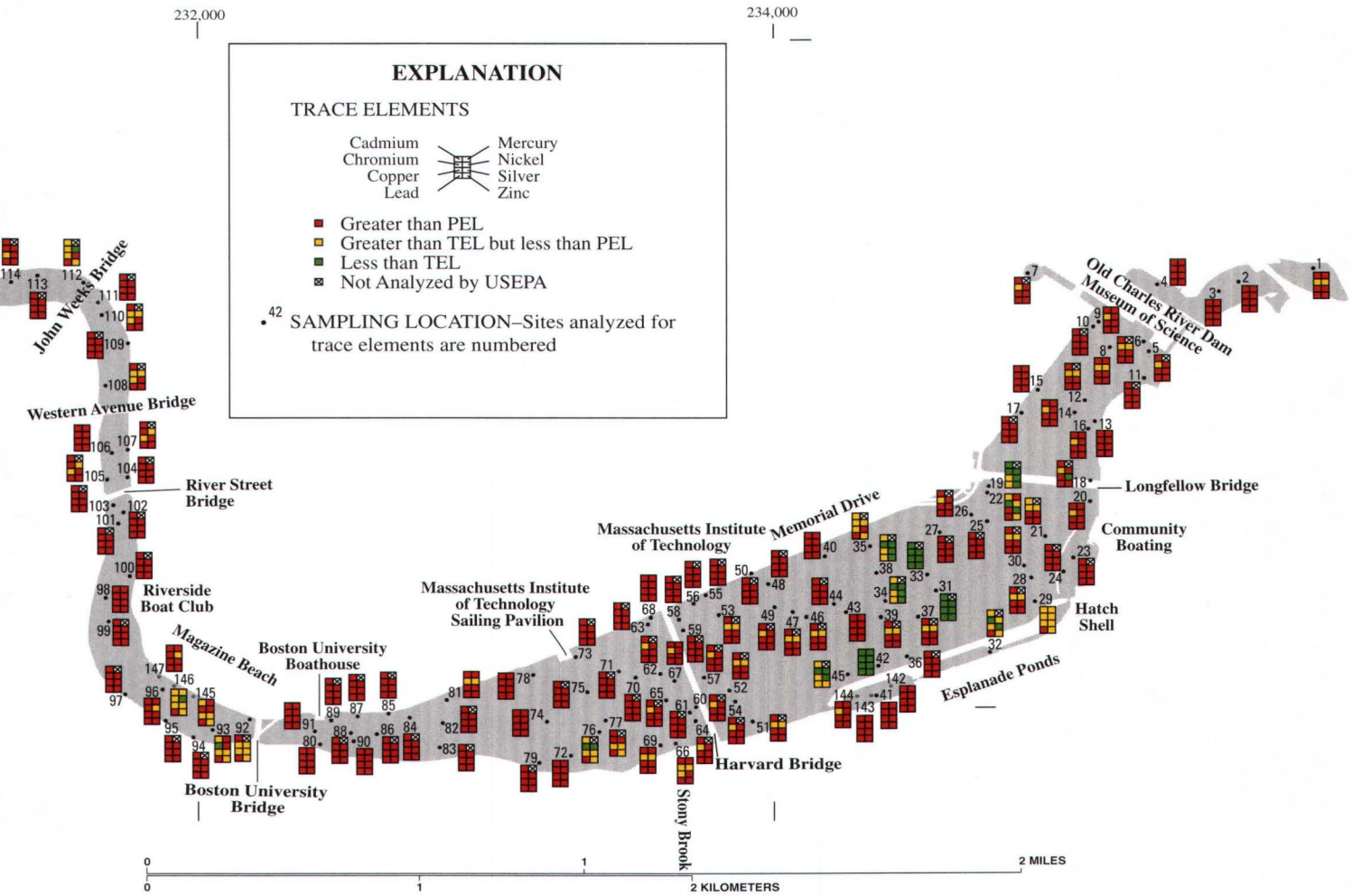


Figure 4. The potential for adverse biological effects by inorganic elements in surficial sedim



dicating threshold and probable effects levels Lower Charles River Basin, Massachusetts.

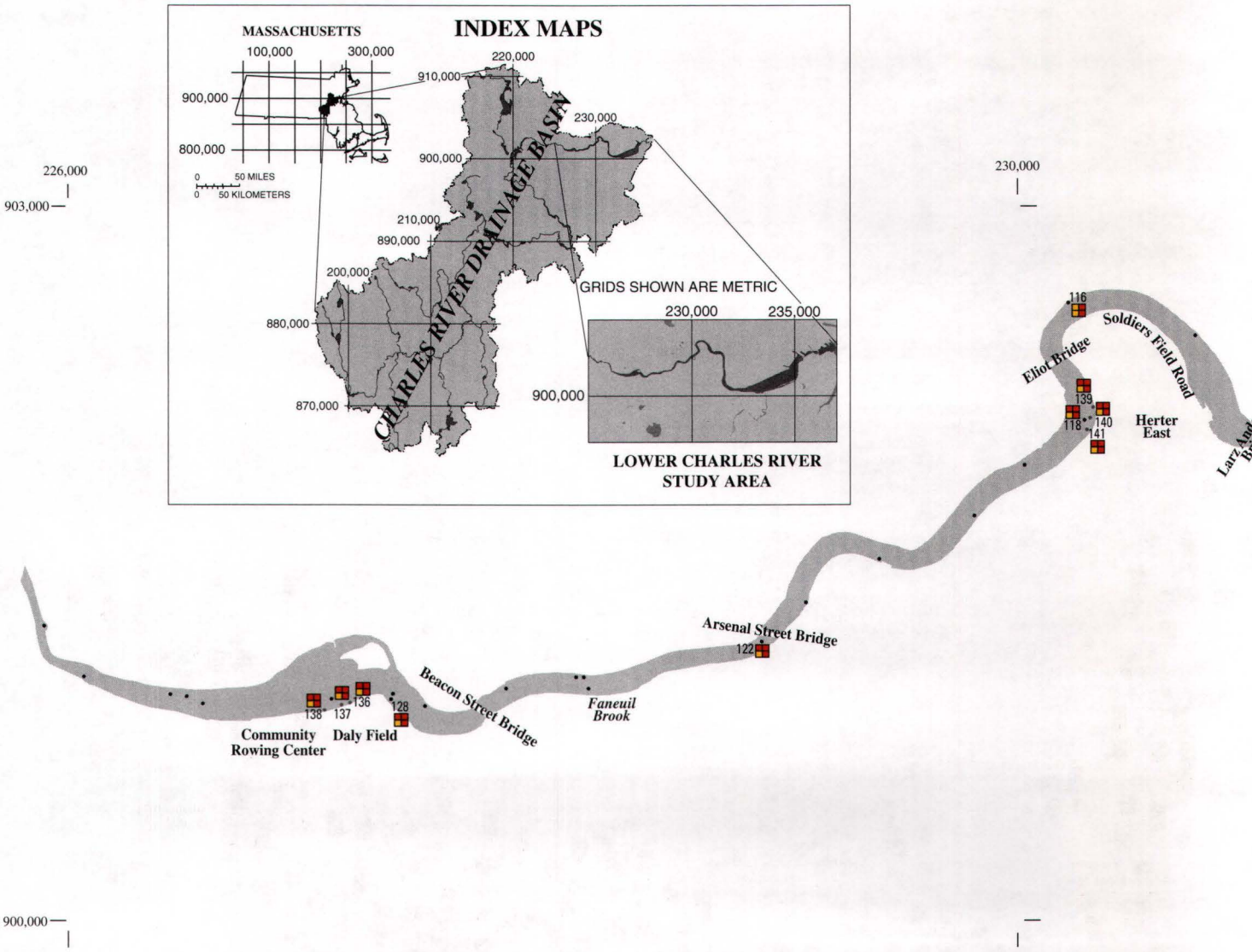
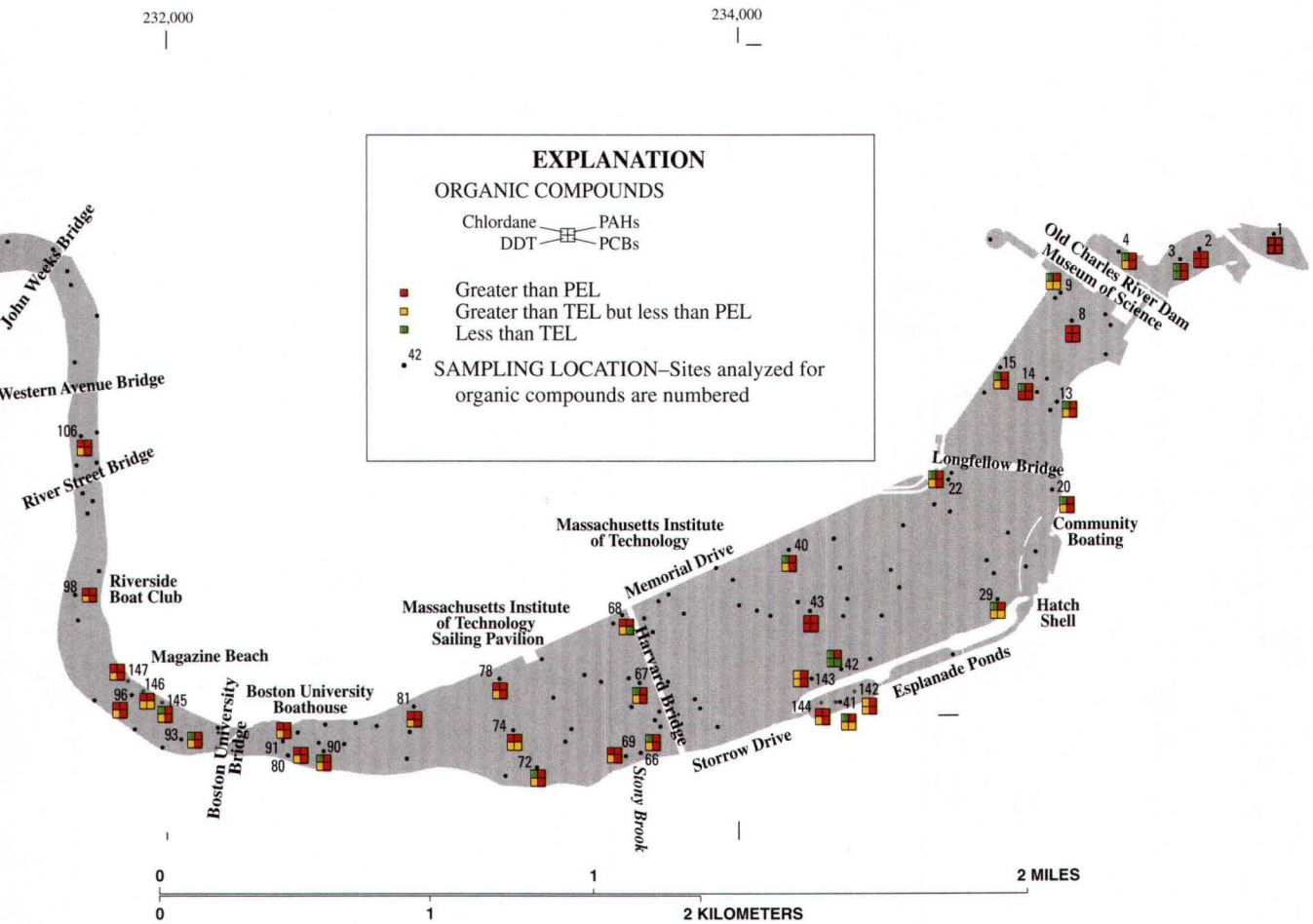


Figure 5. The potential for adverse biological effects by organic compounds in surficial sedim



dicating threshold and probable effects levels, Lower Charles River Basin, Massachusetts.

The presence of multiple contaminants is important for the assessment of the toxicity of the sediment from which they are collected because of possible synergistic effects among the contaminants. Such effects could cause a combination of contaminants to be more toxic than they would be individually. An additional limitation is that the approach does not assess the availability of contaminants to biota, or bioavailability. Therefore, measured concentrations may not reflect accurately the potential toxicity of bottom sediment enriched in inorganic elements and organic compounds.

Bioavailability and the Effects of the Salt Wedge

Under anaerobic conditions, the bioavailability of inorganic elements is partly controlled by the adsorption and coprecipitation of inorganic elements with sulfide minerals (Morse, 1995). The bioavailability of inorganic elements in bottom sediment can be assessed by treatment of bottom-sediment samples with cold hydrochloric acid (HCl). The sulfide fraction that is released in this way consists mostly of iron monosulfides (amorphous iron sulfide and pyrite) but also includes other metal sulfides. The released fraction is referred to as acid volatile sulfide (AVS). The fractions of cadmium, chromium, copper, mercury, nickel, lead, and zinc that are extracted simultaneously during the procedure are termed simultaneously extracted metals (SEM). The ratio of the molar sum of the SEM concentrations divided by the molar concentration of AVS (SEM:AVS), is a measure of the bioavailability of the inorganic elements. For SEM:AVS ratios less than 1, no acute toxicity due to these elements is observed; acute toxicity for these elements is observed when SEM:AVS ratios are greater than 1 (Morse, 1995; table 8). Eighty percent (n=28) of the surficial-sediment samples analyzed for SEM:AVS show ratios less than 1, indicating limited bioavailability for cadmium,

Table 8. Distribution of acid volatile sulfide and simultaneously extracted metals in bottom-sediment samples, lower Charles River, Massachusetts, 1998

[All concentrations are in micromoles per gram dry weight. AVS; acid volatile sulfide; SEM, simultaneously extracted metals; D, field duplicate; No., number; <, less than minimum reporting limit]

Sample No.	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Zinc	AVS	SEM:AVS
1	0.09	1.8	5	4.3	<0.0003	0.44	13.7	239	0.1
2	.11	2.3	5.9	2.2	<.0004	.54	20	49.8	.58
3	.32	1.8	9.2	6.3	<.0006	.6	22.2	158	.24
4	<.17	1.6	6	4.6	<.003	<.97	13	363	.06
8	<.13	1	5	4.1	<.002	<.98	9.5	652	.03
9	<.95	6.2	5.3	4.4	<.01	<5.5	12	632	.03
13	.11	1.5	6.7	4.5	<.0007	.89	10	97.2	.23
14	.18	.39	4.6	3.8	<.003	1	9.5	612	.03
15	.0008	.01	.05	.03	<.000006	.005	.1	132	.001
20	.05	.81	3.8	3.6	<.0004	.5	6.7	20.7	.7
22	.02	.26	1.1	.54	<.0002	.11	2	.82	4.5
29	.02	.44	.95	.52	<.0002	.28	2.4	5.7	.73
40	.09	1.6	7.1	5.4	<.002	.74	12.6	211	.12
41	.11	.86	3.7	2.1	<.0003	.39	8.7	12.2	12
42	<.01	.12	.28	.18	<.0001	.07	.8	.24	5.6
43	<.13	1.2	4.7	3.6	<.002	<.72	11	330	.06
66	.04	.46	1.2	2	<.0006	.28	6.6	10.9	.93
67	.05	.73	4.1	4	<.0003	.41	11.6	94.2	.21
68	.08	1.1	5.7	4.8	<.0005	.44	12.4	249	.09
69	.04	.6	2.9	3.4	<.0004	.39	9.9	34.3	.5

Table 8. Distribution of acid volatile sulfide and simultaneously extracted metals in bottom-sediment samples, lower Charles River, Massachusetts, 1998—*Continued*

Sample No.	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Zinc	AVS	SEM:AVS
72	0.09	1.2	3.9	3.1	<0.0005	0.44	7.9	13.2	1.2
74	.08	1.2	4.6	3.2	<.002	.56	11.3	158	.12
78	.11	1.3	4.9	3.5	<.001	.62	11.8	168	.12
80	.08	1.2	5.7	3.7	<.001	.58	12.6	34.4	.66
81	.07	.89	4.7	2.1	<.0006	.44	8.7	17.8	.9
90	.09	1.1	5.2	3.5	<.0009	.62	11.8	28.6	.74
91	.11	1.2	5.9	3.4	<.0005	.47	9	28.4	.67
93	.07	.41	1.2	2.8	<.0003	.24	7.2	18.4	.63
96	.1	.99	3.5	2.8	<.0004	.44	10.4	5.4	3.2
98	.07	1.1	3	2.8	<.0007	.4	10.6	8.7	1.9
98-D	.06	1.1	3	2.8	<.0006	.39	11.1	10.3	1.7
106	.11	1.1	3.9	4.2	<.0007	.41	10.3	19.5	.98
106-D	.13	1.2	4.2	4.6	<.0008	.41	11	21.4	.95
116	<.03	.22	.66	1.2	<.0002	.14	3.1	7.5	.68
118	.09	.66	2.2	1.8	<.0009	.37	7.8	19.9	.61
118-D	<.12	.62	2.2	1.8	<.001	.42	8.3	21.5	.57
122	.06	.6	1.6	1.8	<.0003	.24	6.3	5	1.99
128	.15	.86	3	2.9	<.0006	.52	8.2	12.2	.24
136	.11	.96	1.8	1.9	<.0004	.22	5.4	17	.56
137	.1	2	3.2	3.5	<.0004	.36	10.9	13.7	1.3
138	.13	2.6	3.4	3.8	<.0004	.4	10.9	42.6	.44
139	.43	2.8	11.2	5	<.0007	.67	11.6	67.1	.43
140	.29	1.8	7.5	4.1	<.0005	.5	.29	44.7	.48
141	.07	.75	2.2	1.5	<.0003	.34	5.4	14.1	.67
141-D	.07	.75	2.2	1.5	<.0003	.34	5.4	14.1	.67
142	.05	.81	2.2	5.4	<.0004	1.7	33.9	.29	.29
143	.07	.94	3.17	2.4	<.0005	.45	7.2	47.6	.28
144	.07	.86	3	2.1	<.0004	.52	6.3	22.3	.54
145	<.03	.57	.79	.9	<.0002	.23	2.4	11.2	.39
146	.14	1.5	3	3.6	<.002	.82	10	29.9	.59
147	.13	1.1	3.6	3.1	<.0003	.4	5.7	33.2	.39

chromium, copper, lead, mercury, nickel, and zinc due to binding by sulfide. The remaining 20 percent of the samples predict metal bioavailability.

