Work/Quality Assurance Project Plan

for

MWRA Boston Harbor and Massachusetts Bay Monitoring Program

Benthic Biology, Sediments, and Chemical Monitoring Summer 1992 Field Program

prepared for

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

prepared by

James A. Blake
Victoria R. Gibson
Raymond Valente

SCIENCE APPLICATIONS INTERNATIONAL CORPORATION
89 Water Street
Woods Hole, MA 02543
(508) 540-7882

23 October 1992

1992-MS-06

Work/Quality Assurance Project Plan

for

MWRA Boston Harbor and Massachusetts Bay Monitoring Program

Benthic Biology, Sediments, and Chemical Monitoring Summer 1992 Field Program

23 October 1992

APPROVALS:

SAIC Program Manager: [redacted]
James Blake — Date

MWRA Task Manager: [redacted]
Kenneth Keay — 10/26/92 Date

MWRA Project Manager: [redacted]
Wendy Smith — 10/26/92 Date

MWRA Enviro. Qual. Dept. Director: [redacted]
Michael Connor — 10/26/92 Date

1. PROJECT NAME

MWRA Boston Harbor and Massachusetts Bay Monitoring Program
Benthic Biology, Sediments, and Chemical Monitoring: Summer 1992 Field Program

2. PROJECT REQUESTOR

Massachusetts Water Resources Authority

3. DATE OF REQUEST

15 April 1992

4. DATE OF PROJECT INITIATION

15 July 1992

5. PROJECT MANAGEMENT

MWRA Department Director
Dr. Michael Connor

MWRA Project Manager
Ms. Wendy Smith

MWRA Task Manager
Mr. Ken Keay

SAIC Program Manager
Dr. James Blake

SAIC Task Managers
Dr. James Blake (Work Order 1: Task 1; Work Order 3: Task 1)
Dr. Drew Carey (Work Order 1: Tasks 2 & 3)
Dr. Brigitte Hilbig (Work Order 2: Task 1)
Dr. Jo Ann Muramoto (Work Order 2: Task 2)
Dr. Donald Rhoads (Work Order 2: Task 2)

6. Quality Assurance Officer

Mr. Raymond Valente

LIST OF FIGURES

TABLE OF CONTENTS

Introduction

The work described in this Combined Work/Quality Assurance Project Plan (Work/QA Plan) is part of a continuing effort by the Environmental Quality Department of the Massachusetts Water Resources Authority (MWRA) to monitor environmental conditions in the areas of its past, present, and proposed sewage discharges. The work is being conducted under the Marine Environmental Science Technical Assistance Contract between MWRA and SAIC (Contract No. 0039) and is divided into three work orders:

1. **Field Program**
   REMOTS® sediment profile imagery and collection of sediments and biota in Boston Harbor, at nearfield stations in Massachusetts Bay, and at farfield stations in Massachusetts Bay and Cape Cod Bay. The field program, conducted between 13 and 21 August 1992, was funded by MWRA Task Order No. 52 and also covers the preparation of this Work/QA Plan.

2. **Laboratory Analysis**
   (1) Taxonomic analysis of benthic biology samples collected in spring 1992 as part of the U.S. Geological Survey (USGS) sediment chemistry survey of farfield stations in Massachusetts Bay and (2) analysis of nearfield and farfield sediment and biota samples collected in Massachusetts Bay and Boston Harbor in August 1992 by SAIC under the **Field Program** (#1 above). This work has been funded under MWRA Task Order No. 54.

3. **Data Analysis and Reporting**
   Analysis of the data from the **Laboratory Analysis** (#2 above), analysis of the REMOTS® profiles (#1 above), and preparation of two reports—one on Boston Harbor and one on Massachusetts Bay and Cape Cod Bay. MWRA has not yet issued a work order to fund these tasks.

Work in Boston Harbor is a continuation of a benthic monitoring project begun in 1989 (SAIC, 1990); work in Massachusetts Bay and Cape Cod Bay is associated with the MWRA Effluent Outfall Monitoring Plan (MWRA, 1991). Monitoring in both areas includes REMOTS® sediment profile imagery and biological, microbiological, and sedimentary analyses.

Objective and Scope

Field Surveys

Boston Harbor Survey

The general objective of the Boston Harbor Survey is to monitor the recovery of the benthos and the amount of sewage contamination at the Deer Island outfall after sludge abatement. Objectives for other activities are described under Laboratory Analyses.

Massachusetts Bay Survey

The general objective of the Massachusetts Bay Survey is to determine baseline benthic conditions and existing sewage contamination at depositional areas in Massachusetts and Cape Cod Bays for comparison with observations to be made after the effluent outfall begins operation. Results of this comparison will be used to determine whether the effluent is in compliance with the terms of the discharge permit granted by the U.S. Environmental Protection Agency (EPA) and to assess the effects of the discharge.

Nearfield Sampling. Sampling in the nearfield is intended to establish local conditions in Massachusetts Bay at and near the site of the future effluent discharge. These data will later provide for detection of change and assessment of the scale of any change detected.

REMOTS® sediment profile images from approximately 30 candidate nearfield locations receive "quick look" assessment to evaluate the nearfield sedimentary environment and identify suitable soft-bottom sites. Any remaining sites will be located by reconnaissance REMOTS® and sedimentary sampling to designate a total of 20 stations. Objectives for other activities are described under Laboratory Analyses.

Farfield Sampling. Sampling in the farfield is intended to establish regional conditions at depositional locations representative of Massachusetts Bay and Cape Cod Bay. Objectives for other activities are described under Laboratory Analyses.

Laboratory Analysis

Benthic Biology

The overall objective of the benthic biology component is to characterize the infaunal community in depositional areas of each targeted area (i.e., Boston Harbor, nearfield Massachusetts Bay, and farfield Massachusetts Bay and Cape Cod Bay). Infaunal analysis is used to provide ground truth for the REMOTS® images; to assess population structure and composition as an indicator of change due to enrichment, toxic contamination, burial, etc.; and to address secondary production and potential food web pathways of contamination.

Clostridium perfringens Spores

Enumeration of spores of the sewage indicator bacterium *C. perfringens* is designed to provide a measure of sewage contamination and aid in determining the fate of effluent particles.

Grain Size

Information on grain size of sediment at a sampling location is needed to assess transport and fate of particles. In conjunction with benthic biology, this measurement is intended to assess changes in sediment depositional areas and to correlate with benthic community parameters.

Total Organic Carbon (TOC)

TOC is a measure of the biological productivity of the surrounding environment and the rate of accumulation at the particular site. TOC measurements thus are useful in evaluating enrichment and sedimentary regime.

Sediment Chemistry

The objective of the sediment chemistry analyses is to determine the concentrations of various organic compounds and trace metals in the sediment. These analyses will be carried out under a separate contract.

Data Usage

Data from the Boston Harbor Survey will be used to evaluate recovery of the benthos now that sludge is no longer discharged into the harbor. Data will be compared with results obtained in 1991 and spring 1992 (SAIC, 1992).

