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

for

SOFT-BOTTOM BENTHIC MONITORING: 1993-94

Tasks 10, 11, 12, 13
MWRA Harbor and Outfall Monitoring Program

submitted to

MASSACHUSETTS WATER RESOURCES AUTHORITY
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MWRA Harbor and Outfall Monitoring Project

2. PROJECT REQUESTED BY

Massachusetts Water Resources Authority

3. DATE OF REQUEST

December 6, 1992

4. DATE OF PROJECT INITIATION

December 6, 1992

5. 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 Soft-Bottom Monitoring Project Area Manager

Dr. Carlton Hunt, Battelle Project Manager for Harbor and Outfall Monitoring
Dr. Jack Kelly, Battelle Technical Director
Dr. Roy Kropp, Soft-Bottom Benthic Monitoring Project Area Leader

6. QUALITY ASSURANCE MANAGEMENT

Ms. Rosanna Buhl, Battelle Project QA Officer

7. PROJECT DESCRIPTION

7.1 Objective and Scope

The first overall objective of the Soft-Bottom Benthic Monitoring Program is to document recovery of benthic communities and reduced sediment contamination following sludge abatement and to gather baseline data to document changes following improvements in combined sewer overflows (CSO) in Boston Harbor. The second overall objective is to provide baseline data for both the soft-bottom communities and the contaminant concentrations in surficial sediments in Massachusetts Bay and Cape Cod Bay prior to effluent discharge.

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

- 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. This analysis (part of Tasks 10 and 13) will be done on samples collected during April and August of each year of the study (1993 and 1994).

- Provide for broader geographical coverage of benthic communities in the Harbor by using a combination of sediment profile images (SPI) and rapid processing of sediment grab samples (Subtask 10.2).

- Develop and implement a benthic survey to refine understanding of CSO discharge impacts on local sediment quality of a defined area within Boston Harbor (Subtask 10.3).

- Determine the status of the sediment physicochemical constituents in Boston Harbor subsequent to the cessation of sludge discharge (Tasks 10 and 12).

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

- Characterize the baseline benthic macrofaunal community in the vicinity of the outfall (nearfield) and at reference stations throughout Massachusetts Bay and Cape Cod Bay (farfield) prior to effluent discharge. Use detailed taxonomic analysis of nearfield and farfield sediment samples to determine the abundance and distribution of macrofaunal animals in the study area (Tasks 11 and 13).

- Characterize the baseline sediment chemical constituents at the nearfield and farfield stations in Massachusetts Bay and Cape Cod Bay prior to effluent discharge (Tasks 11 and 12).

7.2 Data Usage

Data resulting from the Soft-Bottom Monitoring Program will be comparable to recent studies in the Harbor and the Bay, and will provide a continuous record of conditions and be useful for the estimation of trends.

Data from the various components of the Harbor and Outfall Monitoring will be integrated and used to produce, under Task 25, synthesis reports describing the environmental conditions observed during the studies and the relation between benthic biology and environment.

Detailed taxonomic analysis of samples collected during the semi-annual traditional surveys (Subtask 10.1) will generate data to allow quantitative investigation of the recovery process. The data obtained under Subtask 10.2 will provide qualitative/semi-quantitative characterization of benthic conditions in the Harbor on a relatively broad scale. These two subtasks represent the third and fourth years of an ongoing project.

Infaunal analysis of sediment samples collected during Task 11 will be used to provide baseline data for both the benthic infaunal communities and the concentrations of contaminants in the associated sediments in Massachusetts Bay and Cape Cod Bay. These data are intended to provide an ability to detect possible changes in infaunal community structure and composition in either bay as a result of effluent discharge into Massachusetts Bay. Task 11 represents the second and third years of an ongoing project.

Results of the sediment chemistry analyses will be used to evaluate the impact of discharging effluent into Massachusetts Bay, the recovery of Boston Harbor, and the effluent-related inputs of chemical contaminants to the sediments of Massachusetts Bay.

7.3 Technical Approach

7.3.1 Boston Harbor Studies

Two sampling approaches will be used to document the conditions of the macrofaunal communities and sediment chemical constituents after the cessation (December 1991) of sludge discharge into Boston Harbor. The first approach

involves use of standard grab sampler to obtain sediment samples from eight stations (Table 1) that were selected after consideration of historical sampling sites and Harbor circulation patterns (Kelly and Kropp, 1992). Note that the target coordinates for the station designated "T5a" are those for the station designated "R6" in Kelly and Kropp (1992). The change was necessary because of difficulty finding suitable substrate at the coordinate of the original station T5. Samples from these stations ("traditional") will be collected twice each year (April and August) for detailed taxonomic analysis. This will permit study of the community during the spring recruitment season and the late summer season before population declines that may occur during the fall.

The second approach, used only during August of each year, will provide for greater geographic coverage of community recovery within the Harbor. This approach will incorporate modified taxonomic analysis (Kelly and Kropp, 1992) of grab samples from 24 stations ("reconnaissance") and analysis of SPI obtained at all 32 grab-sample stations and an additional 18 stations that will be analyzed only by SPI.

The Boston Harbor CSO study has not been designed, pending completion of associated studies. When requested by MWRA, Battelle will

- Develop a testable hypothesis, recognizing that objectives must clarify the need to document Harbor-wide, communal CSO effects versus localized, individual CSO effects.
- Design a statistically sound study capable of testing a defined hypothesis.
- Provide a detailed scope and a table of parameters, stations, and replicates necessary to implement the study as part of the August 1994 survey plan.
- Implement and report study results.

Field and laboratory techniques described in this CW/QAPP for other Harbor tasks will be employed as needed for the CSO study. Any deviations from the CW/QAPP will be described in the August 1994 survey plan. The CSO study will not be discussed further in this CW/QAPP.

Details of the field sampling and laboratory methods to be used in the Harbor studies are provided in Section 12.

7.3.2 Outfall Studies

Including 20 stations in the nearfield sampling program allows relatively broad-scale coverage for examining possible effects of effluent discharge on the macrofaunal community and the chemical constituents of the sediments. The target locations (Table 2) of the nearfield stations are as listed in Blake *et al.* (1992). These stations will be designated NF1-NF20.

Table 1. Boston Harbor Sampling Stations[1]

Station	*Latitude*	*Longitude*	*Depth (m)*
T1	42°20.95′ N	70°57.81′ W	5.6
T2	42°20.57′ N	71°00.12′ W	7.4
T3	42°19.81′ N	70°57.72′ W	8.1
T4	42°18.60′ N	71°02.49′ W	3.4
T5a	42°20.38′ N	70°57.64′ W	17.9
T6	42°17.61′ N	70°56.66′ W	4.9
T7	42°17.36′ N	70°58.71′ W	5.2
T8	42°17.12′ N	70°54.75′ W	12.7
R2	42°20.66′ N	70°57.69′ W	14.5
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	TBD	TBD	TBD
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°52.67′ 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

TBD: To be determined.
[1]There is no Station R1; Stations R26-R43 (for SPI analysis) have not been selected.

Table 2. Locations of Nearfield and Farfield Benthic Stations

Station	*Latitude*	*Longitude*	*LORAN C (time delays)*		*Depth (m)*
		Nearfield Stations			
NF1	42°20.35′N	70°50.51′W	13977.61,	25788.82	21
NF2	42°20.31′N	70°49.69′W	13972.55,	25783.64	26
NF3	42°20.67′N	70°49.35′W	13968.74,	25782.67	30
NF4	42°24.93′N	70°48.27′W	13940.90,	25801.28	35
NF5	42°25.62′N	70°50.03′W	13948.41,	25816.97	28
NF6	42°24.30′N	70°49.99′W	13955.15,	25808.99	32
NF7	42°24.60′N	70°48.89′W	13946.07,	25802.95	33
NF8	42°24.00′N	70°51.81′W	13967.99,	25819.58	29
NF9	42°23.99′N	70°50.69′W	13961.15,	25811.60	29
NF10	42°23.57′N	70°50.29′W	13960.32,	25806.55	32
NF11	42°23.39′N	70°50.25′W	13961.13,	25805.38	31
NF12	42°23.40′N	70°49.83′W	13958.18,	25802.42	34
NF13	42°23.40′N	70°49.35′W	13955.22,	25799.28	33
NF14	42°23.20′N	70°49.36′W	13956.21,	25798.18	33
NF15	42°22.93′N	70°49.67′W	13959.68,	25798.67	32
NF16	42°22.70′N	70°50.26′W	13964.64,	25801.03	29
NF17	42°22.88′N	70°48.89′W	13954.97,	25792.74	29
NF18	42°23.81′N	70°49.24′W	13952.55,	25800.65	32
NF19	42°22.30′N	70°48.30′W	13954.00,	25785.11	32
NF20	42°22.69′N	70°50.69′W	13967.25,	25803.80	28
		Farfield Stations[1]			
FF1	42°27.94′N	70°37.31′W	13855.31,	25748.30	69
FF4	42°17.30′N	70°25.50′W	13835.22,	25606.84	87
FF5	42°08.00′N	70°25.35′W	13880.05,	25543.90	61
FF6	41°53.90′N	70°24.20′W	13939.00,	25440.65	33
FF7	41°57.50′N	70°16.00′W	13873.39,	25414.75	37
FF8	42°25.80′N	70°00.00′W	13636.82,	25529.61	180
FF9	42°18.75′N	70°39.40′W	13915.09,	25703.65	49
FF10	42°24.84′N	70°52.72′W	13969.61,	25830.99	27
FF11	42°39.50′N	70°30.00′W	13747.46,	25776.39	87
FF12	42°23.40′N	70°53.98′W	13984.81,	25830.93	22
FF13	42°19.19′N	70°49.38′W	13975.92,	25773.83	19
FF14	42°25.00′N	70°39.29′W	13882.76,	25742.18	70

[1]There are no stations designated FF2 and FF3.

Twelve stations, relatively removed from the site of future effluent discharge, are located in Massachusetts and Cape Cod Bays and may serve as reference points with which to compare patterns detected among the nearfield stations. These stations also may be used to provide a warning that effects of the discharge are more far-reaching than expected. The target locations (Table 2) of the farfield stations are as listed in Blake *et al.* (1992). Farfield stations will be designated FF1 and FF4-FF14. The station designations FF2 and FF3 will not be used.

Details of the field sampling and laboratory methods to be used in the Outfall studies are provided in Section 12.

7.4 Monitoring Parameters and Collection Frequency

The numbers of stations and field samples per survey are listed in Table 3. The types of field samples, measurements, and shipboard processing requirements are summarized in Table 4.

7.5 Parameter Table

The SPI parameters to be measured in the laboratory and the methods to be used are listed in Table 5. The chemical parameters to be analyzed in the laboratory and the methods to be used are summarized in Table 6. A more detailed list of the analytes included in Task 12 is presented in Section 11 (Table 10). Under the sampling/analysis protocols specified by NOAA for the National Status & Trends Mussel Watch Project, no sediment holding times are specified. Sediment chemistry samples will be frozen as soon as possible after sampling and they will remain at −20 °C until sample processing begins. It is assumed that if the samples are properly handled and remain frozen, their integrity will not be compromised prior to processing.

8. PROJECT FISCAL INFORMATION

This project is being carried out under the Harbor and Outfall Monitoring contract (Contract No. S138) between MWRA and Battelle Ocean Sciences.

