COMBINED WORK/QUALITY ASSURANCE PROJECT PLAN (CW/QAPP)

for

BENTHIC MONITORING: 1995-1997

Tasks 17-20
MWRA Harbor and Outfall Monitoring Project

submitted to

MASSACHUSETTS WATER RESOURCES AUTHORITY
Environmental Quality Department
100 First Avenue
Charlestown Navy Yard
Boston, MA 02129
(617) 242-6000

prepared by

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July, 1995

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1.0 PROJECT NAME

MWRA Harbor and Outfall Monitoring Project
Tasks 17-20
Benthic Monitoring, 1995 - 1997

2.0 PROJECT REQUESTED BY

Massachusetts Water Resources Authority

3.0 DATE OF REQUEST

November 2, 1994

4.0 DATE OF PROJECT INITIATION

November 2, 1994

5.0 PROJECT MANAGEMENT

Dr. Michael Connor, MWRA Director of Environmental Quality Department
Dr. Michael Mickelson, MWRA Harbor and Outfall Monitoring Project Manager
Mr. Ken Keay, MWRA Harbor and Outfall Monitoring Deputy Project Manager and Soft-Bottom Monitoring Project Area Manager

Dr. James Blake, ENSR Harbor and Outfall Monitoring Project Manager and Benthic Monitoring Area Manager
Dr. James Bowen, ENSR Harbor and Outfall Monitoring Technical Director

6.0 QUALITY ASSURANCE (QA) MANAGEMENT

Ms. Debra McGrath, ENSR Project QA Director

7.0 PROJECT DESCRIPTION

7.1 Objective and Scope

The primary objectives of the Benthic Monitoring component of the MWRA Harbor and Outfall Monitoring Program are (1) to document recovery of benthic communities and the decrease in sediment contamination following cessation of sludge discharge, and (2) to gather baseline data to document changes following improvements in combined sewer overflows (CSO) in Boston Harbor. Additional objectives include (1) to continue the collection of baseline data on both the soft- and hard-bottom communities and the contaminant concentrations in surficial sediments in Massachusetts and Cape Cod Bays prior to effluent discharge and (2) to continue collection of these data after relocation of the effluent discharge to Massachusetts Bay to document any changes associated with the operation of the new outfall.

The specific goals associated with documenting changes in Boston Harbor benthic communities are to

- Characterize, through detailed taxonomic analysis, the benthic communities at eight stations placed in areas near to and removed from the point of previous MWRA sludge disposal. Samples for this analysis (part of Tasks 17 and 20) will be collected during April and August of each year of the study (1995 through 1997).

- Provide for broader geographical coverage (reconnaissance) of benthic communities in the Harbor by using sediment profile images obtained with the REMOTS® system (or equivalent sediment profile imagery) at 60 stations throughout the Harbor (Subtask 17.2). Reconnaissance surveys will be carried out in August of each year of this project.

- Develop and implement a benthic survey (in 1997) to refine understanding of the potential impact of CSO discharges on the sediment quality of defined areas within Boston Harbor (Subtask 17.3).

- Determine the status of the sediment physicochemical constituents in Boston Harbor just prior to relocation of the effluent discharges to Massachusetts Bay (Tasks 17 and 19).

The specific goals associated with providing baseline data on benthic communities and sediment chemistry in Massachusetts and Cape Cod Bays are to:

- Characterize the benthic macrofaunal community in the vicinity of the outfall (nearfield) and at reference stations throughout Massachusetts and Cape Cod Bays (farfield) prior to effluent discharge. This characterization will employ quantitative taxonomic analysis of nearfield and farfield sediment samples to determine the abundance and distribution of macrofauna in the study area (Tasks 18 and 20).

- Continue this analysis after start-up of the new outfall to document any changes in macrofaunal communities.

- Characterize the baseline sediment chemical constituents at the 20 nearfield and 11 farfield stations in Massachusetts and Cape Cod Bays prior to effluent discharge (Tasks 18 and 19).

- Continue those same efforts after relocation of the outfall to Massachusetts Bay to document any changes related to effluent discharge.

- Provide qualitative/semi-quantitative video coverage of hard-bottom nearfield areas with a remotely operated vehicle (ROV) to supplement the quantitative soft-bottom samples. This survey, conducted during June or July of each year, will include eight transects (six within 2 km and two within 3-5 km of the diffuser). This task (Subtask 18.2) may be combined with the diffuser survey (Task 30), tentatively scheduled for 1996, if requested by the Authority.

7.2 Data Usage

Data resulting from the MWRA/HOM Benthic Monitoring Program will be comparable to recent studies in the Harbor and the Bay, and will continue to add to the understanding of the baseline conditions in the study area. Data collected after commissioning of the new outfall will be used to test the hypothesis that increased nutrient input to the Bay will secondarily influence the benthos. The benthic monitoring

database will be integrated with data from the water column monitoring, nutrient flux, and fish and shellfish monitoring tasks to provide a system-wide view of the effects of nutrient inputs from the new outfall.

Data from the various components of the Harbor and Outfall Monitoring portion of the Benthic Monitoring Program will be used to produce annual synthesis reports (Task 33). Results of quantitative taxonomic analysis of samples collected during the semi-annual traditional surveys in the Harbor (Subtask 17.1) will allow continued documentation of the response of the soft-bottom benthos to the improvements in sewage treatment and disposal. The data obtained with the sediment profile imaging system (e.g. REMOTS®, or equivalent) will provide qualitative/semi-quantitative characterization of benthic conditions in the Harbor as a whole and supplement the quantitative data collected at the eight traditional stations (Subtask 17.2).

Analysis of sediment samples collected annually in Massachusetts and Cape Cod Bays (Subtasks 18.1 and 18.3) will be used to provide baseline data for both the benthic infaunal communities and the concentrations of contaminants in the associated sediments prior to relocation of the outfall. Once the outfall is operational, these data will be used to assess the extent and severity of any changes associated with the new outfall. The farfield stations are expected to remain in baseline condition. The data from the benthic video survey (Subtask 18.2) will supplement the soft-bottom data with qualitative/semi-quantitative observations in nearfield areas, such as boulder and cobble fields, where quantitative soft-bottom grab samples cannot be obtained. Prior to effluent discharge, a baseline will be established against which changes can be measured once the new outfall goes on line.

7.3 Technical Approach

7.3.1 Boston Harbor Studies

Two sampling approaches will be used to document the condition of the macrofaunal communities and the levels of sediment chemical constituents following cessation of sludge discharge (which occurred in December 1991) and the planned termination of all sewage discharges into Boston Harbor (scheduled for 1997). The first approach will use a standard grab sampler to obtain sediment samples from eight "traditional" stations (Table 1, Figure 1) that were selected after consideration of historical sampling sites and Harbor circulation patterns (Kelly and Kropp, 1992). Samples from these stations will be collected twice each year (April and August) for quantitative taxonomic analysis. This sampling design will permit

TABLE 1

Target Locations for the Harbor Traditional Survey Stations

Station	Latitude	Longitude	Depth (m)
T1	42°20.95′N	70°57.81′W	4.0
T2	42°20.57′N	71°00.12′W	6.0
T3	42°19.81′N	70°57.72′W	9.0
T4	42°18.60′N	71°02.49′W	3.5
T5A	42°20.38′N	70°57.64′W	18.0
T6	42°17.61′N	70°56.66′W	6.0
T7	42°17.36′N	70°58.71′W	7.0
T8	42°17.12′N	70°54.75′W	11.0

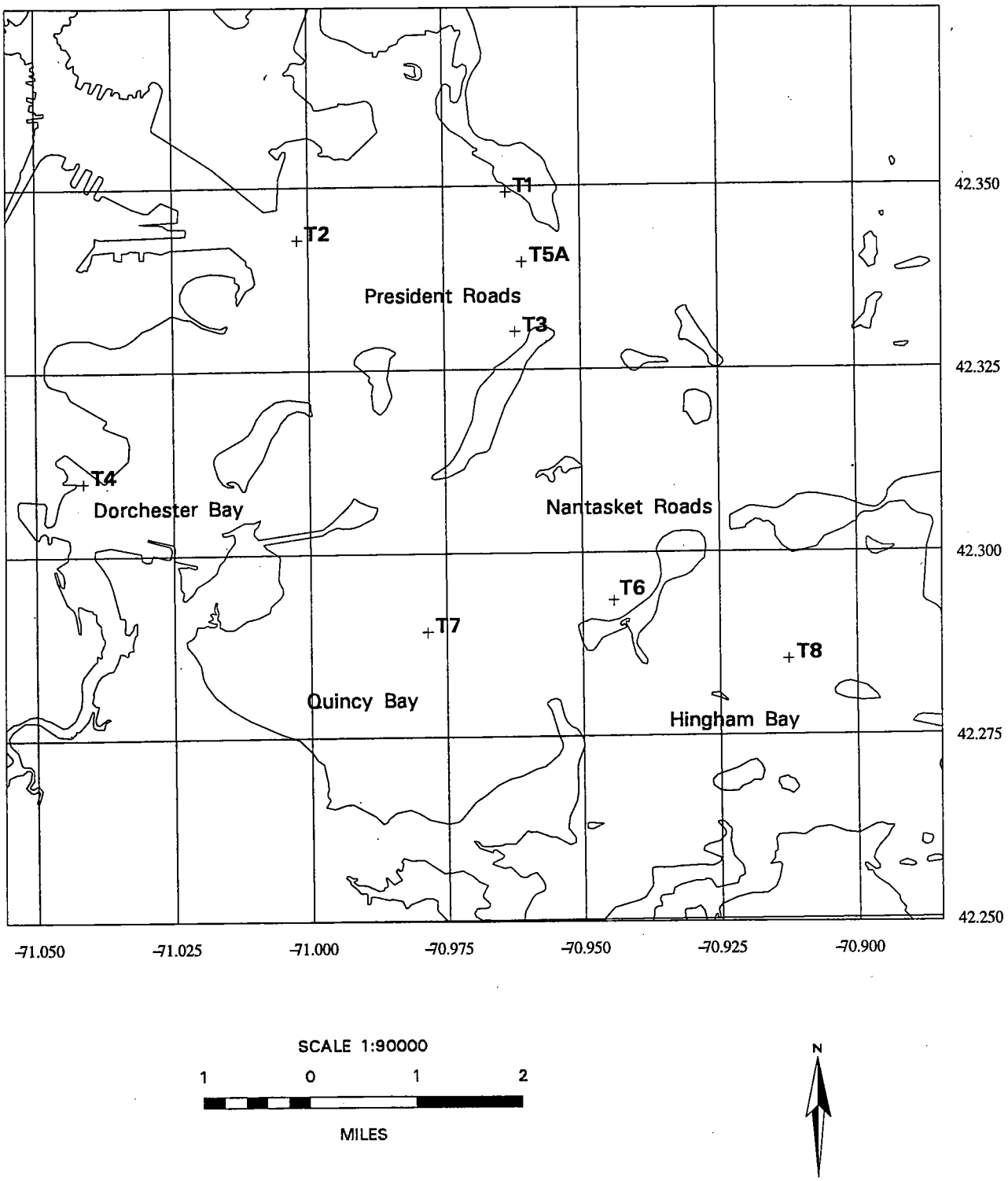

FIGURE 1
Station Locations for Harbor Traditional Benthic Survey

assessment of the community during the spring recruitment season and again during the late summer season when population densities are at their maximum.

Multiple samples will be collected at all Harbor stations. One chemistry and three biology samples will be collected at each station, and an additional two chemistry samples will be taken at each station during a survey designated by the Authority as being closest to the time of relocation of the effluent to Massachusetts Bay.

The reconnaissance survey, conducted only during August of each year, will provide for greater geographic coverage of community recovery throughout the Harbor. Sediment profiling images (REMOTS®, or equivalent) will be obtained at 60 "reconnaissance" stations, including 10 new stations selected for this project in addition to the 50 reconnaissance stations sampled in 1993 and 1994 (Table 2, Figure 2). The coordinates of some of the new stations will be recommended by ENSR to the Authority prior to the first reconnaissance survey in the spring of 1995. It is possible that some of these stations will have to be relocated during the survey.

The Boston Harbor CSO study will be performed in the same manner as similar studies conducted in 1990 and 1994. The CSO study will be implemented in 1997 as part of the April or August survey in the Harbor, depending on a decision by the Authority. Pending any changes desired by the MWRA, the same 14 stations will be occupied as in 1994 and three chemistry samples collected at each station (Table 3, Figure 2). A detailed scope will be developed jointly by ENSR, MIT, and the Authority based on a refined model that is to be finalized as part of the Authority's Sewer System Master Plan.

Details of the field sampling and laboratory methods to be used in the Harbor benthic studies are provided in Section 12.0.

7.3.2 Outfall Studies

The sampling design for the soft-bottom Outfall studies in Massachusetts and Cape Cod Bays has been modified relative to the previous program (1993/1994) to allow for broader areal coverage and improved statistical comparability of nearfield and farfield samples. The target station locations for the nearfield stations (Table 4, Figure 3) are as listed in Campbell (1994). Three of these stations (NF12, NF17, and NF24) will be replicated, with three biology and two chemistry samples collected at each station; the remaining 17 stations will be non-replicated (one biology and one chemistry sample per station).

TABLE 2

Target Locations for Harbor Reconnaissance Survey Stations

Station	Latitude	Longitude	Depth (m)
T1	42°20.95'N	70°57.81'W	4.0
T2	42°20.57'N	71°00.12'W	6.0
T3	42°19.81'N	70°57.72'W	9.0
T4	42°18.60'N	71°02.49'W	3.5
T5A	42°20.38'N	70°57.64'W	18.0
T6	42°17.61'N	70°56.66'W	6.0
T7	42°17.36'N	70°58.71'W	7.0
T8	42°17.12'N	70°54.75'W	11.0
R2	42°20.66'N	70°57.69'W	12.0
R3	42°21.18'N	70°58.37'W	5.5
R4	42°21.52'N	70°58.78'W	8.5
R5	42°21.38'N	70°58.68'W	7.1
R6	42°19.91'N	70°57.12'W	6.8
R7	42°20.85'N	70°58.53'W	5.9
R8	42°20.66'N	70°59.50'W	2.8
R9	42°20.80'N	71°00.98'W	11.8
R10	42°21.32'N	71°02.20'W	13.5
R11	42°19.28'N	70°58.48'W	7.0
R12	42°19.10'N	70°58.47'W	6.3
R13	42°19.03'N	70°58.84'W	7.2
R14	42°19.25'N	71°00.77'W	7.9
R15	42°18.92'N	71°01.15'W	3.6
R16	42°18.95'N	70°57.68'W	6.9
R17	42°18.29'N	70°58.63'W	8.2
R18	42°17.33'N	70°57.67'W	7.9
R19	42°16.92'N	70°56.27'W	9.7
R20	42°19.49'N	70°56.10'W	9.7
R21	42°18.53'N	70°56.78'W	7.0
R22	42°18.02'N	70°56.37'W	8.3
R23	42°17.63'N	70°57.00'W	10.5
R24	42°17.78'N	70°57.51'W	8.3
R25	42°17.48'N	70°55.72'W	6.8
R26	42°16.13'N	70°55.80'W	5.8

TABLE 2 (Continued)

Target Locations for Harbor Reconnaissance Survey Stations

Station	Latitude	Longitude	Depth (m)
R27	42°16.83'N	70°54.98'W	3.7
R28	42°16.90'N	70°54.52'W	8.2
R29	42°17.38'N	70°55.25'W	8.8
R30	42°17.43'N	70°54.25'W	5.2
R31	42°18.05'N	70°55.03'W	9.8
R32	42°17.68'N	70°53.82'W	5.5
R33	42°17.65'N	70°59.67'W	4.0
R34	42°17.33'N	71°00.42'W	3.4
R35	42°17.05'N	70°59.28'W	4.3
R36	42°16.53'N	70°59.20'W	2.7
R37	42°17.93'N	70°59.08'W	4.0
R38	42°17.08'N	70°57.83'W	4.6
R39	42°17.73'N	70°58.22'W	6.4
R40	42°19.73'N	71°01.45'W	4.6
R41	42°18.67'N	71°01.50'W	5.5
R42	42°19.18'N	71°01.50'W	3.7
R43	42°18.40'N	71°00.13'W	4.0
R44	TBD	TBD	TBD
R45	TBD	TBD	TBD
R46	42°20.40'N	70°58.75'W	14.5
R47	42°20.67'N	70°58.72'W	8.3
R48	42°21.36'N	71°02.03'W	11.8
R49	42°16.39'N	70°54.49'W	8.4
R50	42°16.50'N	70°53.92'W	7.6
R51	42°15.80'N	70°56.53 'W	2.4
R52	42°15.71'N	70°56.09'W	2.1
R53	42°16.15'N	70°56.27'W	3.0

TBD = To be determined.