Data from the Massachusetts Bay Survey will be used to determine existing benthic conditions and sewage contamination in areas where any effects of discharge from the proposed effluent outfall are likely to be observed. Data will be combined with results from continued baseline monitoring between 1992 and 1995 and will subsequently be compared with results obtained from postdischarge monitoring.

Data from both surveys will be entered into the MWRA database.

Technical Approach

This section provides an overview of the work to be conducted under this Work/QA Plan. Details on methods of sampling, analysis, data management, and reporting are described in later sections of this Plan.

Work Order No. 1: Field Program

Task 1: Program Management/QA Plan Preparation/Quality Assurance

This task covers overall management, including quality assurance functions, of the project by the SAIC Program Manager, Task Leaders, and QA Officer. It includes preparation of this Work/QA Plan, which complies with the general format specified in OWRS QA-1, *Guidance for Preparation of Combined Work/Quality Assurance Project Plans for Environmental Monitoring* (EPA, 1984).

Task 2: Massachusetts Bay Field Work

Under this task, a benthic field survey was conducted at nearfield stations in Massachusetts Bay (Figure 1) and farfield stations in Massachusetts Bay and Cape Cod Bay (Figure 2). Sampling for this task was combined with sampling of stations in Boston Harbor under Task 3, Boston Harbor Field Work. A single survey operation, with one mobilization/demobilization, was conducted

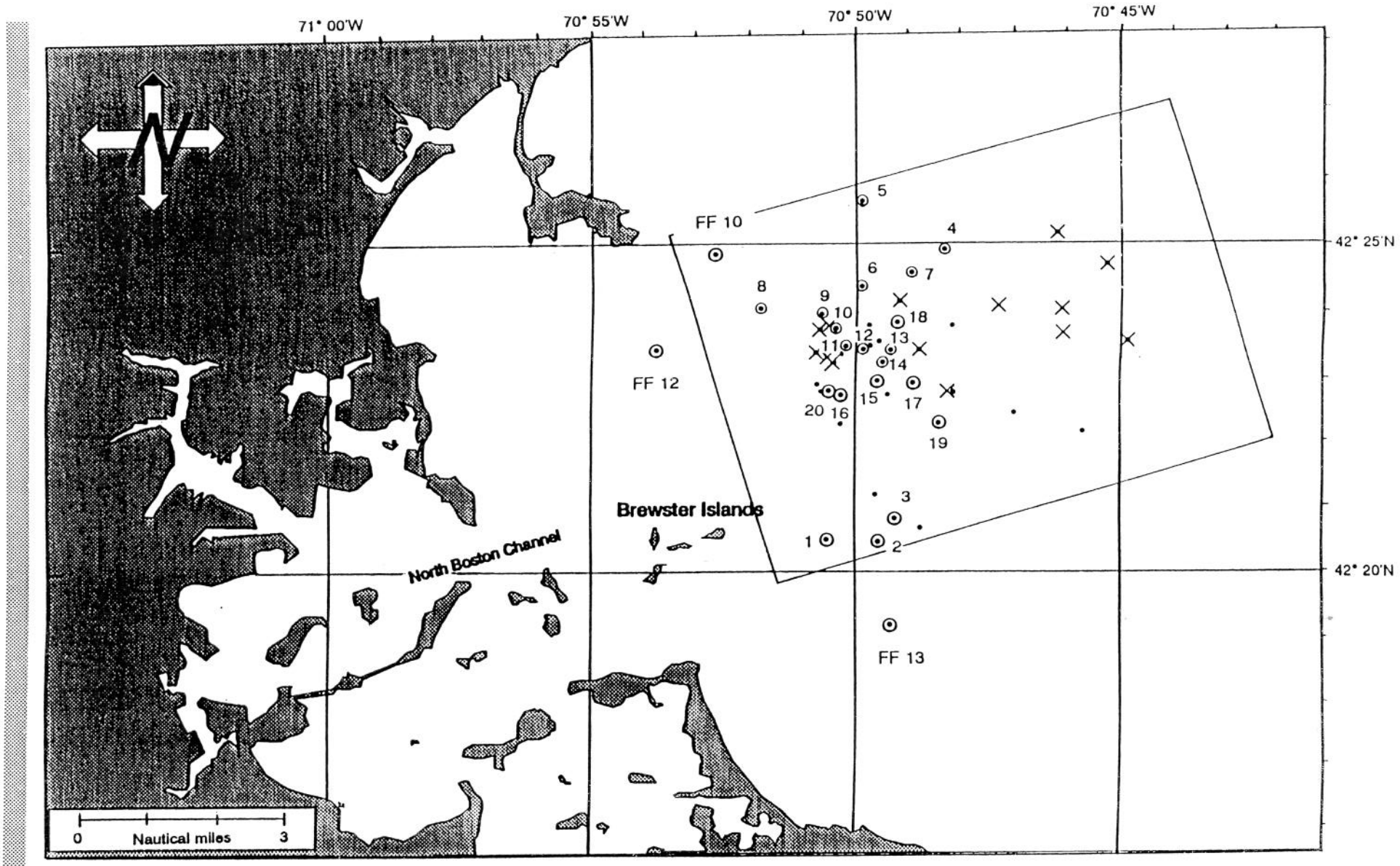


Figure 1. Location of Nearfield Stations in Massachusetts Bay.

Numbered donuts indicate 20 stations where biology, chemistry, and sediment samples were collected in addition to the REMOTS® photographs. Small filled circles indicate REMOTS® stations that showed substrate unsuitable for grab sampling or, in a few cases, stations close to stations where grabs were taken. Crosses mark stations where the grab was unable to collect sediment. Three farfield stations (FF 10, 12, 13) are included.