Table 3. Samples to be Collected During the Soft-Bottom Monitoring Surveys

	Harbor Surveys					*Outfall Surveys*			
	Traditional		*Reconnaissance*		*CSO Study*[1]	*Nearfield*		*Farfield*	
	Survey	*Total*	*Survey*	*Total*	*Total*	*Survey*	*Total*	*Survey*	*Total*
Number of Stations	8	—	50	—	14	20	—	12	—
Benthic Infauna	24	96	24	48	0	60	120	36	72
Analyzed	24	96	24	48	0	20	40	36	72
Archived	0	0	0	0	0	40	80	0	0
Sediment Chemistry[2]	8	32			42	20	40	24	48
Analyzed	0	0			42	20	40	24	48
Archived	8	32			0	0	0	0	0
Ancillary Physicochemical Parameters									
Total Organic Carbon	8	32			42	20	40	24	48
Grain Size	8	32			42	20	40	24	48
Clostridium perfringens	8	32			42	20	40	24	48
Coprostanol					42				
Sediment Profile Images			150	300					

[1]A detailed Scope of Work for the CSO Study has not been developed; there is only one survey.
[2]1992 samples to be analyzed under Task 12 are not included in this table.

Table 4. 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 nested 0.5- & 0.3-mm mesh sieves. Fix in buffered 10% formalin
Macrofauna	R2-R25	1 grab	Clean, labeled jar	Wash over 0.5-mm mesh sieve. Fix in buffered 10% formalin
Chemistry	T1-T8[2] NF1-NF20 FF1-FF14	1-2 grabs[3]/ 400 mL	Clean, labeled jar	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	1-2 grabs[3]/ 75 mL	Sterile WhirlPak™ bag	As for chemistry
Clostridium perfringens	T1-T8 NF1-NF20 FF1-FF14	1-2 grabs[3]/ 100 mL	Sterile sample cup	As for chemistry
Sediment Profile Images	T1-T8 R2-R43	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-R43	—	—	Record to nearest 0.5 cm
Sediment Texture	All[4]	—	—	Describe qualitatively
Reduction-oxidation 1Potential Discontinuity Depth	All[4]	—	—	Record to nearest 0.5 cm

[1]Stations T1-T8 and R2-R43 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 grab at T1-T8 and NF1-NF20; from 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.

Table 5. Parameters Measured from Sediment Profile Images

Parameter	*Units*	*Method*	*Description*
Sediment Grain Size	Modal phi invertal	V	Determined from comparison of image to images of known grain size
Prism Penetration	cm	V	Average of maximum and minimum distance from sediment surface to bottom of prism window
Sediment Surface Relief	cm	V	Maximum minus minimum depth of penetration
Reduction-oxidation Potential Discontinuity Depth (from color change in sediment)	cm	CA	Area of aerobic divided by width of digitized image
Presence/Absence of Dredged Material	cm, cm^2	V	Measure thickness above original sediment surface and delineate area
Methane/Nitrogen Gas Voids	#, cm, cm^2	V, CA	Count, measure depth from sediment surface, delineate area
Epifaunal Occurrence	#	V	Count, identify
Tube Density	$\#/cm^2$	V, CA	Count
Tube Type			
Burrow Structures	—	V, CA	Identify
Pelletal Layer	cm, cm^2	V, CA	Measure thickness, area
Microbial Aggregations			
Infaunal Occurrence	#	V, CA	Count, identify
Feeding Voids	#, cm, cm^2		Measure thickness, area
Apparent Successional Stage	—		

V: Visual measurement or estimate
CA: Computer analysis

Table 6. 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]	Wet-sieving	Folk, 1974	Freeze
Clostridium perfringens	spores/g	—	Emerson & Cabelli, 1982[4]	Freeze[5]
Total Organic Carbon	%	LECO carbon analyzer	see Section 12	Freeze
Linear alkyl benzenes	ng/g	GC/MS (SIM)	see Section 12	Freeze
Major Metals			see Section 12	
Al	µg/g	XRF	see Section 12	Freeze
Fe	µg/g	XRF	see Section 12	Freeze
Trace Metals			see Section 12	
Ag	µg/g	GFAA	see Section 12	Freeze
Cd	µg/g	GFAA	see Section 12	Freeze
Cr	µg/g	XRF	see Section 12	Freeze
Cu	µg/g	XRF	see Section 12	Freeze
Hg	µg/g	CVAA	see Section 12	Freeze
Ni	µg/g	XRF	see Section 12	Freeze
Pb	µg/g	XRF	see Section 12	Freeze
Zn	µg/g	XRF	see Section 12	Freeze

[1]Dry weight basis.
[2]See Section 20 for literature references.
[3]For gravel, sand silt, and clay — percent of total sample.
[4]As modified by Saad (see Section 12).
[5]Once thawed, refrigerate, do not refreeze.

9. SCHEDULE OF ACTIVITIES AND DELIVERABLES

Soft-bottom benthic monitoring activities will span the period from the date of project initiation (see Section 4.0) until April 1995, 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 25). These activities and deliverables will occur according to the schedules shown in Tables 7 and 8.

10. PROJECT ORGANIZATION

The project organization is shown in Figure 1. Dr. Michael Mickelson is the MWRA Project Manager. He will be informed of all matters pertaining to work described in this CW/QAPP. Mr. Ken Keay is the MWRA Project Area Manager. Dr. Carlton Hunt is the Battelle Project Manager responsible for the overall performance of this project. Dr. Roy Kropp is the Battelle Project Area Leader responsible for the overall performance of the soft-bottom benthic tasks described in this CW/QAPP. Mr. Dane Hardin of Marine Research Specialists (MRS) is the Task Leader for the Harbor Surveys (Task 10), the Outfall Surveys (Task 11), and the Faunal Analysis (Task 13). Mr. Greg Durell (Battelle) will have overall responsibility for all analyses conducted under Task 12. Ms. Rosanna Buhl, Project QA Officer, will oversee the QA activities for all technical work conducted by Battelle.

Mr. James Campbell (MRS) will oversee all vessel mobilization/demobilization activities, as well as at-sea survey operations. Mr. Campbell will also write all Survey Plans and Survey Reports required for the soft-bottom benthic monitoring (see Section 9 and Section 19). Battelle will provide a qualified staff member to operate navigation equipment for each survey. This person will be named in each survey plan.

Dr. Robert Diaz (R.J. Diaz and Daughters; D&D) will supervise collection and analysis of SPI, and will provide data for the two data reports (see Section 9 and Section 19). He will also provide descriptions of methods, results and interpretation from the SPI for the annual synthesis reports.

Mr. Dion Lewis (Battelle) will be responsible for the analysis of metals. Total organic carbon (TOC) analyses will be performed by Global Geochemistry Corporation (GGC), Canoga Park, California. Grain-size analyses will be performed by GeoPlan Associates (GPA), Hingham, Massachusetts. MTH Environmental Associates (MTH), Marstons Mills, Massachusetts, will analyze sediment samples for *Clostridium perfringens* spores. Analyses of samples for

Table 7. Schedule of Surveys and Associated Reports

Survey	*Report*	*Date Due*[1]	
		Draft	*Final*
April 1993			
	Traditional Survey Plan	03/31/93	
	Traditional Survey Report	05/06/93	06/07/93
August 1993			
	Harbor/Outfall Survey Plan	07/31/93	
	Harbor/Outfall Survey Report	08/28/93	09/26/93
April 1994			
	Traditional Survey Plan	03/31/94	
	Traditional Survey Report	04/24/94	05/23/93
August 1994			
	Harbor/Outfall Survey Plan[2]	07/31/94	
	Harbor/Outfall Survey Report[2]	08/29/94	09/27/94

[1]Approximate dates: Survey plans due one week before the survey, a draft survey report is due two weeks after the survey, final survey reports are due one month after submittal of the draft.

[2]Includes CSO Study.

Table 8. Dates Due for Data and Synthesis Reports

Task	*Report*	*Survey Date*	*Date Due*	
			Draft	*Final*
12	Sediment Chemistry Data Report	August 1992	04/30/93	05/29/93
12	Sediment Chemistry Data Report	April 1993	09/30/93	10/29/93
13	Faunal Analysis Data Report	April 1993	09/30/93	10/29/93
10.2	Reconnaissance Survey Data Report	August 1993	11/30/93	12/29/93
12	Sediment Chemistry Data Report	August 1993	12/31/93	01/29/94
13	Faunal Analysis Data Report	August 1993	12/31/93	01/29/94
12	Sediment Chemistry Data Report	April 1994	09/30/94	10/29/94
13	Faunal Analysis Data Report	April 1994	09/30/94	10/29/94
10.2	Reconnaissance Survey Data Report	August 1994	11/30/94	12/29/94
10.3	CSO Sediment Data Report	August 1994	12/15/94	01/29/95
12	Sediment Chemistry Data Report	August 1994	12/31/94	01/29/95
13	Faunal Analysis Data Report	August 1994	12/31/94	01/29/95
25	1993 Annual Soft-Bottom Synthesis Report		03/31/94	04/29/94
25	1994 Annual Soft-Bottom Synthesis Report		03/31/95	04/29/95

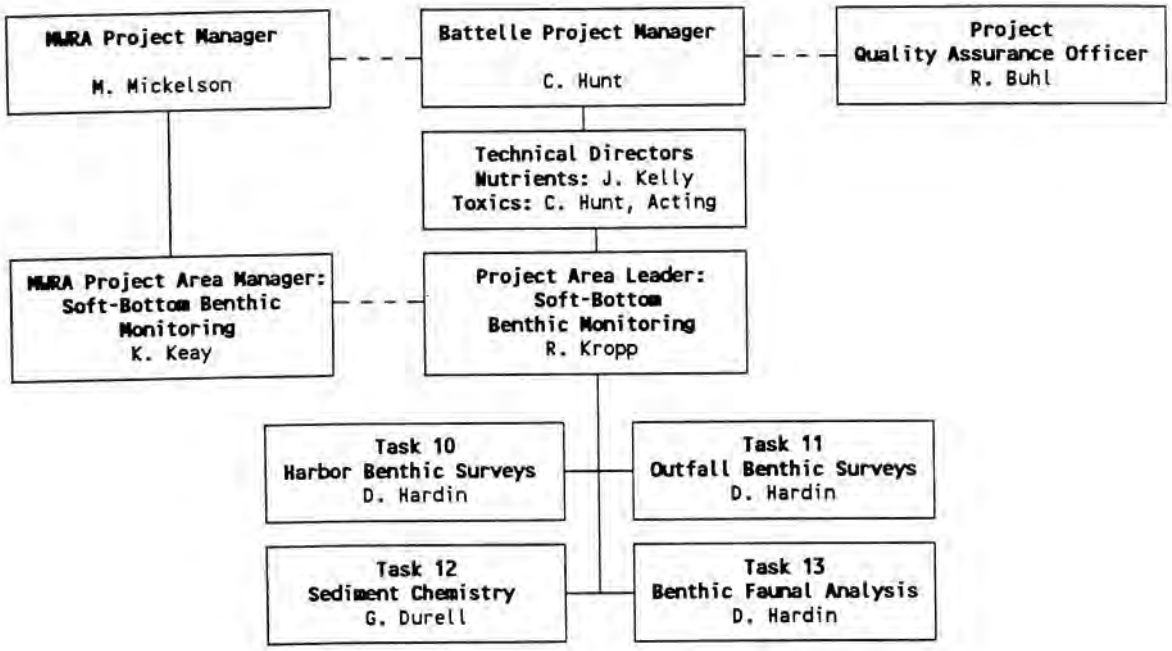

Figure 1. Organization Chart for Soft-Bottom Benthic Monitoring.

organic analytes, including polynuclear aromatic hydrocarbons (PAH), linear alkylbenzenes (LAB), coprostanol, polychlorinated biphenyls (PCB), and chlorinated pesticides and metals will be performed by Battelle.

MRS will be responsible for the sorting, identification, and enumeration of organisms from the benthic samples collected for Subtask 10.1, Subtask 11.1, and Subtask 11.2, as well as for submittal of associated data reports. Taxonomy will be performed by Mr. Eugene Ruff of Ruff Systematics, Mr. Russ Winchell of Ocean's Taxonomic Services, and Dr. Roy Kropp. Dr. Kropp will be responsible for these activities for samples collected for Subtask 10.2.

11. DATA QUALITY REQUIREMENTS AND ASSESSMENTS

The quality of the data produced for the soft-bottom benthic monitoring activities depends on the accuracy, precision, representativeness, comparability, and completeness of the data.