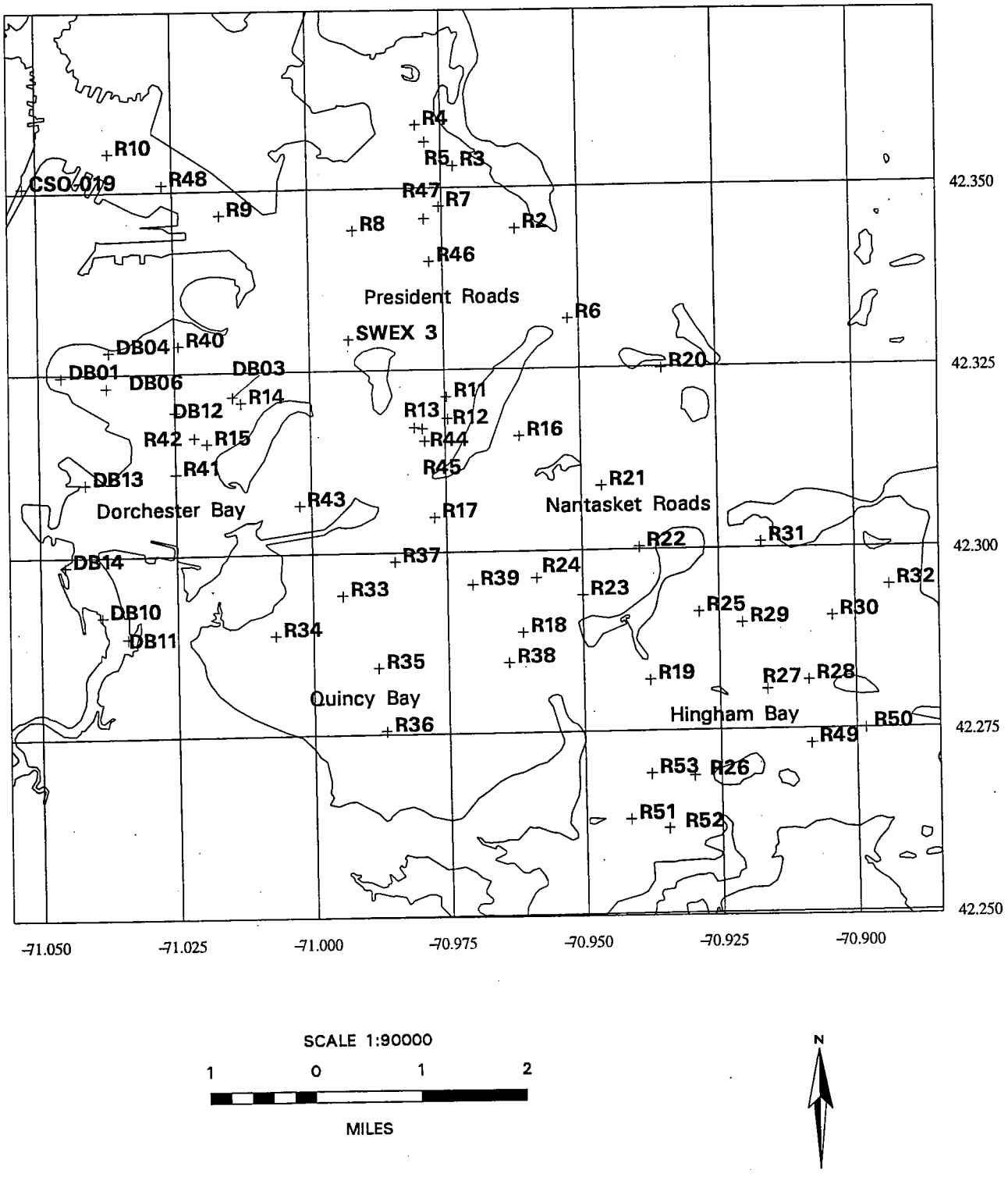

FIGURE 2
Station Locations for Harbor Reconnaissance Benthic Survey and CSO Survey

TABLE 3

Target Locations for Harbor CSO Survey Stations

Station	Latitude	Longitude	Depth (m)
T1	42°20.95′N	70°57.81′W	4.0
T2	42°20.57′N	71°00.12′W	6.0
T8	42°17.12′N	70°54.75′W	11.0
DB01	42°19.48′N	71°02.75′W	1.5
DB03	42°19.30′N	71°00.86′W	5.2
DB04	42°19.68′N	71°02.22′W	2.7
DB06	42°19.39′N	71°02.25′W	2.0
DB10	42°17.50′N	71°02.33′W	1.2
DB11	42°17.32′N	71°02.05′W	2.4
DB12	42°18.97′N	71°01.29′W	6.4
DB13	42°18.60′N	71°02.50′W	5.5
DB14	42°17.92′N	71°02.73′W	2.0
CSO 019	42°21.04′N	71°03.15′W	9.0
SWEX 3	42°19.76′N	71°59.56′W	8.0

TABLE 4

Target Locations for Outfall Survey Stations

Station	Latitude	Longitude	Depth (m)
	Nearfield Stations		
NF2	42°20.31′N	70°49.69′W	30
NF4	42°24.93′N	70°48.39′W	36
NF5	42°25.62′N	70°50.03′W	36
NF7	42°24.60′N	70°48.89′W	33
NF8	42°24.00′N	70°51.81′W	32
NF9	42°23.99′N	70°50.69′W	29
NF10	42°23.57′N	70°50.29′W	35
NF12	42°23.40′N	70°49.83′W	34
NF13	42°23.40′N	70°49.35′W	33
NF14	42°23.20′N	70°49.36′W	33
NF15	42°22.93′N	70°49.67′W	32
NF16	42°22.70′N	70°50.26′W	29
NF17	42°22.88′N	70°48.89′W	29
NF18	42°23.80′N	70°49.31′W	35
NF19	42°22.30′N	70°48.30′W	32
NF20	42°22.69′N	70°50.69′W	28
NF21	42°24.16′N	70°50.19′W	33
NF22	42°20.87′N	70°48.90′W	36
NF23	42°23.86′N	70°48.10′W	36
NF24	42°22.83′N	70°48.10′W	37
	Farfield Stations		
FF1A	42°33.84′N	70°40.55′W	32
FF4	42°17.30′N	70°25.50′W	87
FF5	42°08.00′N	70°25.35′W	61
FF6	41°53.90′N	70°24.20′W	33
FF7	41°57.50′N	70°16.00′W	37
FF9	42°18.75′N	70°39.40′W	49
FF10	42°24.84′N	70°52.72′W	27
FF11	42°39.50′N	70°30.00′W	87
FF12	42°23.40′N	70°53.98′W	22
FF13	42°19.19′N	70°49.38′W	19
FF14	42°25.00′N	70°39.29′W	77

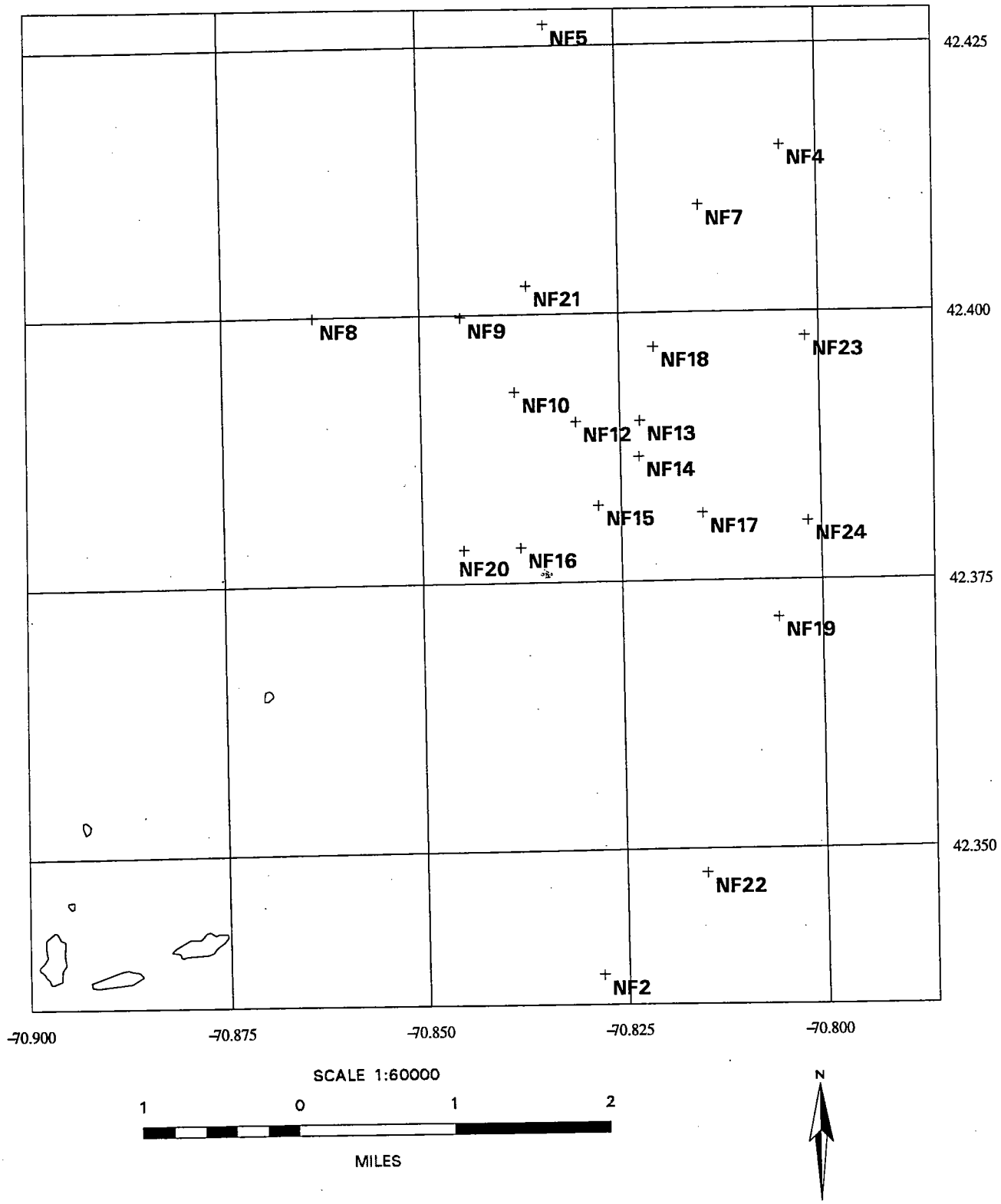

FIGURE 3
Station Locations for Nearfield Benthic Survey

In September of 1994, the hard bottom areas in the nearfield were surveyed with an ROV. Six transects (T1-T6) were occupied in depths ranging from 22 m - 34 m. The length of individual transects ranged from 0.7 km to more than 2.2 km. In addition, observations were made along the location of the diffuser. For 1995, the results of the 1994 survey will be used as a guide to determine if the same transects will be reoccupied, and additional transects may be added upon request by the Authority. At present, video surveys are planned for the nearfield area with supplementary 35-mm still photographs to document the sediments and organisms on the rock surfaces. The 1994 reference coordinates for the ROV transects are listed in Table 5, and plotted in Figure 4.

The 11 farfield stations are located in Massachusetts and Cape Cod Bays including Stellwagen Basin, distant from the future outfall. This station array is intended to provide a farfield baseline that can be used as reference for the nearfield stations and as true monitoring stations in the unlikely event that the effects of the sewage discharge extend further than currently expected. The target locations for the farfield stations (Table 4, Figure 5) are as listed in Campbell (1994). Three biology and two chemistry samples will be collected at each station.

Details of the field sampling and laboratory methods to be used in the Outfall studies are provided in Section 12.0.

7.4 Monitoring Parameters and Collection Frequency

A summary of the numbers of stations to be visited and the types and numbers of field samples to be collected in the Harbor and in Massachusetts and Cape Cod Bays during this project is given in Table 6. The number of samples is listed both per survey and for all six semi-annual or three annual surveys of this project combined.