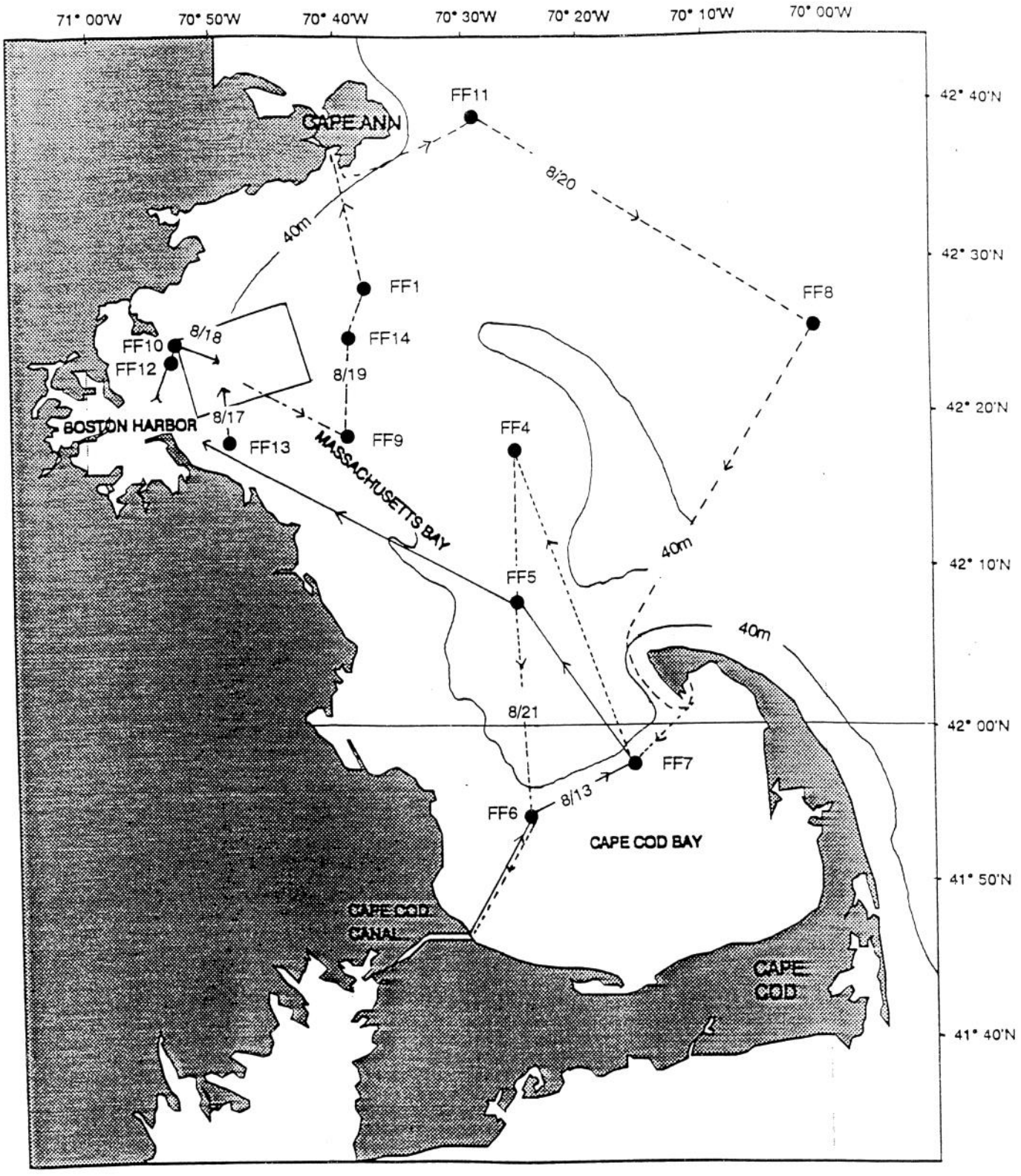


Figure 2. Location and Cruise Track for Farfield Stations in Massachusetts Bay and Cape Cod Bay. Dates are included for each daily cruise track.

between 13 and 21 August aboard the vessel *Beavertail.* A plan for the combined survey was submitted to MWRA on 11 August 1992. The sampling procedures are described in detail in Section 12.

Mobilization was carried out on 13 August 1992 in Sandwich, Massachusetts. Survey operations were conducted for 9 days, with the vessel returning to a designated port each night. Complete details of the logistics are documented in the survey plan and report.

Station location and vessel positioning was accomplished using the SAIC Portable Integrated Navigation and Survey System (PINSS), which is described in Section 12. Sampling equipment consisted of the REMOTS® (Remote Ecological Monitoring of the Seafloor) sediment profile imaging system and two sizes of Ted Young grab samplers. REMOTS® was used for two purposes: first, for "quick look" sampling to assess the suitability of sites for grab sampling; second, to assess the sedimentary characteristics at each station. Photographs were developed each evening so that any missed or poor-quality profiles could be retaken the next day. Ted Young grabs were used to sample benthic infauna (0.04-m^2 sampler) and sediment (0.1-m^2 sampler).

A series of candidate nearfield stations were selected before the survey on the basis of previous REMOTS® surveys of the area (SAIC, 1987a,b), a side-scan sonar map of the area (Bothner *et al.*, 1991), and consultation with the MWRA Task Manager. During the survey these sites were occupied with REMOTS® and, after analysis of the photographs, approximately 12 soft-bottom sites suitable for grab sampling were selected from the list of candidate stations. The remaining eight stations were selected by reconnaissance REMOTS® and grab sampling. At each station, three replicate 0.04-m^2 grab samples for biological analysis (number and species of benthic infauna) and one 0.1-m^2 grab sample for chemical and physical analysis (grain size, TOC, *C. perfringens* spores, and selected metals and organic compounds) were taken.

Twelve farfield stations were selected in Massachusetts Bay and Cape Cod Bay before the survey. At each station three REMOTS® photographs were taken, along with three grabs for biological analysis and two grabs for chemical and physical analysis.

Analysis of the benthic infauna, grain size, TOC, and *C. perfringens* samples is being carried out under Work Order 2, and the sediment profiles will be analyzed under Work Order 3. The metal and organic samples are being archived for analysis under a separate contract.

Task 3: Boston Harbor Field Work

The Boston Harbor portion of the survey (Figure 3) consisted of REMOTS® photography at 69 stations sampled in the spring 1992 survey (SAIC, 1992) and collection of sediment samples from 8 of those stations. Three of those samples (0.04 m^2) were for analysis of benthic infauna and the fourth (0.1 m^2) was for analysis of grain size, TOC, and *C. perfringens* spores. These samples are being analyzed under Work Order 2.

Work Order No. 2: Laboratory Analysis

Task 1: Biology Laboratory Analysis

This tasks covers the identification and enumeration of 90 benthic infauna samples:

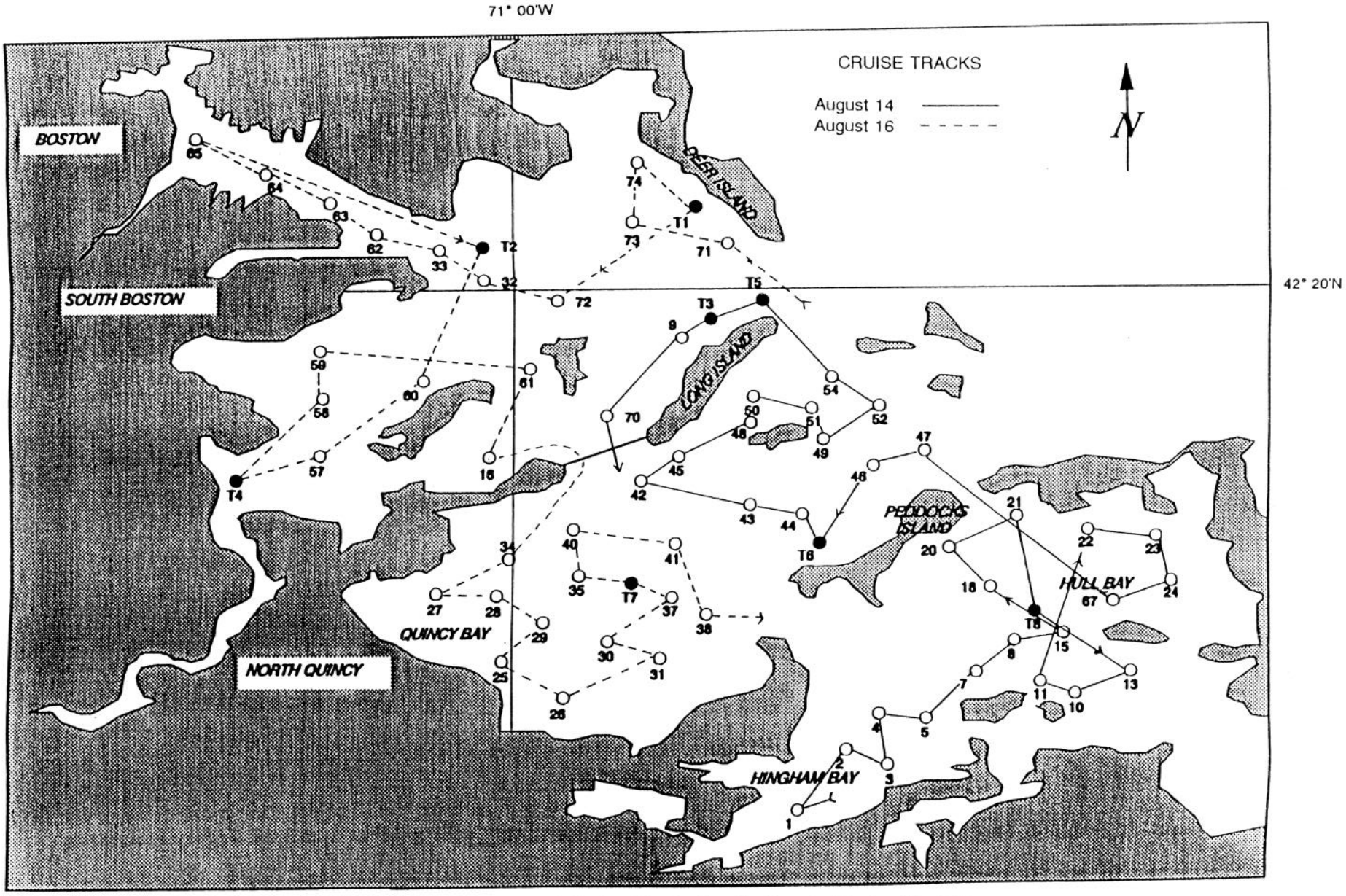


Figure 3. Location and Cruise Tracks for Stations in Boston Harbor.
Open circles are REMOTS® stations;
filled circles are stations where biology and sediment samples were collected in addition to the REMOTS® photographs.

- 10 samples collected in spring 1992 as part of the U.S. Geological Survey (USGS) sediment chemistry survey of farfield stations in Massachusetts Bay
- 20 nearfield and 36 farfield samples collected in Massachusetts Bay and in Cape Cod Bay in August 1992 by SAIC under the **Field Program** (#1 above)
- 24 samples collected in Boston Harbor in August 1992 by SAIC under the **Field Program.**

These samples are being processed as a joint effort by SAIC and Cove Corporation, with the coordination of Dr. Brigitte Hilbig. Analytical procedures are described in Section 12.

Task 2: Sediment Laboratory Analysis

This task covers the analysis of grain size, TOC, and *C. perfringens* spores from 20 nearfield samples from Massachusetts Bay, 24 farfield samples from Massachusetts Bay and Cape Cod Bay, and 8 samples from Boston Harbor. These analyses are being coordinated by Dr. Jo Ann Muramoto and conducted by GEO/PLAN Associates (grain size), the Geochemical and Environmental Research Group (GERG) of Texas A&M University (TOC), and SAIC Environmental Research Laboratory, Narragansett, RI *(C. perfringens).* Analytical procedures are described in Section 12.

Work Order No. 3: Data Analysis and Reporting

This work order provides for analysis of the data from the **Laboratory Analysis** (#2 above), analysis of the sediment profile photographs, and preparation of two reports—one on Boston Harbor and one on Massachusetts Bay. Report preparation is described in more detail in Section 19.

Task 1: Biology/Sediment Data and Reports

The SAIC Task Leaders for Biology and Sediment Laboratory Analyses will synthesize and interpret the data and report the results in a way that can be combined with REMOTS® data to produce integrated reports for Boston Harbor and for Massachusetts Bay.

Task 2: REMOTS Laboratory Data and Reports

Procedures for image analysis of the sediment profile photographs obtained with REMOTS® are described in detail in Section 12. Dr. Donald Rhoads will coordinate the analysis, synthesize the data, and report the results in a way that can be integrated with the other biology and sediment results into reports on Boston Harbor and Massachusetts Bay.

8. PROJECT FISCAL INFORMATION

The work described in this Work/QA Plan is being carried out under the Marine Environmental Science Technical Assistance Contract (Contract No. 0039) between MWRA and SAIC. The field work (first work element) has been funded by MWRA under Task Order No. 52); the laboratory analysis (second work order) is funded under Task Order No. 54; and data analysis and reporting (third work order) have not yet been funded.

Field Work

The Boston Harbor and Massachusetts Bay surveys were conducted between 13 and 21 August 1992. Sampling was combined into a single deployment aboard the vessel *Beavertail*. A survey plan was filed with MWRA on 11 August and a survey report was submitted in September. This Work/QA Plan is also a deliverable under the work order for the field work.

Laboratory Analysis

Sample analysis and data entry will proceed from September through December 1992.

Data Analysis and Reporting

Two draft final reports will be produced: one for Boston Harbor and one for Massachusetts Bay. These reports will integrate the REMOTS®, biology, and sediment results for each area. Deliverable dates depend upon MWRA approval of an extension to the current contract to provide for review of the reports by the Outfall Monitoring Task Force and subsequent revision by SAIC. If approval is received, SAIC would submit the draft reports in March 1993. These drafts will be revised into final reports on the basis of comments from MWRA; they will be due 3 weeks after receipt of MWRA comments.

Project organization is shown in Figure 4. Ms. Wendy Smith is the MWRA Project Manager for the Marine Environmental Services Technical Assistance Contract and oversees cost and schedule. Mr. Kenneth Keay is the MWRA Task Manager in charge of the work described in this Work/QA Plan. Dr. James Blake is the SAIC Program Manager in charge of all work elements. Mr. Raymond Valente is the Quality Assurance Officer for all technical work performed by SAIC under this Work/QA Plan. Specific assignments for each task are described below.