Data quality requirements will be enforced to ensure that samples with similar sediment characteristics are sampled from locations previously occupied, and are analyzed by methods similar to those previously used in studies conducted for MWRA. In this way, natural changes in benthic infaunal community characteristics can be separated from changes associated with either reduced and improved discharges in the Harbor or initiation of discharge from the new outfall.

11.1 Field Activities

11.1.1 Precision

The precision of the Northstar 8000 differential global positioning system (GPS) will be checked daily. GPS coordinates (latitude/longitude) will be recorded at the dock before departure. These will be compared with a set of GPS coordinates recorded at the same dock after return from sampling and a correction will be applied to the station coordinates if the difference is $\geq$ the accuracy of the GPS.

The precision of successive grab samples will be ensured through use of navigation equipment that will allow samples to be taken within an area 10 m across. Rejection of grab samples for the conditions listed for "Accuracy," will also improve the precision of the samples by ensuring the similarity among samples for volume and surface area of sediment collected.

11.1.2 Accuracy

Navigation will be accomplished with a Northstar 8000 differential GPS with an absolute accuracy of 5 m. Differential GPS will allow all sampling to be conducted within ±5 m of stations for which the locations were previously determined. The system is internally calibrated (updated every minute) and requires no manually entered offset as does a LORAN system. However, before each survey, the accuracy of Northstar will be checked at Battelle at a known position having an accuracy of 5 m. The offset (if any) will be checked and applied into the BOSS software (not the GPS). The Northstar output will also be checked twice daily for approximate accuracy at the dock against charted coordinates (charts even to the 10000:1 scale are not accurate enough to discern 5 m) before departure and after return to the dock.

The accuracy of the grab samples collected will be ensured by requiring each sample to satisfy a set of criteria concerning the depth of penetration and disturbance of the sediment within the grab. In this way, each sample will normally contain the top 10 cm of sediment within the area of the grab jaws. Samples will be rejected for any of the following conditions:

- There is a rock or shell fragment wedged between the jaws of the grab allowing the sample to wash out.
- The surface of the sample is significantly disturbed.
- The grab is less than half filled indicating under-penetration of the grab.
- The sample is uneven from side to side, indicating that the grab was tilted when it penetrated the sediment.
- The surface of the sample is in contact with the top doors of the grab indicating over-penetration of the grab and possible loss of material around the doors.

11.1.3 Completeness

The Northstar differential GPS will output navigation positions at an interval of 1 or 2 s. These GPS output intervals are well within the 1-min output intervals required by the project. The BOSS software system will display all position fixes and save them in an electronic file during all sampling operations. Thus, even with a few bad data streams from the Northstar to the computer, the software will provide enough fixes within each 1-min period for 100% data collection. During transit between stations, the BOSS software system will save vessel coordinates in an electronic file every 5 min.

The completeness of the benthic grab sample collections will be ensured by collecting all the required samples from each station.

The completeness of SPI collection will be ensured by checking the film counter after every station or replicate deployment of the camera to confirm that the

system is functioning properly. Any misfires or improper camera operation then can be corrected while on station. Most electronic or mechanical failures of the profile camera can be repaired in the field. Spare parts and a back-up camera will be carried on all surveys.

11.1.4 Comparability

The Massachusetts Bay and Boston Harbor charts will be displayed on the navigation CRT monitor. GPS latitude/longitude positions will be recorded, and these positions will be comparable to those obtained by other researchers that have used or are using differential GPS.

The comparability of grab samples and SPI between this and previous projects, and within this project, will be ensured through the consistent use of methods that have been previously used. This comparability will also be enhanced through the rejection of samples for the conditions described above for "Accuracy." A description of the sediment characteristics for each sample will be written in the field to verify the comparability among samples.

11.1.5 Representativeness

GPS latitude/longitude positions are representative of the actual vessel coordinates and survey track because position data are collected and reviewed at a frequency that ensures that the measured latitude/longitude positions represent the actual vessel position.

The representativeness of grab samples and SPI will be ensured by sampling at previously sampled locations that were originally chosen based on similarity of habitat or to allow for wide geographic coverage. Re-occupation of previously sampled sites will be possible within the precision and accuracy provided by the navigation equipment.

11.2 Laboratory Activities – Sediment Chemistry

11.2.1 Precision

Analytical precision will be determined using the concentrations of duplicate samples (eg., matrix spikes for organics samples), with percent differences between duplicate analyses serving as a measure of precision. The goal for

relative percent difference (RPD) 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.

Data quality objectives for accuracy and precision are presented in Table 9.

11.2.2 Accuracy

Analytical accuracy will be evaluated based on percent recoveries of analytes in National Institute of Standards and Technology (NIST) standard reference materials (SRM), matrix spike samples, the recovery of surrogate internal standards (SIS) that are added to every sample (organics only), as well as the results of the procedural blanks which will be analyzed with each batch of field samples. QC procedures for organic analyses will be designed such that every set of field samples (consisting of no more than 20 samples) will contain an SRM sample, a matrix spike and matrix spike duplicate sample, and a procedural blank. QC procedures for metals analyses will be designed such that every set of field samples (consisting of no more than 20 samples) will contain a field or laboratory duplicate sample and an SRM or certified control material.

Deviations from the above analytical scheme will be noted in the laboratory records associated with the analytical batch and in project files. All QC data will be reported with the sample data. The data quality objective for organics and metals QC analytical results (accuracy) is $\pm 30\%$ difference between the calculated concentrations and the certified values (or known values, in the case of matrix spikes) for each individual analyte when concentrations are at least 10 times the analytical detection limits (in SRM samples only). Procedural blanks are to contain less than 5 times the method detection limit (MDL) of any target analyte.

The chemical analytes included in this project and their respective method detection limits (MDL) are listed in Table 10.

All field samples, blanks, and matrix QC samples processed for organics 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. Acceptable SIS recovery range should be 50%-150%. It is considered acceptable if one of the PAH surrogate internal standards lies outside this range as long as the others are within the acceptable range. Because samples are quantified relative to the recovery of the

Table 9. Data Quality Objectives for Organics and Metals Samples

QC Sample Type and Frequency	*Data Quality Objective*	*Corrective Action*
Procedural Blank Organics: 1/batch of <20	< 5 × MDL	Reextraction, reanalysis, and/or blank subtraction — determined by Task Leader; all corrective actions documented
Method Blank Metals: 1/batch of <20 TOC: 1/batch of 50[1]	< 5 × MDL	TOC sample concentrations will be blank subtracted
SRM Organics (PAH)[2]: 1/batch of <20 Metals: 1/batch of <20	± 30% difference vs. certified values	Reextraction, reanalysis, and/or blank subtraction — determined by Task Leader; all corrective actions documented
MS/MSD Organics: 1 set/batch of <20	50-150% recovery ≤ 30% RPD	Document deviations
Duplicates Metals: 1/batch of <20	Average % CV: ± 35% individual analyte ± 30% average of all analytes	
TOC: every 10th sample	± 5% RPD	
Triplicates Grain-size: 5% of samples	% CV = ± 20% for sand, silt, clay	
SIS Every organics sample	50-150% recovery (one PAH SIS may exceed)	Results examined by project management or task leader. Corrective action (reextraction, reanalysis) or justification documented.
Calibrations: Initial	Organics: ± 25% RSD individual analyte ± 10% RSD average of all analytes Metals: Calibration regression coeff (r) > 0.99	Reanalyze or document and justify.
Check	Organics: ± 25% RSD individual analyte ± 10% RSD average of all analytes Metals: ± 15% of true value TOC: ± 10% of true value	Remedial maintenance, new initial calibration, reanalyze samples at discretion of analyst and task leader. 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.

Table 10. Sediment Chemistry Analytes and Method Detection Limits (MDL)

Analyte	*MDL*[1]
Physical Sediment Parameters/Sewage Tracers	
Total organic carbon	100
Grain size	—
Clostridium perfringens	—
Linear alkyl benzenes (C_{10}-C_{14})	5[2]
Coprostanol (CSO Study)	—[3]
Metals	
Al Aluminum	6000
Fe Iron	20
Ag Silver	0.25
Cd Cadmuim	0.025
Cr Chromium	10
Cu Copper	5
Hg Mercury	0.025
Ni Nickel	6
Pb Lead	5
Zn Zinc	3
Polychlorinated biphenyls	
2,4,-Cl_2(8)	0.87
2,2',5-Cl_3(18)	0.48
2,4,4'-Cl_3(28)	0.23
2,2',3,5'-Cl_4(44)	0.67
2,2',5,5'-Cl_4(52)	0.26
2,3',4,4'-Cl_4(66)	0.43
3,3',4,4'-Cl_4(77)	0.60
2,2'4,5,5'-Cl_5(101)	0.49
2,3,3',4,4'-Cl_5(105)	0.60
2,3',4,4'5-Cl_5(118)	0.45
3,3',4,4',5-Cl_5(126)	0.60
2,2',3,3,4,4'-Cl_6(128)	0.34
2,2',3,4,4',5-Cl_6(138)	0.45
2,2'4,4',5,5'-Cl_6(153)	0.82
2,2'3,3,4,4',5-Cl_7(170)	0.67
2,2',3,4,4',5,5'-Cl_7(180)	0.49
2,2',3,4,5,5',6-Cl_7(187)	0.58
2,2',3,3',4,4',5,6-Cl_8(195)	0.61
2,2',3,3'4,4',5,5',6-Cl_9(206)	0.96
Decachlorobiphenyl-Cl_{10}(209)	0.63
Polynuclear Aromatic Hydrocarbons (PAH)[4]	
naphthalene	0.48
C_1-naphthalenes	0.87
C_2-naphthalenes	1.19
C_3-naphthalenes	1.35
C_4-naphthalenes	2
acenaphthylene	1.36
acenaphthene	1.05
fluorene	0.83
PAH (continued)	
C_1-fluorenes	1
C_2-fluorenes	2
C_3-fluorenes	2
anthracene	1.32
phenanthrene	1.41
C_1-phenanthrenes/anthracene	1.74
C_2-phenanthrenes/anthracene	2
C_3-phenanthrenes/anthracene	2
C_4-phenanthrenes/anthracene	2
dibenzothiophene	1
C_1-dibenzothiophenes	1
C_2-dibenzothiophenes	1
C_3-dibenzothiophenes	1
fluoranthene	2.70
pyrene	2.42
C_1-fluoranthenes/pyrenes	2
benzo[*a*]anthracene	1.49
chrysene	1.83
C_1-chrysene	2
C_2-chrysene	2
C_3-chrysene	2
C_4-chrysene	2
benzo[*b*]fluoranthene	1.40
benzo[*k*]fluoranthene	1.67
benzo[*a*]pyrene	0.99
dibenzo[*a,h*]anthracene	1.39
benzo[*g,h,i*]perylene	2.56
indeno[1,2,3-*c,d*]pyrene	2.36
perylene	4.63
biphenyl	1.15
benzo[*e*]pyrene	1.51
dibenzofuran	1
Pesticides	
Hexachlorobenzene	0.28
Lindane	0.20
Heptachlor	0.54
Aldrin	0.42
Heptachlorepoxide	0.46
alpha-chlordane	0.39
trans-Nonachlor	0.42
Dieldrin	0.40
Endrin	1.14
Mirex	0.49
2,4'-DDD	0.49
4,4'-DDD	0.58
2,4'-DDE	0.32
4,4'-DDE	0.25
2,4'-DDT	0.37
4,4'-DDT	0.62

[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
[3] To be determined.
[4] Approximate MDLs of 1 and 2 ng/g have been assigned to PAH for which a formal MDL determination has not been performed. The assigned MDLs are based on the analytes known response relative to PAH with determined MDLs and recent historical data.

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 subtask leader to determine the necessity of reextraction or reanalysis. All corrective actions will be documented. When a sample does not meet the data quality objective and is not reanalyzed, the justification for this decision will be documented.