The reconnaissance survey parameters to be measured in the laboratory and the methods to be used are listed in Table 7. The chemical parameters to be analyzed in the laboratory and the methods to be used are summarized in Table 8. A more detailed list of the analytes included in Task 19 is presented in Section 11.0. Under the sampling/analysis protocols specified by NOAA for the National Status & Trends Mussel Watch Project, no sediment holding times are specified. The U.S. EPA has suggested some holding times by reference to water sample holding times, for example, the interim final Monitoring Guidance for the National Estuary Program (EPA document #503/8-91-002). Sediment chemistry samples will be refrigerated or frozen as soon as possible after sampling and they will remain cold or frozen until sample processing begins. It is assumed that if the samples are properly handled and remain

TABLE 5

Hard-Bottom Video Survey Stations Sampled in 1994

Transect	First End Point	Second End Point	Depth Range (m)	Length (km)
T1	42°23.89′N, 70°48.96′W	42°23.55′N, 70°48.00′W	22-30	1.47
T2	42°23.65′N, 70°47.92′W	42°23.35′N, 70°46.81′W	29-33	1.63
T3	42°23.36′N, 70°47.44′W	42°23.00′N, 70°47.30′W	27-33	0.70
T4	42°23.83′N, 70°48.10′W	42°23.05′N, 70°46.80′W	27-34	1.84
T5	42°22.21′N, 70°48.37′W	42°22.83′N, 70°46.97′W	27-33	2.25
T6	42°23.00′N, 70°47.64′W	42°22.61′N, 70°46.12′W	27-30	2.22
Diffuser	42°23.05′N, 70°48.23′W	42°23.33′N, 70°46.81′W	31-33	2.03

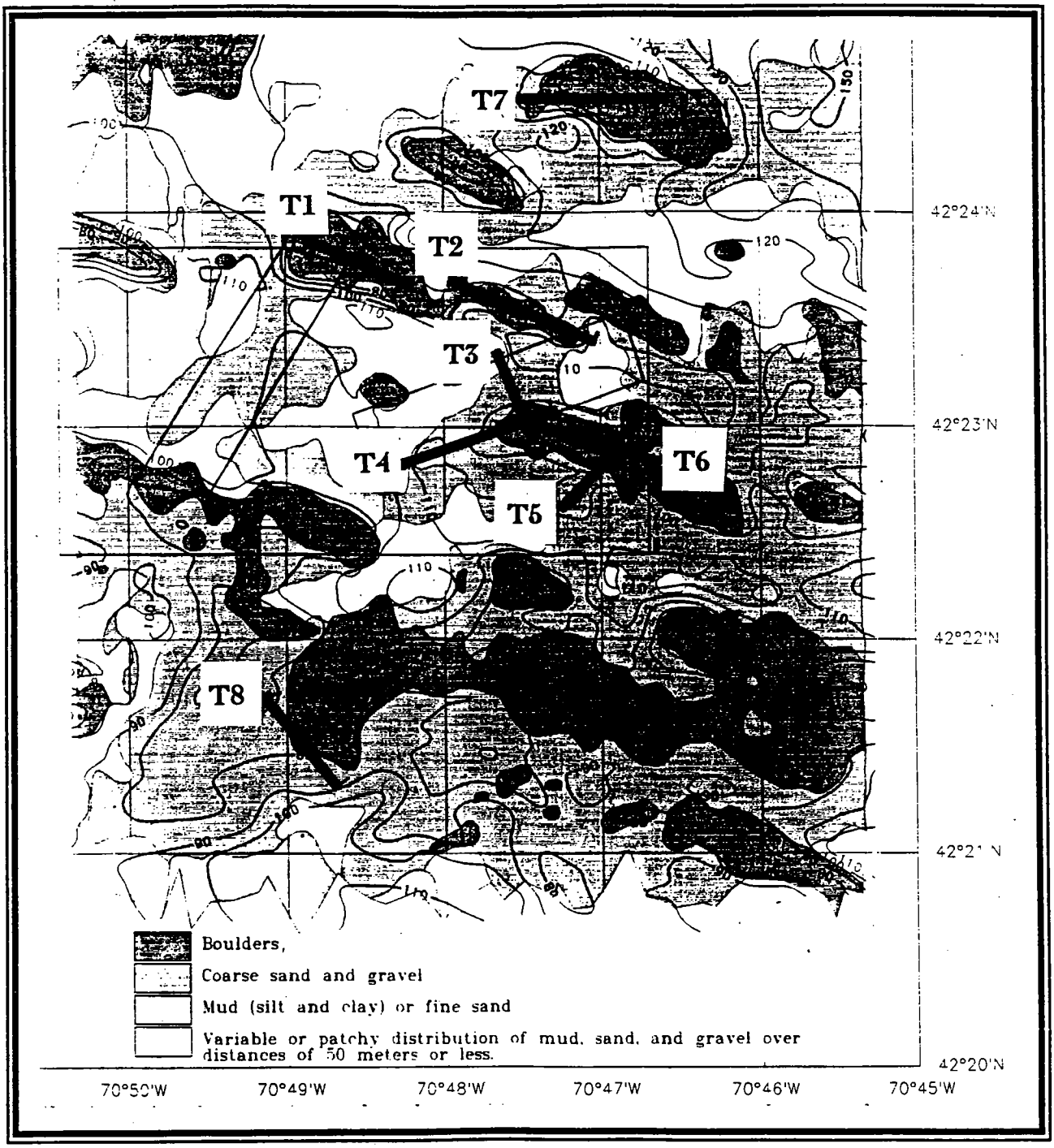

FIGURE 4
Location of Nearfield Hardbottom Survey Transects

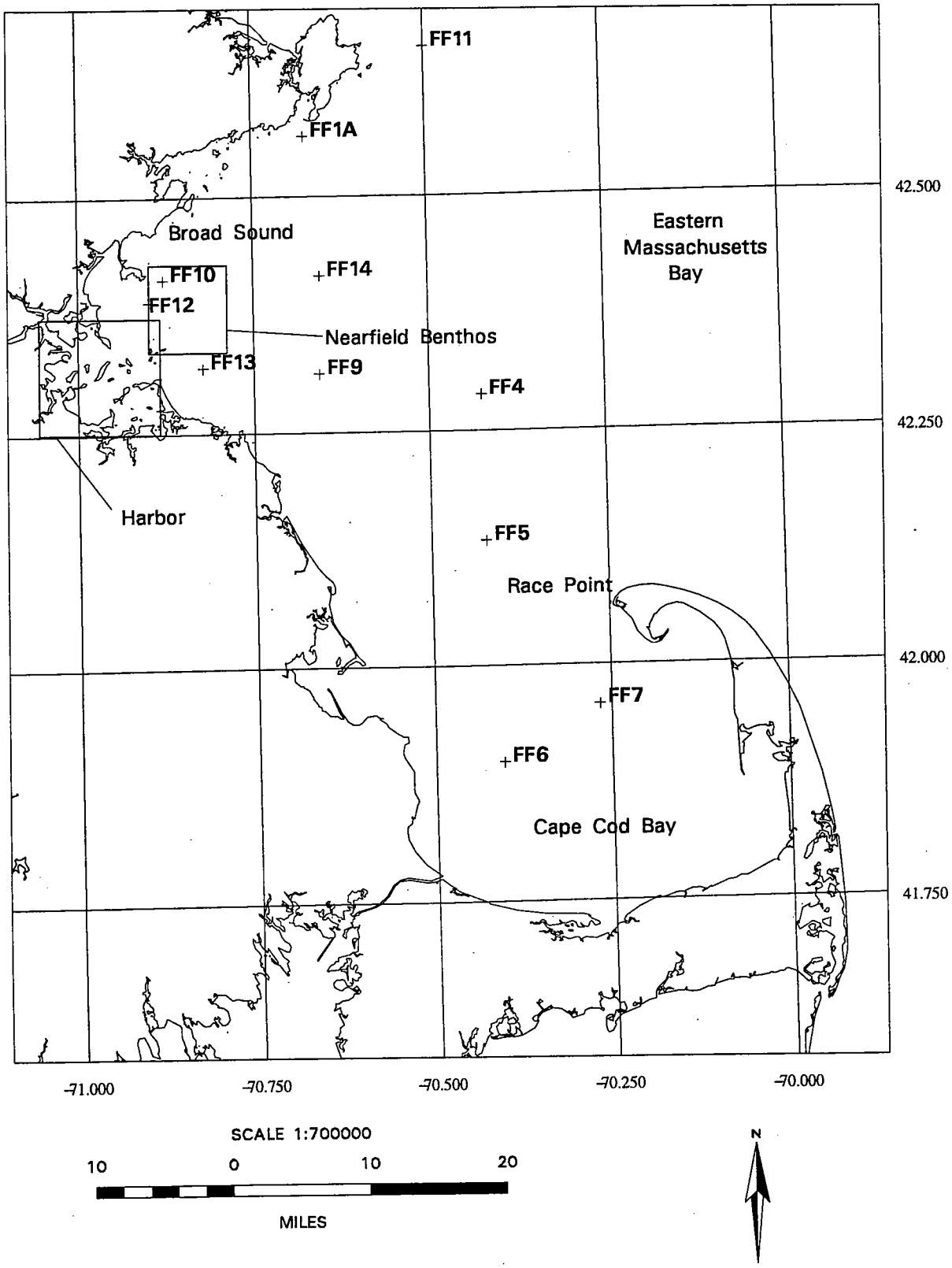

FIGURE 5
Station Locations for Farfield Benthic Survey

TABLE 6

Summary of Samples To Be Collected during This Program

	Harbor Surveys					Outfall Surveys			
	Traditional 8 Stations		Reconnaissance 60 Stations		CSO Study 14 Stations	Nearfield 20 Stations		Farfield 11 Stations	
	1 Survey	*Total 6 Surveys*	*1 Survey*	*Total 3 Surveys*	*Total 1 Survey*	*1 Survey*	*Total 3 Surveys*	*1 Survey*	*Total 3 Surveys*
Benthic Infauna	24	144				26	78	33	99
Sediment Chemistry	8	64[1]			42	23	69	22	66
TOC	8	64			42	23	69	22	66
Grain Size	8	64			42	23	69	22	66
C. perfringens	8	64			42	23	69	22	66
Enterococcus					42				
Fecal Coliform Bacteria					42				
Profile Images			180	540					

[1]Includes 2 additional chemistry samples per station during single survey to be designated by MWRA (spring or summer 1996).

TABLE 7

Summary of Sediment Profiling Parameters To Be Measured during Harbor Reconnaissance Surveys

Parameter	Unit	Description
Sediment grain size major mode, range	phi	Comparison with photographs of known grain sizes (Udden-Wentworth classes), spanning <4 phi to >1 phi
Prism penetration depth	cm	Measure maximum and minimum distance between bottom of photograph and sediment-water interface; calculate mean depth
Boundary roughness	cm	Difference between minimum and maximum penetration depth; determine biogenic or physical origin if possible
Mud clasts	#, mm	Count and measure diameter of most numerous size class (classes usually in mm)
Presence of dredged material	çm, cm^2	Identified by texture and color; measure area and maximum and minimum thickness, calculate mean thickness
Apparent RPD depth	cm	Identified by change in reflectance; measure maximum and minimum, caculate mean
Redox rebound	cm	Same as apparent RPD depth (refers to relict RPD)
Low dissolved oxygen in overlying water	NA	Inferred from absence of an oxidized surficial sediment layer (no RPD), identified by reflectance
Methane bubbles	#, mm	Identified by reflectance; count, measure diameter of most numerous size class (classes usually in mm)
Infaunal successional stage	NA	Identified by type of biogenic structures such as tubes and feeding voids and the presence of animals
Other characters	NA	May include sediment color and fabric; shell lag deposits; fecal pellets; fluid mud; ripples, depressions, and mounds
Organism-Sediment Index (OSI)	NA	Calculated by assigning dimensionless scores to several physical, chemical, and biological parameters and summarizing; range is -10 to +11.

RPD = Redox potential discontinuity
NA = Not Applicable

TABLE 8

Laboratory Analyses and Methods

Parameter	Units[1]	Method	Reference[2]	Preservation
Polychlorinated Biphenyls	ng/g	GC/ECD	see Section 12	Freeze
Polynuclear Aromatic Hydrocarbons	ng/g	GC/MS (SIM)	see Section 12	Freeze
Pesticides	ng/g	GC/ECD	see Section 12	Freeze
Grain Size	%[3]	Dry-sieving/pipet	Plume, 1981	Refrigerate
Clostridium perfringens	spores/g	Sonification, extraction, membrane filtration	Emerson & Cabelli, 1982[4]	Refrigerate
Total Organic Carbon	%	CHN analyzer	see Section 12	Refrigerate
Linear alkyl benzenes	ng/g	GC/MS (SIM)	see Section 12	Refrigerate
Major Metals				
Al	µg/g	ICP/MS	see Section 12	Refrigerate
Fe	µg/g	ICP/MS	see Section 12	Refrigerate
Trace Metals				
Ag	µg/g	ICP/MS	see Section 12	Refrigerate
Cd	µg/g	ICP/MS	see Section 12	Refrigerate
Cr	µg/g	ICP/MS	see Section 12	Refrigerate
Cu	µg/g	ICP/MS	see Section 12	Refrigerate
Hg	µg/g	CVAA	see Section 12	Refrigerate
Ni	µg/g	ICP/MS	see Section 12	Refrigerate
Pb	µg/g	ICP/MS	see Section 12	Refrigerate
Zn	µg/g	ICP/MS	see Section 12	Refrigerate

[1]Dry weight basis.
[2]See Section 20 for literature references.
[3]For gravel, silt, and clay - percent of total sample; sand fraction will be analyzed to full ϕ sizes.
[4]As modified by Saad (see Section 12).
[5]Most Probable Number

cold or frozen, their integrity will not be compromised prior to processing, and that all sample processing and analyses will occur well within any suggested holding times.

8.0 PROJECT FISCAL INFORMATION

This project is being carried out under the terms of Contract S186 between the MWRA and ENSR Consulting and Engineering. The budgets for all tasks comprising the Benthic Monitoring Project Area are presented in the contract documents.

9.0 SCHEDULE OF ACTIVITIES AND DELIVERABLES

Benthic monitoring activities will span the period from the date of project initiation (see Section 4.0) until April 1998, when the last annual synthesis report is due. Activities include field sampling and laboratory analyses, with deliverables consisting of associated survey plans, survey reports, data reports, and synthesis reports (prepared under Task 33). A schedule for these activities and deliverables is outlined in Tables 9 and 10.

10.0 PROJECT ORGANIZATION

The project organization is shown in Figure 6. Dr. Michael Mickelson is the MWRA Project Manager and Mr. Ken Keay is the MWRA Project Area Manager for the Benthic Monitoring. Dr. James A. Blake is the ENSR Project Manager responsible for the overall performance of this project. He also serves as ENSR Project Area Manager for the benthic tasks described in this CW/QAPP.

The Harbor Benthic Surveys (Task 17.1) will be coordinated by Dr. Brigitte Hilbig (ENSR), while Dr. Robert Diaz of Diaz and Daughters will be responsible for the Harbor Reconnaissance Surveys (Task 17.2). Dr. Jo Ann Muramoto (ENSR) will coordinate the CSO Surveys (Task 17.3). The Outfall Benthic Surveys (Tasks 18.1 and 18.3) and the Nearfield Hard-Bottom Surveys (Task 18.2) will be coordinated by Dr. Hilbig.