Program Management/QA Plan

Dr. Blake is responsible for overall management of all tasks. He will coordinate the efforts of the Task Leaders and ensure the quality and timeliness of all deliverables. Dr. Blake, with the assistance of Ms. Victoria Gibson, Mr. Valente, and SAIC Task Leaders, produced this Work/QA Plan.

Field Surveys

Dr. Drew Carey is the Task Leader for all field work. Mr. Robert Williams of SAIC served as Chief Scientist for the combined surveys. Other members of the scientific party were Mr. Adam Polcek, SAIC (Navigation/REMOTS®); Ms. Isabelle Williams, SAIC, Ms. Marguerite Pelletier, SAIC, and Mr. George Hampson, Woods Hole Oceanographic Institution (benthic sampling). Ms. Francesca Bona, a visiting scientist from Italy, also participated in the field program to observe field monitoring methods.

Biology Laboratory Analysis

Dr. Brigitte Hilbig of the SAIC Woods Hole office is the Task Leader for the analysis of the benthic biology samples. Cove Corporation of Lusby, Maryland, is sorting all samples and performing the taxonomic identifications for the Boston Harbor samples. Ms. Nancy Mountford is the Cove Subtask Leader for these analyses. Cove and SAIC are jointly identifying and enumerating the Massachusetts Bay samples. SAIC staff members Ms. Isabelle Williams and Ms. Paula Winchell are assisting Dr. Hilbig in this subtask. Data entry is also a joint responsibility of Cove and SAIC, under the supervision of Dr. Hilbig.

Sediment Laboratory Analysis

Dr. Jo Ann Muramoto of the SAIC Woods Hole office is the Task Leader for analysis of the sediment samples. GEO/PLAN Associates of Hingham, Massachusetts, is performing grain size determinations under the supervision of Dr. Peter Rosen. *C. perfringens* spores are being enumerated by the SAIC Environmental Research Laboratory in Narragansett, Rhode Island. Total organic

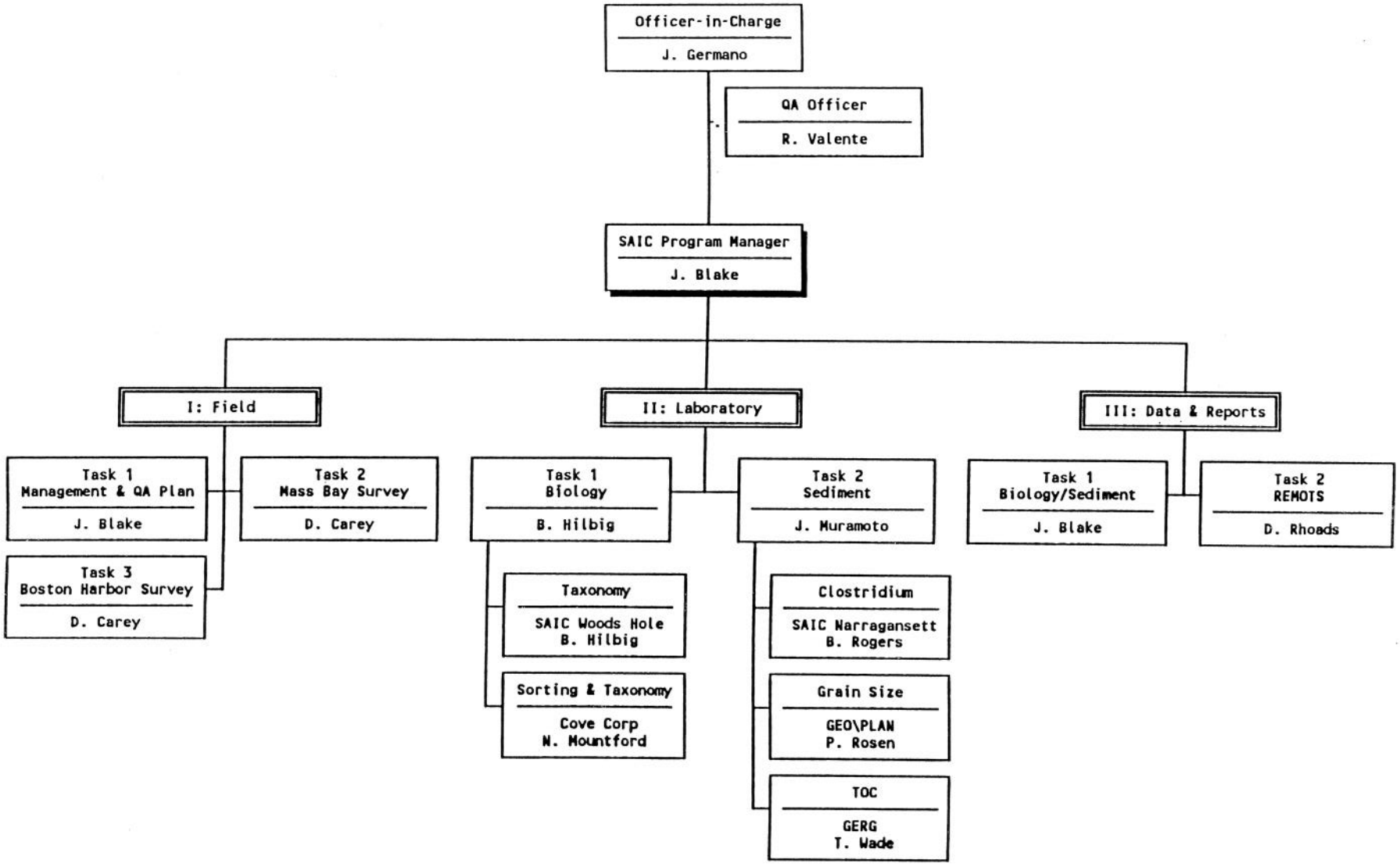


Figure 4. Project Organization.

carbon content of the sediment is being determined by the Geochemical and Environmental Research Group (GERG) of Texas A&M University. Dr. Muramoto will oversee data compilation and entry.

Biology/Sediment Data and Reports

With coordination provided by Dr. Blake, Drs. Hilbig and Muramoto will synthesize the data from their respective laboratory tasks. Each will produce relevant sections of the draft final reports for Boston Harbor and Massachusetts Bay. With the assistance of Ms. Victoria Gibson, Dr. Blake will integrate these sections with sections on sediment profile images (see next task).

REMOTS® Laboratory Data and Reports

Dr. Donald Rhoads of the SAIC Woods Hole office is the Task Leader for the analysis, interpretation, and reporting of the REMOTS® sediment profile images. Dr. Rhoads will produce report sections for incorporation into the draft deliverables on Boston Harbor and Massachusetts Bay.

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

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

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

Representativeness: The extent to which measurements represent true systems.