Although sedimentary sulfide minerals are believed to reduce the bioavailability of inorganic elements, that influence should be interpreted with caution. For example, Cooper and Morse (1998) demonstrated that SEM:AVS ratios measured by hydrochloric digestions cannot be used by themselves to predict the potential for adverse effects of elements, including copper, mercury, and nickel, whose sulfides are not readily soluble in water. Changes in water temperature at the sediment-water interface can also indirectly affect AVS because of the influence of water temperature on primary productivity and sediment microbial activity (Leonard and others, 1993). The dependence of AVS on oxygen content and temperature is important because of the dynamic nature of the salt wedge in the basin. Under certain conditions, the salt wedge can be flushed from the basin and oxygen-rich water of a different temperature can come into direct contact with bottom-sediment (Breault and others,

2000). This influx of oxygen-rich water can oxidize metastable sulfide minerals and sedimentary pyrite (iron sulfide), releasing inorganic elements that were previously sequestered by sulfide (Morse, 1995). The newly released inorganic elements may be sequestered quickly by organic matter or precipitated as hydroxides and redeposited on the river bottom. The effects of sequestration of trace elements by organic matter and hydroxides in terms of controlling metal bioavailability, however, is poorly understood. Finally, care should be taken when interpreting the SEM:AVS ratios calculated on bottom-sediment samples because of the depth dependence of this ratio. For example, Hare and others (1994) measured an AVS peak at about 2 in. below the sediment-water interface that was about 4 times the AVS concentration measured at the sediment-water interface. They attribute the difference in AVS concentrations with depth to the oxidation of AVS minerals at the sediment-water interface. This may explain why SEM:AVS ratios less than 1 were measured outside of the influence of the anoxic salt wedge during the time of sampling. It is likely that a subsurface peak in the concentration of AVS minerals was located between the sediment-water interface and a depth of about 4.0 in. (the average depth that surficial-sediment samples were collected in this study). Therefore, the SEM:AVS ratios measured in the top 4 inches of surficial-sediment may be inappropriate to assess the bioavailability of cadmium, chromium, copper, lead, mercury, nickel, and zinc at the sediment-water interface, where many organisms live and feed.

Humans

Direct-contact, exposure-based soil standards (Method 2, soil category S-1; Massachusetts Department of Environmental Management, 1996; table 9) define contaminant concentrations at which direct skin contact and incidental ingestion, or both, may cause an adverse effect on human health. Adverse effects can include, but are not limited to, allergic reactions, contact dermatitis, hypertension, carcinogenesis, hematological effects, and gastrointestinal distress (Klaassen and others, 1986). Because these numerical guidelines were developed for soil, not aquatic sediment, they may underestimate the health

Table 9. Guidelines for epidermal contact with and incidental ingestion of contaminated sediment

[PAH, polychlorinated hydrocarbons; PCB, polychlorinated biphenyls; ppb, parts per billion; ppm, parts per million]

Inorganic elements (ppm)	
Arsenic	30
Barium	1,000
Beryllium	.7
Cadmium	30
Chromium	1,000
Lead	300
Mercury	20
Nickel	300
Silver	100
Vanadium	400
Zinc	2,500
PCBs (ppb)	
Aroclor-1016	2,000
Aroclor-1221	2,000
Aroclor-1232	2,000
Aroclor-1242	2,000
Aroclor-1248	2,000
Aroclor-1254	2,000
Aroclor-1260	2,000
Aroclor-1262	2,000
Aroclor-1268	2,000
Total PCBs	2,000

Organochlorine pesticides (ppb)	
Aldrin	500,000
gamma-BHC	400
Alpha Chlordane	1,000
gamma Chlordane	1,000
Chlordane (technical)	1,000
Total Chlordane	1,000
4,4'-DDD	2,000
4,4'-DDE	2,000
4,4'-DDT	2,000
total DDT	2,000
Dieldrin	30
Endosulfan I	100,000
Endosulfan II	100,000
Endrin	6,000
Heptachlor	100
Heptachlor epoxide	60
Methoxychlor	100,000

PAHs (ppb)	
TPH	800,000
Acenaphthene	1,000,000
Acenaphthylene	100,000
Anthracene	1,000,000
Benzo(b)floranthene	700
Benzo(k)floranthene	7,000
Benzo(a)pyrene	700
Benzo(ghi)perylene	1,000,000
Chrysene	7,000
Dibenzo(a,h)anthracene	700
Floranthene	1,000,000
Florene	1,000,000
Indeno(1,2,3-cd)pyrene	700
Naphthalene	100,000
Phenanthrene	1,000,000
Pyrene	700,000

risk posed by aquatic sediment. For example, persons wading or swimming in an area with contaminated sediment might be exposed over a greater surface area with more potential portals of entry than would persons exposed to contaminated soils. These standards could be used by environmental policy makers in conjunction with other site-specific information to support practical and informed decisionmaking regarding potential human heath risks associated with direct contact and incident ingestion of bottom sediment at the proposed public swimming beaches. The evaluation here is not intended to preclude the use of other measures that are designed to determine if a substance will produce harm to humans under specific conditions.

Daly Field

Median concentrations of lead, TPHs (table 10), and some of the PAHs [benzo(b)fluoranthracene, benzo(k)fluoranthracene, benzo(a)pyrene, chrysene, dibenzo(a, h)anthracene, and indeno(1,2,3-cd)pyrene] measured in core sediment collected at Daly Field exceeded the exposure-based soil standards. In general, contaminant concentrations exceeded standards at the Daly Field site more frequently than at any of the other sites. The median TPH concentration from Daly Field sediment exceeded the exposure-based standard by 25 times; lead by a factor of 2, and PAHs by 2 to 50 times.

Herter East Park

Median concentrations of lead, TPHs, total PCBs, and some of the PAHs, [benzo(b)fluoranthracene, benzo(a)pyrene, dibenzo(a, h)anthracene, and indeno(1,2,3-cd) pyrene] measured in core sediment collected at Herter East Park exceeded their exposure-based soil standard. The median lead concentration from the Herter East Park site exceeded the exposure-based standard for by a factor of 2, TPH by 23 times, PAHs by 1 to 10 times, and PCBs by 3 times.

Magazine Beach

Median concentrations of TPHs and some of the PAHs [benzo(b)fluoranthracene, benzo(a)pyrene, and indeno(1,2,3-cd)pyrene] at Magazine Beach exceeded the respective exposure-based soil standard standards. The median TPH concentration measured in core sediment collected from Magazine Beach exceeded the standard by 11 times and median PAH concentrations exceeded standards by 2 to 4 times. The number of exceedances of exposure-based soil standards are generally less in core sediment collected from the Magazine Beach compared to the other proposed public beaches.

Table 10. Distribution of total petroleum hydrocarbons in bottom-sediment samples, lower Charles River, Massachusetts, 1998

[D, field duplicate; No. number; ppm, parts per million]

Station No.	Total petroleum hydrocarbon (ppm)	Station No.	Total petroleum hydrocarbon (ppm)
1	14,000	81	9,300
2	11,000	90	16,000
3	39,000	91	17,000
4	11,000	93	8,200
8	7,540	96	14,000
9	6,300	98	17,000
13	8,800	106	15,000
14	9,010	116	3,000
15	7,800	118	6,820
20	4,800	122	9,000
22	977	128	15,000
29	1,380	136	17,000
40	19,000	137	21,000
41	5,490	138	22,000
42	246	139	994
43	21,000	140	46,000
66	6,900	141	9,300
67	19,000	142	3,470
68	17,000	142-D	1,320
69	11,000	143	5,000
72	17,000	144	6,400
74	4,800	145	1,630
78	14,000	146	2,800
80	20,000	147	22,000

Esplanade Ponds

Median concentrations of TPHs and some of the PAHs [benzo(b)fluoranthracene, benzo(a)pyrene, and indeno(1,2,3-cd)pyrene] in core sediment collected at the Esplanade ponds exceeded the exposure-based standards. The median TPH concentration from the Esplanade ponds exceeded the exposure-based by six times. The median concentrations of the PAHs from the Esplanade ponds exceeded the exposure-based soil standards by two to three times. Constituents measured in core sediment from the Esplanade ponds generally exceed soil standards by less than do the other proposed public beaches, in terms of concentrations.

SUMMARY AND CONCLUSIONS

Sediment at most locations in the lower Charles River Basin has been contaminated by inorganic elements and organic compounds. More specifically, the metals chromium, copper, lead, mercury, nickel, silver, and zinc, and the compounds chlordane, DDT, PAHs, and PCBs were detected in bottom-sediment samples from throughout the basin at concentrations that are likely above background concentrations for these contaminants. Almost all of the concentrations of cadmium, copper, lead, mercury, silver, and zinc concentrations measured in bottom-sediment samples collected from the basin exceeded their respective average crustal-abundance concentrations. Surficial-sediment samples and cores also were enriched in organic compounds, including polychlorinated byphenyls, total organochlorine pesticides, and polyaromatic hydrocarbons. The most frequently detected organic compounds included; polychlorinated byphenyls (Aroclors 1254 and 1260), the organochlorine pesticides (for example, chlordane and DDT), and 16 polyaromatic hydrocarbons. Possible anthropogenic sources of these inorganic elements and organic compounds include urban runoff from streets, atmospheric deposition, inadvertent spills, combined sewer overflows, and illegal sewage connections.

Median concentrations of inorganic elements and organic compounds measured in surficial-sediment samples collected from the lower Charles River ranged from 1.3 to 35 times higher than median concentrations of these constituents measured in samples collected from urban rivers across the conterminous United States by the U.S. Geological Survey's National Water Quality Assessment Program (NAQWA). Possible reasons for the high concentrations of inorganic elements in the basin relative to other urbanized free-flowing rivers are low hydraulic gradients, lack of flushing, a lack of natural uncontaminated sediment—from erosion of upstream soils—that typically dilute contaminated urban sediments, and the presence of an anoxic, sulfide-rich zone within a non-tidal salt wedge.

The distribution of the inorganic elements in surficial-sediment appears to be controlled primarily by in-stream processes associated with sediment transport, and by the anoxic zone within the salt wedge. In contrast, the distribution of organic compounds appears to reflect local point and non-point sources. Inorganic elements and organic compounds in core sediments collected from four proposed public beaches generally were found in the lowest concentrations in erosional areas and areas distant from the main river channel (Magazine Beach and the Esplanade Ponds). The larger contaminant concentrations were found in depositional areas (Daly Field and Herter East Park). Contaminant enrichment in the depositional areas were associated with enrichment of total organic carbon, iron, and abundant fine-grained sediment.

Inorganic elements and organic compounds pose a severe threat to benthic organisms in terms of exceedences of sediment-quality guidelines; these compounds are present at sufficiently high concentrations at many surficial-sediment sampling sites to cause potentially adverse biological effects to benthic organisms living in and on the bottom sediment. Ratios of acid volatile sulfide to simultaneously extracted metals, however, suggest that cadmium, chromium, copper, lead, mercury, nickel, and zinc would be toxic in fewer than 25 percent of the surficial-sediment samples. Concentrations of many individual polyaromatic hydrocarbons, total petroleum hydrocarbons, and lead measured in cores appear to exceed exposure-based soil-concentration standards developed by MADEM for direct contact and incident ingestion at the proposed beaches. Therefore, although best management practices (BMPs), source-reduction programs, and bans of certain constituents (chlordane, DDT, PCBs, and lead in gasoline) have been implemented, the fact that inorganic elements and organic compounds are chemically stable and are not readily broken down by biological, chemical, and physical processes, suggests that these contaminants will continue to be present at elevated concentrations in the bottom-sediment of the lower Charles River and can be expected to persist there for many years to come.

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Tables 11–13

Table 11. Distribution of inorganic elements in bottom-sediment cores, lower Charles River, Massachusetts, 1998

[D, field duplicate; LD, lab duplicate; No., number; USEPA, U.S. Environmental Protection Agency; ppm, parts per million; <, actual value shown is less than minimum reporting limit; --, not analyzed]

Station No.	Inorganic elements									
	Calcium		Magnesium		Sodium	Potassium	Phosphorus, total (as P)	Aluminum		Antimony
	XRAL (percent)	USEPA (percent)	XRAL (percent)	USEPA (percent)	XRAL (percent)	XRAL (percent)	XRAL (percent)	XRAL (percent)	USEPA (percent)	XRAL (ppm)
1	0.90	0.46	0.69	0.62	0.9	0.43	0.11	1.8	1.4	<5
2	.43	.33	.75	.65	.5	.45	.10	2.0	1.5	<5
3	.75	.47	.69	.59	.9	.51	.20	1.9	1.2	<5
4	.57	.50	.75	.84	.8	.39	.15	2.0	1.6	<5
5	.41	--	.76	--	.4	.47	.11	2.0	--	<5
5-D	.34	--	.65	--	.3	.41	.09	1.8	--	<5
6	.46	--	.66	--	.5	.29	.11	1.6	--	<5
6-D	.48	--	.70	--	.5	.32	.12	1.7	--	<5
7	.48	--	.43	--	.1	.20	.13	1.2	--	<5
8	.59	.54	.96	1.09	2.4	.59	.11	2.1	1.4	<5
9	.62	.51	.86	.88	1.2	.45	.12	2.1	1.7	<5
10	.58	--	.86	--	1.6	.41	.12	1.7	--	<5
11	.51	--	.70	--	.5	.31	.14	1.6	--	<5
11-LD	.50	--	.65	--	.5	.29	.13	1.5	--	<5
12	.54	--	.86	--	1.7	.40	.15	1.8	--	<5
13	.57	.48	.68	.64	.1	.35	.14	2.2	1.7	<5
14	.51	.52	.60	.99	.2	.29	.14	1.6	1.7	<5
15	.64	.41	.93	.59	1.8	.44	.14	2.0	1.3	<5
16	.56	--	.78	--	.8	.37	.16	1.9	--	<5
17	.59	--	.68	--	.3	.37	.20	2.0	--	<5
18	.26	--	.21	--	.03	.07	.08	.5	--	<5
19	.23	--	.27	--	.03	.07	.05	.6	--	<5
20	.51	.38	.63	.52	.1	.39	.10	1.8	1.3	<5
21	.51	--	.59	--	.1	.26	.12	1.5	--	<5
21-D	.47	--	.54	--	.1	.24	.11	1.4	--	<5
22	.33	.22	.30	.26	.03	.12	.06	.8	.6	<5
23	.63	--	.59	--	.1	.29	.18	1.7	--	<5
24	.59	--	.62	--	.1	.31	.21	1.9	--	<5
24-LD	.62	--	.66	--	.1	.35	.22	2.0	--	<5
24-LD	.68	--	.68	--	.1	.37	.23	2.1	--	<5
25	.62	--	.72	--	.2	.33	.16	2.0	--	<5
26	.48	--	.58	--	.1	.22	.15	1.5	--	<5
27	.47	--	.60	--	.1	.26	.16	1.6	--	<5
27-D	.43	--	.56	--	.1	.23	.15	1.5	--	<5
28	.59	--	.73	--	.9	.32	.15	1.7	--	<5
29	.68	.35	.82	.60	.1	.67	.11	2.5	1.5	<5

Table 11. Distribution of inorganic elements in bottom-sediment samples, lower Charles River, Massachusetts, 1998—*Continued*

Station No.	Inorganic elements									
	Calcium		Magnesium		Sodium	Potassium	Phosphorus, total (as P)	Aluminum		Antimony
	XRAL (percent)	USEPA (percent)	XRAL (percent)	USEPA (percent)	XRAL (percent)	XRAL (percent)	XRAL (percent)	XRAL (percent)	USEPA (percent)	XRAL (ppm)
30	0.59	--	0.80	--	1.0	0.33	0.17	1.8	--	<5
31	.34	--	.42	--	.04	.22	.06	1.1	--	<5
32	.36	--	.34	--	.03	.10	.07	.7	--	<5
32-LD	.38	--	.33	--	.0	.12	.06	.7	--	<5
33	.26	--	.37	--	.02	.07	.03	.7	--	<5
33-LD	.31	--	.47	--	.0	.06	.04	.8	--	<5
34	.29	--	.37	--	.02	.14	.08	.8	--	<5
35	.41	--	.38	--	.1	.15	.09	1.0	--	<5
36	.66	--	.55	--	.1	.30	.13	1.9	--	<5
37	.49	--	.73	--	.9	.30	.13	1.6	--	<5
38	.30	--	.23	--	.03	.08	.06	.6	--	<5
39	.70	--	.54	--	.1	.27	.21	1.8	--	<5
40	.62	0.53	0.71	.71	.2	.32	.20	2.1	1.8	<5
41	.66	.41	.57	.45	.1	.37	.13	2.1	1.3	<5
42	.29	.21	.23	.20	.02	.09	.05	.6	.5	<5
43	.58	.66	.81	.78	.8	.27	.20	1.8	1.8	<5
44	.64	--	.71	--	.3	.36	.19	2.1	--	<5
45	.28	--	.21	--	.02	.08	.06	.6	--	<5
45-LD	.36	--	.24	--	.0	.10	.05	.7	--	<5
46	.55	--	.61	--	.3	.30	.13	1.7	--	<5
47	.73	--	.79	--	.6	.39	.19	2.2	--	<5
48	.79	--	.78	--	.2	.39	.19	2.3	--	<5
49	.76	--	.77	--	.3	.38	.20	2.3	--	<5
50	.47	--	.31	--	.04	.11	.08	.8	--	<5
51	.70	--	.58	--	.1	.30	.17	1.9	--	<5
52	.67	--	.66	--	.1	.34	.18	2.1	--	<5
52-D	.67	--	.66	--	.1	.35	.18	2.1	--	<5
53	.63	--	.76	--	.4	.31	.21	2.0	--	<5
54	.64	--	.55	--	.1	.28	.16	1.8	--	<5
54-LD	.68	--	.59	--	.1	.31	.19	2.0	--	<5
54-LD	.69	--	.59	--	.1	.29	.19	1.9	--	<5
55	.69	--	.66	--	.2	.35	.19	2.0	--	<5
55-D	.65	--	.64	--	.1	.35	.15	2.0	--	<5
56	.77	--	.79	--	.6	.44	.18	2.3	--	<5
57	.70	--	.64	--	.1	.31	.21	2.0	--	<5
58	.65	--	.63	--	.1	.34	.16	2.0	--	<5
59	.66	--	.64	--	.2	.31	.17	1.9	--	<5
60	.54	--	.37	--	.1	.19	.10	1.3	--	<5