11.2.3 Completeness

The completeness of chemical analyses will be ensured by comparing the chain-of-custody forms received by the laboratory with the list of samples analyzed. All samples will be analyzed for the parameters listed in Table 3, and these analyses will be documented in the Chemistry Department project files.

11.2.4 Comparability

All data developed for this project must be demonstrated to be comparable to data generated by other laboratories. To accomplish this, Battelle participates in a series of interlaboratory calibration exercises for analysis of PAHs, PCBs, pesticides, and metals in sediments and tissues. Materials and instructions for organics analyses are provided by the National Institute of Standards and Technology (NIST). National Research Council Canada (NRCC) provides materials and instructions for metals intercomparison exercises. In addition, the use of written standardized procedures ensures that sample preparation and analyses will be comparable throughout the project and with other projects.

11.2.5 Representativeness

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

11.3 Laboratory Activities – Macrofaunal/SPI Analysis

11.3.1 Precision

The precision of sorting procedures will be verified by the QC checks described for "Accuracy." If essentially all the organisms are removed from a sample, then both the accuracy and precision of the sorting procedure are ensured.

Even with careful control on SPI film development, there is variation in either the film lots or processing that causes subtle color differences between finished prints to occur. To correct for this problem, the first and last picture taken each field day will be a standard color card (Macbeth Colorchecker™) with red,

green, blue, white, and neutral gray densities. Color-card images allow day-to-day or film-to-film variation to be determined. Color variations can then be accounted for in the computer image analysis.

SPI analysis is accomplished through a series of macro commands executed from a video screen menu. After every step the analyzer is asked if the results are satisfactory and given the chance to redo any step. Slight variation of image areas within and between slides may occur because of operator error. To quantify this error, 10% of all slides will be reanalyzed and compared to previous results.

11.3.2 Accuracy

The accuracy of benthic faunal analyses can be defined only within the variability imposed by sampling and sample processing methods. For example, the number of organisms retained by the screens will depend on the size, shape, and orientation of the organisms at the time of sieving. This inherent, and assumed slight inaccuracy, would be very difficult to measure (e.g., by sorting, identifying, and enumerating the organisms from unsieved samples).

Nevertheless, procedures will be employed to ensure that at least 95% of the organisms retained on the screens and transferred to the laboratory will be sorted from the sample debris, identified, and enumerated. As samples are sorted by each technician, they will be arranged into batches of 10, from which one will be chosen randomly for resorting by a different technician. If any sample is found to contain a number of organisms exceeding 5% of the number that were originally sorted from the sample, all the samples in that batch of 10 will be resorted by another technician. This process will be repeated until the batch of samples passes the quality control check.

The accuracy of species identifications will be ensured by using taxonomists who are experienced with the fauna from Boston Harbor, Massachusetts Bay, and Cape Cod Bay. Infaunal animals will be identified to the lowest possible taxon, usually to the species level. The number of specimens belonging to each taxon will be counted. Only an animal having a head or other consistently discernable feature (e.g., the umbo of a bivalve shell) will be counted. Colonial organisms (e.g., hydroids) that cannot be counted may be recorded as present. Taxa not identifiable to species will be clearly marked in the data report.

To ensure accuracy of SPI analysis, a standard set of instructions — including system warm-up time, video camera-to-slide distance, light table color check, and cleaning of the lens and color filters — will be followed during the set-up of the image processor. Once the system is functioning properly, a standardized

scale slide will be measured to ensure that the linear measurements made on the profile images will be accurate.

11.3.3 Completeness

The completeness of benthic faunal analysis will be ensured by analyzing all samples, except those that are randomly selected for archival under Subtask 11.1. Verification that all samples are analyzed will be provided by tracking the progress of sample analyses through a project sample log book.

To ensure completeness of SPI analysis, only established and reputable laboratories will be used to develop the exposed film. All images will be analyzed.

11.3.4 Comparability

The comparability of samples subjected to benthic faunal analysis or SPI will be ensured by consistent application of the QC procedures described for "Accuracy" and by using the same taxonomists or analysts throughout the project, whenever possible.

11.3.5 Representativeness

The representativeness of the sorting, identification, and enumeration procedures will be ensured by sorting the entire sample, and by identifying and enumerating all the organisms that are sorted from the sample.

Because of the extreme habitat heterogeneity in the nearfield area surrounding the outfall, the representativeness and comparability of samples will be more difficult to achieve and may require repeated grabs to obtain the necessary number of samples. Written descriptions of the sediment characteristics in each grab will verify the representativeness and comparability of samples. If soft sediments cannot be consistently found at a site, station locations may be adjusted through ship-to-shore discussions with MWRA staff.

12. SAMPLING AND ANALYTICAL PROCEDURES

12.1 Navigation

The vessel will approach each station bow into the wind (or swell). When on station, the ship's master will keep the ship's bow into the wind for stability and maneuverability. The vessel will be maintained within a radius of 5 m on calm days and 15 m (if possible) on windy days. If the ship's master is unable to maintain position within the desired radius, he will reposition before collecting the sample.

Vessel positioning during the sampling operations will be accomplished using the BOSS navigation system. This system consists of a Northstar differential integrated GPS interfaced to the BOSS computer and has an absolute accuracy of 5 m. The GPS receiver has six dedicated channels and is capable of locking onto six different satellites at one time. This ensures strong signal reception and accurate and reliable positioning with 1- or 2-s updates. The GPS/Loran system (accurate to only 50 m) will serve as a backup system to the differential GPS system and will automatically choose between GPS and Loran, based on best accuracy. Navigation equipment will be operated according to the manufacturer's guidelines.

The BOSS software acquires data from all onboard electronic sampling systems and navigation systems. The software queries each system four times per second. The software displays all of the information once per second on a color monitor. Once the data are acquired, all of the data is automatically written to a data file and logged concurrently with position data from the navigation system. The navigation portion of the display will show the digitized coastlines, navigation aids, sampling stations, and vessel track. A second monitor will be furnished to the helmsman as a steering display. During grab sampling, position fixes will be electronically recorded at 2-s intervals. Hard-copy printouts of position fixes will be made during discrete sampling events such as collection of a grab sample. During transit operations between stations, position fixes will be electronically recorded at 5-min intervals.

12.2 Benthic Sample Collection/Shipboard Processing

At all stations, the station coordinates, time, seastate and other weather conditions, and water depth will be recorded on the BOSS Station Log (see Section 13).

12.2.1 Grab Sample Collection

A Kynar coated, Young-modified Van Veen grab sampler having an area of 0.04 m^2 will be used to collect all soft-bottom monitoring grab samples. Once the survey vessel is on station and coordinates have been verified, the sediment grab will be deployed. The grab will be allowed to descend slowly until the last few meters when the rate of decent is accelerated. This acceleration will drive the jaws of the grab into the sediment. Upon retrieval of the grab, the sample will be inspected for acceptability (see Section 11). If the grab is unacceptable, it will be emptied, rinsed with filtered seawater, and redeployed. If the grab 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 estimated by using a syringe to

withdraw a small core from the sample and measuring the depth of the uppermost portion of the black subsurface sediments as the core is extruded. The material from the core will be returned to the grab for processing with the remainder of the sediment. The grab will be placed over a bucket, the jaws will be opened, and filtered seawater will be used to gently wash the sample into the bucket. Once thoroughly washed, the grab will be redeployed until the required number of acceptable samples have been obtained for infaunal or chemical analysis.

Precautions will be taken during the deployment and retrieval of the grab sampler to prevent contamination of the sample to be used for chemical analyses. Before the grab may be used, the vessel must be positioned so that the engine exhaust will not contaminate the sample when it has been brought on deck. All smoking also must be terminated during collection of sediment chemistry samples. To remove organic contaminants, the grab, sampling scoop, and spatula will be cleaned between sediment 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. The numbers of grab samples to be collected at each station for macrofaunal or chemical analyses are listed in Table 4.

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 nested 0.5-mm and 0.3-mm mesh sieves. At Harbor reconnaissance stations, grab samples will be rinsed through a 0.5-mm mesh sieve only. The subsamples 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 400 mL of the sample (for chemical analyses including organics, metals, and TOC) will be placed into a clean Teflon sample container. This sample will be split in the laboratory as described in Section 12.3.3. A subsample (75 mL) to be used for grain size analysis will be placed in a sterile WhirlPak™ bag. A subsample (100 mL) to be used for *Clostridium perfringens* analysis will be placed into a sterile sample cup. All subsamples will be labeled properly and frozen immediately (−20°C) for storage and transport to the laboratories. The grab will be washed between stations.

12.2.3 Sediment Profile Image Collection

The sediment profile camera system consists of a camera enclosed in a pressure-resistant housing, a 45° prism, and a mirror that reflects an image of the sediment through the camera lens. A strobe mounted inside the prism is used to illuminate the sediment. Prior to every field deployment all essential items are gathered and tested for proper operation. The camera/prism system is mounted in a cradle that is secured to a larger frame that ensures that the prism penetrates the sediment at a 90° angle. A winch is used to lower the entire assembly (at a consistent rate) to the seafloor. When the system is on the seabed, the penetration rate of the camera/prism assembly into the sediment is controlled by a hydraulic piston. Contact with the seabed triggers the camera. To permit proper penetration of the sediment by the prism, a brief time delay occurs between contact with the seafloor and the first exposure. The delay ranges from 1 s in soft mud to 15 s in hard sand. After the required number of exposures, the camera assembly is returned to the ship and an estimate of the prism penetration depth is made by visually measuring the displacement of a moveable sleeve placed on the camera assembly. A more accurate estimate is obtained during subsequent laboratory analysis of the images.

12.3 Laboratory Processing

12.3.1 Reconnaissance Survey Grab Sample Analyses

Grab samples collected during Subtask 10.2 will be analyzed by Dr. Roy Kropp of Battelle and Eugene Ruff (Battelle's subcontractor, Ruff Systematics), according to the procedures detailed below.

The laboratory processing procedures are shown in Figure 2. Prior to laboratory processing, an estimate of the settled depth of the sediment in each 1-gal jar (14.5 cm dia.) will be made by placing a millimeter rule against the outside of the jar and recording the depth of the sediment in the jar. For unevenly settled samples high and low measurements will be obtained and the midpoint of these measurements will be entered into the data file.