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

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

Station Selection

The representativeness and comparability of all the data generated under this Work/QA Plan depend to some extent upon the selection of the sampling sites. In Boston Harbor, eight traditional stations were sampled. This is one in a series of REMOTS® surveys to document benthic habitat at these stations (SAIC 1987a,b; 1990; 1992) and the second time that grab samples were taken. Approximately 30 candidate locations for nearfield Massachusetts Bay stations were chosen on the basis of a side-scan sonar map of the area (Bothner *et al.*, 1991) and previous REMOTS® surveys (SAIC, 1987a,b). A REMOTS® quick-look assessment and reconnaissance sediment sampling were employed during the August survey to identify the 20 most suitable sampling sites. Farfield stations in Massachusetts Bay and Cape Cod Bay were selected in consultation with Mr. Ken Keay of MWRA.

Navigation

The SAIC PINSS was used for positioning during the Boston Harbor and Massachusetts Bay surveys. This system consists of a Northstar 800 LORAN-C and MX4200 Global Positioning System (GPS) receiver interfaced to a laptop computer. SAIC proprietary software incorporates this positioning data to provide real-time navigation (range and homing) to designated station locations. The LORAN-C was calibrated to the GPS signal during each day of the survey. Calibration factors derived from this procedure were entered into the PINSS. Navigation by calibrated LORAN-C allows stations to be reoccupied to within 25 m.

Sediment-Profile Imagery

Acquisition and analysis of sediment-profile images with REMOTS® is based on standardized techniques described in Rhoads and Germano (1982, 1986) and SAIC (1992).

Accuracy and Precision

Image Acquisition

All REMOTS® cameras are cleaned and tested before a field operation. A detailed packing and assembly checklist is verified by line item. At the beginning of each survey day, the time on the data logger mounted on the REMOTS® camera is synchronized with the navigation system clock. Each REMOTS® station replicate is identified by the time recorded on the film and on disk along with vessel position. Test shots are fired on deck at the beginning and end of each roll of film to verify that all internal electronic systems are working to design specifications. Redundant sample logs are kept by the field crew and on computer disk. Three replicate samples are taken at each station.

Image Analysis

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

Measurements can be plotted (and contoured if desired) on a base map of the survey area. All mapped data are verified against the raw tabulated data by a staff scientist.

Representativeness

REMOTS® is a standard technique recognized as producing images that, when interpreted by an experienced analyst, characterize benthic conditions in the area surveyed. For this project, the image analysis is supervised by the system's inventor, Dr. Donald Rhoads.

Comparability

Methods for image acquisition and analysis are consistent with previous studies in the area (SAIC, 1987a,b; SAIC, 1992).

Completeness

Spare parts, including extra cameras and charged batteries, are carried in the field at all times to ensure uninterrupted sample acquisition. At regular intervals during each survey day, the frame counter is checked to make sure that the desired number of replicates has been taken. In shallow

water, when the camera hits the seabed, the sheave leading the wire from the winch relaxes, giving a visual confirmation that a sample has been taken. A prism penetration depth indicator on the camera frame is checked after each lowering of the camera to see that the optical prism has penetrated the bottom to a sufficient depth to acquire a profile image. If images have been missed (frame counter indicator) or the penetration depth is insufficient (penetration indicator), then proper adjustments are made (e.g., weight is added to the frame) and additional replicates are taken.

At the end of every survey day, film is developed to verify successful data acquisition; strict controls are maintained for development temperatures, times, and chemicals to ensure consistent density on the film emulsion to minimize interpretive error by the computer image analysis system. The film is then inspected visually under magnification. Any images that are of insufficient quality for image analysis are noted, and the appropriate station is reoccupied on the next survey day.

Grab Sampling

Samples for benthic biology and physical and chemical sediment analysis are collected with a Ted Young grab. All five quality criteria demand recovery of a sample whose surface is undisturbed. Undisturbed samples are achieved by careful attention to established deployment and recovery procedures. SAIC's procedures cover the following aspects of deployment and recovery:

- Thorough washdown before each deployment
- Control of penetration by adding or removing weights to the frame and adjusting the rate of fall
- Slow recovery until grab is free of the bottom
- Inspection for signs of leakage
- Securing the grab on deck.

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

- Sampler is not overfilled with sediment; the jaws must be fully closed and the top of the sediment preferably below the level of the opening doors. In very soft sediments, the surface may touch the doors as long as no sediment is lost.
- Overlying water is present and not excessively turbid.
- Sampler is at least half full, indicating that the desired penetration was achieved.

Benthic Infauna

Sampling

Acquisition of a grab sample of acceptable quality is described in the preceding section. Once a sample for biological examination has been deemed acceptable, it is washed, sieved, and preserved in 10% buffered formalin. The samples are transferred to 70-80% ethanol between 2 days and 2 weeks after collection to ensure that molluscs and other organisms with calcareous structures are not damaged.

Accuracy, Precision, and Representativeness

Since no subsampling is performed, the accuracy, precision, and representativeness of the sampling depend upon the factors discussed under Grab Sampling.

Comparability

Procedures for washing, sieving, and preserving the samples are consistent with methods used in previous studies in Boston Harbor in 1991.

Completeness

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

Analysis

Accuracy

Benthic infauna are identified by experienced taxonomists at Cove Corp. and SAIC Woods Hole under the direction of Dr. Brigitte Hilbig, a recognized authority on benthic infauna. Dr. James Blake is also available for consultation. In the case of questions about organisms in particular taxonomic groups, specimens are sent to recognized experts for a second opinion on the identification. Standard references are used and selected specimens are retained as part of a voucher collection.

Precision

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

Representativeness

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

Completeness

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

Comparability

Methods of analysis are comparable to those used in previous benthic investigations in Boston Harbor and Massachusetts Bay.

Sediment

Sampling

Acquisition of a grab sample of acceptable quality is described in a preceding section. Once a sample for sediment analysis has been deemed acceptable, the top 1-cm of sediment is removed to a jar and homogenized. Separate subsamples are obtained for determination of number of *C. perfringens* spores, grain size, and TOC (Boston Harbor); and the preceding plus organic compounds and metals (Massachusetts Bay and Cape Cod Bay).

Accuracy, Precision, and Representativeness

These qualities are determined partially by the factors discussed under Grab Sampling (above) and partially by the homogenization, subsampling, and preservation (where necessary) processes. The latter were conducted in accordance with written instructions based on National Status and Trends protocols for grain size, TOC, and organic and metal analyses and on recommendations from the SAIC Narragansett laboratory for *C. perfringens*.

Comparability

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

Completeness

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

Analysis

Sediment samples collected in Boston Harbor, Massachusetts Bay, and Cape Cod Bay will be analyzed for grain size, TOC, and concentration of *C. perfringens* spores. Samples for determination of sediment chemistry (organic compounds and metals) will not be analyzed under this Work/Quality Assurance Plan.

Accuracy and Precision

Sediment Grain Size. Precision is measured by triplicate analysis of 10% of samples and expressed as the percent coefficient of variation (%CV) calculated as

$$\%CV = \frac{sd}{\bar{x}} \times 100\%$$

Analyses of sand, silt, and clay fractions must show less than 20% CV to be acceptable. There is no limit on variation for gravel because its natural variability is high. If the sample has less than 5% weight percent of sand, silt, or clay fractions, this criterion is not utilized. If the criterion is not met, the techniques will be evaluated and, if necessary, samples reanalyzed.