Table 11. Distribution of inorganic elements in bottom-sediment samples, lower Charles River, Massachusetts, 1998—*Continued*

Station No.	Inorganic elements									
	Calcium		Magnesium		Sodium	Potassium	Phosphorus, total (as P)	Aluminum		Antimony
	XRAL (percent)	USEPA (percent)	XRAL (percent)	USEPA (percent)	XRAL (percent)	XRAL (percent)	XRAL (percent)	XRAL (percent)	USEPA (percent)	XRAL (ppm)
61	0.56	--	0.33	--	0.04	0.15	0.13	1.1	--	<5
61-D	.92	--	.62	--	.1	.27	.21	2.0	--	<5
62	.68	--	.45	--	.1	.23	.23	1.6	--	<5
63	.70	--	.71	--	.2	.35	.19	2.2	--	<5
64	.61	--	.36	--	.1	.17	.13	1.2	--	<5
64-LD	.64	--	.37	--	.1	.17	.16	1.2	--	<5
65	.64	--	.34	--	.04	.16	.15	1.2	--	<5
66	.66	0.32	.43	0.32	.1	.32	.11	1.4	0.8	<5
67	.65	.46	.58	.49	.1	.33	.22	1.9	1.3	<5
68	.66	.47	.75	.64	.3	.44	.21	2.3	1.6	<5
69	.51	.43	.36	.31	.04	.14	.17	1.1	.9	<5
69-LD	.51	--	.36	--	.04	.14	.16	1.1	--	<5
70	.75	--	.69	--	.1	.35	.22	2.2	--	<5
71	.72	--	.63	--	.1	.28	.23	2.0	--	<5
72	.47	.42	.47	.45	.1	.23	.12	1.4	1.2	<5
73	.71	--	.63	--	.1	.30	.23	2.0	--	<5
74	.67	.54	.73	.70	.3	.29	.24	2.1	1.7	<5
75	.71	--	.60	--	.2	.29	.18	1.9	--	<5
75-D	.72	--	.60	--	.2	.28	.19	1.9	--	<5
76	.42	--	.26	--	.03	.11	.05	.8	--	<5
77	.45	--	.28	--	.04	.14	.06	.9	--	<5
78	.63	.53	.70	.66	.2	.29	.24	2.2	1.7	<5
79	.68	--	.65	--	.2	.30	.21	2.0	--	<5
80	.73	.55	.52	.44	.1	.28	.25	1.8	1.2	<5
81	.55	.46	.46	.45	.1	.19	.16	1.4	1.3	<5
82	.77	--	.60	--	.1	.28	.20	2.0	--	<5
83	.91	--	.61	--	.1	.28	.20	2.0	--	<5
84	.78	--	.57	--	.1	.24	.17	1.8	--	<5
85	.86	--	.58	--	.1	.27	.20	2.0	--	<5
86	.89	--	.57	--	.1	.26	.20	1.9	--	<5
87	.89	--	.56	--	.1	.24	.19	1.9	--	<5
88	.89	--	.58	--	.1	.26	.21	1.9	--	<5
89	.75	--	.56	--	.1	.25	.22	1.8	--	<5
90	.64	.58	.46	.44	.1	.18	.21	1.4	1.2	<5
91	.54	.45	.40	.36	.1	.18	.14	1.2	.9	<5
92	.40	--	.23	--	.02	.11	.06	.8	--	<5
93	.39	.30	.29	.26	.03	.09	.08	.7	.6	<5

Table 11. Distribution of inorganic elements in bottom-sediment samples, lower Charles River, Massachusetts, 1998—*Continued*

Station No.	Inorganic elements									
	Calcium		Magnesium		Sodium	Potassium	Phosphorus, total (as P)	Aluminum		Antimony
	XRAL (percent)	USEPA (percent)	XRAL (percent)	USEPA (percent)	XRAL (percent)	XRAL (percent)	XRAL (percent)	XRAL (percent)	USEPA (percent)	XRAL (ppm)
94	0.85	--	0.56	--	0.1	0.25	0.20	1.8	--	<5
95	.77	--	.57	--	.1	.27	.20	2.0	--	<5
96	.80	0.64	.57	0.50	.1	.28	.24	2.0	1.6	<5
96-LD	.84	--	.59	--	.1	.33	.24	2.1	--	<5
97	.88	--	.58	--	.1	.28	.20	2.0	--	<5
98	.67	.57	.50	.45	.1	.20	.16	1.5	1.2	<5
99	.92	--	.62	--	.1	.27	.20	2.1	--	<5
99-LD	.94	--	.63	--	.1	.29	.20	2.1	--	<5
99-LD	.97	--	.66	--	.1	.28	.21	2.2	--	<5
100	.81	--	.55	--	.1	.24	.18	1.8	--	<5
101	.82	--	.64	--	.1	.28	.26	2.2	--	<5
101-D	.89	--	.69	--	.1	.34	.27	2.5	--	<5
102	.91	--	.67	--	.1	.32	.25	2.4	--	<5
102-LD	.96	--	.70	--	.1	.34	.25	2.5	--	<5
103	.87	--	.69	--	.1	.34	.28	2.4	--	<5
104	.85	--	.62	--	.1	.30	.20	2.1	--	<5
105	.82	--	.55	--	.1	.26	.19	1.9	--	<5
106	.69	.60	.59	.56	.1	.24	.21	1.8	1.5	<5
107	.43	--	.30	--	.04	.12	.10	1.0	--	<5
108	.73	--	.46	--	.1	.23	.12	1.6	--	<5
109	.83	--	.61	--	.1	.29	.18	2.0	--	<5
110	.77	--	.46	--	.1	.23	.11	1.6	--	<5
110-LD	.82	--	.47	--	.1	.22	.12	1.6	--	<5
111	.71	--	.62	--	.1	.27	.15	1.9	--	<5
112	.38	--	.23	--	.03	.07	.10	.6	--	<5
113	.86	--	.58	--	.1	.27	.20	2.1	--	<5
114	.88	--	.55	--	.1	.26	.17	2.0	--	<5
114-D	.97	--	.60	--	.1	.27	.21	2.1	--	<5
115	.60	--	.37	--	.04	.15	.10	1.1	--	<5
116	.48	.32	.32	.23	.02	.10	.13	.8	.5	<5
117	.80	--	.56	--	.1	.22	.17	1.8	--	<5
118	.73	.58	.54	.46	.2	.18	.16	1.4	1.1	<5
119	.67	--	.59	--	.1	.26	.13	1.9	--	<5
120	.82	--	.49	--	.1	.20	.11	1.5	--	<5
121	.80	--	.65	--	.1	.28	.18	2.1	--	<5
122	.56	.43	.35	.35	.04	.13	.10	1.0	.9	<5
122-LD	.59	--	.38	--	.04	.14	.11	1.1	--	<5
123	.83	--	.53	--	.1	.20	.09	1.5	--	<5
124	.73	--	.62	--	.1	.33	.16	2.0	--	<5
125	.86	--	.76	--	.1	.34	.22	2.5	--	<5

Table 11. Distribution of inorganic elements in bottom-sediment samples, lower Charles River, Massachusetts, 1998—*Continued*

Station No.	Inorganic elements									
	Calcium		Magnesium		Sodium	Potassium	Phosphorus, total (as P)	Aluminum		Antimony
	XRAL (percent)	USEPA (percent)	XRAL (percent)	USEPA (percent)	XRAL (percent)	XRAL (percent)	XRAL (percent)	XRAL (percent)	USEPA (percent)	XRAL (ppm)
126	0.89	--	0.68	--	0.1	0.28	0.17	2.2	--	<5
127	.90	--	.85	--	.1	.60	.07	2.6	--	<5
127-D	.86	--	.86	--	.1	.61	.08	2.7	--	<5
128	.65	0.46	.48	0.40	.1	.19	.14	1.5	1.0	<5
129	.47	--	.39	--	.1	.12	.10	1.0	--	<5
130	.32	--	.30	--	.03	.08	.06	.7	--	<5
131	.34	--	.35	--	.03	.07	.06	.7	--	<5
132	.26	--	.24	--	.02	.06	.04	.5	--	<5
133	.21	--	.25	--	.02	.05	.04	.5	--	<5
133-D	.42	--	.74	--	.5	.43	.10	2.0	--	<5
134	.56	--	.51	--	.04	.07	.06	1.0	--	<5
135	.24	--	.22	--	.02	.06	.05	.5	--	<5
136	.24	.37	.21	.44	.02	.06	.07	.5	1.0	<5
137	.70	.55	.70	.63	.1	.23	.14	2.0	1.6	<5
138	.69	.51	.70	.65	.1	.23	.16	2.1	1.6	<5
138-LD	.69	--	.71	--	.1	.23	.17	2.0	--	6.0
139	.60	.50	.63	.65	.2	.24	.18	1.8	1.5	<5
140	.65	.51	.60	.59	.2	.23	.15	1.7	1.4	<5
141	.59	.44	.50	.51	.2	.17	.09	1.2	1.1	<5
142	.56	.44	.71	.65	.1	.44	.10	2.2	1.7	<5
143	.62	.47	.82	.71	.1	.54	.10	2.7	2.0	<5
144	.58	.42	.70	.51	.1	.38	.08	2.0	1.4	<5
145	.73	.41	.41	.37	.1	.20	.11	1.1	.9	<5
146	.38	.24	.32	.27	.02	.11	.06	.7	.7	<5
147	.53	.43	.39	.38	.1	.14	.09	1.0	.9	<5

Station No.	Inorganic elements										
	Arsenic		Barium		Beryllium		Bismuth	Cadmium		Chromium	
	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)	USEPA (ppm)
1	<3	<23.6	147	128	1.2	1.0	<5	10.0	8.2	155	150
2	9.0	<20	160	164	<.5	1.4	<5	13.0	12.1	206	200
3	21	<40	462	423	1.5	1.1	<5	38	30	177	157
4	6	<20	141	149	<.5	1.4	<5	7	6	130	115
5	16	--	192	--	<.5	--	<5	9	--	158	--
5-D	15	--	180	--	<.5	--	<5	8	--	140	--

Table 11. Distribution of inorganic elements in bottom sediment samples, Charles River, Massachusetts, 1998—*Continued*

Station No.	Inorganic elements										
	Arsenic		Barium		Beryllium		Bismuth	Cadmium		Chromium	
	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)	USEPA (ppm)
6	7	--	85	--	<0.5	--	<5	5	--	96	--
6-D	4	--	94	--	<.5	--	<5	6	--	106	--
7	4	--	133	--	<.5	--	<5	4	--	88	--
8	<3	<20	134	107	1.4	1.1	<5	9	5.1	109	94
9	7	<20.2	95	100	<.5	1.4	<5	5	5.4	108	102
10	<3	--	105	--	<.5	--	<5	5	--	99	--
11	11	--	114	--	<.5	--	<5	5	--	96	--
11-LD	8	--	104	--	<.5	--	<5	5	--	90	--
12	6	--	113	--	<.5	--	<5	5	--	96	--
13	10	<20.2	185	193	<.5	1.7	<5	11	10.8	134	126
14	5	<19.6	157	123	<.5	1.4	<5	8	5.2	106	98
15	6	<20.2	123	167	<.5	1.1	<5	6	13	100	104
16	9	--	154	--	<.5	--	<5	6	--	109	--
17	7	--	177	--	<.5	--	<5	8	--	123	--
18	6	--	652	--	<.5	--	<5	7	--	89	--
19	<3	--	39	--	<.5	--	<5	<1	--	21	--
20	7	<19.6	134	127	<.5	1.1	<5	5	5.4	82	70
21	4	--	134	--	<.5	--	<5	4	--	79	--
21-D	<3	--	119	--	<.5	--	<5	4	--	82	--
22	4	<9.8	61	69	<.5	<.6	<5	2	<2.9	30	26
23	<3	--	241	--	<.5	--	<5	11	--	199	--
24	<3	--	225	--	<.5	--	<5	9	--	154	--
24-LD	10	--	240	--	<.5	--	<5	10	--	162	--
24-LD	8	--	257	--	<.5	--	<5	10	--	175	--
25	6	--	166	--	<.5	--	<5	6	--	106	--
26	5	--	161	--	<.5	--	<5	7	--	113	--
27	6	--	161	--	<.5	--	<5	5	--	94	--
27-D	<3	--	177	--	<.5	--	<5	5	--	88	--
28	4	--	133	--	<.5	--	<5	5	--	85	--
29	<3	<12	130	86	1.3	.8	<5	3	2	56	40
30	5	--	146	--	<.5	--	<5	5	--	90	--
31	4	--	47	--	<.5	--	<5	<1	--	26	--
32	<3	--	49	--	<.5	--	<5	3	--	31	--
32-LD	<3	--	50	--	<.5	--	<5	3	--	28	--
33	<3	--	18	--	<.5	--	<5	<1	--	14	--
33-LD	<3	--	17	--	<.5	--	<5	<1	--	16	--
34	<3	--	47	--	<.5	--	<5	1	--	25	--
35	4	--	90	--	<.5	--	<5	3	--	59	--
36	<3	--	169	--	<.5	--	<5	9	--	103	--
37	3	--	142	--	<.5	--	<5	7	--	101	--
38	4	--	40	--	<.5	--	<5	1	--	23	--

Table 11. Distribution of inorganic elements in bottom sediment samples, Charles River, Massachusetts, 1998—*Continued*

Station No.	Inorganic elements										
	Arsenic		Barium		Beryllium		Bismuth	Cadmium		Chromium	
	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)	USEPA (ppm)
39	3	--	252	--	<0.5	--	<5	6	--	95	--
40	9	<20.2	216	231	<.5	1.4	<5	10	9.9	153	154
41	<3	<15	152	128	1.2	1.1	<5	15	12	106	96
42	<3	<10.1	27	25	<.5	<.5	<5	<1	<1.5	14	13
43	6	<20.4	182	195	<.5	1.3	<5	7	5.6	185	93
44	3	--	429	--	<.5	--	<5	6	--	102	--
45	<3	--	37	--	<.5	--	<5	3	--	22	--
45-LD	<3	--	42	--	<.5	--	<5	3	--	24	--
46	<3	--	159	--	<.5	--	<5	5	--	83	--
47	<3	--	202	--	<.5	--	<5	7	--	103	--
48	4	--	237	--	<.5	--	<5	9	--	161	--
49	<3	--	218	--	<.5	--	<5	7	--	112	--
50	4	--	131	--	<.5	--	<5	11	--	137	--
51	5	--	238	--	<.5	--	<5	8	--	108	--
52	<3	--	238	--	<.5	--	<5	8	--	109	--
52-D	4	--	249	--	<.5	--	<5	8	--	108	--
53	6	--	211	--	<.5	--	<5	7	--	95	--
54	<3	--	226	--	<.5	--	<5	7	--	142	--
54-LD	<3	--	255	--	<.5	--	<5	8	--	111	--
54-LD	<3	--	251	--	<.5	--	<5	8	--	112	--
55	3	--	236	--	<.5	--	<5	8	--	146	--
55-D	<3	--	222	--	<.5	--	<5	8	--	142	--
56	<3	--	183	--	<.5	--	<5	6	--	106	--
57	<3	--	244	--	<.5	--	<5	7	--	113	--
58	<3	--	240	--	<.5	--	<5	16	--	190	--
59	<3	--	215	--	<.5	--	<5	6	--	103	--
60	<3	--	191	--	<.5	--	<5	5	--	73	--
61	<3	--	193	--	<.5	--	<5	7	--	184	--
61-D	3	--	250	--	1.2	--	<5	12	--	122	--
62	<3	--	216	--	<.5	--	<5	5	--	89	--
63	7	--	231	--	<.5	--	<5	7	--	145	--
64	<3	--	207	--	<.5	--	<5	8	--	84	--
64-LD	4	--	218	--	<.5	--	<5	8	--	92	--
65	<3	--	188	--	<.5	--	<5	4	--	86	--
66	<3	<12	150	128	1	.6	<5	6	3.1	51	35
67	3	<20	240	211	1.2	1	<5	7	5.5	88	68
68	5	<30	286	246	1.5	1.1	<5	11	7.8	124	102
69	7	<12	149	143	<.5	.7	<5	4	3	53	52
69-LD	3	--	143	--	<.5	--	<5	3	--	53	--
70	4	--	259	--	<0.5	--	<5	8	--	124	--
71	<3	--	245	--	<.5	--	<5	7	--	106	--
72	5	<20	166	179	<.5	1.2	<5	8	8.6	100	104
73	4	--	249	--	<.5	--	<5	7	--	100	--
74	4	<19.6	254	264	<.5	1.3	<5	8	8	114	106

Table 11. Distribution of inorganic elements in bottom sediment samples, Charles River, Massachusetts, 1998—*Continued*