To facilitate sorting, samples will be stained (usually overnight) in a saturated solution of Rose Bengal. Laboratory processing will be initiated with a visual inspection of the sample to determine the presence or absence of a "heavy fraction," typically mollusc shells or rocks. If a heavy fraction is present, the sample will be poured into a 0.5-mm-mesh sieve and rinsed with fresh water to remove the formalin. The sample then will be transferred to a large dishpan for elutriation. Elutriation is accomplished by adding enough water to the pan to cover the sediment sample and carefully agitating the sample by rocking the pan back and forth to bring relatively light material into suspension. Agitation is

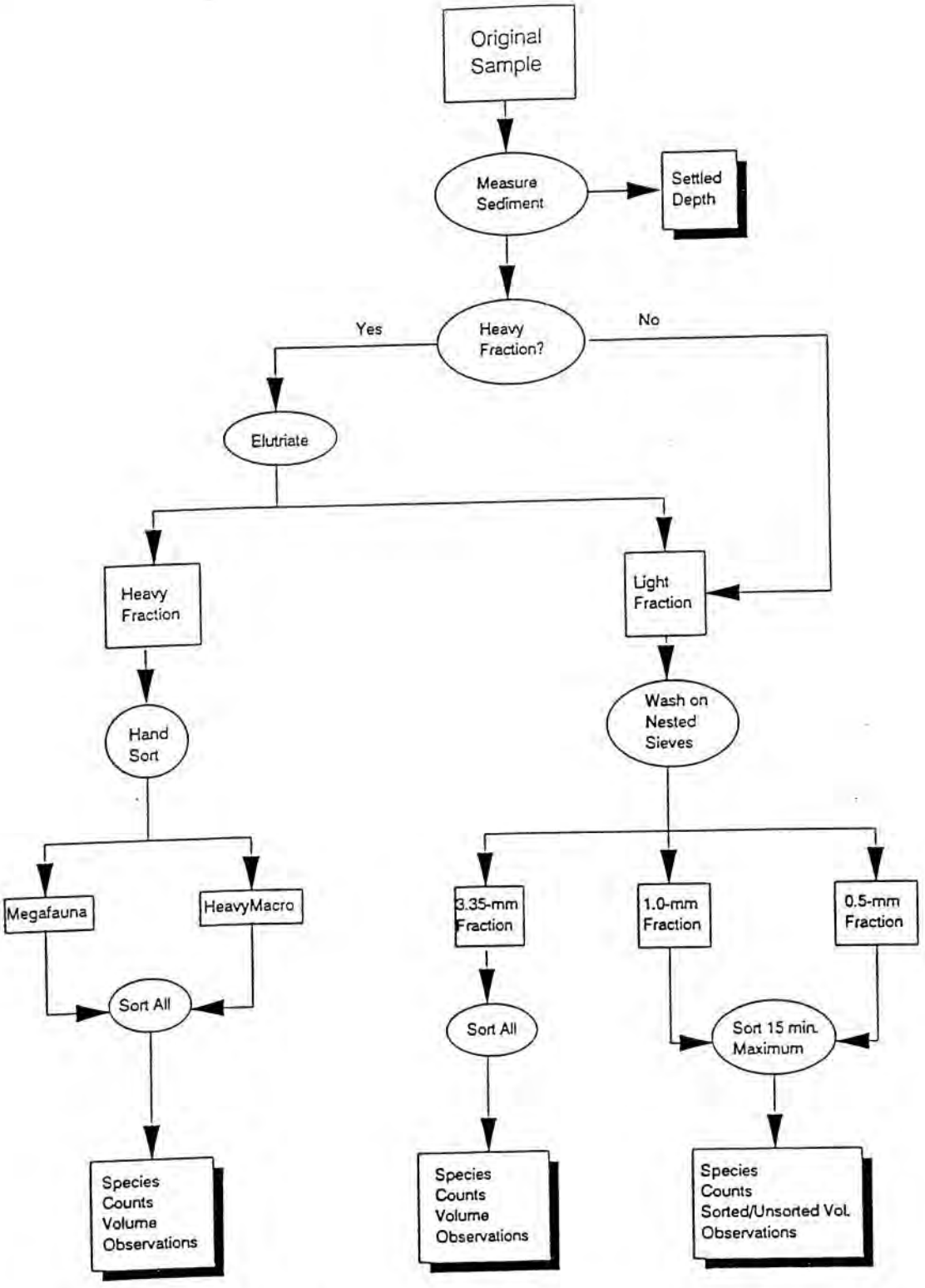

Figure 2. Flow Chart of Laboratory Assessment To Be Conducted during Subtask 10.2.

followed by decanting the water into a 0.5-mm-mesh sieve. The process is repeated until it appears that no more material is being suspended in the water above the sample. The material retained on the sieve is termed the "light fraction" and that remaining in the pan is the "heavy fraction." Any remaining "megafauna" (e.g., a seastar) will be removed, placed into a labeled jar, and covered with 70% ethanol. The remaining "heavy-macro" fraction will be placed in a jar, labeled, and covered with 70% ethanol. The light fraction will be rinsed over a stack of nested 3.35-, 1.0-, and 0.5-mm-mesh sieves. The material remaining on the sieves will be placed in separate, labeled jars and covered with 70% ethanol. Each fraction is named after the mesh size of the sieve on which it is retained. If no heavy fraction is present, the sample will be washed over the nested sieves as described above for the light fraction. All fractions will be delivered to the taxonomists for analysis.

Megafauna present in the sample will be identified and counted. All sediment in the heavy-macro and the 3.35-mm fractions will be examined; all organisms present will be removed and identified to the lowest possible taxonomic level. Sediment in the 1.0- and 0.5-mm fractions of each replicate will be sorted by the two expert taxonomists who will remove all organisms encountered. The maximum time allowed to sort a fraction will be 15 min. After the expiration of the time limit, the sorted residue and any material not sorted will be placed in separate labeled jars and covered with 70% ethanol. Any noteworthy observations regarding the nature of the sediment, such as the type of debris, will be recorded. All organisms removed during sorting will be identified to the lowest possible taxonomic level within a short time period (about 5 min) and counted. The volume of each of the sorted and unsorted residues will be obtained by pouring the residues into graduated cylinders and allowing them to settle for 3 min.

12.3.2 Reconnaissance Survey — SPI Analysis

Sediment profile images collected during Subtask 10.2 will be analyzed by D&D. Control of the computer image analysis includes system preparation, actual image analysis, and data reduction. The parameters measured and the methods used in the analysis are summarized in Table 5.

During image analysis, two computer files are opened to receive data from each image. One file includes all statements executed by the computer and the resultant data. This file will be archived and can be used, if necessary, to document how the analysis of a particular slide was conducted. The second file, generated at the same time as the first, contains only the selected image data to be used in reports. After the computer analysis, all slides are put into the SPI photo archives maintained by D&D.

12.3.3 Sediment Chemistry (Task 12)

The physical parameters and chemical analytes of interest are listed in Table 10. In addition to the analyses of sediment samples collected under Tasks 10 and 11, Task 12 will include analysis of 44 archived samples that were collected in 1992 under separate contract. These samples will be analyzed for organic compounds, metals, and linear alkyl benzenes.

Sample Splitting

Sediment chemistry samples will be removed from the freezer just prior to splitting. Once thawed, a Teflon spatula that has been acid-cleaned and rinsed with solvent and deionized water (in that order) will be used to mix the samples thoroughly. The sample will be divided into three aliquots, one each to be analyzed for metals, organics, and TOC. The metals aliquot, approximately 100 g, will be placed in an acid-cleaned polypropylene jar. The TOC split, approximately 5 g, will be placed in a 25-mL glass vial that has been baked in a muffle furnace at 550 °C for 5 h. The vials will be covered with foil-lined caps; the foil also will have been baked at 550 °C prior to use. The remaining sediment will be transferred to cleaned I-Chem jars and used as the organic chemistry aliquot. Each sample container will be labeled with the program name and number, sample number, and sample type (e.g., TOC, metals). All subsamples will be frozen immediately after splitting.

Organic Chemical Analyses

Sediment samples will be extracted for PAH, LAB, chlorinated pesticides, and PCB following methods developed by Battelle in support of NOAA's National Status & Trends Mussel Watch Project. 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, spiked with the appropriate surrogate internal standards, solvent will be added, the jar shaken for the appropriate amount of time and centrifuged. The extract will be decanted into an Erlenmeyer flask. After each extraction (total of three solvent additions) the centrifuged 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.

This preparation scheme will be slightly modified when extracting sediments for coprostanol analysis (to be done for the CSO study) in addition to PAH, LAB, PCB, and pesticides. Once the sediment aliquot is extracted three times and the extracts combined, Kuderna-Danish and nitrogen concentration techniques will be used to concentrate these combined extracts to approximately 1 mL. This 1-mL extract will be chromatographed through a 20-g F-20 alumina column and separated into fractions for analysis. A combined fraction containing saturated, aromatic, and chlorinated hydrocarbons, including PAH, LAB, PCB, and chlorinated pesticides will be eluted with 100 mL DCM (F_1 fraction). The polar fraction (F_2) containing the sterols will be eluted with a two-step process using 25 mL of 10% methanol in DCM, and 50 mL of 20% methanol in DCM. The two F_2 fractions will be combined immediately after elution from the column, concentrated under nitrogen to approximately 1 mL, spiked with the appropriate recovery internal standard and analyzed for sterols. The F_1 fraction will be concentrated to 900 μL and introduced to the HPLC for further cleanup and final preparation as described in the first paragraph of this section.

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). Sample extracts will be analyzed for coprostanol using gas chromatography with flame ionization detection (GC/FID). All analytes will be determined by the method of internal standard, using surrogate internal standards for quantification.

Inorganic Analyses

Freeze-dried and homogenized sediment samples will be split for three separate processing and analysis methods for the metals measurements. A ball mill will be used to grind one subsample to a fine powder for quantitation of aluminum, chromium, copper, iron, nickel, lead, and zinc by energy dispersive X-ray fluorescence (EDXRF). EDXRF spectroscopy does not require sediments to be processed beyond freeze drying and grinding. A second subsample will be digested with an HNO_3/HF acid mixture for silver and cadmium measurements. Briefly, approximately 0.5-g subsamples of the dried sediment are transferred to Teflon digestion vessels, mixed with HNO_3 and HF, and heated in a microwave oven for 25 minutes. The digestion solution is then transferred to storage containers and diluted for final analysis by graphite furnace atomic absorption

spectrometry. The third subsample will also undergo acid digestion combined with microwave heating for mercury measurements. These subsamples will be treated with an HCl/HNO_3 acid mixture, heated, and again diluted for analysis by cold vapor atomic absorption spectrometry (CVAAS).

12.3.4 Ancillary Physicochemical Parameters (Task 12)

Total Organic Carbon

A LECO model 761-100 carbon analyzer will be used to determine the TOC content of solid samples. The principle of its operation is the high-temperature conversion of all carbon in the treated sample to carbon dioxide in the presence of oxygen. The carbon dioxide can then be quantified by thermal conductivity detection.

For TOC analysis, 175 to 250 mg of dry, finely ground, and homogenized sample will be weighed to 0.1 mg and placed in a LECO model 761-100 filtration crucible that has been precombusted for 2 h at 450 °C. The sample will be treated with 6N HCl to remove inorganic carbon. Iron and copper chips will be added to the sample just prior to analysis to accelerate combustion. One hour after no further reaction is observed, the sample will be neutralized with deionized water and dried overnight.

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 min, 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 min.

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

Sediment grain size analysis will be performed according to methods presented in Folk (1974). Briefly, coarse and fine fractions will be separated by wet-sieving through a 62 μm-mesh sieve. The fine fraction (silt and clay) will be further separated by suspending the sediment in a deflocculant solution and taking aliquots of the settling sediment at timed intervals after the solution is thoroughly mixed. The coarse fraction (sand and gravel) will be dried and then separated by sieving through a 2-mm screen. Grain size will be reported as percentage (based on dry weight) of each fraction of the total sample weight.

12.3.5 Macrofaunal Analysis (Task 13)

From each survey conducted under Subtask 10.1 and Subtask 11.2, three replicates from each station will be sorted; one replicate from each station will be sorted from surveys conducted under Subtask 11.1. The remaining two samples from each station occupied during the survey conducted under Subtask 11.1 will be archived at Battelle. Samples obtained for benthic faunal analysis will be transferred from formalin to 70% ethanol and then shipped to the MRS Laboratory for sorting.

Sorting will consist of using fine dissecting forceps and binocular dissecting microscopes to pick the organisms from the sample debris. Organisms will be sorted into major taxonomic categories—polychaetes, arthropods, molluscs, and miscellaneous. 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, usually species. Data will be recorded on project-specific data sheets (Figure 3). When the taxonomists have finished identifying and enumerating the organisms, the specimens and data sheets will be returned to MRS and the data will be entered into a computer.

13. SAMPLE CUSTODY

Battelle's standard procedures for sample tracking and custody will be used on all soft-bottom monitoring surveys. Field samples are identified by an unique sample ID which is a concatenation of *event_id* (5-character ID unique to each survey; Table 11) and *marker_no* (which is a non-repeating number for each survey generated by the BOSS software). Before the field surveys, a checklist of all samples to be collected is prepared. To identify the suite of subsamples removed from each grab, a protocol coding system has been developed for this project. Also, a protocol code for the sediment profile images to be collected under Subtask 10.2 has been developed. Table 12 lists the protocol codes and the laboratory that will have custody of the associated samples. Based on the project sampling requirements, station sampling plans have been developed for

MWRA Harbor and Outfall Monitoring Project
Contract No. S138
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 _____

Figure 3. Sample Macrofauna Data Sheet.