Total Organic Carbon. Quality control samples are processed in the same manner as actual samples. As a measure of accuracy, a method blank is run with every 20 samples or every sample set, whichever is more frequent. Blank levels may be no more than 3 times the method detection limit. Leco pin and ring carbon standards are analyzed as reference materials and standards. Precision is monitored through analysis of duplicate samples with every 20 samples or every sample set, whichever is more frequent. Duplicate values must be $\pm 20\%$ for low-level ($< 1\%$ carbon) samples and $\pm 10\%$ for normal/high-level ($> 1\%$ carbon) samples.

***Clostridium* Spores.** *C. perfringens* spores are quantitated in accordance with the method described by Emerson and Cabelli (1982). The authors estimated the recovery efficiency (i.e., accuracy) of this method to be higher than 85% and significantly greater than with the most-probable-number (MPN) method tested. Precision, based on duplicate analyses of 87 sediment samples, was also better than that obtained theoretically with the MPN procedure. The median coefficient of variation for pairs of values was 8.4%, which approached the value of 7.4% theoretically obtainable by counting two plates at the upper counting limit of 85 colonies per plate.

Comparability

Sediment Grain Size. Procedures for analysis of grain size follow standard methods (Folk, 1974) and are comparable to those used to characterize sediment at proposed MWRA outfall sites.

Total Organic Carbon. TOC is determined in accordance with methods used in the NOAA National Status and Trends Program for samples taken from marine coastal environments nationwide, including in Boston Harbor.

***Clostridium* Spores.** The method used has been employed in previous MWRA studies of Boston Harbor and Massachusetts Bay.

Representativeness

The degree to which results of the analyses for grain size, TOC, and *C. perfringens* spores are representative of the respective areas in which they were taken depends upon the sampling and subsampling factors previously discussed.

Completeness

It is expected that all subsamples for grain size, TOC, and *C. perfringens* spores will be analyzed.

Methods for collection and analysis of samples are described in the following sections.

Navigation

Vessel positioning was achieved with the SAIC Portable Integrated Navigation and Survey System (PINSS). This system consists of Northstar 800 Loran-C and MX4200 Global Positioning System (GPS) receivers interfaced to an 80486/487 laptop computer and a Hewlett-Packard Thinkjet printer. The system provides accurate vessel position and a visual plot of the position in relation to the station location. This information is relayed to the helmsman through a remote CRT display. Position fixes showing date, local time, latitude and longitude are recorded on magnetic disk and sent to the printer as hard-copy backup. Position fixes are recorded manually when samples are taken as well as automatically at specified intervals (5 minutes for this survey).

REMOTS®

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

Image Acquisition

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

Three replicate photographs were taken at each station. Ektachrome 100 ASA color slide film was used for all photographs. Film was developed at the end of each sampling day using a JOBO E6 rotary processor to determine the success of the REMOTS® sampling for that day and, in the case of the quick-look survey, to permit the photographs to be used to select appropriate nearfield stations.

Image Analysis

Replicate photographs are analyzed with the SAIC REMOTS® image analysis system. This system uses a SPARCstation 1+ Sun WorkStation integrated with a PULNIX TMC-50 video camera and frame grabber. Color slides are digitally recorded as color images on computer disk. The image analysis software is a menu-driven program that incorporates user commands via keyboard and trackball. This system displays each color slide on the CRT while measurements of all physical and biological parameters are obtained.

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

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

Grab Sampling

Samples for benthic infauna, sediment chemistry, grain size, TOC, and *C. perfringens* spores were obtained with a Ted Young grab. The 0.04-m^2 grab was used for biology samples and a Kynar-coated 0.1-m^2 grab was used for the chemical and physical samples.

Benthic Infauna

For analysis of benthic infauna, three 0.04-m^2 grabs were taken at all stations in Boston Harbor, Massachusetts Bay, and Cape Cod Bay. Undisturbed samples are obtained by adjusting the weight of the grab, its rate of entry into the sediment, or both so that the surface of the sediment sample remains below the top of the grab and does not touch the doors. Successful sampling of softer sediments requires that weights be removed from the grab and the rate of entry be very slow so that mud does not splash against the doors and cause fauna to be lost.

After retrieval of the grab, the sample is examined for quality and integrity. Samples may only be used if the sediment appears intact. The grab is placed into a stand constructed so that the jaws can be opened and the sample washed into a bucket positioned below the grab. The entire sample is gently washed into the bucket with seawater filtered through a 5-μm filter cartridge. The sample is then sieved through a 300-μm-mesh screen; the portion retained on the screen is transferred to a prelabeled 1-L plastic jar and fixed in 10% buffered formalin in seawater for two to three days. Any anemones found are preserved separately in small jars provided by Cove Corp. to prevent mucus, exuded by the anemones even after fixation, from contaminating the entire sample, making it difficult to sort. To prevent decalcification of molluscs, all samples are transferred to 70–80% ethanol, following a freshwater rinse to avoid formation of a precipitate, as soon as practical after collection.

Sediment

At stations in Boston Harbor, Massachusetts Bay, and Cape Cod Bay, samples for sediment analysis were obtained with a 0.1-m^2 Kynar-coated grab whose doors were lined with Teflon panels. One grab was collected at Boston Harbor and nearfield stations and two replicates were collected at the farfield stations. At all stations, subsamples were taken for determination of grain size and TOC and for enumeration of *C. perfringens* spores. In addition, in Massachusetts Bay and Cape Cod Bay, subsamples were taken for analysis of selected organic compounds and metals.

The following procedure conforms to methods used in the NOAA National Status and Trends program. It was written up prior to the survey and provided to and followed by the sampling team.

Samples are obtained with a specially coated 0.01-m^2 Ted Young grab. To remove organic contaminants and fulfill the sterility requirements for the collection of *C. perfringens*, the grab is cleaned between stations and the sampling scoop, spatula, and homogenizing jar are cleaned between grabs as follows:

1. Soap (Microclean) and water wash
2. Distilled water rinse
3. Methanol rinse
4. Methylene chloride rinse.

Before the doors of the grab are opened, the captain of the vessel is asked to turn the ship to position the stern sampling area upwind so that stack gases do not contaminate the sample. Water overlying the sediment surface is allowed to drain away so that the sediment remains undisturbed. The top 1 cm of sediment, except that adjacent to the grab walls or doors, is removed with a Teflon scoop and quickly transferred to a 1-L Teflon-lined jar, which is immediately capped.

Homogenization of the sample is carried out in the ship laboratory to avoid contamination by stack gases. The sample is thoroughly stirred with a Teflon spatula and then subsampled, using the same spatula, into five prelabeled containers.