Station No.	Inorganic elements										
	Arsenic		Barium		Beryllium		Bismuth	Cadmium		Chromium	
	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)	USEPA (ppm)
75	<3	--	224	--	<.5	--	<5	8	--	108	--
75-D	3	--	225	--	<.5	--	<5	7	--	103	--
76	<3	--	63	--	<.5	--	<5	3	--	31	--
77	<3	--	84	--	<.5	--	<5	4	--	99	--
78	8	<20.4	253	253	<.5	1.3	<5	8	7.5	113	104
79	<3	--	229	--	<.5	--	<5	7	--	137	--
80	<3	<20	364	353	1.1	1	<5	10	8.6	111	105
81	5	<15	170	188	<.5	1	<5	7	8	79	82
82	<3	--	288	--	<.5	--	<5	8	--	119	--
83	<3	--	248	--	1.3	--	<5	12	--	119	--
84	<3	--	207	--	1.1	--	<5	11	--	102	--
85	<3	--	304	--	1.3	--	<5	12	--	121	--
86	<3	--	352	--	1.2	--	<5	12	--	123	--
87	<3	--	258	--	1.2	--	<5	13	--	115	--
88	<3	--	295	--	1.2	--	<5	12	--	118	--
89	<3	--	241	--	1.1	--	<5	16	--	145	--
90	4	<20	340	386	<.5	1.1	<5	8	8.8	104	104
91	5	<10	217	200	<.5	.9	<5	12	11.8	124	111
92	<3	--	251	--	.5	--	<5	4	--	47	--
93	<3	<9.6	111	96	<.5	.5	<5	3	<3	37	46
94	<3	--	242	--	1.2	--	<5	13	--	124	--
95	<3	--	234	--	1.2	--	<5	12	--	114	--
96	4	<22	239	237	1.2	1.2	<5	11	9	107	103
96-LD	<3	--	248	--	1.3	--	<5	11	--	112	--
97	<3	--	313	--	1.2	--	<5	12	--	135	--
98	<3	<20	194	204	<.5	1	<5	7	7	162	111
99	4	--	240	--	1.3	--	<5	13	--	120	--
99-LD	<3	--	246	--	1.3	--	<5	13	--	124	--
99-LD	4	--	254	--	1.4	--	<5	14	--	129	--
100	<3	--	225	--	1.1	--	<5	16	--	131	--
101	3	--	251	--	1.4	--	<5	13	--	133	--
101-D	<3	--	272	--	1.5	--	<5	14	--	133	--
102	<3	--	290	--	1.4	--	<5	15	--	135	--
102-LD	<3	--	303	--	1.5	--	<5	16	--	144	--
103	<3	--	283	--	1.4	--	<5	17	--	145	--
104	<3	--	248	--	1.3	--	<5	14	--	126	--
105	4	--	215	--	1.1	--	<5	11	--	107	--
106	<3	<104	229	240	<.5	1.4	<5	10	10.9	111	112
107	19	--	129	--	1.5	--	<5	6	--	51	--
108	3	--	172	--	1	--	<5	9	--	87	--

Table 11. Distribution of inorganic elements in bottom sediment samples, Charles River, Massachusetts, 1998—*Continued*

Station No.	Inorganic elements										
	Arsenic		Barium		Beryllium		Bismuth	Cadmium		Chromium	
	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)	USEPA (ppm)
109	7	--	222	--	1.3	--	<5	22	--	164	--
110	<3	--	248	--	1	--	<5	10	--	82	--
110-LD	<3	--	242	--	1	--	<5	9	--	85	--
111	15	--	233	--	1.3	--	9	9	--	125	--
112	3	--	121	--	<.5	--	<5	3	--	72	--
113	4	--	234	--	1.2	--	<5	13	--	134	--
114	<3	--	220	--	1.2	--	<5	12	--	113	--
114-D	3	--	244	--	1.3	--	<5	14	--	126	--
115	<3	--	122	--	.7	--	<5	8	--	70	--
116	<3	<10.2	86	60	<.5	.3	<5	2	1.7	37	28
117	<3	--	219	--	1.1	--	<5	13	--	111	--
118	5	<18.9	180	191	<.5	.8	<5	7	6.1	76	71
119	18	--	196	--	1.3	--	<5	10	--	166	--
120	<3	--	188	--	1	--	<5	11	--	91	--
121	20	--	254	--	1.3	--	5	16	--	160	--
122	5	<22.5	140	145	<.5	.7	<5	6	6.1	62	61
122-LD	<3	--	149	--	<.5	--	<5	6	--	64	--
123	<3	--	147	--	.9	--	<5	11	--	88	--
124	9	--	210	--	1.2	--	<5	71	--	258	--
125	8	--	245	--	1.4	--	<5	31	--	194	--
126	8	--	196	--	1.2	--	<5	26	--	161	--
127	<3	--	125	--	1.3	--	<5	4	--	61	--
127-D	<3	--	132	--	1.3	--	<5	4	--	61	--
128	5	<18.5	184	166	<.5	.7	<5	16	14	122	106
129	<3	--	129	--	<.5	--	<5	6	--	65	--
130	6	--	59	--	<.5	--	<5	2	--	567	--
131	<3	--	34	--	<.5	--	<5	<1	--	25	--
132	<3	--	25	--	<.5	--	<5	<1	--	15	--
133	<3	--	26	--	<.5	--	<5	<1	--	16	--
133-D	6	--	158	--	<.5	--	<5	13	--	204	--
134	<3	--	31	--	<.5	--	<5	<1	--	18	--
135	7	--	27	--	<.5	--	<5	<1	--	16	--
136	<3	<18.8	74	140	<.5	.8	<5	5	13.8	46	109
137	14	<103	168	153	<.5	1.1	<5	10	9.8	202	200
138	13	<104	184	183	<.5	1.2	<5	12	13.8	266	232
138-LD	16	--	187	--	<.5	--	<5	13	--	269	--
139	<3	<104	239	255	<0.5	1.3	<5	38	43.2	227	220
140	5	<105	233	210	<.5	1.3	<5	31	34.1	199	201
141	3	<25	79	96	<.5	.9	<5	7	9.5	81	97
142	<3	<25	130	96	<.5	1.1	<5	8	5.7	103	73
143	7	<25	160	128	<.5	1.5	<5	8	7.5	107	92

Table 11. Distribution of inorganic elements in bottom sediment samples, Charles River, Massachusetts, 1998—*Continued*

Station No.	Inorganic elements										
	Arsenic		Barium		Beryllium		Bismuth	Cadmium		Chromium	
	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)	USEPA (ppm)
144	3	<20	110	86	<.5	1.1	<5	7	7.1	88	74
145	7	<16.5	81	580	<.5	.6	<5	2	1.9	153	45
146	<3	<10.3	50	49	<.5	.4	<5	2	2.2	39	33
147	<3	<20	102	136	<.5	.7	<5	11	14.6	103	127

Station No.	Inorganic elements										
	Cobalt		Copper		Iron		Lanthanum	Lead		Manganese	
	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)	USEPA (ppm)	XRAL (percent)	USEPA (percent)	XRAL (ppm)	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)	USEPA (ppm)
1	11	12.7	315	327	3.1	3	19.3	887	790	342	296
2	12	12.2	511	522	3	2.6	19.4	517	508	392	346
3	10	11	649	602	3.5	2.8	17.3	1,300	1,140	333	238
4	15	15.6	413	413	5	4.5	19.1	967	905	499	462
5	13	--	401	--	3.1	--	20.3	846	--	360	--
5-D	11	--	335	--	2.7	--	18	762	--	308	--
6	14	--	306	--	4.2	--	17.2	715	--	397	--
6-D	16	--	343	--	4.6	--	18.9	792	--	436	--
7	11	--	323	--	2.1	--	16.7	524	--	276	--
8	13	14.6	325	326	4.5	4.3	18.1	741	699	291	242
9	16	17.4	341	354	4.9	4.8	19.1	730	724	384	375
10	14	--	298	--	4.8	--	19	670	--	325	--
11	13	--	292	--	4.4	--	18.4	707	--	392	--
11-LD	13	--	271	--	4.1	--	16.9	673	--	372	--
12	13	--	275	--	4.6	--	18.9	654	--	333	--
13	14	14.7	417	428	3.6	3.2	22.9	889	836	423	403
14	16	16.4	341	326	3.7	4.6	16.6	602	739	402	342
15	14	14.2	295	368	4.9	3.2	18.1	714	654	342	384
16	15	--	288	--	3.8	--	20.9	678	--	449	--
17	17	--	387	--	4.3	--	20.1	765	--	570	--
18	25	--	213	--	7.3	--	8.3	4,690	--	488	--
19	5	--	39	--	1.2	--	10.8	89	--	232	--
20	11	12.4	226	210	3	2.5	19.1	538	522	396	342
21	12	--	203	--	3.1	--	17.4	456	--	387	--
21-D	10	--	189	--	2.8	--	16.1	422	--	356	--
22	6	6.1	278	98	1.5	1.4	13.1	117	129	245	201
23	16	--	480	--	3.2	--	20.3	1,050	--	505	--
24	15	--	419	--	3.5	--	20.5	814	--	624	--
24-LD	16	--	435	--	3.7	--	21.3	845	--	649	--
24-LD	16	--	447	--	3.9	--	23.6	885	--	689	--
25	16	--	285	--	4.1	--	20.5	638	--	469	--

Table 11. Distribution of inorganic elements in bottom sediment samples, Charles River, Massachusetts, 1998—*Continued*

Station No.	Inorganic elements										
	Cobalt		Copper		Iron		Lantha-num	Lead		Manganese	
	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)	USEPA (ppm)	XRAL (percent)	USEPA (percent)	XRAL (ppm)	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)	USEPA (ppm)
26	13	--	321	--	3.1	--	17.5	715	--	435	--
27	11	--	255	--	3.2	--	17.7	516	--	485	--
27-D	10	--	261	--	3.1	--	16.4	495	--	412	--
28	13	--	223	--	3.8	--	17.5	528	--	397	--
29	14	13.4	75	67	3	2.4	30.1	109	98	498	364
30	13	--	244	--	4.1	--	18.4	575	--	433	--
31	6	--	25	--	1.8	--	14	29	--	291	--
32	10	--	73	--	1.5	--	12.1	155	--	224	--
32-LD	9	--	67	--	1.5	--	11.2	180	--	209	--
33	6	--	7	--	1	--	11.9	10	--	164	--
33-LD	7	--	7	--	1.2	--	10.4	10	--	179	--
34	5	--	45	--	1.7	--	11.9	58	--	337	--
35	9	--	162	--	2.1	--	13.1	279	--	277	--
36	13	--	254	--	3	--	19.3	645	--	464	--
37	13	--	305	--	4.2	--	18	721	--	406	--
38	5	--	76	--	1	--	13.4	65	--	272	--
39	13	--	273	--	3.1	--	20.2	768	--	445	--
40	15	16.5	428	471	3.9	3.7	20.3	1,030	1,050	506	538
41	13	13	299	289	2.8	2.4	23.3	482	470	405	331
42	4	4.4	25	25	1	.9	13.1	34	35	202	192
43	15	15.2	293	296	4.1	3.7	18.5	680	658	458	450
44	14	--	270	--	4.1	--	20.1	624	--	476	--
45	5	--	54	--	1	--	10.8	90	--	200	--
45-LD	6	--	51	--	1.1	--	13.8	83	--	217	--
46	11	--	228	--	3.3	--	16.3	559	--	369	--
47	14	--	291	--	4.2	--	20.9	698	--	487	--
48	17	--	381	--	4.4	--	22.1	885	--	566	--
49	16	--	314	--	4.4	--	21.1	706	--	466	--
50	12	--	963	--	2	--	10.9	512	--	278	--
51	13	--	294	--	3.3	--	19.9	807	--	511	--
52	13	--	306	--	3.6	--	20.2	786	--	506	--
52-D	12	--	302	--	3.6	--	21.1	778	--	494	--
53	11	--	272	--	3.7	--	19.3	629	--	481	--
54	11	--	292	--	3.2	--	19	810	--	456	--
54-LD	13	--	313	--	3.5	--	20.4	868	--	492	--
54-LD	11	--	309	--	3.5	--	20.5	871	--	489	--
55	15	--	444	--	3.8	--	19.8	868	--	554	--
55-D	14	--	437	--	3.6	--	20	840	--	544	--
56	15	--	277	--	4.6	--	21.4	676	--	523	--
57	13	--	339	--	3.4	--	19.2	761	--	498	--
58	14	--	466	--	3.8	--	21.4	1,220	--	501	--
59	12	--	273	--	3.5	--	19	702	--	471	--
60	11	--	207	--	2.3	--	16	857	--	300	--

Table 11. Distribution of inorganic elements in bottom sediment samples, Charles River, Massachusetts, 1998—*Continued*

Station No.	Inorganic elements										
	Cobalt		Copper		Iron		Lanthanum	Lead		Manganese	
	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)	USEPA (ppm)	XRAL (percent)	USEPA (percent)	XRAL (ppm)	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)	USEPA (ppm)
61	10	--	214	--	2.1	--	16	897	--	291	--
61-D	15	--	251	--	3.5	--	23	737	--	692	--
62	11	--	252	--	2.8	--	17.6	763	--	430	--
63	14	--	396	--	4	--	20.7	820	--	554	--
64	10	--	236	--	2.2	--	15.9	967	--	345	--
64-LD	12	--	240	--	2.4	--	17.3	1,020	--	363	--
65	10	--	198	--	2.3	--	16	734	--	335	--
66	10	9.8	116	112	2.1	1.6	17.2	465	358	300	209
67	11	11.6	281	276	2.7	2.4	21.2	759	709	432	382
68	13	13.9	387	370	3.9	3.5	21.7	937	824	578	511
69	9	9.1	201	181	2.2	1.8	15	678	610	293	263
69-LD	9	--	194	--	2.1	--	13.8	601	--	287	--
70	15	--	337	--	4.1	--	22.1	834	--	606	--
71	13	--	278	--	3.3	--	20.8	705	--	504	--
72	10	11.3	240	272	2.3	2.3	15.8	585	632	340	353
73	13	--	289	--	3.4	--	20.8	767	--	480	--
74	13	14.4	299	300	3.5	3.2	20.7	600	605	565	570
75	12	--	247	--	3	--	19.4	549	--	496	--
75-D	12	--	250	--	3.1	--	19.1	547	--	498	--
76	5	--	63	--	1.3	--	13.9	146	--	228	--
77	8	--	87	--	1.6	--	14.1	218	--	252	--
78	14	14.3	298	291	3.6	3.2	20.3	635	608	528	541
79	14	--	331	--	3.5	--	21.2	613	--	494	--
80	12	14.3	367	379	2.6	2.4	21.5	702	679	512	475
81	11	13.4	319	366	2.4	2.4	16.4	406	424	444	468
82	14	--	252	--	3.4	--	20.6	565	--	630	--
83	14	--	245	--	3.5	--	22.6	722	--	680	--
84	14	--	201	--	3.1	--	19.9	475	--	579	--
85	14	--	240	--	3.3	--	21.8	576	--	654	--
86	15	--	306	--	3.1	--	21.4	672	--	598	--
87	15	--	233	--	3.3	--	21.2	550	--	605	--
88	16	--	281	--	3.1	--	20.4	642	--	676	--
89	16	--	347	--	3.3	--	19.2	985	--	611	--
90	11	13.9	344	393	2.5	2.4	17	653	722	442	469
91	12	12.2	431	392	2.6	2.2	15.4	658	652	367	354
92	7	--	86	--	1.4	--	12.8	573	--	224	--
93	8	7.3	120	103	1.7	1.4	13.4	503	463	231	197
94	15	--	305	--	3.3	--	21.2	794	--	628	--
95	13	--	237	--	3.2	--	21.2	617	--	731	--
96	13	15	225	232	3	3	22.4	511	502	675	648
96-LD	14	--	228	--	3.1	--	23.4	516	--	680	--
97	15	--	278	--	3.2	--	22.3	630	--	609	--

Table 11. Distribution of inorganic elements in bottom sediment samples, Charles River, Massachusetts, 1998—*Continued*

Station No.	Inorganic elements										
	Cobalt		Copper		Iron		Lantha-num	Lead		Manganese	
	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)	USEPA (ppm)	XRAL (percent)	USEPA (percent)	XRAL (ppm)	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)	USEPA (ppm)
98	13	12.7	200	188	3.3	3	18.6	708	600	581	647
99	15	--	223	--	3.5	--	22.4	565	--	784	--
99-LD	15	--	224	--	3.6	--	23.4	572	--	789	--
99-LD	16	--	233	--	3.7	--	24.1	602	--	812	--
100	14	--	343	--	3.2	--	19.5	837	--	640	--
101	16	--	241	--	3.7	--	23.2	631	--	953	--
101-D	16	--	254	--	3.9	--	24.9	669	--	1040	--
102	17	--	271	--	3.7	--	24	681	--	965	--
102-LD	17	--	280	--	3.9	--	26	717	--	1020	--
103	17	--	285	--	3.8	--	23.9	855	--	1010	--
104	16	--	260	--	3.3	--	22	714	--	792	--
105	15	--	187	--	3.1	--	20.8	489	--	709	--
106	12	14.5	244	257	3.2	3.3	20.3	679	786	719	801
107	15	--	7340	--	3.5	--	13.3	214	--	299	--
108	12	--	135	--	2.7	--	19.5	383	--	589	--
109	16	--	511	--	3.4	--	20.6	1,000	--	663	--
110	12	--	141	--	2.6	--	19.4	377	--	560	--
110-LD	13	--	153	--	2.7	--	19.9	380	--	571	--
111	14	--	374	--	3.1	--	17.4	1,020	--	517	--
112	6	--	168	--	1.1	--	9.8	324	--	265	--
113	16	--	207	--	3.4	--	21.8	526	--	854	--
114	14	--	191	--	3.2	--	21.6	508	--	781	--
114-D	15	--	211	--	3.6	--	23.4	569	--	846	--
115	10	--	251	--	1.9	--	11.4	444	--	385	--
116	6	5	182	170	1.3	1	9	216	245	201	151
117	15	--	180	--	2.9	--	20	530	--	744	--
118	13	13.5	149	140	2.8	2.6	16.9	338	369	843	894
119	14	--	258	--	2.9	--	19.7	820	--	410	--
120	14	--	135	--	2.8	--	19.8	477	--	564	--
121	14	--	280	--	3.1	--	20.3	810	--	530	--
122	10	11.1	121	126	2.1	2	15.2	366	391	441	433
122-LD	12	--	130	--	2.2	--	15.4	390	--	451	--
123	15	--	124	--	2.6	--	18.6	710	--	491	--
124	14	--	385	--	3.1	--	19.2	762	--	493	--
125	17	--	330	--	3.6	--	23.2	944	--	616	--
126	16	--	197	--	3.3	--	21.6	1,140	--	640	--
127	20	--	28	--	3.9	--	25.7	56	--	571	--
127-D	21	--	26	--	3.7	--	27.6	49	--	588	--
128	13	12.8	193	144	2.7	2.3	18.2	571	551	545	517
129	12	--	108	--	2.1	--	14.5	424	--	426	--

Table 11. Distribution of inorganic elements in bottom sediment samples, Charles River, Massachusetts, 1998—*Continued*