Dr. Muramoto will coordinate the transport of sediment chemistry samples from the field to the appropriate laboratories and the compilation of the data from the laboratories (Task 19), and Dr. Hilbig

TABLE 9

Overview of Harbor and Outfall Surveys and Associated Deliverables

Survey Date	Deliverable	Due Date
April 1995	Harbor Traditional Survey Plan	March 1995
	Harbor Traditional Survey Report	May 1995
June/July 1995[1]	Nearfield Benthic Video Survey Plan	May/June 1995
	Nearfield Benthic Video Survey Report	July/August 1995
August 1995	Harbor Traditional/Reconnaissance and Soft-Bottom Outfall Survey Plan	July 1995
	Harbor Traditional/Reconnaissance and Soft-Bottom Outfall Survey Report	September 1995
April 1996	Harbor Traditional Survey Plan	March 1996
	Harbor Traditional Survey Report	May 1996
June/July 1996	Nearfield Hard-Bottom Outfall Survey Plan	May/June 1996
	Nearfield Hard-Bottom Outfall Survey Report	July/August 1996
August 1996	Harbor Traditional/Reconnaissance and Soft-Bottom Outfall Survey Plan	July 1996
	Harbor Traditional/Reconnaissance and Soft-Bottom Outfall Survey Report	September 1996
April 1997[2]	Harbor Traditional Survey Plan	March 1997
	Harbor Traditional Survey Report	May 1997
June/July 1997	Nearfield Hard-Bottom Outfall Survey Plan	May/June 1997
	Nearfield Hard-Bottom Outfall Survey Report	July/August 1997
August 1997[2]	Harbor Traditional/Reconnaissance and Soft-Bottom Outfall Survey Plan	July 1997
	Harbor Traditional/Reconnaissance and Soft-Bottom Outfall Survey Report	September 1997

[1] May include diffuser cap survey (Task 30) if desired by MWRA
[2] May include CSO survey; exact date to be determined by MWRA

TABLE 10

Overview of Data and Synthesis Reports

Survey Date	Deliverable	Due Date (Draft)[1]
April 1995	April Faunal Data Report (Harbor Traditional)	September 1995
June/July 1995	Nearfield Benthic Video Data Report	October/November 1995
August 1995	August Reconnaissance Data Report	November 1995
	August Faunal Data Report (Harbor Traditional, Nearfield, Farfield)	December 1995
April 1996	April Faunal Data Report (Harbor Traditional)	September 1996
June/July 1996	Nearfield Benthic Video Data Report	October/November 1996
August 1996	August Reconnaissance Data Report	November 1996
	August Faunal Data Report (Harbor Traditional, Nearfield, Farfield)	December 1996
April 1997	April Faunal Data Report (Harbor Traditional)	September 1997
June/July 1997	Nearfield Benthic Video Data Report	October/November 1997
August 1997	August Reconnaissance Data Report	November 1997
	August Faunal Data Report (Harbor Traditional, Nearfield, Farfield)	December 1997
1995	Benthic Synthesis Report	April 1996
1996	Benthic Synthesis Report	April 1997
1997	Benthic Synthesis Report	April 1998

[1]Final Reports due 30 days after submittal of Draft Reports

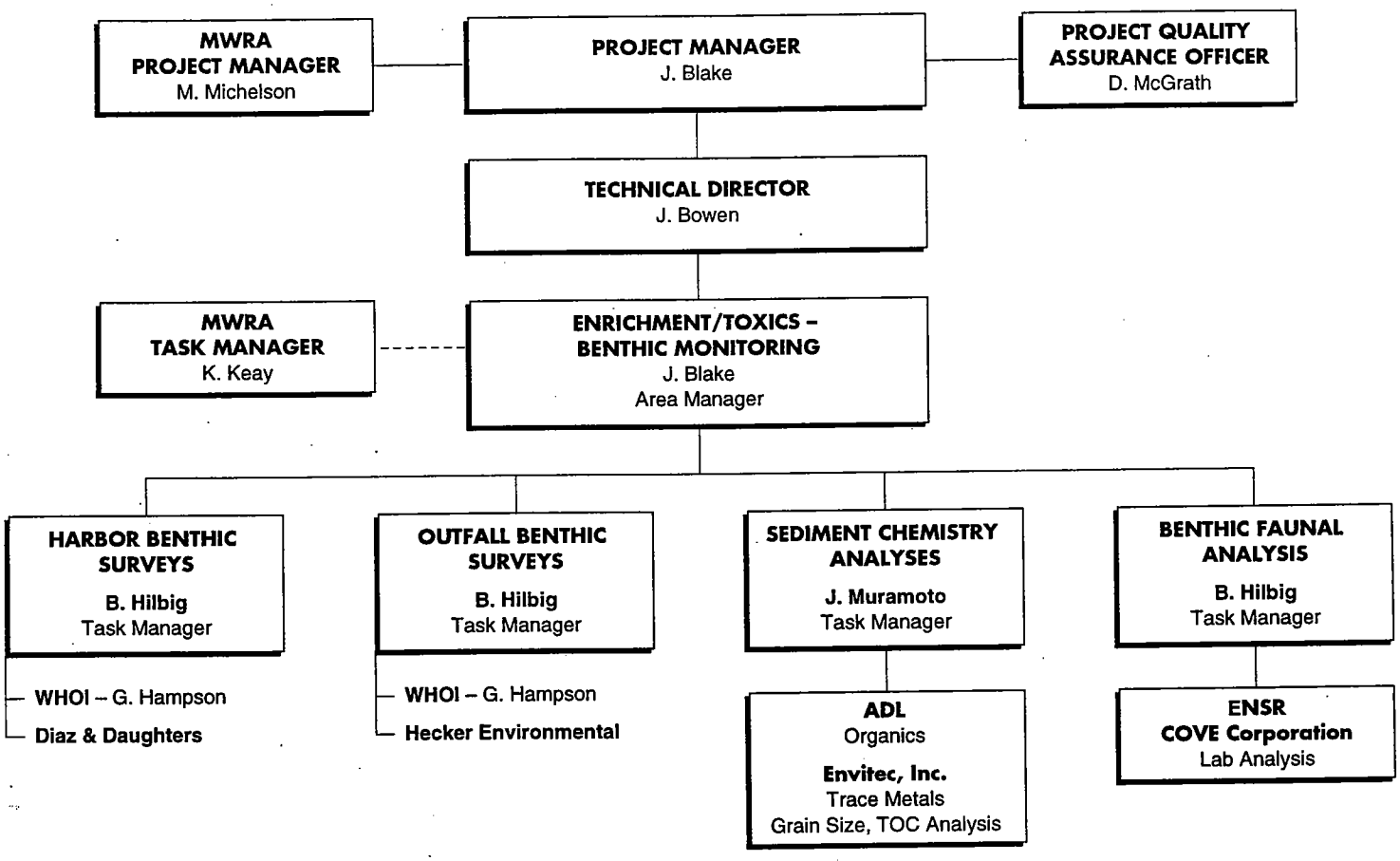

FIGURE 6
Benthic Monitoring Team

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will be responsible for the benthic faunal analyses (Tasks 20.1 and 20.2). The analysis of sediment profile images will be overseen by Dr. Hilbig and quality controlled by Dr. Don Rhoads (SAIC), co-inventor of the system.

Ms. Debra McGrath (ENSR), Project QA Director, will oversee the QA activities for all technical work conducted by ENSR and its subcontractors. She will report concurrently to the ENSR Project Manager and to ENSR senior management.

The Marine Chemistry Division of Arthur D. Little, Inc. (ADL) will perform the analysis for linear alkyl benzenes, polychlorinated biphenyls, polycyclic aromatic hydrocarbons, and chlorinated pesticides.

Biological Analysis Laboratories, Inc. (BAL) will perform the analysis for *Clostridium perfringens* spores, fecal coliform bacteria, and *Enterococcus*. Envitech, Inc. will perform the analysis for the major metals and trace metals, total organic carbon, and sediment grain size.

The benthic infaunal samples will be processed by Cove Corporation, R. Eugene Ruff (service provided by Envitech), and ENSR; day-to-day activities will be supervised by Dr. Hilbig. Cove Corporation will sort all benthic samples from the Harbor traditional and the Nearfield and Farfield benthic surveys; in addition, Cove Corporation will perform the taxonomic analyses of 16 spring and all summer samples from the Harbor. Eight of the spring Harbor samples and all Nearfield and Farfield samples will be identified by ENSR and Mr. Ruff.

The images taken during the Harbor reconnaissance surveys will be analyzed by ENSR under the supervision of Dr. Hilbig. Videotapes from the Nearfield ROV surveys will be analyzed by Dr. Barbara Hecker (Hecker Environmental) and Dr. Hilbig. Data reports will be written by Drs. Hilbig (Subtasks 17.1, 17.2, 18.1, and 18.3), Hecker (Subtask 18.2) and Muramoto (CSO Survey, part of Subtask 17.1), with assistance as needed from Dr. Blake.

11.0 DATA QUALITY REQUIREMENTS AND ASSESSMENTS

Requirements for ensuring that the data are fit for their intended use (that is, are of suitable quality) include accuracy, precision, representativeness, comparability, and completeness. When these requirements are met, the final data product is technically defensible. Data elements for this project are discussed in terms of the appropriate characteristics, defined as follows:

Accuracy: The extent of agreement between a measured value and the true value of interest.

Precision: The extent of mutual agreement among independent, similar, or related measurements.

Representativeness: The extent to which measurements represent true systems.

Comparability: The extent to which data from one study can be compared directly to similar studies.

Completeness: The measure of the amount of data acquired versus the amount of data required to fulfill the statistical criteria for the intended use of the data.

The representativeness and comparability of all the data generated under this CW/QAPP depend to some extent upon the selection of the sampling sites. With the exception of 10 newly selected reconnaissance stations in the Harbor, all stations to be visited during the present project will be the same as those listed in Kropp *et al.* (1993).

11.1 Field Activities

11.1.1 Navigation

The basic navigation system for the Harbor, Outfall, and ROV components of the Benthic Monitoring Program will be differential Global Positioning System (DGPS) using a Northstar 941XD GPS System. When the ROV is used, its position will be recorded with the Trackpoint II system. The 941XD model has both precision and accuracy to 10 meters, 95% of the time, and accuracy to 2-5 meters 65% of the time. This precision allows latitude and longitude positions to be displayed to thousandths of minutes (2 meters). Navigational fixes, sampling events, and any ancillary data will be collected, stored, and output in tabular and graphic form with the WINDOWS based software package HYPACK loaded onto a laptop computer.

11.1.2 Sediment Profile Imagery

Accuracy and Precision

All sediment profile cameras will be cleaned and tested before a field operation. A detailed packing and assembly checklist will be verified by line item. At the beginning of each survey day, the time on the

data logger mounted on the camera will be synchronized with the navigation system clock. Each station replicate will be identified by the time recorded on the film and on disk along with vessel position. Test shots will be fired on deck at the beginning and end of each roll of film to verify that all internal electronic systems are working to design specifications. Redundant sample logs will be kept by the field crew and on computer disk. Three replicate samples will be taken at each station.

Representativeness

Sediment profile imagery (REMOTS®, or equivalent) is a standard technique recognized as producing images that, when interpreted by an experienced analyst, characterize benthic conditions in the area surveyed. The participation of the co-inventor of the system, Dr. Don Rhoads, in an advisory capacity provides assurance that the interpretation of the images will appropriately reflect actual conditions in the bottom sediments.

Comparability

Methods for image acquisition and analysis are consistent with previous studies in the area (SAIC, 1987a, b; SAIC, 1992). Again, Dr. Rhoads' involvement as advisor throughout this portion of the work will ensure comparability with existing methods for image analysis.

Completeness

Spare parts, including extra cameras and charged batteries, will be carried in the field at all times to ensure uninterrupted sample acquisition. At regular intervals during each survey day, the frame counter will be checked to make sure that the desired number of replicates has been taken. Visual observations during sampling also provide confirmation that the camera is working properly. In shallow water, when the camera contacts the seabed, the sheave leading the wire from the winch relaxes, giving a visual confirmation that a sample has been taken. A prism penetration depth indicator on the camera frame will be checked after each lowering of the camera to see that the optical prism has penetrated the bottom to a sufficient depth to acquire a profile image. If images have been missed (frame counter indicator) or the penetration depth is insufficient (penetration indicator), then proper adjustments will be made (e.g., weight will be added to the frame) and additional replicates will be taken.

At the end of every survey day, film will be developed to verify successful data acquisition; strict controls will be maintained for developer temperatures, times, and chemicals to ensure consistent density on the

film emulsion to minimize interpretive error by the computer image analysis system. The film then will be inspected visually under magnification. Any images that are of insufficient quality for image analysis will be noted, and the appropriate station will be reoccupied on the next survey day.

11.1.3 Grab Sampling

Samples for benthic biology and physical and chemical sediment analysis will be collected with a Ted Young grab. During the nearfield benthic surveys, a video camera will be mounted on the frame to ensure high precision in grab deployment in the heterogeneous bottoms in the nearfield. All five quality criteria demand recovery of a sample whose surface is undisturbed. Undisturbed samples will be achieved by careful attention to established deployment and recovery procedures. ENSR's procedures cover the following aspects of deployment and recovery:

- thorough washdown before each deployment;
- control of penetration by adding or removing weights to the frame and adjusting the rate of fall;
- slow recovery until grab is free of the bottom;
- inspection for signs of leakage; and
- securing the grab on deck.

Each sample will be inspected for signs of disturbance. If the following acceptability criteria are not met, the sample will be discarded and a new sample taken.

- Sampler is not overfilled with sediment; the jaws must be fully closed and the top of the sediment below the level of the opening doors.
- Overlying water is present and not excessively turbid.
- Sampler is at least half full, indicating that the desired penetration was achieved.

11.1.3.1 Benthic Infauna

Accuracy, Precision, and Representativeness

Because no subsampling will be performed, the accuracy, precision, and representativeness of the sampling will depend upon the factors discussed above under Grab Sampling.

Comparability

Procedures for washing, sieving, and preserving the samples will be consistent with methods used in previous studies. The use of 300-µm sieves only, rather than stacked 500-µm and 300-µm sieves as in 1993 and 1994, will have no impact on the comparability of the samples because the faunal abundances will be compared with the total abundances (300-µm and 500-µm fractions summed) reported in previous years.

Completeness

The entire sample will be sieved, and all material retained on the 300-µm screen will be preserved for analysis.

11.1.3.2 Sediment

Once a sample for sediment analysis has been deemed acceptable, the top 2 cm of sediment will be removed, pooled in a Teflon® lined container (stainless steel bowl if no metals subsamples are taken), and homogenized. Separate subsamples will be obtained for determination of number of *C. perfringens* spores, grain size, and TOC (Boston Harbor); and the preceding plus organic compounds and metals (Massachusetts and Cape Cod Bays and some Harbor samples).

Accuracy, Precision, and Representativeness

These qualities will be determined partially by the factors discussed under Grab Sampling (above) and partially by the homogenization, subsampling, and preservation (where necessary) processes. The latter will be conducted in accordance with written instructions derived from and/or based on National Status and Trends protocols (where applicable and available) for grain size, TOC, and organic and metal analyses. Analyses for *C. perfringens* will be conducted using methods currently in place for the HOM Program.

Comparability

Procedures for sampling and subsampling will be comparable to those used in similar investigations.

Completeness

Subsample size will be specified for each type of analysis and determined in advance to provide material in excess of the amount needed for successful analysis.

11.1.4 ROV Video Survey

Accuracy and Precision

The video display on monitors and as recorded on tapes will indicate the date, time, transect number, position, and water depth. Beginning and end points of each transect will be recorded on each tape as well. In addition to DGPS, the ROV will be tracked while underwater using the LXT Track Point II ultrashort positioning system (USBL). Real-time position of the ROV and display of the vessel position and heading will be provided on monitors.