Table 11. Event_ID Designations for Each Survey

Survey Date	*Type*	*Event_ID*
April 1993	Harbor—Traditional	S9301
August 1993	Harbor—Traditional/ Reconnaissance	S9302
August 1993	Nearfield/Farfield	S9303
April 1994	Harbor—Traditional	S9401
August 1994	Harbor—Traditional/ Reconnaissance	S9402
August 1994	Nearfield/Farfield	S9403

Table 12. Protocol Codes and Related Samples

Protocol	*Lab*	*Description*
MAC3	MRS	Macrofauna-0.3 mm
MAC5	MRS/BOS	Macrofauna-0.5 mm
TOC	GGC	Total Organic Carbon
GRS	GPA	Sediment Grain Size
CLO	MTH	*Clostridium perfringens*
CHM	BOS	Sediment Chemistry
SPI	D&D	Sediment Profile Image

Task 10 and Task 11 (see Table 13). Based on the information included in Table 13, a set of Chain-of-Custody (COC) forms will be generated for each survey. Each completed COC will be signed and dated by the staff member entering the information.

The COC set will have a form for each station and will be used by the BOSS computer operator. These COC forms will be put into a BOSS survey notebook. The COC forms include fields for entering pertinent information about each

Table 13. Sampling Plan for Task 10[1] and Task 11

Subtask Stations	*Grab 1*	*Grab 2*	*Grab 3*	*Grab 4*	*Grab 5*	*Other*
Subtask 10.1						
T1-T8	MAC3/ MAC5	MAC3/ MAC5	MAC3/ MAC5	CHM/TOC/ GRS/CLO		
Subtask 10.2						
T1-T8						SPI
R2-R25	MAC5					SPI
R26-R43						SPI
Subtask 11.1						
NF1-NF20	MAC3/ MAC5	MAC3/ MAC5	MAC3/ MAC5	CHM/TOC/ GRS/CLO		
Subtask 11.2						
FF1-FF14[2]	MAC3/ MAC5	MAC3/ MAC5	MAC3/ MAC5	CHM/TOC/ GRS/CLO	CHM/TOC/ GRS/CLO	

[1]A detailed Scope of Work for the CSO study has /not been developed.
[2]There are no stations designated FF2 and FF3.

station, such as time on station, bottom depth, weather observations, *marker_no* data, and general comments. When a grab sample is retrieved, this action will be electronically flagged in the BOSS data file using an unique *marker_no* so that pertinent information can be recorded. When this *marker_no* is created by BOSS, the software electronically saves the following information in a log file:

- Station ID
- Marker_no
- Event_ID
- Date and time of event
- Position of vessel at time of event
- Water depth
- Protocol code
- Lab code

This same information will be printed on barcoded labels. The barcode contains the sample ID. One label will be attached to the BOSS station log form (Figure 4), one label will be attached to each sample container, and another label

STATION LOG

For Benthic Sediment Grab Samples

Project Name: Harbor and Outfall Monitoring – MWRA Contract No. S138

Survey: Harbor-Traditional Date: April 1993 Weather: Seas:	Comments: Recorded By:
Station: Date: Time:	Grab Penetration:
Grab No.: Depth:	Sediment Volume:
Event ID:	Redox Depth:
Marker No:	Comment:
Latitude:	
Longitude:	
Protocol: Lab: Sampled By:	
Station: Date: Time:	Grab Penetration:
Grab No.: Depth:	Sediment Volume:
Event ID:	Redox Depth:
Marker No:	Comment:
Latitude:	
Longitude:	
Protocol: Lab: Sampled By:	
Station: Date: Time:	Grab Penetration:
Grab No.: Depth:	Sediment Volume:
Event ID:	Redox Depth:
Marker No:	Comment:
Latitude:	
Longitude:	
Protocol: Lab: Sampled By:	
Station: Date: Time:	Grab Penetration:
Grab No.: Depth:	Sediment Volume:
Event ID:	Redox Depth:
Marker No:	Comment:
Latitude:	
Longitude:	
Protocol: Lab: Sampled By:	
Station: Date: Time:	Grab Penetration:
Grab No.: Depth:	Sediment Volume:
Event ID:	Redox Depth:
Marker No:	Comment:
Latitude:	
Longitude:	
Protocol: Lab: Sampled By:	

PLEASE RETURN THE ORIGINAL OF THIS COMPLETED STATION LOG FORM TO ROY KROPP-BATTELLE

Figure 4. Sample Station Log Form.

will be attached to the sample's accompanying COC form (Figure 5 through Figure 10).

The appropriate COC form will accompany samples to their final destination. If the custody of appropriate samples is transferred between laboratories, the COC form will be signed by both the staff member that relinquishes custody and the staff member assuming custody of the samples. Copies of all COC forms will be returned to Battelle's soft-bottom monitoring Project Area Leader.

13.1 Custody of Electronic Data

Field custody of electronic data will be the responsibility of the primary BOSS software operator for a specific survey. This person will be identified in each survey plan. The field custody of the electronic data consists of creating floppy-disk backup files of all electronic data generated each day. Each floppy disk label will include a survey ID, date, name of person creating the backup files, and a disk number. When the equipment is returned to Battelle's laboratory, a second complete backup set, labeled as "Set 2," will be generated on floppy disks. Set 2 will be in the custody of Mr. Carl Albro at Battelle.

13.2 Custody of Sediment Samples

MRS will assume custody of samples immediately upon sample collection. Field documentation will consist of laboratory notebooks, field log sheets, and COC forms containing the project name, station code, sample type designation, alphanumeric sample codes, and other pertinent information about the sample. During field collection, COC forms will be completed and labels will be affixed to the sample containers, thereby creating a link between the sample and data recorded on the COC form. The COC forms will have a duplicate label that also contains the same alphanumeric code as the corresponding label on the sample container, ensuring the tracking of sample location and the status. The original COC form will be submitted to Battelle's database manager and maintained in the data sources notebook.

Upon completion of the survey, custody of chemistry, grain size, and *Clostridium* samples will be transferred to Battelle for shipment to the appropriate laboratory (Table 12). Laboratory custody of all samples will be the responsibility of the appropriate Battelle department or subcontractor. Upon receipt of samples at the laboratory, the recipient will examine the samples received, verify that the information recorded on the COC forms is accurate, and log the samples into the laboratory by signing the COC form on the *Received By*

CHAIN-OF-CUSTODY RECORD

For Benthic Macrofauna Samples

Project Name: Harbor and Outfall Monitoring — MWRA Contract No. S138

Survey: Harbor-Traditional Date: April 1993 Fraction: Recorded by:	Marine Research Specialists 2825 Rodeo Gulch Rd., Suite 3 Soquel, CA 95073 Protocol: MAC3/MAC5
Station: Date: Time:	Station: Date: Time:
Grab No.: Depth:	Grab No.: Depth:
Event ID:	Event ID:
Marker No:	Marker No:
Latitude:	Latitude:
Longitude:	Longitude:
Protocol: Lab: Sampled By:	Protocol: Lab: Sampled By:
Station: Date: Time:	Station: Date: Time:
Grab No.: Depth:	Grab No.: Depth:
Event ID:	Event ID:
Marker No:	Marker No:
Latitude:	Latitude:
Longitude:	Longitude:
Protocol: Lab: Sampled By:	Protocol: Lab: Sampled By:
Station: Date: Time:	Station: Date: Time:
Grab No.: Depth:	Grab No.: Depth:
Event_ID:	Event ID:
Marker_No:	Marker_No:
Latitude:	Latitude:
Longitude:	Longitude:
Protocol: Lab: Sampled By:	Protocol: Lab: Sampled By:
Station: Date: Time:	Station: Date: Time:
Grab No.: Depth:	Grab No.: Depth:
Event_ID:	Event_ID:
Marker_No:	Marker_No:
Latitude:	Latitude:
Longitude:	Longitude:
Protocol: Lab: Sampled By:	Protocol: Lab: Sampled By:

Released By/Date/Time/Company	Transporter/Airbill #	Received By/Date/Time/Company

PLEASE RETURN THE ORIGINAL OF THIS COMPLETED CHAIN-OF-CUSTODY FORM TO ROY KROPP-BATTELLE

Figure 5. Sample Chain-of-Custody Form for Benthic Macrofauna Samples.

CHAIN-OF-CUSTODY RECORD

For Benthic Sediment Chemistry Samples

Project Name: Harbor and Outfall Monitoring — MWRA Contract No. S138

Survey: Harbor-Traditional Date: April 1993 Recorded by:	Battelle Ocean Sciences 397 Washington Street Duxbury, MA 02332 Protocol: CHM
Station: Date: Time:	Station: Date: Time:
Grab No.: Depth:	Grab No.: Depth:
Event ID:	Event ID:
Marker No:	Marker No:
Latitude:	Latitude:
Longitude:	Longitude:
Protocol: Lab: Sampled By:	Protocol: Lab: Sampled By:
Station: Date: Time:	Station: Date: Time:
Grab No.: Depth:	Grab No.: Depth:
Event ID:	Event ID:
Marker No:	Marker No:
Latitude:	Latitude:
Longitude:	Longitude:
Protocol: Lab: Sampled By:	Protocol: Lab: Sampled By:
Station: Date: Time:	Station: Date: Time:
Grab No.: Depth:	Grab No.: Depth:
Event ID:	Event ID:
Marker No:	Marker No:
Latitude:	Latitude:
Longitude:	Longitude:
Protocol: Lab: Sampled By:	Protocol: Lab: Sampled By:
Station: Date: Time:	Station: Date: Time:
Grab No.: Depth:	Grab No.: Depth:
Event ID:	Event ID:
Marker No:	Marker No:
Latitude:	Latitude:
Longitude:	Longitude:
Protocol: Lab: Sampled By:	Protocol: Lab: Sampled By:

Released By/Date/Time/Company	Transporter/Airbill #	Received By/Date/Time/Company

PLEASE RETURN THE ORIGINAL OF THIS COMPLETED CHAIN-OF-CUSTODY FORM TO ROY KROPP-BATTELLE

Figure 6. Sample Chain-of-Custody Form for Sediment Chemistry Samples.

CHAIN-OF-CUSTODY RECORD	
For Benthic Sediment TOC Samples	
Project Name: Harbor and Outfall Monitoring – MWRA Contract No. S138	
Survey: Harbor-Traditional Date: April 1993 Recorded by:	Global Geochemistry Corp. 6919 Eton Avenue Canoga Park, CA 91303 Protocol: TOC
Station: Date: Time:	Station: Date: Time:
Grab No.: Depth:	Grab No.: Depth:
Event ID:	Event ID:
Marker No:	Marker No:
Latitude:	Latitude:
Longitude:	Longitude:
Protocol: Lab: Sampled By:	Protocol: Lab: Sampled By:
Station: Date: Time:	Station: Date: Time:
Grab No.: Depth:	Grab No.: Depth:
Event ID:	Event ID:
Marker No:	Marker No:
Latitude:	Latitude:
Longitude:	Longitude:
Protocol: Lab: Sampled By:	Protocol: Lab: Sampled By:
Station: Date: Time:	Station: Date: Time:
Grab No.: Depth:	Grab No.: Depth:
Event ID:	Event ID:
Marker No:	Marker No:
Latitude:	Latitude:
Longitude:	Longitude:
Protocol: Lab: Sampled By:	Protocol: Lab: Sampled By:
Station: Date: Time:	Station: Date: Time:
Grab No.: Depth:	Grab No.: Depth:
Event ID:	Event ID:
Marker No:	Marker No:
Latitude:	Latitude:
Longitude:	Longitude:
Protocol: Lab: Sampled By:	Protocol: Lab: Sampled By:

Released By/Date/Time/Company	Transporter/Airbill #	Received By/Date/Time/Company

PLEASE RETURN THE ORIGINAL OF THIS COMPLETED CHAIN-OF-CUSTODY FORM TO ROY KROPP-BATTELLE

Figure 7. Sample Chain-of-Custody Form for Sediment TOC Samples.