Station No.	Inorganic elements										
	Cobalt		Copper		Iron		Lantha-num	Lead		Manganese	
	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)	USEPA (ppm)	XRAL (percent)	USEPA (percent)	XRAL (ppm)	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)	USEPA (ppm)
130	9	--	48	--	1.6	--	10.5	179	--	228	--
131	6	--	35	--	1.5	--	11.7	80	--	264	--
132	4	--	12	--	.9	--	7.7	43	--	174	--
133	4	--	14	--	1	--	7	106	--	215	--
133-D	11	--	507	--	2.9	--	18.4	501	--	383	--
134	9	--	16	--	1.9	--	12	35	--	429	--
135	5	--	12	--	1.9	--	11.8	58	--	278	--
136	4	11.8	58	150	1.5	2.7	6.7	166	477	137	305
137	15	15	223	206	3.2	2.8	20.7	644	684	451	404
138	13	15.2	244	226	3.1	2.9	20.1	700	761	413	378
138-LD	15	--	245	--	3.2	--	20.4	720	--	415	--
139	14	14.9	610	700	3.3	3.2	18.2	845	993	421	448
140	13	15.5	529	527	3.1	3	17.7	842	928	546	560
141	12	14.4	150	185	2.5	2.8	14.1	291	403	343	370
142	12	13.6	236	154	3.3	2.9	22.7	439	346	372	336
143	15	16.2	248	215	3.6	3.2	25.4	511	508	394	354
144	12	11.5	205	180	2.9	2.3	21.3	383	387	341	272
145	15	8	142	76	4.9	2.1	14	178	170	376	225
146	6	5.6	53	55	1.4	1.2	10	149	153	196	192
147	8	8.8	205	286	2	2.1	12.9	498	689	253	246

Station No.	Inorganic elements											
	Mercury		Molyb-denum	Nickel		Scandium		Silver		Stron-tium	Tin	
	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)	XRAL (ppm)	USEPA (ppm)
1	6	2.1	11	39	38.8	4.1	<11.8	12	13	76.6	32	<12
2	<1	2.1	7	50	46.5	4.3	<10	15.6	15	45.3	<10	<10
3	2	7	9	53	41.7	4.7	<9.9	24.1	17	114	104	<10
4	2	1.9	10	53	48.4	3.9	<12	11.3	10	65.2	23	<10
5	<1	--	8	54	--	4.9	--	6.9	--	63.4	17	--
5-D	4	--	8	47	--	4.2	--	6.4	--	55	11	--
6	<1	--	10	39	--	3.2	--	5.3	--	55.7	17	--
6-D	<1	--	13	45	--	3.5	--	6	--	58.1	18	--
7	2	--	5	47	--	2.1	--	5.1	--	35.8	<10	--
8	2	2.2	19	42	34.9	4.4	<10.5	7.7	8	77.6	24	<10
9	<1	1.9	18	48	46	4.2	<10.1	5.3	4	65.9	13	<10

Table 11. Distribution of inorganic elements in bottom sediment samples, Charles River, Massachusetts, 1998—*Continued*

Station No.	Inorganic elements											
	Mercury		Molybdenum	Nickel		Scandium		Silver		Strontium	Tin	
	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)	XRAL (ppm)	USEPA (ppm)
10	<1	--	21	41	--	3.7	--	4.5	--	71.7	19	--
11	<1	--	13	41	--	3.4	--	4.2	--	60.2	21	--
11-LD	<1	--	13	38	--	3.3	--	3.7	--	56.8	18	--
12	<1	--	14	37	--	3.7	--	4.1	--	72	13	--
13	1	3	5	75	67.7	4.6	<10.1	5.1	4	69	<10	<10
14	2	1.5	5	47	39.9	3.5	<9.8	7.6	6	51.1	20	<10
15	2	3.3	15	39	44.9	3.9	<10.1	5.0	6	75.2	12	<10
16	<1	--	6	47	--	4.3	--	4	--	69.2	<10	--
17	3	--	10	48	--	4.1	--	5.5	--	57.8	19	--
18	<1	--	2	39	--	.7	--	.4	--	30.9	15	--
19	<1	--	<1	11	--	1.4	--	.3	--	16.3	<10	--
20	<1	1.3	2	50	41.2	4.4	<9.8	1.8	2	47.9	<10	<10
21	<1	--	5	35	--	3.4	--	3.3	--	47.8	<10	--
21-D	<1	--	5	35	--	3.1	--	3	--	44.3	<10	--
22	<1	.7	<1	18	15.1	2	<9.8	.7	<2	29.6	<10	<10
23	<1	--	3	57	--	3.8	--	13	--	55.8	12	--
24	<1	--	3	51	--	3.8	--	8	--	49.9	13	--
24-LD	<1	--	3	53	--	4.2	--	8.5	--	53.3	14	--
24-LD	<1	--	4	57	--	4.7	--	8.9	--	57.1	18	--
25	<1	--	10	43	--	4.2	--	4.4	--	60.9	11	--
26	<1	--	4	43	--	2.9	--	6.3	--	48.3	14	--
27	3	--	4	38	--	3.3	--	4.3	--	48.2	<10	--
27-D	1	--	4	35	--	3	--	4	--	45.2	<10	--
28	<1	--	9	32	--	3.6	--	3.7	--	63.9	<10	--
29	<1	.3	1	33	24.4	6.5	<10	.9	<3	48.4	<10	<10
30	<1	--	9	35	--	3.6	--	4	--	69.6	12	--
31	<1	--	<1	13	--	2.5	--	.4	--	22.5	<10	--
32	<1	--	<1	21	--	1.8	--	.5	--	26	<10	--
32-LD	<1	--	<1	21	--	2	--	.4	--	29	<10	--
33	<1	--	<1	12	--	1.4	--	<.2	--	21.1	<10	--
33-LD	<1	--	<1	14	--	1.4	--	<.2	--	26.1	<10	--
34	<1	--	<1	13	--	1.8	--	.5	--	16	<10	--
35	<1	--	1	26	--	2.2	--	2.7	--	35.2	<10	--
36	1	--	2	53	--	4.5	--	4.4	--	61.5	19	--
37	<1	--	8	39	--	3.3	--	6.7	--	65	16	--
38	1	--	<1	12	--	1.5	--	.5	--	21.3	<10	--
39	<1	--	4	38	--	3.7	--	3.3	--	62.5	11	--
40	2	2.5	8	56	55.7	4.1	<10.1	9.4	5	62.2	12	<10
41	<1	1.7	1	51	41.2	4.9	<10.5	3.8	4	60.1	26	<10
42	5	<.12	<1	8	6.9	1.5	<10.1	<.2	2	17.4	<10	<10
43	2	1.4	9	72	36.8	3	<10.2	4.3	4	65.6	<10	<10

Table 11. Distribution of inorganic elements in bottom sediment samples, Charles River, Massachusetts, 1998—*Continued*

Station No.	Inorganic elements											
	Mercury		Molybdenum	Nickel		Scandium		Silver		Strontium	Tin	
	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)	XRAL (ppm)	USEPA (ppm)
44	<1	--	6	38	--	4.5	--	4.1	--	67.6	12	--
45	<1	--	<1	11	--	1.3	--	.6	--	20.6	<10	--
45-LD	<1	--	<1	12	--	1.7	--	.4	--	23.7	<10	--
46	<1	--	5	32	--	3.7	--	3.6	--	61.5	<10	--
47	<1	--	6	41	--	4.6	--	4.5	--	78.4	13	--
48	<1	--	6	62	--	5	--	7.1	--	74	23	--
49	3	--	6	43	--	4.8	--	4.9	--	77.4	17	--
50	<1	--	1	127	--	2.3	--	2	--	55.1	12	--
51	<1	--	4	42	--	4	--	4.3	--	64.1	10	--
52	2	--	3	41	--	4.3	--	4.7	--	70.4	14	--
52-D	<1	--	4	41	--	4.3	--	4.6	--	71.1	<10	--
53	<1	--	4	39	--	3.7	--	4	--	68.5	<10	--
54	1	--	4	56	--	3.9	--	4.4	--	61.4	14	--
54-LD	<1	--	3	44	--	4.1	--	4.6	--	66.3	20	--
54-LD	<1	--	3	44	--	4	--	4.7	--	65.1	17	--
55	<1	--	4	59	--	4.5	--	7.4	--	67.2	18	--
55-D	<1	--	4	57	--	4.5	--	7.3	--	64.9	11	--
56	2	--	11	40	--	5	--	4.2	--	74.4	15	--
57	<1	--	12	55	--	3.9	--	6.7	--	65	20	--
58	<1	--	6	74	--	4.4	--	9	--	68.3	18	--
59	<1	--	4	41	--	4	--	4.4	--	65	<10	--
60	<1	--	<1	37	--	3	--	2	--	57	<10	--
61	<1	--	4	79	--	2.6	--	4.1	--	56.3	10	--
61-D	1	--	2	45	--	4.7	--	3	--	70.5	<10	--
62	3	--	2	38	--	3.1	--	3.3	--	53.6	14	--
63	<1	--	6	51	--	4.5	--	5.8	--	68.6	16	--
64	<1	--	2	39	--	2.7	--	2.9	--	60.3	<10	--
64-LD	<1	--	2	44	--	2.9	--	3	--	61.3	14	--
65	2	--	2	37	--	2.4	--	1.9	--	51.5	<10	--
66	<1	.8	1	32	23.6	3.8	<8.1	5.8	<2	67.2	14	<8
67	<1	2.7	4	38	30.8	4.1	<9.4	3.6	4	69.5	23	<9
68	2	2.8	5	50	39.7	4.7	<10.6	6.3	7	75.4	23	<11
69	4	1.4	2	30	27.3	1.8	<9.3	1.8	2	43.3	<10	<9
69-LD	2	--	1	30	--	1.5	--	1.7	--	42.8	<10	--
70	2	--	4	48	--	4.6	--	5.1	--	69.1	20	--
71	2	--	3	39	--	3.9	--	4.3	--	65	13	--
72	2	1.8	2	37	40.2	3	<10	5.7	7	42.1	<10	<10
73	2	--	3	40	--	4	--	4	--	67.9	14	--
74	<1	1.7	3	40	35.8	3.8	<9.8	5.3	6	66.6	<10	<10

Table 11. Distribution of inorganic elements in bottom sediment samples, Charles River, Massachusetts, 1998—*Continued*

Station No.	Inorganic elements											
	Mercury		Molybdenum	Nickel		Scandium		Silver		Strontium	Tin	
	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)	XRAL (ppm)	USEPA (ppm)
75	<1	--	3	38	--	4.2	--	4.8	--	62.5	<10	--
75-D	2	--	2	37	--	4	--	4.5	--	61.3	<10	--
76	<1	--	<1	17	--	2	--	1	--	26.6	<10	--
77	2	--	1	43	--	2.3	--	1.4	--	32.6	<10	--
78	<1	1.8	4	40	37.4	3.7	<10.2	5.2	6	59.5	<10	<10
79	<1	--	4	49	--	4	--	5.2	--	62.9	<10	--
80	2	3	4	52	48.3	3.9	<10.2	12.8	14	63.9	43	<10
81	<1	2	2	34	34.1	2.8	<9.9	4.7	5	42.8	<10	<10
82	<1	--	3	40	--	4.4	--	5.1	--	62.7	<10	--
83	<1	--	2	45	--	4.7	--	3.2	--	70.4	<10	--
84	<1	--	2	39	--	4.1	--	3.1	--	57	<10	--
85	5	--	2	42	--	4.6	--	4.9	--	66.4	<10	--
86	<1	--	2	48	--	4.3	--	7.8	--	67.9	<10	--
87	<1	--	2	45	--	4.4	--	3.7	--	66.6	<10	--
88	<1	--	3	46	--	4.3	--	7.6	--	67	<10	--
89	1	--	4	59	--	4.1	--	14	--	65.6	<10	--
90	2	3.5	3	47	45.9	2.4	<10	10.3	16	52.6	14	<10
91	<1	1.7	4	47	45.7	2.9	<5.2	10	10	53.6	23	<10
92	<1	--	1	18	--	1.8	--	1.1	--	40.8	<10	--
93	1	.7	<1	37	17.8	1.6	<9.6	1.1	2	33.7	<10	<10
94	<1	--	4	50	--	4.4	--	5.4	--	69.8	<10	--
95	<1	--	3	41	--	4.4	--	3.5	--	59.4	<10	--
96	5	1.5	2	35	30.8	4.4	<11.6	3.4	5	63.2	19	<12
96-LD	3	--	2	36	--	4.8	--	3.5	--	67	22	--
97	<1	--	3	50	--	4.5	--	6	--	67.5	<10	--
98	2	.9	3	36	30.8	3.6	<8.5	2	3	53.5	<10	<9
99	<1	--	2	41	--	4.8	--	3	--	68.1	<10	--
99-LD	1	--	2	43	--	5	--	3.1	--	70	<10	--
99-LD	<1	--	3	45	--	5.2	--	3.5	--	71.5	<10	--
100	<1	--	2	49	--	4.4	--	3.8	--	65.1	<10	--
101	5	--	2	46	--	4.9	--	3.9	--	64.1	<10	--
101-D	<1	--	2	47	--	5.6	--	4.2	--	70.6	<10	--
102	<1	--	2	48	--	5.4	--	4.9	--	70.6	<10	--
102-LD	<1	--	2	50	--	5.8	--	4.8	--	74.8	<10	--
103	<1	--	1	48	--	5.6	--	5.7	--	72.4	<10	--
104	<1	--	2	46	--	5.1	--	4.6	--	68.9	<10	--
105	4	--	2	35	--	4.6	--	2.8	--	61.1	<10	--
106	<1	1.4	2	36	40.1	4.5	<51.8	4.8	6	62	<10	<52
107	<1	--	2	38	--	3.1	--	1.4	--	60.1	<10	--
108	<1	--	2	30	--	3.9	--	2	--	53.2	<10	--

Table 11. Distribution of inorganic elements in bottom sediment samples, Charles River, Massachusetts, 1998—*Continued*

Station No.	Inorganic elements											
	Mercury		Molybdenum	Nickel		Scandium		Silver		Strontium	Tin	
	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)	XRAL (ppm)	USEPA (ppm)
109	<1	--	2	54	--	4.8	--	6.3	--	67.3	<10	--
110	<1	--	<1	31	--	3.9	--	2	--	60.8	<10	--
110-LD	<1	--	1	30	--	4	--	2.2	--	65.1	<10	--
111	<1	--	2	37	--	4.6	--	6.7	--	71.9	12	--
112	5	--	<1	17	--	1.3	--	9.4	--	27.8	<10	--
113	<1	--	2	46	--	4.8	--	2.9	--	63.4	<10	--
114	<1	--	1	39	--	4.6	--	2.9	--	62.8	<10	--
114-D	<1	--	2	41	--	4.8	--	3.3	--	68.8	<10	--
115	<1	--	2	30	--	2.7	--	2.3	--	41.8	<10	--
116	<1	1.2	<1	16	12	2	<5.1	4.8	5	30.5	14	<10
117	4	--	1	38	--	4.3	--	3.2	--	60.4	<10	--
118	<1	.9	1	30	27.2	3.5	<9.5	1.7	3	57.4	<10	<10
119	<1	--	2	41	--	4.6	--	7.6	--	73.4	<10	--
120	<1	--	<1	34	--	4.1	--	3.6	--	60.5	<10	--
121	<1	--	1	41	--	5	--	11	--	83.3	<10	--
122	<1	1	2	22	25.8	2.6	<11.2	2.5	3	44.2	<10	<12
122-LD	<1	--	2	23	--	2.7	--	3.4	--	46.7	<10	--
123	6	--	1	33	--	4.2	--	1.3	--	64.2	<10	--
124	<1	--	3	63	--	4.8	--	14.1	--	66.4	<10	--
125	<1	--	4	59	--	5.9	--	8.8	--	83.1	<10	--
126	1	--	2	45	--	5.3	--	4.1	--	79.4	<10	--
127	<1	--	<1	37	--	7.1	--	<.2	--	48.2	<10	--
127-D	<1	--	<1	40	--	7	--	.2	--	52.1	<10	--
128	<1	1	2	32	31.1	3.6	<9.2	3.4	3	54.8	<10	<10
129	<1	--	<1	25	--	2.4	--	1.2	--	36.7	<10	--
130	<1	--	8	165	--	1.7	--	.2	--	23.3	<10	--
131	<1	--	<1	12	--	2	--	<.2	--	24.6	<10	--
132	<1	--	<1	7	--	1.4	--	.3	--	19.7	<10	--
133	<1	--	<1	9	--	1.1	--	<.2	--	15.2	<10	--
133-D	<1	--	8	49	--	4.1	--	14.3	--	44.3	<10	--
134	<1	--	<1	14	--	2.7	--	<.2	--	41	<10	--
135	<1	--	<1	9	--	1.4	--	<.2	--	15.1	<10	--
136	<1	.9	<1	14	29.1	1.5	<9.4	1	4	29.2	<10	<10
137	<1	1.9	2	35	30.7	5.1	<51.9	5	<8	77.6	11	<52
138	<1	1.8	2	37	38.6	5.1	<52.1	6.1	<8	77.4	<10	<55
138-LD	<1	--	1	37	--	5.2	--	6.1	--	77.7	12	--
139	<1	2.1	4	57	56.7	4.4	<52.2	11.3	13	73.9	17	<55
140	<1	2.1	4	49	52.1	4.2	<53	9.4	11	67.9	19	<53
141	<1	.9	2	29	32.9	3.4	<8.6	1.9	4	54.2	11	<10
142	<1	1.1	1	46	39.5	5.7	<9.3	2.6	2	51	<10	<10
143	<1	1.5	<1	52	45.5	6.9	<9.6	2.5	3	66.2	<10	<10

Table 11. Distribution of inorganic elements in bottom sediment samples, Charles River, Massachusetts, 1998—*Continued*

Station No.	Inorganic elements											
	Mercury		Molybdenum	Nickel		Scandium		Silver		Strontium	Tin	
	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)	XRAL (ppm)	USEPA (ppm)
144	<1	.9	1	41	37.6	5.2	<5.1	2.7	3	74.4	<10	<6
145	<1	.9	11	70	19.3	3	<8.3	.9	1	65.6	150	<10
146	3	.4	1	16	13.5	1.7	<10.3	.8	1	31	<10	<11
147	<1	.9	2	35	35.7	2.7	<9.7	3.3	5	54.5	<10	<10