Representativeness

Underwater video images obtained with ROVs are now a standard method of monitoring. Earlier surveys funded by MWRA in 1986 will serve as an important baseline.

Comparability

Methods used will ensure comparability with the 1994 survey. Unless otherwise directed, the new surveys will follow the same transects to ensure that video data will be comparable with the 1994 results.

Completeness

All transects will be occupied in such a manner that the nature of the epifauna and sedimentary environment in the hard bottom area can be compared to the previous surveys. The real-time viewing of videotapes during the surveys will ensure that the tapes will be of sufficient quality to achieve the objectives of the survey. Only EHG (extra high grade) magnetic videotapes will be used for this project.

11.2 Laboratory Activities

11.2.1 Sediment Profile Image Analysis

Selected parameters will be measured from the original color slides using a video digitizer and computer image analysis system. The video digitizer will be calibrated to a known scale for every image analyzed. Automatic disk storage of all parameters measured will allow data from any variables of interest to be compiled, sorted, displayed graphically, contoured, or compared statistically. Before measurements are stored on disk, a summary display will be made on the screen so that the operator can visually verify whether the values stored in memory for each variable are within the expected range; if anomalous values are detected, software options will allow remeasurement and recalculation before storage on disk. All data will be printed on data sheets, both as a hard-copy backup and for verification by a senior scientist. Data will be edited, as needed, before being approved for final data synthesis, statistical analysis, and interpretation. Measurements will be plotted (and contoured if desired) on a base map of the survey area. All mapped data will be verified against the raw tabulated data by a staff scientist.

11.2.2 Infaunal Analysis

Accuracy

Benthic infauna will be identified by experienced taxonomists at Cove Corporation, Ruff Systematics (through Envitech), and ENSR Woods Hole under the direction of Dr. Brigitte Hilbig, a recognized authority on benthic infauna. Dr. James Blake is also available for consultation. In the case of questions about organisms in specific taxonomic groups, specimens will be sent to recognized experts for a second opinion on the identification. Standard references will be used, and selected specimens of newly found species will be retained as part of an already existing voucher collection.

Precision

Sorting technicians will remove all organisms from the samples and separate them into major taxonomic groups. All residual material will be labeled and stored for QC analysis. The first five samples processed by a sorter will be resorted by a second technician. If fewer than 5% of the total number of organisms have been missed by the first sorter, only a random selection of that sorter's samples will be rechecked. If more than 5% of the total organisms have been missed, the first sorter will be required to resort all subsequent samples until five consecutive samples pass the QC check.

Representativeness

Because all of the sample will be analyzed, representativeness will be determined by sampling factors.

Completeness

All samples collected are scheduled for analysis. Because three replicates will be collected at each station, loss of a sample would still permit data to be obtained for that station. One hundred percent completeness is thus expected.

Comparability

Methods of analysis will be comparable to those used in previous benthic investigations in Boston Harbor and Massachusetts Bay. Comparability of the identifications will be ensured through the use of a voucher collection provided by the Authority. This voucher collection will be maintained and, if necessary, expanded by ENSR and turned over to the Authority, or the Authority's designee, at the end of the project.

11.2.3 Sediment Chemistry

A summary of the data quality objectives for sediment chemistry analyses is presented in Table 11.

Accuracy

Analytical accuracy for organic analyses will be evaluated based on percent recoveries of analytes in matrix spike (MS) and matrix spike duplicate (MSD) samples (one set of MS/MSD samples with every 20 sediment samples), the recovery of surrogate internal standards (SIS) that are added to every sample (organics only), the percent recoveries of analytes in NIST standard reference material (NIST SRM 1941A), as well as the results of the procedural blanks which will be analyzed with every 20 samples. The percent recovery of matrix spike samples is calculated by:

$$\%\text{Recovery} = ([\text{spiked result} - \text{unspiked result}]/\text{spike amount}) \times 100$$

The percent recovery of SRM samples is calculated by :

$$\%\text{Recovery} = [(\text{True value} - \text{sample result})/\text{True value})] \times 100$$

TABLE 11

Data Quality Objectives for Sediment Chemistry Samples

QC Sample Type and Frequency	Data Quality Objective	Corrective Action
Procedural Blank Organics: 1/batch of <20	< 5 x MDL	Reextraction, reanalysis, and/or blank subtraction; all corrective actions documented. Performance documented.
Method Blank Metals: 1/batch of <20 TOC: 1/batch of 50[1]	< 5 x MDL < 5 x MDL	TOC sample concentrations will be blank subtracted
SRM Organics (PAH)[2]: 1/batch of <20 Metals: 1/batch of <20 TOC: 1/batch of 50	±35% difference vs. certified values 1 analyte may exceed ±10% difference vs. true values	Reextraction, reanalysis, and/or blank subtraction; all corrective actions documented
Matrix Spikes/Replicates Organics: 1 MS/MSD/batch of <20 Metals: 1 lab duplicate/batch of <20 TOC: 1 lab duplicate/10 samples *C. perfringens*: 1 lab duplicate/20 samples	50-150% recovery ≤ 30% RPD Average % CV: ±35% individual analyte ±30% average of all analytes ±5% RPD ≤25% RPD	Document deviations
Grain-size: 1 triplicate/20 samples	% CV = ±20% for sand, silt, clay	
SIS Every organics sample	50-150% recovery (one PAH SIS may exceed)	Results examined; possible reextraction or reanalysis. Decision documented.
Calibrations, Initial	Organics: ±30% RSD individual analyte (one analyte may exceed) ±20% RSD average of all analytes Metals: Calibration regression coeff (r) > 0.99	Reanalyze or document and justify.
Calibrations, Check	Organics: ±30% RSD individual analyte (one analyte may exceed) ±20% RSD average of all analytes Metals: ±15% of true value TOC: ±10% of true value	Remedial maintenance, new initial calibration, and possible reanalysis of samples. Decision documented and/or justified.

[1]Blanks are run more frequently when results are near the limits of acceptability.
[2]Certified values for NIST SRM 1941 are available only for PAH; consensus values are available for PCB and pesticides.

The data quality objective for accuracy is ≤30% difference between the measured concentrations and the calculated values in the matrix spikes for each individual analyte. Procedural blanks are to contain less than five times the method detection limit (MDL) of any target analyte (except that one analyte may exceed this limit in the PAH analysis).

All sediment samples and associated QC samples processed for organic analysis will be spiked with the appropriate SIS before extraction. Quantification of the SIS will be based on the recovery internal standards (RIS) added to the final extract just before instrumental analysis. The acceptable SIS recovery range is 50%-150%; one of the PAH surrogate internal standards can be outside this range as long as the others are within the acceptable range. Because samples are quantified relative to the recovery of the SIS which is added before extraction, any loss of analytes during processing is corrected by a comparable loss of the SIS. Therefore, recoveries of less than 50% may be considered acceptable. Each sample showing low recoveries will be individually examined by the laboratory manager and/or task leader to determine the necessity of reextraction or reanalysis.

The accuracy of the metals analysis will be evaluated by analyzing the SRM BCSS-1 sediment (from the National Research Council of Canada). In addition, the reference solution provided by NIST (NIST 1643C), will be run after every 5-10 samples to check the accuracy of the instrument response. Furthermore, spike recoveries will be evaluated on 5% of the samples. The goals for blank analyses will be < 5 x MDL. The goal for the percent recovery of spiked samples will be +/- 35% for individual analytes and +/- 30% for the average of all analytes. The goal for the recovery of the calibration check (NIST 1643C) will be +/- 15% of the true value.

Accuracy of TOC analysis will be evaluated by blanks and SRMs. The goal of blank analyses will be < 5 x MDL. SRMs will be analyzed with each batch of samples and must be within 10% of the true value.

Direct measures of the accuracy of the grain size and *Clostridium perfringens* analyses are not possible because there are no standards.

A summary of all parameters to be analyzed and their method detection limits (MDLs) is presented in Table 12.

TABLE 12

Sediment Chemistry Analytes and Method Detection Limits (MDL)

Analyte	MDL[1]	Analyte	MDL[1]
Physical Sediment Parameters/ Sewage Tracers		**PAH (Continued)**	
Total organic carbon	100	C_1-fluorenes	0.25
Grain size	--	C_2-fluorenes	0.25
Clostridium perfringens	--	C_3-fluorenes	0.25
Linear alkyl benzenes (C_{10}-C_{14})	5[2]	anthracene	0.18
		phenanthrene	0.31
Metals		C_1-phenanthrenes/anthracene	0.31
Al Aluminum	6000	C_2-phenanthrenes/anthracene	0.31
Fe Iron	20	C_3-phenanthrenes/anthracene	0.31
Ag Silver	0.25	C_4-phenanthrenes/anthracene	0.31
Cd Cadmium	0.025	dibenzothiophene	0.18
Cr Chromium	10	C_1-dibenzothiophenes	0.18
Cu Copper	5	C_2-dibenzothiophenes	0.18
Hg Mercury	0.025	C_3-dibenzothiophenes	0.18
Ni Nickel	6	fluoranthene	0.23
Pb Lead	5	pyrene	0.23
Zn Zinc	3	C_1-fluoranthenes/pyrenes	0.23
		C_2-fluoranthenes/pyrenes	0.23
Polychlorinated biphenyls		C_3-fluoranthenes/pyrenes	0.23
2,4-Cl_2(8)	0.021	benzo(*a*)anthracene	0.22
2,2',5-Cl_3(18)	0.044	chrysene	0.29
2,4,4'-Cl_3(28)	0.030	C_1-chrysene	0.29
2,2',3,5'-Cl_4(44)	0.015	C_2-chrysene	0.29
2,2',5,5'-Cl_4(52)	0.013	C_3-chrysene	0.29
2,3',4,4'-Cl_4(66)	0.016	C_4-chrysene	0.29
3,3',4,4'-Cl_4(77)	0.024	benzo(*b*)fluoranthene	0.30
2,2'4,5,5'-Cl_5(101)	0.012	benzo(*k*)fluoranthene	0.26
2,3,3',4,4'-Cl_5(105)	0.014	benzo(*a*)pyrene	0.14
2,3',4,4'5-Cl_5(118)	0.019	dibenzo(*a,h*)anthracene	0.33
3,3',4,4',5-Cl_5(126)	0.037	benzo(*g,h,i*)perylene	0.30
2,2',3,3,4,4'-Cl_6(128)	0.016	indeno(1,2,3-*c,d*)pyrene	0.22
2,2',3,4,4',5-Cl_6(138)	0.018	perylene	0.10
2,2'4,4',5,5'-Cl_6(153)	0.016	biphenyl	0.20
2,2'3,3,4,4',5-Cl_7(170)	0.063	benzo(*e*)pyrene	0.25
2,2',3,4,4',5,5'-Cl_7(180)	0.018	dibenzofuran	0.66
2,2',3,4,5,5',6-Cl_7(187)	0.028	benzothiazole	0.66
2,2',3,3',4,4',5,6-Cl_8(195)	0.013		
2,2',3,3'4,4',5,5',6-Cl_9(206)	0.011	**Pesticides**	
Decachlorobiphenyl-Cl_{10}(209)	0.013	Hexachlorobenzene	0.020
		Lindane	0.017
Polynuclear Aromatic Hydrocarbons (PAH)[4]		Heptachlor	0.019
		Aldrin	0.018
		Heptachlorepoxide	0.023
naphthalene	0.26	alpha-chlordane	0.017
C_1-naphthalenes	0.26	trans-Nonachlor	0.010
C_2-naphthalenes	0.26	Dieldrin	0.022
C_3-naphthalenes	0.26	Endrin	0.0061
C_4-naphthalenes	0.26	Mirex	0.020
acenaphthylene	0.19	2,4'-DDD	0.017
acenaphthene	0.19	4,4'-DDD	0.029
fluorene	0.25	2,4'-DDE	0.020
		4,4'-DDE	0.016
		2,4-DDT	0.026
		4,4'-DDT	0.023
		DDMU	0.029

[1]µg/g dry weight for metals and total organic carbon; ng/g dry weight for organic analytes
[2]Approximately 5 ng/g dry weight per isomer group

Note: MDLs determined as recommended by EPA (40 CFR, Ch. 1, Part 136, Appendix B). MDLs based on a sample size of 50 g dry weight and a pre-injection volume (PIV) of 0.5 mL.

Precision

Analytical precision for organic analyses will be determined using the concentrations of matrix spike (MS) and matrix spike duplicate (MSD) samples, with the relative percent difference (RPD[1]) between duplicate analyses serving as the measure of precision. The RPD goal for MS/MSD samples is 30%. The RPD is calculated by

$$RPD = [\ 2\ (D_1 - D_2)\ /\ (D_1 + D_2)] \times 100$$

where D_1 = concentration of the first duplicate sample and
D_2 = concentration of the second duplicate sample.

Laboratory duplicates for metals analyses will be performed at a frequency of not fewer than one per 20 samples. The RPD goal for these analyses will be 20%.

The precision of TOC analysis will be measured by laboratory duplicates run at a frequency of 10%. The RPD objective for duplicate analysis is 5%. The RPD will be calculated as described above from MS/MSD samples.

The precision of grain size analysis will be evaluated using laboratory triplicates. Triplicate analysis will be run at a frequency of 5%. The goal for these analyses will be a relative standard deviation (RSD) of ≤20% for the individual fractions of sand, silt, and clay.

The precision of *C. perfringens* analyses will be measured through replicate analysis of samples that are split in the laboratory. Precision for particulate and sediment samples generally ranges from 5 to 25%. Results from a recent interlaboratory comparison indicate that agreement between two laboratories can range from 25 to 55%, or possibly higher if the sample is unusually heterogeneous (Parmenter and Bothner, 1993).

[1]Not to be confused with RPD in sediment characterization (Redox Potential Discontinuity)

Representativeness

Representativeness has been addressed primarily in the sample collection design through sampling locations, number of grab samples, and collection of grab samples. Representativeness will also be ensured by proper handling, storage, and analysis of samples so that the material analyzed reflects the material collected as accurately as possible.

Completeness

The completeness of analyses will be ensured by comparing the samples received by the laboratory with the samples analyzed. All samples will be analyzed for the parameters listed in Table 12, and these analyses will be documented in the laboratory project files. The data quality objective is 95% completion. Completeness will be calculated as:

Completeness = ([Valid data obtained]/[Total data planned]) x 100

Comparability

All data developed for this project must be demonstrated to be comparable to similar data generated by other laboratories or by other similar studies. To accomplish this goal, field samplers and subcontractor laboratories will employ methods that are modifications of EPA methods and that are comparable to those used on previous sediment characterization studies (NOAA, 1993a; Shea, 1993 and 1994; ENSR, 1991). In addition, these methods are comparable to those being used in other related studies of water, sediment, and animal tissue [e.g., for the MWRA, Massachusetts Bays Program (MBP), and NOAA NS&T Program]. In addition, ADL participates in an interlaboratory calibration exercise for analysis of PAHs, PCBs, and pesticides in water, sediment, and tissue using methods that are similar to those proposed for this task (see Section 11.1.1).