CHAIN-OF-CUSTODY RECORD

For Benthic Sediment *Clostridium perfringens* Samples

Project Name: Harbor and Outfall Monitoring – MWRA Contract No. S138

Survey: Harbor-Traditional Date: April 1993 Recorded by:	MTH Environmental Associates 183 White Moss Drive Marstons Mills, MA 02648 Protocol: CLO

Station: Date: Time:	Station: Date: Time:
Grab No.: Depth:	Grab No.: Depth:
Event ID:	Event ID:
Marker No:	Marker No:
Latitude:	Latitude:
Longitude:	Longitude:
Protocol: Lab: Sampled By:	Protocol: Lab: Sampled By:
Station: Date: Time:	Station: Date: Time:
Grab No.: Depth:	Grab No.: Depth:
Event ID:	Event ID:
Marker No:	Marker No:
Latitude:	Latitude:
Longitude:	Longitude:
Protocol: Lab: Sampled By:	Protocol: Lab: Sampled By:
Station: Date: Time:	Station: Date: Time:
Grab No.: Depth:	Grab No.: Depth:
Event ID:	Event ID:
Marker No:	Marker No:
Latitude:	Latitude:
Longitude:	Longitude:
Protocol: Lab: Sampled By:	Protocol: Lab: Sampled By:
Station: Date: Time:	Station: Date: Time:
Grab No.: Depth:	Grab No.: Depth:
Event ID:	Event ID:
Marker No:	Marker No:
Latitude:	Latitude:
Longitude:	Longitude:
Protocol: Lab: Sampled By:	Protocol: Lab: Sampled By:

Released By/Date/Time/Company	Transporter/Airbill #	Received By/Date/Time/Company

PLEASE RETURN THE ORIGINAL OF THIS COMPLETED CHAIN-OF-CUSTODY FORM TO ROY KROPP-BATTELLE

Figure 8. Sample Chain-of-Custody Form for Sediment *Clostridium perfringens*.

CHAIN-OF-CUSTODY RECORD	
For Benthic Sediment Grain Size Samples	
Project Name: Harbor and Outfall Monitoring — MWRA Contract No. S138	
Survey: Harbor-Traditional Date: April 1993 Recorded by:	GeoPlan Associates 30 Main Street Hingham, MA 02043 Protocol: GRS
Station: Date: Time:	Station: Date: Time:
Grab No.: Depth:	Grab No.: Depth:
Event ID:	Event ID:
Marker No:	Marker No:
Latitude:	Latitude:
Longitude:	Longitude:
Protocol: Lab: Sampled By:	Protocol: Lab: Sampled By:
Station: Date: Time:	Station: Date: Time:
Grab No.: Depth:	Grab No.: Depth:
Event ID:	Event ID:
Marker No:	Marker No:
Latitude:	Latitude:
Longitude:	Longitude:
Protocol: Lab: Sampled By:	Protocol: Lab: Sampled By:
Station: Date: Time:	Station: Date: Time:
Grab No.: Depth:	Grab No.: Depth:
Event_ID:	Event_ID:
Marker_No:	Marker_No:
Latitude:	Latitude:
Longitude:	Longitude:
Protocol: Lab: Sampled By:	Protocol: Lab: Sampled By:
Station: Date: Time:	Station: Date: Time:
Grab No.: Depth:	Grab No.: Depth:
Event_ID:	Event_ID:
Marker_No:	Marker_No:
Latitude:	Latitude:
Longitude:	Longitude:
Protocol: Lab: Sampled By:	Protocol: Lab: Sampled By:

Released By/Date/Time/Company	Transporter/Airbill #	Received By/Date/Time/Company

PLEASE RETURN THE ORIGINAL OF THIS COMPLETED CHAIN-OF-CUSTODY FORM TO ROY KROPP-BATTELLE

Figure 9. Sample Chain-of-Custody Form for Sediment Grain-Size Samples.

CHAIN-OF-CUSTODY RECORD		
For Sediment Profile Images		
Project Name: Harbor and Outfall Monitoring – MWRA Contract No. S138		
Survey: Date: Recorded by:	R.J. Diaz & Daughters Route 623 Ware Neck, VA 23178	
Station: Date: Time:	Prism Penetration:	
Deployment No.: Depth:	Counter Number:	
Event_ID:	Comment:	
Marker_No:		
Latitude:		
Longitude:		
Protocol: Lab: Sampled By:		
Station: Date: Time:	Prism Penetration:	
Deployment No.: Depth:	Counter Number:	
Event_ID:	Comment:	
Marker_No:		
Latitude:		
Longitude:		
Protocol: Lab: Sampled By:		
Station: Date: Time:	Prism Penetration:	
Deployment No.: Depth:	Counter Number:	
Event_ID:	Comment:	
Marker_No:		
Latitude:		
Longitude:		
Protocol: Lab: Sampled By:		
Station: Date: Time:	Prism Penetration:	
Deployment No.: Depth:	Counter Number:	
Event_ID:	Comment:	
Marker_No:		
Latitude:		
Longitude:		
Protocol: Lab: Sampled By:		
Released By/Date/Time/Company	Transporter/Airbill #	Received By/Date/Time/Company
PLEASE RETURN THE ORIGINAL OF THIS COMPLETED CHAIN-OF-CUSTODY FORM TO ROY KROPP-BATTELLE		

Figure 10. Sample Chain-of-Custody Form for SPI.

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. Sample numbers that include the complete field ID number will be used to track the samples through the laboratory. All archived samples will remain in the custody of the appropriate Battelle or subcontractor laboratory for a period of 1 y after sample collection, at which time the MWRA will be contacted about their disposition.

14. CALIBRATION PROCEDURES AND PREVENTIVE MAINTENANCE

14.1 Navigation Equipment

The differential GPS receiver is calibrated at 1-min intervals. Positions will also be checked at certain fixed calibration points; the absolute positions of these calibration points will be obtained from published charts (accuracy may be worse than 5 m) and light lists. The time and position of the calibration sites will be printed out by the BOSS software and entered in the BOSS survey notebook. Calibration will be checked and documented twice daily. Cable connections and antenna mounts and brackets will be inspected and secured at regular intervals.

The fathometer is calibrated annually by the manufacturer.

14.2 Sediment Profile Image System

Once the SPI system is assembled onboard the research vessel, a system check that includes all features of the SPI system — from tightening all bolts to testing the profile camera—is initiated. After the camera is operating properly, the standard color card is photographed and the film counter reset. Every 50 to 60 photographs the system is checked on deck for proper functioning (exposure timing, strobe flash, and film advance).

At the end of every workday, the water is drained from the prism, the camera housing is washed with fresh water, and the batteries are recharged for the next day.

At the end of each job, in addition to these procedures, the film is removed from the camera and developed.

14.3 Laboratory Equipment

14.3.1 Organics

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 within 25% of the mean for each individual analyte, and the mean of all analyte RSDs is 10%. Any initial calibration that does not meet these criteria will be reviewed by the task leader and reanalyzed. Any exceptions will be documented and justified by the task leader.

The system calibration will be verified a minimum of once every 24 h by 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., 25% for individual analytes, 10% 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, at the discretion of the analyst and project management. Because gas chromatography with electron-capture detection (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 should not require reanalysis. Reanalyses will be performed at the discretion of the analyst and program management. Deviations from calibration or data objectives will be documented in the project files.

Samples analyzed by GC/ECD, GC/FID, 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.

14.3.2 Metals

The EDXRF instrumentation that will be used for Al, Cr, Cu, Fe, Ni, Pb, and Zn measurements in this program has been calibrated using thin film standards at 50-100 $\mu g/cm^2$. Continuing accuracy checks of the calibration (as NIST, NRC, or USGS certified sediments) will be performed every 16 samples. Instrument operation will be reviewed if values fall outside the certification range. If appropriate, corrective action will be taken. Samples will be analyzed once for quantitation; all duplication exercises will be performed as field duplicates.

The atomic absorption instrumentation will be calibrated daily before samples are analyzed. Calibration standards will be prepared each day and sediment sample digestion solutions will be quantified by GFAAS for Ag and Cd using the method of additions to avoid inaccuracies resulting from chemical interferences. Calibration standard check samples (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 15% of its true value will be rejected and reanalyzed after corrective action is taken (as needed). GFAAS measurements will be made in duplicate for each sample; if the relative percent difference (RPD) between duplicate injections is greater than 10%, 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 15% acceptance criteria), prepared by an analyst other than the analyst that prepares the calibration standards (aqueous mercury SRMs are not currently available for mercury). 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). All instrumental maintenance will be documented in instrument logbooks.

14.3.3 Total Organic Carbon

Instrumental performance will be assessed through the daily analysis of standards. These standards will be used to prepared daily calibration curves. After calibration, one standard will be analyzed after every 10 samples analyzed to ensure instrument calibration throughout sample analysis. Calibration check samples must be within $\pm 5\%$ of true values to be acceptable.

14.3.4 Grain-Size Determination

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

14.4 Instrument Maintenance

14.4.1 Field Equipment

Instrumentation associated with the BOSS navigation system and SPI system will be properly calibrated and maintained in accordance with manufacturer instructions as specified in operations manuals.

14.4.2 Gas Chromatography

Detector response (electron-capture detectors, flame ionization 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, and PCB mixtures, coprostanol 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. In addition, a maintenance log containing a detailed record of all maintenance performed will be maintained for each instrument.

14.4.3 Spectrophotometry, Spectroscopy, and X-Ray Fluorescence

Maintenance of the GFAAS instrumentation includes complete furnace and furnace window cleaning, graphite tube and stabilized temperature platform observation and replacement. The associated maintenance log forms are filled out each day for each parameter and include the above actions and the hollow cathode or electrodeless discharge lamp energy for continued monitoring of elemental lamp performance.

The XRF instrument calibration is checked daily through the analysis of certified reference materials. If the instrument is not within the certified range for these standards, corrective action recommended by the manufacturer will be taken.

15. DOCUMENTATION, DATA REDUCTION, AND REPORTING

15.1 Documentation

Initially, all data will be recorded either (1) electronically onto computer storage media from BOSS or other laboratory systems or (2) manually into laboratory notebooks or on established data forms. All notes will be written in ink. Corrections to hand-entered data will be initialed, dated, and justified. Completed forms, 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 laboratory managers to ensure that all data entries and hand calculations are verified. Laboratory records of sample preparation will be maintained in sample batch books. 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 Battelle.

Documentation for the SPI activities includes the recording of field data onto a COC form. Data recorded include station ID, station position, date, time, camera counter number, depth of prism penetration as determined from the deployment frame, water depth, and other observations. After the film is developed, each slide is labeled with station and replicate data.

15.2 Data Reduction

Data reduction involves 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. It also involves the use of various formulae to calculate indices describing community structure or the similarity between samples.

15.2.1 Reconnaissance Survey Data (Subtask 10.2)

Because of the semi-quantitative nature of the analysis of the grab samples collected during the reconnaissance survey, data reduction for this subtask will convert raw numbers to data that can be compared visually. Selected graphical and tabulation techniques similar to those presented in Kelly and Kropp (1992) will be used. Comparisons will include the total sediment volume of a sample, the portion of each fraction that was sorted and not sorted, the numbers of taxa and individuals per fraction, and the general distribution of various taxa.

The first analysis of images gathered by the SPI system involves the projection of the images and the recording of observed visual features in data files. After visual analysis, the images will be analyzed by a computer image analysis system. Data from both analyses are combined and tabulated for reporting. Statistical analyses include parametric (e.g., *t*-test, ANOVA) or nonparametric (e.g., logistic regression, log-linear modeling, Friedman's test, Mann-Whitney test) techniques.