Station No.	Inorganic elements								
	Titanium		Tungsten	Vanadium		Yttrium	Zinc		Zirconium
	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)
1	0.11	<23.6	<10	81	69	12	790	770	13.5
2	.09	<20	<10	127	114	12.7	1,470	1,360	12.0
3	.13	<19.8	<10	99	68	11.5	1,510	1,280	9.1
4	.10	<20.4	<10	105	92	13.0	895	786	18.2
5	.09	--	<10	122	--	13.1	643	--	13.8
5-D	.08	--	<10	102	--	11.4	564	--	11.7
6	.07	--	<10	88	--	11.2	615	--	15.0
6-D	.08	--	<10	97	--	12.4	689	--	16.8
7	.05	--	<10	59	--	9.0	804	--	6.3
8	.11	<21	<10	89	69	12.4	573	518	18.4
9	.10	<20.2	<10	92	84	13.2	1,040	866	17.9
10	.08	--	<10	88	--	12.5	619	--	16.7
11	.08	--	<10	86	--	12.0	657	--	14.9
11-LD	.07	--	<10	80	--	11.3	628	--	13.7
12	.08	--	<10	83	--	12.5	580	--	17.9
13	.09	<20.2	<10	163	138	17.4	638	601	19.3
14	.09	<19.6	<10	92	81	11.4	622	589	13.3
15	.10	<20.2	<10	87	85	12.6	605	1,250	17.1
16	.08	--	<10	100	--	14.1	594	--	16.0
17	.10	--	<10	98	--	13.1	673	--	12.5
18	.04	--	<10	31	--	4.7	452	--	6.7
19	.05	--	<10	22	--	5.1	73	--	4.4
20	.10	<19.6	<10	92	69	12.7	377	326	12.2
21	.08	--	<10	70	--	11.5	433	--	13.1
21-D	.08	--	<10	64	--	10.7	400	--	11.6
22	.06	<19.6	<10	36	26	7.9	148	124	6.0
23	0.06	--	<10	110	--	13.1	893	--	13.5
24	.07	--	<10	102	--	13.0	736	--	11.7
24-LD	.08	--	<10	108	--	13.9	767	--	11.9
24-LD	.09	--	<10	118	--	15.0	810	--	13.2
25	.09	--	<10	85	--	13.5	598	--	14.7

Table 11. Distribution of inorganic elements in bottom sediment samples, Charles River, Massachusetts, 1998—*Continued*

Station No.	Inorganic elements								
	Titanium		Tungsten	Vanadium		Yttrium	Zinc		Zirconium
	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)
26	.07	--	<10	89	--	11.0	565	--	10.7
27	.08	--	<10	78	--	11.6	463	--	11.0
27-D	.07	--	<10	73	--	10.7	439	--	9.6
28	.08	--	<10	69	--	11.7	516	--	13.9
29	.18	<20	<10	80	46	16.8	190	146	16.7
30	.09	--	<10	73	--	12.3	551	--	13.4
31	.07	--	<10	31	--	8.1	62	--	7.3
32	.06	--	<10	32	--	7.7	237	--	7.4
32-LD	.06	--	<10	32	--	6.7	227	--	6.5
33	.05	--	<10	20	--	5.6	31	--	3.7
33-LD	.06	--	<10	22	--	5.0	36	--	3.9
34	.06	--	<10	26	--	6.6	104	--	4.3
35	.07	--	<10	53	--	8.1	261	--	7.3
36	.09	--	<10	123	--	13.8	528	--	15.3
37	.07	--	<10	80	--	11.8	629	--	16.9
38	.05	--	<10	23	--	7.2	87	--	4.8
39	.06	--	<10	77	--	13.8	785	--	10.1
40	.09	<20.2	<10	104	97	13.6	763	762	14.7
41	.14	<21	<10	99	66	13.8	634	585	14.9
42	.06	<20.2	<10	19	15	7.1	63	60	3.4
43	.09	<20.4	<10	75	71	12.5	672	618	8.5
44	.10	--	<10	82	--	14.2	617	--	15.6
45	.05	--	<10	22	--	6.3	130	--	4.8
45-LD	.06	--	<10	26	--	8.0	127	--	5.3
46	.05	--	<10	67	--	11.8	558	--	14.7
47	.10	--	<10	84	--	14.6	720	--	19.0
48	.13	--	<10	109	--	15.3	812	--	19.1
49	.12	--	<10	90	--	15.1	727	--	16.5
50	.04	--	<10	78	--	8.3	546	--	8.5
51	.06	--	<10	88	--	14.1	790	--	11.7
52	.08	--	<10	89	--	14.4	785	--	14.2
52-D	.07	--	<10	90	--	14.6	772	--	14.7
53	.10	--	<10	75	--	13.2	655	--	10.2
54	.08	--	<10	89	--	13.6	762	--	12.4
54-LD	.10	--	<10	95	--	14.4	827	--	13.6
54-LD	.09	--	<10	94	--	14.3	820	--	11.8
55	.10	--	<10	117	--	13.8	770	--	15.2
55-D	.07	--	<10	114	--	13.6	746	--	16.1
56	0.12	--	<10	88	--	15.0	676	--	20.1
57	.08	--	<10	85	--	13.2	857	--	8.2
58	.08	--	<10	149	--	13.8	830	--	15.4
59	.07	--	<10	81	--	13.4	700	--	12.8
60	.03	--	<10	69	--	11.2	639	--	11.9

Table 11. Distribution of inorganic elements in bottom sediment samples, Charles River, Massachusetts, 1998—*Continued*

Station No.	Inorganic elements								
	Titanium		Tungsten	Vanadium		Yttrium	Zinc		Zirconium
	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)
61	.04	--	<10	78	--	10.8	680	--	8.5
61-D	.05	--	<10	87	--	15.3	853	--	14.2
62	.06	--	<10	74	--	12.4	758	--	7.3
63	.10	--	<10	100	--	14.4	781	--	15.4
64	.05	--	<10	85	--	11.5	749	--	9.9
64-LD	.06	--	<10	94	--	12.0	799	--	9.3
65	.03	--	<10	59	--	10.9	725	--	7.7
66	.11	<16.2	<10	49	28	11.2	402	341	12.2
67	.12	<18.8	<10	76	57	14.2	735	658	4.8
68	.14	<21.2	<10	102	72	14.6	803	680	8.5
69	.04	<18.6	<10	50	42	9.4	619	540	3.1
69-LD	.04	--	<10	48	--	9.3	572	--	2.9
70	.12	--	<10	96	--	15.1	796	--	13.3
71	.08	--	<10	79	--	14.3	775	--	8.5
72	.06	<20	<10	103	101	10.6	495	503	7.7
73	.08	--	<10	83	--	14.5	794	--	10.7
74	.07	<19.6	<10	77	66	14.2	702	674	9.1
75	.05	--	<10	72	--	13.7	679	--	12.1
75-D	.05	--	<10	73	--	13.6	679	--	10.7
76	.04	--	<10	32	--	8.5	192	--	6.2
77	.04	--	<10	42	--	9.4	257	--	7.6
78	.09	<20.4	<10	79	68	14.2	710	650	9.2
79	.06	--	<10	89	--	14.2	803	--	10.6
80	.13	<20.4	<10	81	63	13.1	765	722	4.7
81	.05	<19.8	<10	58	54	10.8	516	530	6.6
82	.04	--	<10	75	--	14.7	687	--	11.1
83	.04	--	<10	86	--	15.3	830	--	14.4
84	.06	--	<10	68	--	13.6	634	--	12.7
85	.05	--	<10	72	--	15.1	723	--	13.7
86	.06	--	<10	78	--	14.5	853	--	13.4
87	.07	--	<10	70	--	14.3	738	--	13.6
88	.07	--	<10	73	--	14.1	781	--	13.6
89	.09	--	<10	88	--	12.9	801	--	13.3
90	.05	<20	<10	68	62	11.1	750	776	5.1
91	.08	<11	<10	78	65	10.1	583	520	7.4
92	.04	--	<10	24	--	7.6	269	--	6.0
93	.05	<19.2	<10	45	32	6.6	349	373	5.0
94	0.05	--	<10	96	--	14.3	826	--	14.5
95	.05	--	<10	76	--	14.1	724	--	13.0
96	.13	<23.2	<10	68	54	14.9	646	612	3.8
96-LD	.14	--	<10	71	--	15.6	663	--	4.5
97	.05	--	<10	79	--	15.1	819	--	13.2

Table 11. Distribution of inorganic elements in bottom sediment samples, Charles River, Massachusetts, 1998—*Continued*

Station No.	Inorganic elements								
	Titanium		Tungsten	Vanadium		Yttrium	Zinc		Zirconium
	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)
98	.07	<18	<10	57	46	12.4	755	670	11.3
99	.06	--	<10	75	--	15.5	750	--	14.0
99-LD	.06	--	<10	78	--	16.1	748	--	14.4
99-LD	.07	--	<10	80	--	16.5	785	--	14.4
100	.08	--	<10	102	--	13.4	735	--	13.5
101	.07	--	<10	81	--	15.6	728	--	13.7
101-D	.07	--	<10	88	--	16.8	784	--	15.0
102	.07	--	<10	83	--	16.3	753	--	13.9
102-LD	.06	--	<10	88	--	17.3	791	--	15.2
103	.07	--	<10	89	--	16.3	769	--	14.1
104	.05	--	<10	82	--	15.0	711	--	14.2
105	.06	--	<10	69	--	14.3	625	--	11.5
106	.08	<102	<10	70	59	13.5	639	643	11.9
107	.05	--	<10	50	--	10.1	332	--	12.0
108	.04	--	<10	57	--	12.7	505	--	9.9
109	.10	--	<10	120	--	14.2	763	--	12.8
110	.04	--	<10	58	--	12.5	473	--	9.5
110-LD	.04	--	<10	58	--	12.5	484	--	10.4
111	.10	--	<10	73	--	12.3	1,030	--	13.6
112	.03	--	<10	26	--	5.4	264	--	3.3
113	.06	--	<10	70	--	15.1	675	--	14.0
114	.04	--	<10	67	--	14.6	646	--	12.4
114-D	.06	--	<10	74	--	16.1	709	--	12.7
115	.03	--	<10	65	--	8.1	363	--	7.7
116	.03	<10.2	19.0	23	16	5.8	243	210	5.3
117	.04	--	<10	64	--	13.7	638	--	11.9
118	.06	<19	<10	57	45	11.7	535	492	8.1
119	.05	--	<10	65	--	13.3	692	--	11.1
120	.04	--	<10	60	--	13.5	603	--	11.0
121	.08	--	<10	70	--	14.8	880	--	14.7
122	.05	<23	<10	41	33	9.6	460	398	6.2
122-LD	.05	--	<10	43	--	10.0	452	--	7.1
123	.05	--	<10	61	--	13.0	575	--	10.6
124	.09	--	<10	106	--	13.1	621	--	11.1
125	.12	--	<10	125	--	16.2	705	--	16.1
126	0.07	--	<10	88	--	14.9	732	--	13.4
127	.12	--	<10	73	--	16.1	109	--	17.3
127-D	.13	--	<10	69	--	16.0	110	--	17.6
128	.05	<19	<10	64	45	12.1	565	474	7.3
129	.05	--	<10	44	--	9.2	405	--	6.2

Table 11. Distribution of inorganic elements in bottom sediment samples, Charles River, Massachusetts, 1998—*Continued*

Station No.	Inorganic elements								
	Titanium		Tungsten	Vanadium		Yttrium	Zinc		Zirconium
	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)	XRAL (ppm)	USEPA (ppm)	XRAL (ppm)
130	.07	--	<10	29	--	6.2	160	--	5.7
131	.07	--	<10	29	--	6.2	98	--	5.6
132	.05	--	<10	18	--	4.3	63	--	4.4
133	.04	--	<10	18	--	3.9	74	--	2.9
133-D	.09	--	<10	127	--	12.1	1,460	--	11.5
134	.09	--	<10	38	--	6.8	80	--	5.1
135	.05	--	<10	33	--	5.9	64	--	4.6
136	.06	<19	<10	26	47	4.1	172	402	3.5
137	.11	<104	<10	70	53	14.8	722	666	17.0
138	.09	<104	<10	73	60	14.9	749	694	15.3
138-LD	.11	--	<10	74	--	15.1	757	--	16.4
139	.08	<104	<10	117	109	13.1	717	708	11.1
140	.11	<105	<10	103	92	12.7	691	664	11.6
141	.09	<20	<10	56	50	10.2	371	425	8.7
142	.12	<19	<10	93	62	14.1	498	343	15.2
143	.14	<20	<10	96	72	15.6	567	479	16.5
144	.11	<11	<10	87	64	12.5	432	370	12.6
145	.10	<17	<10	42	26	9.5	199	415	11.1
146	.05	<21	<10	27	22	6.1	155	132	4.8
147	.06	<20	<10	74	81	8.1	367	153	7.8

Table 12. Statistical summary for bottom-sediment samples lower Charles River, Massachusetts, 1998

[mg/L, milligrams per liter; ppb, parts per billion; ppm, parts per million; <, less than detection limit; --, not analyzed]

Constituent	Surficial sediments						Cores					
	Minimum	Lower quartile	Median	Upper quartile	Maximum	Percent detects	Minimum	Lower quartile	Median	Upper quartile	Maximum	Percent detects
ANALYZED BY U.S. ENVIRONMENTAL PROTECTION AGENCY												
Sulfides, total (ppm)	2	460	977	4,95	27,000	100	204	576	1,250	1,600	4120	100
Solids, total (ppm)	8.1	14.2	23.9	32.9	69.9	100	22.4	32.0	35.7	37.9	58.2	100
Carbon, organic, total as C (percent)	.6	8.6	10.3	12.7	21.7	100	2.5	4.9	6.6	10.6	12.0	100
Petroleum hydrocarbons, total (ppm.)	246	6,860	11,000	16,500	39,000	100	994	3,300	7,850	21,300	46,000	100
Inorganic elements												
Calcium (percent)	0.2	0.4	0.5	0.5	0.7	100	0.2	0.4	0.4	0.5	0.6	100
Magnesium	.2	.4	.5	.6	1.1	100	.3	.4	.6	.7	.7	100
Aluminum (percent)	.5	1.1	1.3	1.6	1.8	100	.7	1.0	1.4	1.6	2.0	100
Arsenic (ppm)	<	<	<	<	<	0	<	<	<	<	<	0
Barium (ppm)	25	128	167	221	423	100	49	96	138	190	580	100
Beryllium (ppm)	<	.8	1.1	1.3	1.7	97	.37	.76	1.1	1.2	1.5	100
Cadmium (ppm)	<	5.3	7.5	9.5	30	91	1.9	6.8	9.7	14	43	100
Chromium (ppm)	12.6	69	102	109	200	100	33	73.4	103	200	232	100
Cobalt (ppm)	4	12	13	15	17	100	6.0	11	14	15	16	100
Copper (ppm)	25	176	291	369	602	100	55	153	196	241	700	100
Iron (ppm)	.9	2.3	2.6	3.2	4.8	100	1.2	2.3	2.8	2.9	3.2	100
Lead (ppm)	35	467	610	723	1,140	100	153	377	493	707	993	100
Manganese (ppm)	151	314	382	493	894	100	192	266	345	385	560	100
Mercury (ppm)	<	1.1	1.7	2.2	7	97	.4	.9	1	1.8	2.1	100
Nickel (ppm)	7	29	37	43	68	100	14	30	37	41	57	100
Selenium (ppm)	<	<	<	<	<	0	<	<	<	<	<	0
Silver (ppm)	<	3	5	7	17	91	<	1	3	4	13	83
Tin (ppm)	<	<	<	<	<	0	<	<	<	<	<	0
Titanium (ppm)	<	<	<	<	<	0	<	<	<	<	<	0
Vanadium (ppm)	15	45	65	72	138	100	22	49	61	74	109	100
Zinc (ppm)	60	483	601	701	1,360	100	132	363	420	665	708	100

Table 12. Statistical summary for bottom-sediment samples lower Charles River, Massachusetts, 1998—*Continued*

Constituent	Surficial sediments						Cores					
	Minimum	Lower quartile	Median	Upper quartile	Maximum	Percent detects	Minimum	Lower quartile	Median	Upper quartile	Maximum	Percent detects
ANALYZED BY U.S. ENVIRONMENTAL PROTECTION AGENCY—*Continued*												
Polychlorinated biphenyls												
Aroclor-1016 (ppb)	<	<	<	<	<	0	<	<	<	<	<	0
Aroclor-1221 (ppb)	<	<	<	<	<	0	<	<	<	<	<	0
Aroclor-1232 (ppb)	<	<	<	<	<	0	<	<	<	<	<	0
Aroclor-1242 (ppb)	<	<	<	<	<	0	<	<	<	<	<	0
Aroclor-1248 (ppb)	<	<	<	<	<	0	<	<	<	<	<	0
Aroclor-1254 (ppb)	<	310	530	960	14,000	94	140	330	660	1,200	5,200	100
Aroclor-1260 (ppb)	<	<	210	440	1,000	60	100	270	420	1,000	2,700	100
Aroclor-1262 (ppb)	<	<	<	<	<	0	<	<	<	<	<	0
Aroclor-1268 (ppb)	<	<	<	<	<	0	<	<	<	<	<	0
Total (ppb)	<	370	660	1,600	14,000	94	260	640	1,100	2,200	7,900	100
Organochlorine pesticides												
Aldrin (ppb)	<	<	<	<	58	6	<	<	<	<	<	0
Alpha Chlordane (ppb)	<	<	8	43	170	51	3	7	17	37	140	100
alpha-BHC (ppb)	<	<	<	<	<	0	<	<	<	<	<	0
beta-BHC (ppb)	<	<	<	<	23	11	<	<	<	<	<	0
Chlordane (technical) (ppb)	<	<	<	<	<	0	<	<	<	<	<	0
Total chlordane (ppb)	<	<	7.5	54	170	51	3.8	9.7	21	60	210	100
delta-BHC (ppb)	<	<	<	<	<	0	<	<	<	<	<	0
4,4'-DDD (ppb)	<	11	53	100	300	86	4.6	17	56	110	250	100
4,4'-DDE (ppb)	<	19	51	79	170	89	10	40	52	92	220	100
4,4'-DDT (ppb)	<	<	13	28	200	63	<	6.6	12	38	140	92
Total DDT (ppb)	<	45	120	220	470	97	19	65	130	220	590	92
Dieldrin (ppb)	<	<	<	<	36	20	<	<	<	<	<	0
Enosulfan I (ppb)	<	<	<	<	<	0	<	<	<	<	<	0
Enosulfan II (ppb)	<	<	<	<	<	0	<	<	<	<	<	0
Enosulfan sulfate (ppb)	<	<	<	<	<	0	<	<	<	<	<	0
Enrin (ppb)	<	<	<	<	<	0	<	<	<	<	<	0
Enrin aldehyde (ppb)	<	<	<	<	<	0	<	<	<	<	<	0
Enrin ketone (ppb)	<	<	<	<	18	6	<	<	<	<	<	0
gamma Chlordane (ppb)	<	<	<	<	94	17	<	<	<	8	96	33
gamma-BHC (ppb)	<	<	<	<	<	0	<	<	<	<	<	0