Comparability of *C. perfringens* determinations will be ensured by using methods used previously to measure *C. perfringens* in MWRA effluent and sludge samples, sediment samples from Boston Harbor and Massachusetts Bay, and on samples for other sewage disposal studies.

12.0 SAMPLING AND ANALYTICAL PROCEDURES

12.1 Navigation

Vessel positioning during the benthic sampling operations will be accomplished via DGPS using a Northstar 941XD GPS System. When on station, the vessel location will be maintained within a radius of 5 m on calm days and 15 m (if possible) on windy days. If the ship captain is unable to maintain position within the desired radius, the vessel will be repositioned between samples to ensure the maximum dispersion of 15 m.

During the reconnaissance surveys, DGPS and Trackpoint II system will be used for positioning the vessel and the ROV. Both systems are interfaced to a laptop computer. The WINDOWS based software HYPACK is used to integrate these positioning data and provide real-time navigation, including position and heading of the vessel and position of the ROV relative to the vessel. Loran-C will be available as a backup system.

12.2 Benthic Sample Collection/Shipboard Processing

Field samples and measurements are summarized in Table 13. At all stations, the station coordinates, time, sea state and other weather conditions, and water depth will be recorded by hand into a field log book.

12.2.1 Grab Sample Collection

A Kynar-coated, Ted Young-modified 0.04-m^2 Van Veen grab sampler will be used to collect soft-bottom sediment samples for biological analysis. This same grab or a larger 0.1-m^2 Ted Young grab will be used for collection of sediment chemistry samples. The larger grab is superior to the smaller grab for collection of chemistry samples because there is less disturbance and edge effect when the various subsamples are removed and will be used if available.

Once the survey vessel is on station and coordinates have been verified, the sediment grab will be deployed and (Nearfield only) monitored by an Osprey video camera mounted on the frame. Use of this camera will permit real-time control of the grab deployment on a seafloor that is heterogenous. It will be especially useful at those stations where the sediment patches are confined within rocky areas. The video images, stored on videotape, will also permit subsequent assessment of the bottom conditions at the

TABLE 13

Field Samples and Measurements

Parameter	Stations[1]	#/Volume	Container	Shipboard Processing/Preservation
Macrofauna	T1-T8 NF1-NF20 FF1-FF14	3 grabs	Clean, labeled jar	Wash over 0.3-mm mesh sieves. Fix in buffered 10% formalin
Organics (Pest./PCBs/PAH)	T1-T8[2] NF1-NF20 FF1-FF14 DB01-DB14, CSO 019, SWEX 3	1-3 grabs[3]/ 200 ml	Clean, labeled glass jar with teflon-lined cap	Use teflon scoop to remove subsample from top 2 cm of sediment. Freeze (-20°C)
TOC	T1-T8 NF1-NF20 FF1-FF14 DB01-DB14, CSO 019, SWEX 3	1-3 grabs[1]/ 50 ml	Clean, labeled glass jar	Use stainless steel or teflon scoop to remove subsample from top 2 cm of sediment. Refrigerate
Metals	T1-T8[2] NF1-NF20 FF1-FF14 DB01-DB14, CSO 019, SWEX 3	1-3 grabs[3]/ 200 ml	Clean, labeled teflon bottle	Use teflon scoop to remove subsample from top 0-2 cm of sediment surface. Freeze (-20°C)
Grain Size	T1-T8 NF1-NF20 FF1-FF14 DB01-DB14, CSO 019, SWEX 3	1-3 grabs[3]/ 75 ml	Clean, labeled plastic jar	As for TOC
Clostridium perfringens	T1-T8 NF1-NF20 FF1-FF14 DB01-DB14, CSO 019, SWEX 3	1-3 grabs[3]/ 100 ml	Sterile WhirlPak™ bag	As for TOC
Sediment Profile Images	T1-T8 R2-R53	3 per station	--	--
Weather	All	--	--	Record general conditions
Seas	All	--	--	Record general conditions
Bottom Depth	All	--	--	Record to nearest 0.1 m
Grab Penetration	All[4]	--	--	Record to nearest 0.5 cm
Grab Sediment Volume	All[4]	--	--	Record to nearest 0.5 l
Prism Cradle Penetration[5]	T1-T8 R2-R53	--	--	Record to nearest 0.5 cm
Sediment Texture	All[4]	--	--	Describe qualitatively
Reduction-oxidation Potential Discontinuity Depth	All[4]	--	--	Record to nearest 0.5 cm

[1]Stations T1-T8 and R2-R53 are part of the Boston Harbor studys; NF1-NF20 are Outfall nearfield stations; FF1-FF14 are Outfall farfield stations; there are no stations designated FF2 and FF3.
[2]At traditional stations a full chemistry sample will be collected although subsample is required for TOC analysis only; the remainder will be archived.
[3]Subsample is obtained from 1-3 grabs at T1-T8, 1 grab at and NF1-NF20, and 2 grabs at FF1-FF14.
[4]Record for all stations at which grab samples are taken.
[5]Record depth of penetration of sediment profile camera prism cradle relative to support frame.

time the grabs were taken. When slack in the winch wire indicates the grab is on the bottom, the grab and included sample will be brought back to the surface. Upon retrieval of the grab, the sample will be inspected for acceptability (see Section 11.0). If the sample is unacceptable, the grab will be emptied, rinsed, and redeployed.

If the sample is acceptable, the penetration depth, sediment volume, sediment texture, and depth of the apparent redox potential discontinuity will be visually estimated. The depth of the redox potential discontinuity will be determined by cutting a slice of sediment with a plastic ruler and measuring the distance from the surface to the boundary between oxidized and reduced (usually black) sediment. The penetration depth of the grab will be measured in the same manner, with the ruler being pushed down to the bottom of the sample; the volume can then be estimated as a product of the surface area and the penetration depth.

After these measurements are taken, the grab will be placed over a bucket, the jaws will be opened, and the sample emptied into the bucket. For the infaunal samples only, seawater will be used to gently wash the grab sampler into the bucket. Once thoroughly washed (if necessary), the grab will be redeployed until the required number of acceptable samples have been obtained for infaunal and/or chemical analysis.

When a sample for biological examination has been deemed acceptable, it will be washed with filtered seawater, sieved through 300-µm screens, and preserved in 10% buffered formalin. The samples will be transferred to 70-80% ethanol after two days fixation; this procedure will ensure that mollusks and other organisms with calcareous structures are not damaged by the slightly acidic formalin.

Precautions will be taken during the deployment and retrieval of the grab sampler to prevent contamination of samples to be used for chemical analyses. To remove organic contaminants prior to sample collection, the grab, sampling scoop, and spatula will be cleaned between stations by rinsing each with distilled water (three times), methanol, and methylene chloride. Liquid wastes resulting from the latter two rinses will be collected in appropriate containers and returned to the laboratory for proper disposal. Before the grab is retrieved, the vessel must be positioned so that the engine exhaust will not contaminate the sample when it has been brought on deck. All smoking must be terminated during collection of sediment chemistry samples. The numbers of grab samples to be collected at each station for macrofaunal and/or chemical analyses are listed in Table 6.

12.2.2 Shipboard Processing of Grab Samples

At Harbor traditional stations and at all outfall stations, grab samples for macrofaunal analyses will be rinsed with filtered seawater through 300-μm mesh sieves. The samples retained on the screens will be transferred separately to labeled jars and fixed in 10% buffered formalin. Sieves will be washed between samples.

If the grab sample to be used for chemical analyses meets the acceptability criteria, the water overlying the sample will be siphoned from the grab and the surface sediment (0-2 cm) will be collected with a Kynar-coated scoop and transferred to appropriate containers. About 200 ml of sediment will be placed into a clean wide-mouth glass jar (250 ml) with a teflon-lined screw cap for organics analysis. About 200 ml of sample will be placed into a clean teflon container for metals analysis. About 50 ml of sediment will be placed into a wide-mouth glass jar with a aluminum foil-lined screw cap for TOC analysis. A subsample (75 ml) to be used for grain size analysis will be placed in a wide-mouth plastic jar. A subsample (100 ml) to be used for *Clostridium perfringens* analysis will be placed into a sterile WhirlPak™ bag. All subsamples will be labeled properly and refrigerated or frozen immediately for storage and transport to the laboratories. The grab will be washed between stations.

12.2.3 Sediment Profile Image Collection

Sediment profile imagery is a standardized technique (Rhoads and Germano, 1982). A Benthos Model 3731 Sediment Profile Camera will be used in this study (Benthos, Inc., North Falmouth, MA). The camera is designed to obtain *in situ* profile images of the top 15-20 cm of sediment. Functioning like an inverted periscope, the camera consists of a wedge-shaped prism with a front face plate and a back mirror mounted at a 45° angle to reflect the profile of the sediment-water interface up to the camera. The camera is mounted horizontally on top of the prism. The prism assembly is moved up and down by producing tension or slack on the winch wire. Tension on the wire keeps the prism in the up position.

The camera frame is lowered to the seafloor at a rate of about 1 m/s. When the frame settles onto the bottom, slack on the winch wire allows the prism to penetrate the sediment vertically. A passive hydraulic piston ensures that the prism enters the sediment slowly (about 6 cm/s) and does not disturb the sediment-water interface. On impact with the bottom, a trigger activates a 13-s time delay on the shutter release; once the prism comes to rest in the sediment, a photograph is taken. Because the sediment photographed is directly against the faceplate, turbidity of the ambient seawater does not affect image quality. When

the camera is raised, a wiper blade cleans off the faceplate, the film is advanced by a motor drive, the strobe is recharged, and the camera can be lowered for another image.

Three replicate photographs will be taken at each station. Ektachrome 100 ASA color slide film will be used for all photographs. Film will be developed at the end of each sampling day using a JOBO E6 rotary processor to determine the success of the reconnaissance sampling for that day and, if necessary, identify the stations to be revisited the next day.

12.2.4 Video Tapes

The annual ROV survey of the nearfield hard bottom environment will consist of transects that will be approximately 0.75 to 2 km in length. For precision and quality of video along these transects it will probably be necessary to anchor the research vessel and deploy the vehicle along intervals of about 50 m in either direction. The primary information will be gathered with color video. The ROV will be controlled such that constant height and direction will be maintained along transects. Interesting bottom features encountered along the transects, such as unusual organisms and topographic features, or outcrops may be explored more carefully and closely. A 35-mm camera will be available to provide a still photograph of any of these unusual features. The 35-mm camera will be strictly supplementary; only the video images will be analyzed in the laboratory.

During the course of the video survey, the ROV operators will work under the direction of the Chief Scientist who will provide instructions during the realtime video observations. It will be at the discretion of the Chief Scientist to make detailed observations of any unusual feature and to take any required 35-mm images.

12.3 Laboratory Processing

12.3.1 Sediment Profile Image Analysis

Replicate photographs will be analyzed with the ENSR image analysis system. This system uses a PC integrated with a PULNIX TMC-50 video camera and frame grabber. Color slides will be digitally recorded as color images on computer disk. The image analysis software is a menu-driven program that incorporates user commands via keyboard and mouse. This system displays each color slide on the CRT while measurements of all physical and biological parameters are obtained.

Up to 21 variables (see Table 7) will be measured for each image. Data for all parameters will be stored on computer disk and printed out on data sheets for editing by a senior-level scientist before being approved for final data synthesis, statistical analyses, and interpretation. A separate data sheet will be generated for each image. Automatic disk storage of all parameters measured allows data from any variables of interest to be compiled, sorted, displayed graphically, contoured, or compared statistically.

Photographs will be analyzed for sediment type, surface boundary roughness, mud clasts, apparent redox potential discontinuity depth, sedimentary methane, and infaunal successional stages following procedures used for previous Boston Harbor surveys (SAIC, 1992).

12.3.2 Sediment Chemistry

The physical parameters and chemical analytes of interest are listed in Table 12.

Organic Chemical Analyses

Sediment samples will be extracted for PAH, LAB, chlorinated pesticides, and PCB following methods developed for NOAA's National Status & Trends Mussel Watch Project (NOAA, 1993a). Briefly, approximately 30 g of sediment will be serially extracted with a 1:1 mixture of dichloromethane (DCM):acetone and sodium sulfate using shaker table techniques. A 10-g aliquot of the original sample will also be taken for dry weight determination. The sample will be weighed into a Teflon extraction jar and spiked with the appropriate surrogate internal standards, solvent will be added, the jar will be shaken for the appropriate amount of time, and the sample will be filtered. The extract will be decanted into an Erlenmeyer flask. After each extraction (total of three solvent additions) the filtered solvent will be combined in the flask. The combined extracts will be processed through an alumina column, concentrated to 900 µl in a Kuderna-Danish apparatus and under nitrogen. The concentrated extract will be further cleaned using size-exclusion high-performance liquid chromatography (HPLC). This procedure will remove common contaminants which interfere with instrumental analysis, including elemental sulfur. The post-HPLC extract will be concentrated to approximately 1 ml under nitrogen and the recovery internal standards will be added to quantify extraction efficiency. The final extract will be split for analysis, one half remaining in DCM for PAH and LAB analysis, and the other half solvent-exchanged with isooctane for PCB and pesticide analysis.

Sample extracts will be analyzed for PAH and LAB compounds by gas chromatography mass spectrometry (GC/MS) operating in the selected-ion-monitoring (SIM) mode. Concentrations of LAB compounds will

be determined as five separate LAB groups (those with alkyl chains containing 10, 11, 12, 13, and 14 carbon atoms, primary ion-m/z 91). LAB will be quantified versus the surrogate internal standard 1-phenylnonane. Pesticides and PCB congeners will be analyzed by gas chromatography electron capture detection (GC/ECD). All analytes will be determined by the method of internal standard, using surrogate internal standards for quantification.

Trace Metals

Metals analyses will follow procedures developed for NOAA's National Status & Trends Mussel Watch Project (NOAA, 1993b). Envitec, Inc. will perform the trace metals analyses by first performing an acid digestion on the samples. Sample extracts and digestates will be analyzed for metals on a Perkin Elmer ELAN 5000 Inductively Couple Plasma-Mass Spectrometer (ICP-MS). A calibration curve of external standards will be prepared for each analytical run. Instrumental drift will be corrected using internal standards, and a reference solution provided by the National Institution of Standards and Technology (NIST #1643c) will be run after every 5 to 10 samples to verify the accuracy of the instrument response. For each element, the calibration will be based on the most abundant isotope of that element free from analytical interferences. The exception is lead, which will be determined as the sum of each isotope of the element (^{204}Pb, ^{206}Pb, ^{207}Pb, and ^{208}Pb) to allow for possible differences in the isotopic composition between the samples and standards. The concentration of metals in each digestate will be determined in triplicate.

Mercury in the digested sediment (microwave Parr Bomb digested) will be analyzed using a flow injection cold vapor technique with atomic absorption detection following preconcentration on gold amalgam as described in McIntosh (1993).