15.2.2 Chemical Analysis Data (Task 12)

GC/MS data will be acquired and reduced on Hewlett-Packard A-series minicomputers with dedicated chromatography software. CG/ECD and GC/FID data will be acquired and reduced by the Hewlett Packard 3350A Laboratory Automation System. Data generated during metals analyses will be transferred from the instruments to PC, where analyte concentrations will be calculated. Organics data will be reported in units of ng/g dry weight; metals concentrations will be reported in μg/g dry weight.

In addition to analyte concentrations in field samples, statistical evaluations will be performed on all quality control samples. Percent recoveries of the spiked analytes will be calculated for all matrix spike and matrix spike duplicate samples:

$$\%\text{recovery} = \frac{(\text{amount recovered} - \text{amount in background matrix})}{\text{amount expected}} \times 100$$

Additionally, the relative percent difference (RPD) between the MS and MSD samples will be calculated:

$$RPD = \frac{2\times(A_{MS} - A_{MSD})}{A_{MS} + A_{MSD}} \times 100$$

where A_{MS} = amount of analyte detected in MS sample
A_{MSD} = amount of analyte detected in MSD sample.

The RPD between sample duplicates, and between certified SRM values and calculated SRM values resulting from sample analysis will also be calculated:

$$RPD = \frac{2\times(C_1 - C_2)}{(C_1 + C_2)} \times 100$$

where C_1 = concentration (ng/g) of analyte detected in sample 1 (or certified SRM value)
C_2 = concentration (ng/g) of analyte detected in sample 2 (or detected in SRM).

Quality control objectives for these calculations are presented in Table 9. Analytes that are not detected will be reported as "ND." Values below the method detection limit will be reported, but will be marked with the qualifier "f."

15.2.3 Faunal Analysis Data (Task 13)

Data reduction for the detailed faunal analysis will include calculation of community parameters such as similarity and diversity indices, and possible transformation of data to improve conformity to the assumptions of the statistical tests being used. These 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-Weaver Diversity Index (Shannon and Weaver, 1949; Green 1979), calculated by the expression:

$$H' = -\sum_j P_j \ln P_j$$

where P_j is the proportion of the population that is of the jth species.

- Dominance Function (Whittaker, 1965; Washington, 1984), calculated by the expression:

$$c = \Sigma(y/N)^2$$

where y is the number of individuals of a given species and N is the sum of individuals for all species in the sample.

- Bray-Curtis Similarity Index (Bray and Curtis, 1957; Boesch, 1977), calculated by the expression:

$$SI = [2W/(A + B)] \times 100$$

where W is the sum of the lesser number of individuals of co-occurring species in samples A and B, A is the number of individuals in sample A, and B is the number of individuals in sample B.

- Clustering of Bray-Curtis Similarity Index values using the unweighted pair-group method 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). ANOVA is a parametric procedure that assumes the following conditions are met:

- Independence among samples
- Homogeneity of variances
- Normality
- Additivity (for sample designs that do not include replication)

Rarely do benthic data meet all of these assumptions. Although ANOVA is robust enough to withstand all but extreme deviations from these assumptions, we will apply a precautionary transformation to improve normality of the data. This transformation will be the square root transformation [$\sqrt{(Y + 0.5)}$] (Sokal and Rohlf, 1969).

The non-replicated design with only two scheduled sampling periods that is proposed for the nearfield analysis is not conducive to rigorous parametric statistical analyses for differences among stations. Instead, tabular and graphical techniques will be used to present the spatial and temporal patterns for numerically dominant species and community parameters. Consequently, data for this subtask will probably not be transformed.

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

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 Leader will be loaded into Battelle's copy of the Harbor Studies Database. All data loaded into the database will follow formats described below. Data provided by Battelle and subcontractors will be loaded into the database by Battelle 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 Battelle 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 BOSS electronic log file will be provided as Lotus spreadsheet files. Columns will include sample_id, stat_id, water_depth, ddate, ttime, latitude, longitude, and protocol code (Table 12).

Analytical Data
Sediment chemistry data will be transferred into Oracle from which the final report tables will be generated. The format for transmittal of the sediment chemistry data is defined in Figure 11.

All data generated by Battelle 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.) as PC-based spreadsheets following the format defined in Figure 12.

MRS will provide PC-based spreadsheets containing species enumeration data for benthic macrofauna. The format for transmittal of the benthic infauna data is defined in Figure 13.

15.3.2 Data Reports
Data reports will be submitted to MWRA in both hard-copy and electronic forms. Data collected under Subtask 11.1 will represent single samples rather than the mean of replicates.

15.3.3 Annual Synthesis Reports
Annual Synthesis Reports for soft-bottom monitoring tasks will include tables and graphics presenting summaries of important results. These presentations may show temporal or spatial trends in sediment chemical parameters and macrofaunal species abundances, or may show the relationships between species abundances and sedimentological or oceanographic characteristics. The objective of these data presentations will be to communicate our understanding of the complex relationships affecting the soft-bottom benthic communities. Other synthesis reports may use the data from the soft-bottom monitoring studies.

MWRA HARBOR STUDIES DATABASE

Data Reporting Format: Analytical Results (Geoplan, MTH, Global Geochem)
Date: February 25, 1993
Contact: John Hennessy
Battelle Ocean Sciences (617) 934 - 0571

Column	Type	Size or Precision	Scale	Must Report	Description
Sample_ID	Char	10		Y	Unique sample ID assigned during field collection (ie) number on bar-coded label.
Param_code	Char	20		Y	Codes include Gravel, Sand, Silt, Clay, Clostridium, and TOC
Anal_date	Date			Y	Date of sample analysis
Value	Number	12	5	Y	Resultant data value determined by analytical procedure
Unit_code	Char	10		Y	Code for value units
Comments	Char	30			Comments

Notes:
1. Precision is the maximum size of a number excluding the decimal point. Scale is the number of places after the decimal point. For example, 10.234 is stored with precision = 5 and scale = 3.

Instruments:
TOC - LECO Model 761-100 Carbon Analyzer
Clostridium - None
Grain Size - Sieve/Settling Column

Methods:
TOC - Section 12 of Soft Bottom Monitoring CW/QAPP
Clostridium - Emerson and Cabelli (1982)
Grain Size - Folk (1974)

Figure 11. Spreadsheet Format for Reporting Sediment Chemistry Data.

MWRA HARBOR STUDIES DATABASE

Data Reporting Format: Analytical Results (Geoplan, MTH, Global Geochem)
Date: February 25, 1993
Contact: John Hennessy
Battelle Ocean Sciences (617) 934 - 0571

Column	Type	Size or Precision	Scale	Must Report	Description
Sample_ID	Char	10		Y	Unique sample ID assigned during field collection (ie) number on bar-coded label.
Param_code	Char	20		Y	Codes include Gravel, Sand, Silt, Clay, Clostridium, and TOC
Anal_date	Date			Y	Date of sample analysis
Value	Number	12	5	Y	Resultant data value determined by analytical procedure
Unit_code	Char	10		Y	Code for value units
Comments	Char	30			Comments

Notes:
1. Precision is the maximum size of a number excluding the decimal point. Scale is the number of places after the decimal point. For example, 10.234 is stored with precision = 5 and scale = 3.

Instruments:
TOC - LECO Model 761-100 Carbon Analyzer
Clostridium - None
Grain Size - Sieve/Settling Column

Methods:
TOC - Section 12 of Soft Bottom Monitoring CW/QAPP
Clostridium - Emerson and Cabelli (1982)
Grain Size - Folk (1974)

Figure 12. Spreadsheet Format for Reporting TOC, Grain Size, and *Clostridium perfringens* Data.

MWRA HARBOR STUDIES DATABASE

Data Reporting Format: Soft Bottom Benthic
Date: February 12, 1993
Contact: John Hennessy
Battelle Ocean Science (617) 934-0571

Column	Type	Size	Must Report	Description
Sample_ID	Char	9	Y	Unique sample ID assigned during field collection (ie) number on bar-coded label.
Fraction	Number	1	Y	Sieve size fraction (0.5 mm or 0.3 mm)
Category	Char	40	Y	Scientific name of organism quantified and reported in value column
NODC	Char	40	Y	NODC code for organism
Value	Number	8	Y	Number of organisms per category

Notes:
1) A column to report value qualifier (val_qual) will be added if appropriate.
2) Enumerate to species but if no species name available use SP. A, SP. B, etc - but be consistent across all samples for this program

Figure 13. Spreadsheet Format for Reporting Macrofauna Data.

16. 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 laboratory. The validation procedures that will be performed for data generated by Battelle and its subcontractor laboratories are

- 100% of data that are hand-entered into a database or spreadsheet will be either 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.

- Analytical results and supporting data will be reviewed by the analytical supervisor to ensure that the data are complete, accurate, and technically correct prior to submission to the database.

- 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.

Battelle Task Leaders will be responsible for validation of all data generated by Battelle. Subcontractor Task Leaders will be responsible for conducting similar data validations to ensure that the data provided to Battelle are accurate, complete, and scientifically reasonable. As an additional data validation step, Battelle Task Leaders will review all subcontractor data for technical

reasonableness. The entire process will be fully documented in the data sources notebook.

A primary component of data validation is verification that the analytical processes are in control. Validation of data includes a review of QC sample versus the data quality requirements (Section 11). This review will be conducted by the appropriate task leader at a frequency sufficient to implement corrective action (Section 18). The Project Area Leader will determine whether out-of-control QC results will invalidate or qualify data reported for field samples.

17. PERFORMANCE AND SYSTEM AUDITS

This project will be monitored by the project QA officer. All tabular and graphic data reported in deliverables and associated raw data generated by Battelle will be audited by the QA office. Raw data will be reviewed for traceability, accuracy, completeness, and proper documentation. For laboratory data, statistical random audits of reported values will be conducted to ensure that the data are accurate, traceable, and within the QC specifications of this CW/QAPP. For electronically acquired data (e.g., BOSS data files), the QA office will verify that computer software used to process the data have been validated and that the field logs agree with the BOSS files.

All deliverables generated during the course of this project will be submitted to an internal review prior to delivery of drafts to MWRA. This three-part process consists of technical, editorial, and QA reviews.

Audits of the subcontractor laboratory data-collection programs will be the responsibility of the subcontractor subtask leader. 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 audited by the Battelle or subcontractor QA officer prior to submission to the Project Area Leader and must be accompanied by a signed QA statement (Figure 14) 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 technical personnel. Performance reviews will include assessment of QC samples, such as blanks, spikes, SRMs, and replicates, all of which are discussed in detail in Section 11.

QUALITY ASSURANCE STATEMENT

Contractor _____

Task Title: _____

Task Number: _____ **Subtask Number:** _____

Description of audit and review activities:

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

_____ _____
Signature of QA Officer **Date**

_____ _____
Signature of Project Manager **Date**

Figure 14. Example of a Quality Assurance Statement.

18. CORRECTIVE ACTION

Identification of problems regarding technical performance is 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 Battelle Project Manager. He is 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 Battelle management or with 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 Project Area Leader, 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 Battelle 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. Issues that affect schedule, cost, technical performance, or data quality will be reported to the Battelle Project Area Leader or the Battelle 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 Task QA Officer 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. REPORTS

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

- Survey plans
- Survey reports

- Data reports
- 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 QAPP
- Specific locations and coordinates of each station
- Survey vessel and members of survey team
- Navigational information
- List of sampling equipment
- Protocols for sample collection, handling, preservation, transportation and chain-of-custody

The schedule for submission of the survey plans is presented in Section 9.

19.2 Survey Reports

Following each survey, a survey report will be submitted. Survey reports will include information on sampling operations, number and type of samples collected, descriptions of sieved samples and any observations made during sampling and sieving, 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.

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 MWRA. The due dates for the draft and final data reports are listed in Section 9.

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 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
- Integration of Study Results/Synthesis

The due dates for the draft and final annual synthesis reports are listed in Section 9.

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