Table 12. Statistical summary for bottom-sediment samples lower Charles River, Massachusetts, 1998—*Continued*

Constituent	Surficial sediments						Cores					
	Minimum	Lower quartile	Median	Upper quartile	Maximum	Percent detects	Minimum	Lower quartile	Median	Upper quartile	Maximum	Percent detects
ANALYZED BY U.S. ENVIRONMENTAL PROTECTION AGENCY—*Continued*												
Organochlorine pesticides—*Continued*												
Heptachlor (ppb)	<	<	<	<	<	0	<	<	<	<	<	0
Heptachlor epoxide (ppb)	<	<	<	<	<	0	<	<	<	<	<	0
Methoxychlor (ppb)	<	<	<	<	<	0	<	<	<	<	<	0
Toxaphene (ppb)	<	<	<	<	<	0	<	<	<	<	<	0
Polyaromatic hydrocarbons												
Acenaphthene (ppb)	12	230	310	760	67,000	100	84	153	410	620	4,000	100
Acenaphthylene (ppb)	7	150	200	260	72,000	100	40	110	200	630	2,000	100
Anthracene (ppb)	34	620	900	1,800	120,000	100	150	310	810	1,600	4,800	100
Benzo(a)anthracene (ppb)	210	3,000	4,000	6,400	110,000	100	1,000	1,800	3,400	9,700	26,000	100
Benzo(a)pyrene (ppb)	280	3,700	4,300	6,200	89,000	100	1,100	1,900	3,400	9,600	28,000	100
Benzo(b)floranthene (ppb)	400	5,500	7,200	9,600	120,000	100	1,500	2,700	4,700	13,000	39,000	100
Benzo(ghi)perylene (ppb)	200	2,400	3,000	4,000	42,000	100	790	1,400	2,300	6,200	20,000	100
Benzo(k)floranthene (ppb)	100	1,700	2,200	3,400	50,000	100	510	1,100	1,700	5,100	16,000	100
Chrysene (ppb)	280	4,000	5,300	7,600	100,000	100	1,200	2,000	3,600	11,000	31,000	100
Dibenzo(a,h)anthracene (ppb)	43	670	860	1,300	15,000	100	180	360	640	1,700	4,300	100
Floranthene (ppb)	480	7,100	9,700	15,000	3,400,000	100	2,100	3,600	6,700	23,000	60,000	100
Florene (ppb)	14	250	350	730	120,000	100	92	220	600	1,100	4,500	100
Ideno(1,2,3-cd)pyrene (ppb)	<	3,000	3,700	5,100	56,000	97	940	1,800	2,800	7,900	25,000	100
Naphthalene (ppb)	8.5	170	240	420	180,000	100	<	140	230	400	2,000	92
Phenanthrene (ppb)	220	2,300	4,100	7,800	3,400,000	100	830	1,600	4,300	7,400	38,000	100
Pyrene (ppb)	450	6,500	8,700	13,000	2,700,000	100	1,900	3,500	6,600	20,000	50,000	100
Total (ppb)	3,000	40,000	57,000	81,000	10,000,000	100	13,000	22,000	42,000	126,000	330,000	100

Table 12. Statistical summary for bottom-sediment samples lower Charles River, Massachusetts, 1998—*Continued*

Constituent	Surficial sediments						Cores					
	Minimum	Lower quartile	Median	Upper quartile	Maximum	Percent detects	Minimum	Lower quartile	Median	Upper quartile	Maximum	Percent detects
ANALYZED BY U.S. ENVIRONMENTAL PROTECTION AGENCY—*Continued*												
Acid volatile sulfide/simultaneously extracted metals												
Acid Volatile Sulfide (mg/L)	0.24	12.2	28.6	163	652	100	0.29	14	26.1	43.13	67.1	100
Cadmium (mg/L)	<	.03	.08	.11	.32	83	<	.07	.11	.13	.43	92
Chromium (mg/L)	.01	.6	1	1.2	6.2	100	.57	.85	1.03	1.85	2.8	100
Copper (mg/L)	.05	2.55	4.1	5.25	9.2	100	.79	2.2	3.09	3.45	11.2	100
Lead (mg/L)	.03	2.1	3.4	4.1	6.3	100	.9	2.1	3.3	3.9	5.4	100
Mercury (mg/L)	<	<	<	<	<	0	<	<	<	<	<	0
Nickel (mg/L)	<	.26	.44	.55	1	91	.22	.35	.43	.56	1.7	100
Zinc (mg/L)	.1	7.5	9.9	11.8	22.2	100	.29	5.4	6.8	10.9	33.9	100
Toxicity characteristic leaching procedure												
Arsenic (ppm)	--	--	--	--	--	--	<	<	<	<	0.12	17
Barium (ppm)	--	--	--	--	--	--	0.38	0.46	0.49	0.53	.69	100
Cadmium (ppm)	--	--	--	--	--	--	<	.03	.06	.09	.17	83
Chromium (ppm)	--	--	--	--	--	--	<	<	<	<	<	0
Lead (ppm)	--	--	--	--	--	--	.23	0.48	0.58	0.82	1.2	100
Mercury (ppm)	--	--	--	--	--	--	<	<	<	<	.21	8
Selenium (ppm)	--	--	--	--	--	--	<	<	<	<	<	0
Silver (ppm)	--	--	--	--	--	--	<	<	<	<	<	0
ANALYZED BY XRAL LABORATORIES												
Inorganic elements												
Calcium (percent)	0.2	0.5	0.6	0.8	0.9	100	0.2	0.6	0.6	0.7	0.7	100
Magnesium (percent)	.21	.43	.58	.68	.96	100	.21	.41	.61	.7	.82	100
Sodium (ppm)	.02	.05	.07	.17	2.4	100	.02	.07	.08	.14	.2	100
Potassium (ppm)	.05	.19	.27	.33	.67	100	.06	.16	.23	.27	.54	100
Phosphorus (percent)	.03	.11	.16	.2	.28	100	.06	.09	.1	.14	.18	100
Alluminum (percent)	.5	1.2	1.8	2.0	2.6	100	.5	1.1	1.7	2.0	2.7	100
Antimony (ppm)	<	<	<	<	<	0	<	<	<	<	<	0
Arsenic (ppm)	<	<	3.0	5.0	21	50	<	<	3	7	14	58
Barium (ppm)	18	133	192	240	652	100	50	81	120	172	239	100
Beryllium (ppm)	<	<	<	1.1	1.5	33	<	<	<	<	<	0

Table 12. Statistical summary for bottom-sediment samples lower Charles River, Massachusetts, 1998—*Continued*

Constituent	Surficial sediments						Cores					
	Minimum	Lower quartile	Median	Upper quartile	Maximum	Percent detects	Minimum	Lower quartile	Median	Upper quartile	Maximum	Percent detects
ANALYZED BY XRAL LABORATORIES—*Continued*												
Inorganic elements—*Continued*												
Bismuth (ppm)	<	<	<	<	9	1	<	<	<	<	<	0
Cadmium (ppm)	<	5	7	11	71	93	2	7	8	11	38	100
Chromium (ppm)	14	83	106	126	567	100	39	86	105	200	266	100
Cobalt (ppm)	4	11	13	15	25	100	4	11	13	14	15	100
Copper (ppm)	7	192	270	317	7340	100	53	148	214	245	610	100
Iron, in percent	.9	2.4	3.2	3.6	7.3	100	1.4	2.4	3.1	3.3	4.9	100
Lantium (ppm)	7	16	19.2	20.8	30.1	100	6.7	13.7	18	20.9	25.4	100
Lead (ppm)	10	480	642	764	4,690	100	149	263	469	658	845	100
Manganese (ppm)	164	341	466	568	1,010	100	137	319	374	415	546	100
Mercuy (ppm)	<	<	<	2.0	6	30	<	<	<	<	3	8
Molybdenum (ppm)	<	1	2	5	21	83	<	1	2	3	11	83
Nickel (ppm)	7	35	40	48	165	100	14	34	39	50	70	100
Scandium (ppm)	.7	2.9	3.9	4.5	7.1	100	1.5	2.9	4.3	5.1	6.9	100
Silver (ppm)	<	2.2	4.2	5.7	24.1	95	.8	1.7	2.7	5.3	11.3	100
Strontium (ppm)	15.1	48.2	61.5	67.6	114	100	29.2	53.4	65.9	74	77.6	100
Tin (ppm)	<	<	<	14	104	38	<	<	<	13	150	42
Titanium (ppm)	0.03	0.05	0.07	.09	.18	100	0.05	0.07	0.09	.11	.14	100
Tungsten (ppm)	<	<	<	<	19	1	<	<	<	<	<	0
Vanadium (ppm)	18	59	77	89	163	100	26	53	74	94	117	100
Yttrium (ppm)	3.9	10.9	13	14.2	17.4	100	4.1	9.2	12.6	14.3	15.6	100
Zinc (ppm)	31	484	643	757	1,510	100	155	325	465	698	749	100
Zirconium (ppm)	2.9	7.5	11.9	14	20.1	100	3.5	8.5	11.4	15.2	17	100
Organic element												
Carbon, organic, total as C (percent)	.2	8.5	10.9	12	21.9	100	2.88	6.3	8.2	12.2	15.6	100

Table 13. Distribution of organic compounds in bottom-sediment samples, lower Charles River, Massachusetts, 1998

[All concentrations are in parts per billion. D, field duplicate; No., number; USEPA, U.S. Environmental Protection Agency; <, less than minimum reporting limit; E, estimated]

Sample No.	Polychlorinated biphenyls								
	Aroclor-1016	Aroclor-1221	Aroclor-1232	Aroclor-1242	Aroclor-1248	Aroclor-1254	Aroclor-1260	Aroclor-1262	Aroclor-1268
1	<271	<271	<271	<271	<271	3,000	<271	<271	<271
2	<420	<420	<420	<420	<420	8,000	940	<420	<420
3	<1,383	<1,383	<1,383	<1,383	<1,383	14,000	<1,383	<1,383	<1,383
4	<120	<120	<120	<120	<120	480	<120	<120	<120
8	<168	<168	<168	<168	<168	760	<168	<168	<168
9	<120	<120	<120	<120	<120	90	<120	<120	<120
13	<170	<170	<170	<170	<170	3,400	960	<170	<170
14	<54	<54	<54	<54	<54	810	390	<54	<54
15	<65	<65	<65	<65	<65	320	88	<65	<65
20	<37	<37	<37	<37	<37	340	210	<37	<37
22	<36	<36	<36	<36	<36	150	200	<36	<36
29	<39	<39	<39	<39	<39	110	<39	<39	<39
40	<180	<180	<180	<180	<180	1,700	640	<180	<180
41	<55	<55	<55	<55	<55	240	<55	<55	<55
42	<36	<36	<36	<36	<36	<36	<36	<36	<36
43	<51	<51	<51	<51	<51	600	240	<51	<51
66	<38	<38	<38	<38	<38	380	<38	<38	<38
67	<68	<68	<68	<68	<68	330	<68	<68	<68
68	<262	<262	<262	<262	<262	<262	<262	<262	<262
69	<39	<39	<39	<39	<39	450	210	<39	<39
72	<180	<180	<180	<180	<180	1,300	1,000	<180	<180
74	<85	<85	<85	<85	<85	240	<85	<85	<85
78	<36	<36	<36	<36	<36	390	220	<36	<36
80	<61	<61	<61	<61	<61	580	<61	<61	<61
81	<75	<75	<75	<75	<75	540	400	<75	<75
90	<83	<83	<83	<83	<83	740	510	<83	<83
91	<100	<100	<100	<100	<100	1,400	820	<100	<100
93	<37	<37	<37	<37	<37	290	220	<37	<37
96	<82	<82	<82	<82	<82	570	<82	<82	<82
98	<95	<95	<95	<95	<95	620	480	<95	<95
98-D	<140	<140	<140	<140	<140	600	510	<140	<140
106	<270	<270	<270	<270	<270	1,200	980	<270	<270
106-D	<340	<340	<340	<340	<340	1,200	750	<340	<340
116	<34	<34	<34	<34	<34	210	88	<34	<34
118	<180	<180	<180	<180	<180	530	360	<180	<180
118-D	<170	<170	<170	<170	<170	530	360	<170	<170
122	<51	<51	<51	<51	<51	520	330	<51	<51
128	<260	<260	<260	<260	<260	E1,100	900	<260	<260
136	<80	<80	<80	<80	<80	1,000	880	<80	<80
137	<46	<46	<46	<46	<46	360	380	<46	<46
138	<100	<100	<100	<100	<100	840	590	<100	<100

Table 13. Distribution of organic compounds in bottom-sediment samples, lower Charles River, Massachusetts, 1998

Sample No.	Polychlorinated biphenyls								
	Aroclor-1016	Aroclor-1221	Aroclor-1232	Aroclor-1242	Aroclor-1248	Aroclor-1254	Aroclor-1260	Aroclor-1262	Aroclor-1268
139	<590	<590	<590	<590	<590	5,200	2,700	<590	<590
140	<510	<510	<510	<510	<510	4,900	2,500	<510	<510
141	<220	<220	<220	<220	<220	950	460	<220	<220
141-D	<200	<200	<200	<200	<200	870	500	<200	<200
142	<37	<37	<37	<37	<37	250	180	<37	<37
143	<82	<82	<82	<82	<82	410	300	<82	<82
144	<77	<77	<77	<77	<77	480	310	<77	<77
145	<34	<34	<34	<34	<34	180	100	<34	<34
146	<34	<34	<34	<34	<34	140	120	<34	<34
146-D	<34	<34	<34	<34	<34	150	120	<34	<34
147	<290	<290	<290	<290	<290	1,800	1,500	<290	<290

Sample No.	Organochlorine pesticides							
	Aldrin	alpha-BHC	beta-BHC	delta-BHC	gamma-BHC	Alpha Chlordane	gamma Chlordane	Chlordane (technical)
1	<13.3	<13.3	<13.3	<13.3	<13.3	140	<13.3	<271
2	<20.5	<20.5	<20.5	<20.5	<20.5	170	<20.5	<420
3	<67.5	<67.5	<67.5	<67.5	<67.5	<67.5	<67.5	<1383
4	<5.7	<5.7	<5.7	<5.7	<5.7	<5.7	<5.7	<120
8	58	<8.2	<8.2	<8.2	<8.2	62	41	<168
9	<5.7	<5.7	<5.7	<5.7	<5.7	<5.7	<5.7	<120
13	<8.3	<8.3	<8.3	<8.3	<8.3	<8.3	<8.3	<170
14	<2.7	<2.7	<2.7	<2.7	<2.7	<2.7	<2.7	<54
15	<3.2	<3.2	<3.2	<3.2	<3.2	<3.2	<3.2	<65
20	<1.8	<1.8	<1.8	<1.8	<1.8	<1.8	<1.8	<37
22	<1.7	<1.7	<1.7	<1.7	<1.7	<1.7	<1.7	<36
29	<1.9	<1.9	<1.9	<1.9	<1.9	<1.9	<1.9	<39
40	<8.9	<8.9	<8.9	<8.9	<8.9	<8.9	<8.9	<180
41	<2.7	<2.7	8.3	<2.7	<2.7	<2.7	<2.7	<55
42	<1.7	<1.7	<1.7	<1.7	<1.7	<1.7	<1.7	<36
43	<2.5	<2.5	<2.5	<2.5	<2.5	22	<2.5	<51
66	<1.9	<1.9	<1.9	<1.9	<1.9	<1.9	<1.9	<38
67	<3.3	<3.3	<3.3	<3.3	<3.3	<3.3	<3.3	<68
68	<12.8	<12.8	<12.8	<12.8	<12.8	60	<12.8	<262
69	<1.9	<1.9	<1.9	<1.9	<1.9	18	<1.9	<39
72	<8.7	<8.7	<8.7	<8.7	<8.7	<8.7	<8.7	<180
74	<4.2	<4.2	<4.2	<4.2	<4.2	16	<4.2	<85
78	<1.7	<1.7	<1.7	<1.7	<1.7	30	<1.7	<36
80	<3	<3	<3	<3	<3	47	<3	<61
81	<3.7	<3.7	<3.7	<3.7	<3.7	42	<3.7	<75

Table 13. Distribution of organic compounds in bottom-sediment samples, Charles River, Massachusetts, 1998—*Continued*