Approximately 10% to 15% of the samples will be analyzed in replicate to verify the precision of the method. In addition, spike recoveries will be examined on 5% of the samples. The accuracy of the method will be determined by carrying appropriate standard reference material (CASS-1 seawater, BCSS-1 sediment, or DOLT-2 dogfish liver, all from the National Research Council of Canada) through the analytical procedures. Blanks will be determined by carrying high-purity distilled water through all analytical procedures. The number of blanks and standard reference samples run will be set at 10% of the number of samples, with a minimum of three of each.

12.3.3 Ancillary Physicochemical and Microbiological Parameters

Total Organic Carbon

TOC analyses will follow procedures developed for NOAA's National Status Trends Mussel Watch Project (NOAA, 1993c). TOC in sediment will be measured using Perkin Elmer 2400 Series II CHN analyzer. Sediment samples will be dried to constant mass at 105°C. A subsample of dried sediment will be placed in a petri dish and exposed to HCl fumes for 24 hours in a closed vessel to remove inorganic carbon in the form of carbonates. The carbonate-free sediment will be carefully weighed into a tin cup (mass of the cup should be tared before taking sediment) using an AD-4 microbalance. The tin cup will be wrapped as a nodule with the help of forceps. A combustion temperature of 925°C, reduction temperature of 640°C, and detector temperature of 82.5°C will be selected for analysis. The instrument will be calibrated following the conditions outlined in the operator's manual, using the following sequence:

3 blanks
1 conditioning sample (a sample of acetanilide to warm-up the detector)
1 blank
1 conditioning sample
1 blank
3 K-factors (standards)

Upon successful completion of calibration, sample analysis will proceed as follows:

10 samples
1 blank
1 K-factor
10 samples
1 blank
1 K-factor

Standard reference material (BCSS-1 by NIST) will be analyzed with each batch of samples. At least 10% of the samples will be replicated.

Clostridium perfringens

Clostridium perfringens analysis will be performed on sediment samples using methods developed by Emerson and Cabelli (1982) and modified by Saad (D. Saad, MTH Environmental Associates, personal communication). Frozen samples will be thawed and then homogenized, and an aliquot of known weight transferred to a sterile 50-ml polypropylene centrifuge tube. Sterile deionized water will be added to the sample, and the tube will be capped and mixed thoroughly for 10 to 15 s. Sterile metaphosphate will then be added, and the sample remixed. After a settling time of 10 minutes, the supernatant will be removed from the tube with a sterile pipette and placed in a sterile test tube. The tubes will be stored on ice and analyzed within 30 minutes.

The enumeration of *C. perfringens* spore densities will be performed by membrane filtration, using serial half-log dilutions of the extract and the procedure developed by Bisson and Cabelli (1979). The extract will be filtered using filtration apparatus and sterile membrane filters that have been rinsed with sterile phosphate-buffered saline (PBS). The filters will be incubated for 18 to 24 h at 44.5°C, exposed to ammonium hydroxide, and the *C. perfringens* colonies will be counted and recorded. All final data will be reported in units of spores per gram dry weight.

Sediment Grain Size

Grain size analyses will be performed utilizing a combined sieve analysis and pipette analysis (NOAA, 1993c). The sieve analysis will be used to separate and calculate the proportion of sediment particles greater than 62.5 μm (i.e. the sand fraction) up to 2 mm; material over 2 mm will be reported as gravel. Sediment samples will be dry sieved through a sieve series based on the Wentworth grade scale that includes a 2.0 mm, 1.0 mm, 0.5 mm, 0.250 mm, 0.125 mm, and .063 mm sieve. Sediment retained in each sieve will be weighed on an analytical balance accurate to 0.001 g to produce the proportion of sediment in each sediment category. This analysis will yield a result for gravel (greater than 2 mm) and results for each phi class between 2 mm and .063 mm. A more detailed description of this procedure is provided in the Standard Operating Procedure for Sediment Grain Size by Sieve Analysis included as Appendix A.

The pipette portion of the analysis is based on Stokes' Law for determining the settling rate of particles through a column of distilled water. The procedure requires placing the prepared sample into a graduated cylinder and withdrawing a sample with a 20 ml pipette at given times. The sample is placed into a tared crucible, dried at 110° C, and weighed on an analytical balance accurate to 0.001 g. The pipette analysis

will provide two additional data points: total silt (.063 mm to .004 mm) and total clay (< .004 mm). A more detailed description of this procedure is provided in the Standard Operating Procedure for Sediment Grain Size by Pipette Analysis included as Appendix B.

12.3.4 Macrofaunal Analysis

From each survey conducted under Subtasks 17.1 (Harbor benthic survey) and 18.3 (Farfield benthic survey), three replicate samples from each station will be sorted for analysis of macrofaunal community structure; one sample from 17 out of 20 nearfield stations will be sorted from each survey conducted under Subtask 18.1 (nearfield benthic surveys), and three replicate will be sorted from the remaining three nearfield stations. None of the samples collected under these subtasks will be archived, i.e. all samples collected will be processed. Samples obtained for benthic faunal analysis will be transferred from formalin to 70% ethanol and then shipped to Cove Corporation in Lusby, Maryland for sorting.

Samples will be received through 300-μm mesh screens to remove any broken-up mud clasts. To facilitate the sorting process, all samples will then be stained in a saturated alcoholic solution of Rose Bengal at least overnight, but no longer than 48 h to avoid overstaining. After rinsing with clean alcohol, small amounts of the sample will be placed in glass dishes, and all organisms, including anterior fragments of polychaetes, will be removed and sorted to major taxonomic categories such as polychaetes, arthropods, and mollusks.

After samples have been sorted, the organisms will be sent to taxonomists for identification and enumeration. Identifications will be made at the lowest practical taxonomic level (LPTL), usually species. Data will be recorded on project-specific data sheets (Figure 7) and/or entered directly into a computer file. When the taxonomists have finished identifying and enumerating the organisms, the specimens and data sheets will be sent to ENSR Woods Hole and the data will be entered into a spreadsheet.

12.3.5 CSO Study

The detailed scope of work and procedures for the Combined Sewer Overflow (CSO) study to be conducted in 1997 will be developed at a later date. This CW/QAPP will be amended at that time to include the CSO study.

MWRA Harbor and Outfall Monitoring Project
Contract No. S186
Soft-Bottom Benthic Data

Taxon: _____ Page ____ of ____

Taxonomist: _____

Date: _____

Sample ID: _____ Station: _____ Replicate: _____ Fraction: _____ mm

Taxon Name	NODC Code	Count				Comment

NODC Codes Entered _____, Verified

Sample ID Entered _____, Verified Approval: _____

M950098

FIGURE 7
Macrofauna Data Sheet
(Example)

12.3.6 Video Tapes

In the laboratory, the video tapes from each of the transects will be reviewed by qualified observers skilled in the identification of marine organisms. Data will be recorded on the relative abundance of motile organisms such as crabs, lobsters, and fish. These organisms will identified to the LPTL. The relative percent cover of sediments and attached organisms on rocks will also be recorded. These data will be entered into a spreadsheet format and compared transect by transect. The data will be compared with previous results so that any obvious changes in bottom conditions can be determined.

13.0 SAMPLE CUSTODY

During field operations, ENSR will produce printed labels. These labels will contain the project name, station code, sample identification, analytical procedures, and preservation requirements. Sample identifiers will be a unique alphanumeric code that relates to a specific point in time and space as described below. The sample identifier will be a series of alphanumeric characters: AABB-CCDDDDEFF-GH. The first four digit represent the study identification:

AA = project area (BM for benthic monitoring), and
BB = year (e.g., 95),

The next eight digits represent the sample identification:

C = sampling event for that year, beginning with 1 and proceeding sequentially,
DDDD = station (e.g., FF14),
E = station visit, beginning with 1 and proceeding sequentially, and
FF = grab number, beginning with 01 and proceeding sequentially.

The next two digits represent the resample identification (i.e., analytical unit):

G = analyses types

A = macrofauna,
B = organics,
C = metals,

D = TOC,
E = grain size, and
F = C. *perfringens*

H = sample type

1 = sample, and
2 = field duplicate.

Both station codes and sample identifications will conform to the specifications of the Authority. Sample log sheets, pre-printed with the same project-specific information as the labels, will also be generated prior to the field efforts, minimizing the likelihood of transcription errors and increasing sampling efficiency. In addition, the ENSR Chief Scientist will maintain a field log book that will provide a record of daily sampling activities. This log when combined with navigation logs will provide a means to track daily sampling activities.

At the time of sample collection, the pre-printed labels will be attached to the sample containers (not the lids). These labels will be completed with date, time, sampler's initials, and any other pertinent remarks. Hand-written labels indicating the sample number will also be placed inside each of the biology sample containers.

Custody procedures will be initiated upon sample collection (ENSR SOP 7510, Packaging and Shipment of Samples). ENSR standard chain-of-custody forms, modified to include project-specific information whenever possible, will be used to document the transfer of samples from the field to the laboratory or other location (Figure 8). The date, time, and the identities of each person relinquishing and receiving the samples will be recorded each the samples are transferred.

Upon completion of the survey, custody of chemistry, grain size, and *Clostridium* samples will be transferred to ENSR for shipment to the appropriate laboratory. Laboratory custody of all samples will be the responsibility of the appropriate subcontractor. Upon receipt of samples at the laboratory, the recipient will examine the samples received, verify that the information recorded on the custody forms is accurate, and log the samples into the laboratory by signing the custody form on the *Received By* line, and by entering the date and time of sample receipt. Any inconsistencies between samples listed as having been released and samples that were actually received, or any damage to containers, labels, etc., will be noted in the laboratory sample log book and immediately communicated to the Project Area Leader.

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ENSR

CHAIN OF CUSTODY RECORD

Page ___ of ___

Client/Project Name:

Project Location:

Project Number:

Field Logbook No.:

Sampler: (Print Name) /Affiliation:

Chain of Custody Tape No.:

Signature:

Send Results/Report to:

Analysis Requested

Field Sample No./ Identification	Date	Time	Grab	Comp	Sample Container (Size/Matl)	Sample Type (Liquid, Sludge, Etc.)	Preservative	Field Filtered	Lab I.D.	Remarks

Relinquished by: (Print Name) Date: Received by: (Print Name) Date:

Signature: Time: Signature: Time:

Relinquished by: (Print Name) Date: Received by: (Print Name) Date:

Signature: Time: Signature: Time:

Relinquished by: (Print Name) Date: Received by: (Print Name) Date:

Signature: Time: Signature: Time:

Analytical Laboratory (Destination):

Serial No. 18918

FIGURE 8
Example Chain of Custody Form

Sample numbers that include the complete field ID number will be used to track the samples through the laboratory.

Records of sample custody, including sample collection logs, field chain-of-custody records, laboratory log-in sheets, and telephone summaries regarding sample discrepancies, will be maintained as part of the project files. These records will be available for review by the Authority. All archived samples will remain in the custody of the appropriate subcontractor laboratory for a period of one year after sample collection, at which time the MWRA will be contacted about their disposition.

14.0 CALIBRATION PROCEDURES AND PREVENTIVE MAINTENANCE

Logs of maintenance, calibrations, and any repairs made to instruments will be stored in the instrument files maintained by ENSR and by the subcontractors. Maintenance of and repairs to instruments will be in accordance with manufacturers' manuals. Any deviations to this policy will be noted.

14.1 Navigation Equipment

Once the 12 VDC power-supply for the Northstar 941XD navigation system has been switched on, there is typically no other setup interaction necessary between the Seasoft operator and the navigation system. The GPS will conduct an automatic self-test, and then begin acquiring satellites and a beacon. This process normally takes 2 to 5 minutes. An error message will be displayed if the system has trouble acquiring satellites or a beacon. For each survey, the GPS position will be verified by comparing it to previously located benchmarks. At a minimum, the position will be verified once, at the dock. In addition, the geometry and number of satellites will be checked periodically throughout the survey. Cable connections and antenna mounts and brackets will be inspected and secured at regular intervals.

The fathometer and depth finder will be calibrated annually by the manufacturer.

14.2 Image Analysis System

All Ektachrome HC100 color photographs will be analyzed with the ENSR image analysis system. The image analysis system will be calibrated with a scale-slide, depicting a 10-cm and a 4-in scale, before digitally recording the photographs as color image files on computer disk. Calibration factors will be recorded with each image file and will be incorporated into the analysis of each slide.

14.3 Video Camera and ROV

Any maintenance and calibration of the video camera and the ROV will be provided by the vendor.

14.4 Laboratory Equipment

Logs of maintenance, calibrations, and repairs made to instruments will be stored in laboratory files. Maintenance of and repair of instruments will be in accordance with manufacturers' manuals. Any deviations to this policy will be noted.

14.4.1 Calibration Procedures and Response Factor Stability

14.4.1.1 Organic Analysis

Analytical instruments will be calibrated before sample analysis. Response factors (RF) will be generated for each target analyte using the following equation:

$$RF = \frac{A_x}{A_{IS}} \times \frac{C_{IS}}{C_x}$$

where:

	A_x	=	peak area of the analyte in the calibration standard
	A_{is}	=	peak area of the appropriate internal standard in the calibration standard
	C_x	=	concentration of the analyte in the calibration standard
	C_{is}	=	concentration of the appropriate internal standard in the calibration standard.

Three concentrations of standard solutions that encompass the expected range in sample concentrations will be analyzed. Initial calibrations will be acceptable if the relative standard deviations (RSD) are $\leq$ 30% of the mean for each individual analyte (one analyte may exceed 30%), and the mean of all analyte RSDs is $\leq$ 20%.

The system calibration will be verified at least once every 24 h using a mid-range calibration check. Using the mean RF of each analyte from the initial calibration, the percent difference between those mean

values and the RFs from the midrange calibration checks will be calculated. The percent difference is calculated by:

$$\% \text{ Difference} = [(RF_i - RF_r) / RF_i] \times 100$$

where RF_i = average response factor from the initial calibration, and

RF_r = response factor from the midrange calibration check.

The calibration checks will be acceptable under the same criteria as the initial calibration (i.e., 30% for individual analytes [with one allowable exceedance], 20% for the means). If the percent difference between the RFs is greater than the acceptability criteria, remedial maintenance will be performed on the instrument, a new initial calibration will be performed, and the affected batch of samples will be reanalyzed. Because GC/ECD and GC/MS analyses are multicomponent analyses, it may not be necessary to reanalyze all samples. For example, if only certain analytes are detected in a sample, and the calibration is acceptable for those particular analytes, the sample may not require reanalysis. The decision not to reanalyze will be made by the Subcontractor Project Manager, with the approval of the ENSR Task Manager. Deviations from calibration or data objectives will be documented in the project files.

Samples analyzed by GC/ECD and GC/MS will be bracketed by two acceptable calibrations, initial or check. Analytes will be quantified by using the average RFs for that individual analyte generated from the initial calibration unless otherwise stated.