Sample No.	Organochlorine pesticides							
	Aldrin	alpha-BHC	beta-BHC	delta-BHC	gamma-BHC	Alpha Chlordane	gamma Chlordane	Chlordane (technical)
90	<4.1	<4.1	23	<4.1	<4.1	<4.1	<4.1	<83
91	<5.0	<5.0	<5.0	<5.0	<5.0	36	30	<100
93	<1.8	<1.8	<1.8	<1.8	<1.8	<1.8	<1.8	<37
96	<4.0	<4.0	12	<4.0	<4.0	65	94	<82
98	<4.6	<4.6	<4.6	<4.6	<4.6	43	29	<95
98-D	<6.6	<6.6	<6.6	<6.6	<6.6	57	34	<140
106	13	<13	<13	<13	<13	70	<13	<270
106-D	12	<17	<17	<17	<17	80	67	<340
116	<1.7	<1.7	<1.7	<1.7	<1.7	7.5	<1.7	<34
118	<8.9	<8.9	21	<8.9	<8.9	24	19	<180
118-D	<8.3	<8.3	15	<8.3	<8.3	24	30	<170
122	<2.5	<2.5	<2.5	<2.5	<2.5	38	<2.5	<51
128	<13	<13	<13	<13	<13	56	32	<260
136	<3.9	<3.9	<3.9	<3.9	<3.9	33	<3.9	<80
137	<2.2	<2.2	<2.2	<2.2	<2.2	13	<2.2	<46
138	<4.9	<4.9	<4.9	<4.9	<4.9	20	<4.9	<100
139	<29	<29	<29	<29	<29	120	90	<590
140	<25	<25	<25	<25	<25	140	<25	<510
141	<11	<11	<11	<11	<11	32	<11	<220
141-D	<9.7	<9.7	<9.7	<9.7	<9.7	24	<9.7	<200
142	<1.8	<1.8	<1.8	<1.8	<1.8	6	<1.8	<37
143	<4.0	<4.0	<4.0	<4.0	<4.0	7.9	<4.0	<82
144	<3.7	<3.7	<3.7	<3.7	<3.7	11	9.9	<77
145	<1.7	<1.7	<1.7	<1.7	<1.7	3.8	<1.7	<34
146	<1.7	<1.7	<1.7	<1.7	<1.7	3	7.3	<34
146-D	<1.7	<1.7	<1.7	<1.7	<1.7	5.6	6.4	<34
147	<14	<14	<14	<14	<14	48	96	<290

Sample No.	Organochlorine pesticides						
	4,4'-DDD	4,4'-DDE	4,4'-DDT	Dieldrin	Endosulfan I	Endosulfan II	Endosulfan sulfate
1	<13.3	61	38	<13.3	<13.3	<13.3	<13.3
2	140	100	75	36	<20.5	<20.5	<20.5
3	<67.5	<67.5	<67.5	<67.5	<67.5	<67.5	<67.5
4	11	<5.7	<5.7	<5.7	<5.7	<5.7	<5.7
8	170	52	19	<8.2	<8.2	<8.2	<8.2
9	7	7.1	<5.7	<5.7	<5.7	<5.7	<5.7
13	E300	170	<8.3	<8.3	<8.3	<8.3	<8.3
14	100	E77	<2.7	<2.7	<2.7	<2.7	<2.7
15	12	14	6.4	<3.2	<3.2	<3.2	<3.2
20	52	35	<1.8	<1.8	<1.8	<1.8	<1.8

Table 13. Distribution of organic compounds in bottom-sediment samples, Charles River, Massachusetts, 1998—*Continued*

Sample No.	Organochlorine pesticides						
	4,4'-DDD	4,4'-DDE	4,4'-DDT	Dieldrin	Endosulfan I	Endosulfan II	Endosulfan sulfate
22	10	8.2	5.3	<1.7	<1.7	<1.7	<1.7
29	19	<1.9	7.6	<1.9	<1.9	<1.9	<1.9
40	260	95	<8.9	7.4	<8.9	<8.9	<8.9
41	34	26	<2.7	<2.7	<2.7	<2.7	<2.7
42	3.9	2.8	<1.7	<1.7	<1.7	<1.7	<1.7
43	88	48	<2.5	<2.5	<2.5	<2.5	<2.5
66	<1.9	30	<1.9	19	<1.9	<1.9	<1.9
67	210	<3.3	200	<3.3	<3.3	<3.3	<3.3
68	78	78	35	<12.8	<12.8	<12.8	<12.8
69	90	41	E74	22	<1.9	<1.9	<1.9
72	180	130	30	25	<8.7	<8.7	<8.7
74	32	17	<4.2	<4.2	<4.2	<4.2	<4.2
78	35	45	13	<1.7	<1.7	<1.7	<1.7
80	<3	63	22	24	<3	<3	<3
81	90	64	41	<3.7	<3.7	<3.7	<3.7
90	100	89	46	<4.1	<4.1	<4.1	<4.1
91	120	97	<5.0	<5.0	<5.0	<5.0	<5.0
93	54	36	21	<1.8	<1.8	<1.8	<1.8
96	97	79	69	25	<4.0	<4.0	<4.0
98	53	59	11	<4.6	<4.6	<4.6	<4.6
98-D	110	63	20	<6.6	<6.6	<6.6	<6.6
106	<13	120	25	<13	<13	<13	<13
106-D	150	110	9.6	<17	<17	<17	<17
116	7.5	20	14	<1.7	<1.7	<1.7	<1.7
118	41	51	14	<8.9	<8.9	<8.9	<8.9
118-D	54	58	12	<8.3	<8.3	<8.3	<8.3
122	100	52	20	<2.5	<2.5	<2.5	<2.5
128	100	96	20	<13	<13	<13	<13
136	95	90	<3.9	<3.9	<3.9	<3.9	<3.9
137	85	51	17	<2.2	<2.2	<2.2	<2.2
138	105	84	18	<4.9	<4.9	<4.9	<4.9
139	250	200	140	<29	<29	<29	<29
140	250	220	79	<25	<25	<25	<25
141	15	52	33	<11	<11	<11	<11
141-D	38	41	23	<9.7	<9.7	<9.7	<9.7
142	17	29	7	<1.8	<1.8	<1.8	<1.8
143	19	43	7.2	<4.0	<4.0	<4.0	<4.0
144	27	49	7.8	<3.7	<3.7	<3.7	<3.7
145	5.6	10	5.5	<1.7	<1.7	<1.7	<1.7
146	4.6	10	4	<1.7	<1.7	<1.7	<1.7
146-D	6.2	14	6	<1.7	<1.7	<1.7	<1.7
147	120	97	54	<14	<14	<14	<14

Table 13. Distribution of organic compounds in bottom-sediment samples, Charles River, Massachusetts, 1998—*Continued*

Sample No.	Organochlorine pesticides						
	Endrin	Endrin aldehyde	Endrin ketone	Heptachlor	Heptachlor epoxide	Methoxychlor	Toxaphene
1	<13.3	<13.3	<13.3	<13.3	<13.3	<13.3	<271
2	<20.5	<20.5	<20.5	<20.5	<20.5	<20.5	<420
3	<67.5	<67.5	<67.5	<67.5	<67.5	<67.5	<1383
4	<5.7	<5.7	<5.7	<5.7	<5.7	<5.7	<120
8	<8.2	<8.2	<8.2	<8.2	<8.2	<8.2	<168
9	<5.7	<5.7	<5.7	<5.7	<5.7	<5.7	<120
13	<8.3	<8.3	<8.3	<8.3	<8.3	<8.3	<170
14	<2.7	<2.7	<2.7	<2.7	<2.7	<2.7	<54
15	<3.2	<3.2	<3.2	<3.2	<3.2	<3.2	<65
20	<1.8	<1.8	<1.8	<1.8	<1.8	<1.8	<37
22	<1.7	<1.7	<1.7	<1.7	<1.7	<1.7	<36
29	<1.9	<1.9	<1.9	<1.9	<1.9	<1.9	<39
40	<8.9	<8.9	<8.9	<8.9	<8.9	<8.9	<180
41	<2.7	<2.7	<2.7	<2.7	<2.7	<2.7	<55
42	<1.7	<1.7	<1.7	<1.7	<1.7	<1.7	<36
43	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<51
66	<1.9	<1.9	<1.9	<1.9	<1.9	<1.9	<38
67	<3.3	<3.3	<3.3	<3.3	<3.3	<3.3	<68
68	<12.8	<12.8	<12.8	<12.8	<12.8	<12.8	<262
69	<1.9	<1.9	<1.9	<1.9	<1.9	<1.9	<39
72	<8.7	<8.7	<8.7	<8.7	<8.7	<8.7	<180
74	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2	<85
78	<1.7	<1.7	<1.7	<1.7	<1.7	<1.7	<36
80	<3	<3	<3	<3	<3	<3	<61
81	<3.7	<3.7	<3.7	<3.7	<3.7	<3.7	<75
90	<4.1	<4.1	<4.1	<4.1	<4.1	<4.1	<83
91	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<100
93	<1.8	<1.8	<1.8	<1.8	<1.8	<1.8	<37
96	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<82
98	<4.6	<4.6	16	<4.6	<4.6	<4.6	<95
98-D	<6.6	<6.6	13	<6.6	<6.6	<6.6	<140
106	<13	<13	<13	<13	<13	<13	<270
106-D	<17	<17	8.2	<17	<17	<17	<340
116	<1.7	<1.7	<1.7	<1.7	<1.7	<1.7	<34
118	<8.9	<8.9	18	<8.9	<8.9	<8.9	<180
118-D	<8.3	<8.3	18	<8.3	<8.3	<8.3	<170
122	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<51
128	<13	<13	<13	<13	<13	<13	<260
136	<3.9	<3.9	<3.9	<3.9	<3.9	<3.9	<80
137	<2.2	<2.2	<2.2	<2.2	<2.2	<2.2	<46
138	<4.9	<4.9	<4.9	<4.9	<4.9	<4.9	<100

Table 13. Distribution of organic compounds in bottom-sediment samples, Charles River, Massachusetts, 1998—*Continued*

Sample No.	Organochlorine pesticides						
	Endrin	Endrin aldehyde	Endrin ketone	Heptachlor	Heptachlor epoxide	Methoxychlor	Toxaphene
139	<29	<29	<29	<29	<29	<29	<590
140	<25	<25	<25	<25	<25	<25	<510
141	<11	<11	<11	<11	<11	<11	<220
141-D	<9.7	<9.7	<9.7	<9.7	<9.7	<9.7	<200
142	<1.8	<1.8	<1.8	<1.8	<1.8	<1.8	<37
143	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<82
144	<3.7	<3.7	<3.7	<3.7	<3.7	<3.7	<77
145	<1.7	<1.7	<1.7	<1.7	<1.7	<1.7	<34
146	<1.7	<1.7	<1.7	<1.7	<1.7	<1.7	<34
146-D	<1.7	<1.7	<1.7	<1.7	<1.7	<1.7	<34
147	<14	<14	<14	<14	<14	<14	<290

Sample No.	Polyaromatic hydrocarbons							
	Acenaphthene	Acenaphthylene	Anthracene	Benzo(a)–anthracene	Benzo(b)-floranthene	Benzo(k)-floranthene	Benzo(a)-pyrene	Benzo(ghi)-perylene
1	1,400	510	1,900	5,300	6,100	1,700	4,200	1,900
2	260	260	740	3,500	4,800	1,500	3,900	2,300
3	67,000	72,000	120,000	94,000	74,000	22,000	87,000	42,000
4	630	240	1,000	3,700	6,600	1,700	4,200	2,900
8	200	200	670	2,500	5,500	1,900	3,300	2,700
9	220	150	630	2,800	5,400	1,800	3,600	2,800
13	310	220	1,000	4,000	7,400	2,200	4,600	3,200
14	240	210	570	3,000	6,800	2,500	4,300	3,200
15	820	990	2,200	8,600	12,000	3,300	11,000	6,600
20	230	130	610	2,300	3,900	1,400	2,600	1,600
22	190	150	680	3,100	4,000	1,200	3,700	1,800
29	130	39	310	1,200	1,900	680	1,200	850
40	120	150	500	2,900	5,700	2,000	3,600	2,700
41	1,000	160	2,500	5,000	5,800	2,300	4,300	2,500
42	12	7	34	210	400	100	280	200
43	280	200	730	2,900	6,900	1,900	4,100	3,000
66	2,300	240	4,600	11,000	15,000	4,000	9,700	6,200
67	690	230	1,700	6,600	11,000	3,400	6,800	3,800
68	320	260	930	3,900	8,400	2,400	4,700	3,100
69	1,000	150	2,500	6,200	9,000	3,100	6,100	3,700
72	370	100	900	3,000	4,600	1,700	3,300	2,100
74	400	170	840	3,100	5,900	2,100	3,800	2,700
78	80	110	260	1,800	4,000	1,300	2,300	1,700
80	71	23	180	6,800	9,800	290	6,200	310
81	240	200	690	3,500	7,800	1,800	4,300	3,000
90	550	200	1,600	5,500	9,300	3,400	6,000	4,100
91	440	180	980	3,100	5,000	1,800	3,200	2,400

Table 13. Distribution of organic compounds in bottom-sediment samples, Charles River, Massachusetts, 1998—*Continued*

Sample No.	Polyaromatic hydrocarbons							
	Acenaph-thene	Acenaph-thylene	Anthracene	Benzo(a)–anthracene	Benzo(b)-floranthene	Benzo(k)-floranthene	Benzo(a)-pyrene	Benzo(ghi)-perylene
93	50,000	440	64,000	110,000	120,000	50,000	89,000	41,000
96	230	350	1,000	4,100	9,200	2,800	5,100	2,900
98	270	200	610	4,300	7,200	2,900	4,500	3,900
98-D	260	170	550	2,800	4,900	1,700	3,200	2,800
106	290	270	840	4,100	7,300	3,200	4,800	3,900
106-D	310	330	890	4,700	8,000	3,300	5,200	4,100
116	2,300	80	4,200	11,000	14,000	5,100	11,000	6,300
118	280	240	540	5,000	8,100	3,400	5,300	4,000
118-D	280	260	710	6,000	8,800	3,600	5,700	4,200
122	1,300	390	3,000	11,000	14,000	5,300	12,000	7,500
128	530	420	1,400	7,100	12,000	4,400	8,200	5,700
136	4,000	1,300	4,800	23,000	28,000	12,000	22,000	13,000
137	680	1,900	2,300	24,000	38,000	15,000	27,000	18,000
138	1,300	2,000	3,900	26,000	39,000	16,000	28,000	20,000
139	510	400	730	4,800	7,600	2,700	5,100	3,700
140	600	390	890	5,200	8,100	2,800	5,400	3,900
141	310	210	700	3,800	5,600	2,000	4,000	2,700
141-D	200	220	490	3,200	5,000	1,900	3,600	2,500
142	160	110	310	1,800	2,700	1,100	1,900	1,400
143	130	93	290	1,600	2,500	1,000	1,700	1,400
144	110	60	170	1,100	1,800	760	1,200	990
145	280	170	1,100	3,300	3,700	1,200	2,700	1,600
146	84	40	150	1,000	1,500	510	1,100	790
147	580	180	1,300	2,600	3,600	1,300	2,500	1,900

Sample No.	Polyaromatic hydrocarbons							
	Chrysene	Dibenzo(a,h)-anthracene	Floranthene	Florene	Indeno(1,2,3-cd)-pyrene	Naphthalene	Phenan-threne	Pyrene
1	5,800	730	14,000	690	2,600	710	4,500	13,000
2	3,200	670	5,900	310	0	430	2,300	8,100
3	100,000	13,000	180,000	120,000	42,000	180,000	410,000	250,000
4	4,700	830	7,600	390	3,300	310	3,100	7,600
8	3,100	810	6,700	200	3,100	230	1,900	6,100
9	3,700	660	6,200	230	3,000	380	2,100	6,500
13	5,300	810	10,000	330	3,700	320	3,400	10,000
14	3,900	860	7,400	250	3,900	190	2,200	6,500
15	10,000	1,800	14,000	760	7,300	1,400	5,000	15,000
20	2,700	490	4,400	240	1,900	170	2,200	4,600
22	3,400	550	5,200	250	2,200	88	2,600	5,600
29	1,400	260	2,700	140	1,000	76	1,400	2,500
40	4,000	750	6,300	240	3,100	60	2,100	5,800
41	5,100	860	11,000	1,100	3,100	470	9,800	10,000
42	280	43	480	14	210	8.5	220	450

Table 13. Distribution of organic compounds in bottom-sediment samples, Charles River, Massachusetts, 1998—*Continued*

Sample No.	Polyaromatic hydrocarbons							
	Chrysene	Dibenzo(a,h)-anthracene	Floranthene	Florene	Indeno(1,2,3-cd)-pyrene	Naphthalene	Phenan-threne	Pyrene
43	4,500	880	8,100	350	3,500	180	3,400	7,400
66	13,000	1,300	28,000	2,600	7,000	530	23,000	25,000
67	8,400	1,400	17,000	910	5,500	200	9,000	15,000
68	5,400	1,100	9,700	430	3,900	160	3,900	8,600
69	7,600	1,300	15,000	1,100	4,500	360	10,000	13,000
72	4,000	620	8,300	430	2,500	180	500	7,400
74	4,500	750	9,700	460	3,200	260	5,400	9,500
78	2,800	480	4,100	180	2,000	30	1,700	3,800
80	7,600	120	15,000	75	4,800	24	8,100	13,000
81	5,200	890	8,900	320	3,600	170	3,300	7,600
90	7,200	1,200	14,000	640	4,900	240	7,000	12,000
91	4,100	590	8,200	350	3,000	300	4,100	6,300
93	100,000	15,000	3,400,000	43,000	56,000	13,000	3,400,000	2,700,000
96	6,500	1,100	10,000	350	3,900	160	4,100	8,900
98	5,500	940	8,700	410	4,900	250	4,300	8,800
98-D	3,800	650	5,900	320	3,400	220	3,200	6,300
106	5,400	870	8,400	320	4,900	180	3,600	8,200
106-D	5,900	1,100	9,800	360	5,100	200	4,000	8,700
116	11,000	2,000	30,000	2,700	7,500	1,900	25,000	23,000
118	6,200	1,000	9,800	340	5,200	200	4,300	8,700
118-D	6,900	1,100	11,000	410	5,400	190	5,100	11,000
122	13,000	2,000	27,000	1,600	8,400	500	17,000	23,000
128	8,500	1,500	16,000	680	6,200	410	7,500	15,000
136	24,000	3,500	54,000	4,500	17,000	2,000	38,000	45,000
137	29,000	4,300	56,000	1,300	23,000	760	12,000	47,000
138	31,000	4,000	60,000	2,100	25,000	880	18,000	50,000
139	6,200	1,100	10,000	820	4,600	280	5,500	11,000
140	6,600	1,100	12,000	1,000	4,900	270	5,200	11,000
141	3,800	720	7,600	380	3,400	180	3,400	7,100
141-D	3,400	670	7,300	270	3,100	270	2,500	7,000
142	2,000	370	3,700	230	1,800	120	1,700	3,500
143	1,800	340	3,300	190	1,700	180	1,500	3,300
144	1,300	240	2,300	130	1,200	140	1,100	2,400
145	3,200	560	5,400	290	2,000	270	1,600	4,900
146	1,200	180	2,100	92	940	62	830	1,900
147	3,300	430	5,800	910	2,200	0	5,800	6,000