14.4.1.2 Metal Analysis

Calibration standards will be prepared each day and sample digestion solutions will be quantified by ICP-MS for all metals except mercury using the method of additions to avoid inaccuracies resulting from chemical interferences. Calibration standard check samples (such as NIST-certified aqueous sample 1643c or EPA Performance Evaluation samples) will be analyzed every 10 samples to ensure continued accuracy. Measurements that are not bracketed by an accuracy check standard within 10% of its true value will be rejected and reanalyzed after corrective action is taken (as needed). ICP-MS measurements will be made in triplicate for each sample; if the RPD between duplicate injections is greater than 5%, then the sample measurement will be rejected unless the absorbance values are very low and small differences (<0.004 abs

units) result in high RPD values. Sample quantitations will only be accepted if the standard additions quantitation curve has a correlation coefficient of 0.99 or better.

The CVAAS measurements of mercury will be quantified by standard comparisons; mercury calibration standards will be prepared the day of analysis, and samples will be quantified within the linear range of the instrument and below the highest calibration standard. Instrument performance will be monitored using continuing accuracy check standards (with a 10% acceptance criteria), prepared by an analyst other than the analyst that prepares the calibration standards. Samples will be analyzed once for quantitation; all duplication exercises will be laboratory or field duplicates. Sample quantitations will proceed only if the calibration standard curve is linear with a correlation coefficient of 0.99 or better.

If the target correlation coefficient for the calibration curve is not obtained for the atomic absorption instrumentation, then the instrument operation and instrument integrity will be assessed and analytical standards evaluated. Necessary remedial action will be taken, and the calibration procedure repeated until a satisfactory calibration for each trace metal can be obtained. Any sample concentrations that are above the highest calibration atomic absorption standard will be reanalyzed (after appropriate dilution if necessary).

14.4.2 TOC Analysis

The CHN analyzer will be calibrated prior to analysis according to procedures outlined in the operator's manual. Briefly, these procedures involve running the following sequence:

- 3 blanks
- 1 conditioning sample (a sample of acetanilide to warm-up the detector)
- 1 blank
- 1 conditioning sample
- 1 blank
- 3 standards (K-factors)

14.4.3 Grain Size Analysis

Analytical balances used for grain size analysis will be calibrated at least annually by the manufacturer or by an authorized representative. The calibration will be checked daily, prior to use, using Class S or equivalent weights.

14.5 Instrument Maintenance

Analytical instrumentation will be properly calibrated and maintained in accordance with laboratory SOPs, manufacturers' instructions, and analytical methods. A log will be kept for each analytical instrument and will contain a record of all routine maintenance and repairs. Procedures for maintenance of the selected analytical equipment are described below.

14.5.1 Gas Chromatograph Mass Spectrometer

Detector response (electron-capture detectors and mass spectrometer) and capillary column performance will be monitored/calibrated daily by injection of GC standards containing known amounts of targeted compounds (e.g., PAH mixture, pesticides, PCB mixtures, and LAB calibrations). Both the responses per unit amount and the resolution of specific components will be monitored. If any evidence of chromatographic column performance deterioration is observed, the column will be replaced.

14.5.2 ICP-MS

Maintenance of the ICP-MS instrumentation will include complete cleaning of sample and skimmer cones, replacing sampling tubes, and optimizing the instrument sensitivity by adjusting and cleaning the lenses. The base vacuum, operating vacuum, and gas flow rates will also be checked.

14.5.3 CHN Analyzer

Maintenance of the CHN analyzer used for TOC analysis will be performed according to manufacturer's specifications and will be recorded in a maintenance log.

14.5.4 Analytical Balance

Analytical balances used in the determination of grain-size distributions in the sediment samples will be cleaned daily and calibrated using Class S reference weights.

15.0 DOCUMENTATION, DATA REDUCTION, AND REPORTING

15.1 Documentation

All data will be recorded either (1) electronically onto computer storage media from the image-analysis system or other laboratory systems and/or (2) manually into field log books, laboratory notebooks, or on data sheets. All notes will be written in ink. Completed forms, field and laboratory notebooks, or other forms of hand-entered data will be signed and dated by the individual entering the data. It will be the responsibility of the Subcontractor Project Manager to ensure that all data entries and hand calculations are verified. In addition to these documentation procedures, sample logs associated with field and laboratory custody and tracking will be maintained in project files. Manually recorded data from subcontractor laboratories will be entered by the subcontractor into PC-based spreadsheets and submitted to ENSR.

15.2 Data Reduction

Data reduction is the process of converting raw numbers (e.g., numbers of organisms per replicate) into data that can be compared statistically for differences between mean values for sampling times or stations. Data reduction may also involve the use of various formulae to calculate indices describing community structure or the similarity between samples.

GC/MS data will be acquired and reduced on Hewlett-Packard A-series minicomputers with dedicated chromatography software. GC/ECD data will be acquired and reduced on a VG Minichrome Data Acquisition System. Data generated during metals analyses will be transferred from the instruments to PCs, where analyte concentrations will be calculated. Organic analyte data will be reported in units of ng/g dry weight; metals concentrations will be reported in µg/g dry weight; *C. perfringens* data will be reported as spores/100 ml; TOC results will be reported in %; and grain size analysis results will be reported as % for each of the measured size fractions.

15.2.1 Faunal Analysis Data (Task 20)

Data reduction for the detailed faunal analysis will include calculation of community parameters such as similarity and diversity indices, with possible transformation of data to improve conformity to the assumptions of the statistical tests being used. The community parameters, their respective formulae, and any necessary references are:

- Total number of species per replicate, calculated as the total number of identified taxa.
- Shannon-Wiener diversity index (Shannon and Wiener, 1949; Green, 1979).
- Bray-Curtis and NESS similarity indices (Bray and Curtis, 1957; Boesch, 1977).
- Numerical classification analysis (clustering) based on the Bray-Curtis similarity index using the unweighted pair-group method (UPGMA) of Swartz (1978).

The statistical test to be used to determine significant differences in species abundances or community parameters between times or locations will be analysis of variance (ANOVA).

Specimens that cannot be identified to species (juveniles, damaged individuals) will not be included in calculations of species richness, diversity, and similarity, but will be included in estimates of abundance per station.

15.2.2 Video Tape Analysis (Task 18.2)

For the ROV video images, data will be recorded on the relative abundance of large mobile or semi-mobile organisms that will be identified to the LPTL. These organisms will include various species of fish, crabs, the American lobster, and mollusks such as sea scallops. Other data will include the relative percent cover of attached sessile megafauna, percent and depth of cover of rocks by sediment, and condition of the diffuser caps relative to adhering sediment and fouling organisms. The data recorded as part of the video observations will be entered into spreadsheets and worked up transect by transect. Tables and graphs will be used in an initial comparison among transects.

15.3 Reporting

Various methods and formats will be used to report the soft-bottom benthic monitoring data to MWRA. Data generated during the soft-bottom monitoring tasks will be submitted for inclusion in the Harbor Studies Database. Also, two types of reports, Data Reports and Annual Synthesis Reports, will be produced to summarize and interpret the data.

15.3.1 Data to be Included in the Harbor Studies Database

Only data that have been designated as final by the Task Manager will be loaded into ENSR's copy of the Harbor Studies Database. All data loaded into the database will follow formats described below. Data provided by ENSR and subcontractors will be loaded into the database by ENSR data management staff. Upon receipt, each diskette will be logged in and assigned an unique login identifier. Any changes or additions to data, necessary for loading into the database, will be made using well-documented SQL scripts that indicate the original values. The original diskette, SQL scripts, and data-loading documentation will be filed at ENSR according to login identifier. The data sources notebook will contain copies of the COC forms, the MWRA Data Documentation Form, and data entry information.

Navigation and Sample Collection Data

After completion of the survey report, navigation and sample collection data contained in the survey log files will be provided as Lotus spreadsheet files. Columns will include sample_id, stat_id, water_depth, date, time, latitude, longitude, and protocol code.

Analytical Data

Sediment chemistry data will be transferred into Oracle from which the final report tables will be generated. All data generated by ENSR subcontractors will be either electronically transferred from the instrument to a PC-based spreadsheet or read from the instrument display (or optical field of a microscope) and manually entered into laboratory notebooks or data sheets. Data in laboratory notebooks or on data sheets will be manually entered into a PC-based spreadsheet.

Data resulting from the grain-size, TOC, and *Clostridium perfringens* analyses will be submitted by the appropriate subcontractor (Section 10.0) as PC-based spreadsheets. ENSR will provide PC-based spreadsheets containing species enumeration data for benthic macrofauna.

Spreadsheets arising from the nearfield video survey data analysis will also be provided for the Harbor Studies database.

16.0 DATA VALIDATION

All data reported for this project will be reviewed to check for errors in transcription, calculation, or computer input by the technical staff of the appropriate organization. The validation procedures that will be performed for data generated by ENSR and its subcontractor laboratories are:

- 100% of data that are hand-entered into a database or spreadsheet will be verified for accuracy by (1) printing the spreadsheet and proofreading against the original hand entry or by (2) duplicate entry into the database and comparison of the entries to detect any differences. These tasks will be carried out by two people and documented for each data set.

- All manual calculations will be checked for accuracy by a second staff member.

- Calculations performed by software will be checked by a technical staff member at a frequency sufficient to ensure the accuracy of the calculations. All data-reduction algorithms will be verified by the subcontractor prior to final data submission.

- Electronically generated data will be reviewed in graphical form by the technical supervisor to ensure that the data are complete, accurate, and technically reasonable. The removal of all outliers, either manually or by computer algorithm, will be reviewed in graphical form by the technical supervisor.

- Subsets of the analytical data will be reviewed by in-house or subcontractor data validators. The data will be reviewed for adherence to analytical protocols and to pre-establish criteria (e.g., for holding times, surrogate recoveries, initial and continuing calibration, matrix spikes, laboratory duplicates, blank contamination, SRM recoveries).

- Database staff will check the received data and associated documentation for completeness, freedom from errors, and technical reasonableness.

- All new software developed for the soft-bottom monitoring tasks will be validated before entry of data.

ENSR Task Leaders will be responsible for validation of all data generated by ENSR. Subcontractor Project Managers will be responsible for conducting similar data validations to ensure that the data provided to ENSR are accurate, complete, and scientifically reasonable. As an additional data validation step, ENSR Task Leaders will review all subcontractor data for technical reasonableness. The entire process will be fully documented in the data sources notebook.

17.0 PERFORMANCE AND SYSTEM AUDITS

This project will be monitored by the Project QA Director. All tabular and graphic data reported in deliverables and associated raw data generated by ENSR will be audited by the Project QA Director or his/her designee. Raw data will be reviewed for traceability, accuracy, completeness, and proper documentation. All deliverables generated during the course of this project will be submitted to an internal review prior to delivery of drafts to MWRA.

Audits of the subcontractor laboratory data-collection programs will be the responsibility of the subcontractor. During the time work is in progress, an audit will be conducted by the subcontractor QA officer to evaluate the laboratory data-production process. All data must be reviewed by the Subcontractor QA Officer prior to submission to the ENSR Project Area Manager and must be accompanied by a signed QA statement (Figure 9) that describes the types of audits and reviews conducted and any outstanding issues that could affect data quality.

Performance reviews, procedures used to quantitatively determine the accuracy of the total measurement system or its components, will be the responsibility of subcontractory laboratory personnel and may include internal performance evaluation samples and participation in external certification programs (Section 11).

FIGURE 9
HARBOR AND OUTFALL MONITORING PROJECT
Quality Assurance/Review Statement

Subcontractor _____

MWRA Task Title _____

MWRA Task Number _____

Description of Data Set or Deliverable _____

_____

_____

Description of audit and review activities:

Description of outstanding issues or deficiencies which may affect data quality:

_____ _____
Signature of Subcontractor QA Officer/Reviewer **Date**

_____ _____
Signature of Subcontractor Project Manager **Date**

_____ _____
Signature of Recipient (ENSR) **Date**

18.0 CORRECTIVE ACTION

Identification of problems regarding technical performance will be the responsibility of all staff members working on this project. Responsibility for overall conduct of the project, including schedule, costs, and technical performance lies with the ENSR Project Manager. The Project Manager will be responsible for identifying and resolving problems that (1) have not been addressed promptly or successfully at a lower level, (2) influence other components of the project, (3) require changes in this CW/QAPP, or (4) require consultation with ENSR management or with the MWRA.

Technical problems relating to sample collection in the field (schedule changes, modifications to the sampling plan, etc.) will be resolved through discussion with the Chief Scientist, the ENSR Project Area Manager, and the MWRA Project Area Manager. Problems relating to the overall successful completion of the project will be reported to the MWRA Project Area Manager in a timely manner for discussion and resolution between the ENSR and MWRA managers.

Identification of problems that could affect data quality and the appropriate corrective action will be resolved by the laboratory staff or the subcontractor subtask leaders. Table 11 identifies the corrective actions associated with internal laboratory QC checks. Issues that affect schedule, cost, technical performance, or data quality will be reported to the ENSR Project Area Manager or the ENSR Project Manager. They will be responsible for evaluating the overall impact to the project and for discussing corrective actions with the MWRA Project Area Manager.

A QA/QC Corrective Action Log will be maintained by the Project QA Director and submitted to MWRA at quarterly intervals. The log will include documentation of QA/QC activities as they occur, descriptions of the methods and procedures recommended to prevent the problem from reoccurring, and verification that these actions have corrected the problem.

19.0 REPORTS

Documents that will be generated under the soft-bottom benthic monitoring tasks are the following:

- Survey plans;
- Survey reports;

- Data reports; and
- Synthesis reports.

19.1 Survey Plans

Prior to each survey, a survey plan will be submitted. This document will follow guidelines established by the U.S. Environmental Protection Agency for use of the OSV *Anderson*. Each survey plan will contain the following information:

- Documentation of any deviations from this CW/QAPP;
- Specific locations and coordinates of each station;
- Survey vessel and members of survey team;
- Navigational information;
- List of sampling equipment; and
- Protocols for sample collection, handling, preservation, transportation and chain-of-custody.

The schedule for submission of the survey plans is presented in Section 9.0.

19.2 Survey Reports

Following each survey, a survey report will be submitted. Survey reports will summarize information on sampling operations, number and type of samples collected, general observations concerning the condition of each sample such as bulk sediment texture and the presence of megafauna, descriptions of any problems encountered and corrective action taken, and the disposition of the samples collected. The schedule for delivery of the survey reports is presented in Section 9.0.

19.3 Data Reports

Following complete laboratory analysis of samples from each survey, a data report that provides a tabular summary of results of the analyses will be submitted to the MWRA. The due dates for the draft and final data reports are listed in Section 9.0.

19.4 Annual Synthesis Reports

After each monitoring year, an annual synthesis report will be submitted. The synthesis report will analyze, interpret and synthesize various types of data that will allow the MWRA to (1) describe baseline conditions in Massachusetts Bay, (2) describe changes in Boston Harbor, and (3) make modifications to its monitoring plan. Contents for the synthesis reports may include the following:

- Introduction/Objectives;
- Field Survey and Sampling Design;
- Chemical Characterization;
- Biological Characterization; and
- Integration of Study Results/Synthesis.

The due dates for the draft and final annual synthesis reports are listed in Section 9.0.

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