1. The first subsample (except in Boston Harbor) is for organic analysis. Precleaned, prelabeled 4-oz I-Chem jars are one-half to two-thirds filled with sediment. This ensures that the analytical laboratory receives at least 10 g (⅓ oz) of dried sediment. Overfilling is avoided to reduce the chance of jar breakage during freezing. The jars are enclosed in bubble-wrap and frozen and stored on dry ice in a cooler.
2. The second subsample (except in Boston Harbor) is for metal analysis. Clean, prelabeled 4-oz Whirl-Paks are two-thirds filled with sediment. The laboratory needs 2 oz for analysis. The samples are frozen and stored on dry ice covered with a layer of bubble-wrap in a cooler. All metal samples from a given area are kept together in a zipper-closure plastic bag.
3. The third subsample is for *C. perfringens* analysis. Sterile, prelabeled 4-oz Whirl-Paks (unopened bags are sterile) are two-thirds filled with sediment. The laboratory needs 30 g (1 oz) of sample for analysis. The samples are frozen and stored on dry ice covered with a layer of bubble-wrap in a cooler. All *C. perfringens* samples from a given area are kept together in a zipper-closure plastic bag.

4. The fourth subsample is for grain-size analysis. Clean, prelabeled 4-oz Whirl-Paks are two-thirds filled with sediment. The laboratory needs 30 g (1 oz) of dry sediment, excluding sand and water, for analysis. For very watery and sandy sediments, a second sample is collected. The samples are stored cold in a cooler with wet or blue ice to prevent the growth of mold. All grain-size samples from a given area are kept together in a zipper-closure plastic bag.
5. The fifth subsample is for TOC analysis. Clean, prelabeled 4-oz Whirl-Paks are two-thirds filled with sediment. The laboratory needs 10 g (⅓ oz) of sample for analysis. The samples are stored cold in a cooler with wet or blue ice. All TOC samples from a given area are kept together in a zipper-closure plastic bag.

Analysis of Benthic Infaunal and Sediment Samples

At the conclusion of the survey, samples will be distributed and analyzed as discussed below.

Benthic Infauna

Samples for taxonomic analysis of benthic infauna are returned to the SAIC office in Woods Hole where they are transferred from formalin to 70–80% ethanol and shipped to Cove Corp. for sorting. Taxonomic identification and enumeration is a joint effort between Cove Corp. and SAIC. Cove Corp. will process the Boston Harbor samples and Cove and SAIC will jointly process the Massachusetts and Cape Cod Bays samples. Processing is according to the methods described in Section 11.

Sediment Chemistry

Samples for analysis of organic compounds and metals are kept frozen on dry ice until they are returned to SAIC in Woods Hole. They are then archived and stored in a freezer.

Clostridium

Samples for determination of concentration of *C. perfringens* spores are delivered, frozen on dry ice, to the SAIC Environmental Research Laboratory in Narragansett, Rhode Island. Spores are extracted from the sediment according to the sonicate-and-settle method described by Emerson and Cabelli (1982) and enumerated by the mCP membrane filtration method described by Bisson and Cabelli (1979) and also employed by Emerson and Cabelli.

Weighed samples of sediment are pulse sonicated in distilled water for 10 s to separate spores from particles, then allowed to settle. After three washes with distilled water, the spore suspension is membrane filtered and the filters incubated anaerobically at 45 °C for 18 to 24 h on mCP medium. Colonies typical of *C. perfringens* are pale yellow and 1 to 3 mm in diameter. Identification is confirmed by testing for acid phosphatase activity by exposing the colonies to vapors of ammonium hydroxide for 20 to 30 s. Colones that turn red or dark pink are scored as positive and counted. Results are reported as number of colonies per 100 g of sediment.

Grain Size

Samples for analysis of grain size are shipped to GEO/PLAN for analysis by Dr. Peter Rosen. The procedure for measuring weight percent gravel, sand, silt, and clay is based on a standard method (Folk, 1974) and described in Appendix A.

TOC

Samples for determination of TOC are shipped, on ice, to GERG. The samples are analyzed according to standard methods used in the NOAA Status and Trends program and described in GERG SOP-ST14[1]. Sediment is either freeze dried or oven dried at 40 to 50 °C. Samples are acidified with a small amount of 10% HCl in methane, dried overnight at 50 °C, then combusted in an oxygen atmosphere in an induction furnace. Sample combustion produces carbon dioxide, which passes through a dust trap and then into a reaction tube consisting of a two-stage chamber. In the first stage, manganese dioxide absorbs the sulfur oxides formed during combustion; in the second stage, anhydrone removes water vapor. The gas then enters a second, heated, reaction tube filled with platinized silica that acts as a catalyst to convert carbon monoxide into carbon dioxide. The carbon dioxide is detected and measured with an infrared detector.

The signal from the detector is sent to an integrator that reports the quantity of carbon dioxide as a peak area. The counts reported for a sample are substituted for X in the best-fit equation calculated from a standard curve determined daily from combustion of sets of five standards at varying concentrations. The value of Y is divided by the sample weight in grams to determine the percent carbon content.

[1]The SOP is not attached here because it contains proprietary information.

13. SAMPLE CUSTODY

The summer 1992 MWRA field work followed standard SAIC procedures for sample tracking and custody. In preparation for the field surveys, a checklist of all samples to be collected is prepared and sample containers are prelabeled in indelible ink. Benthic infauna samples have inside labels, written in pencil on plasticized paper, as well as outside labels. Label information for the field work conducted under this Work/QA Plan includes month and year; survey location (either Boston Harbor or Massachusetts Bay); station number; sample type; and replicate number.

All pertinent information on field activities and sampling efforts is recorded in a bound logbook. The chief scientist is responsible for ensuring that sufficient detail is recorded. Entries are recorded in indelible ink and include, at a minimum:

- Date and time of starting work
- Names of field supervisor and team members
- Sampling site and activities
- Details of sampling effort, particularly deviations from standard operating procedures
- Field observations
- Field measurements made
- Sample identification
- Type and number of samples collected
- Sample handling and labeling information.

This logbook provides the link between data for each station and for each sample. Sample-specific information is recorded on the sample label and on the chain-of-custody form, which is prepared for each type of sample (Figure 5) and contains an entry for each sample collected. The person who prepares the samples for shipment initials and dates the line entry for each sample shipped and encloses a copy of the form with the shipment. When the shipment arrives at the analytical laboratory, that laboratory assumes custody of the samples. The person who receives the samples acknowledges receipt by initialing and dating the line entry for each sample received. Any damage to samples or discrepancies are noted and the chain-of-custody form is returned to SAIC. Each laboratory is responsible for maintaining a sample tracking log that follows the samples through all stages of processing and analysis. For the benthic infauna samples, residues will be archived at SAIC for 1 year and the identified collections will be kept for a period to be specified by MWRA.

The sediment chemistry samples collected but not analyzed under this Work/QA Plan have been archived in a locked chest-type freezer in the SAIC Woods Hole office. The samples are stored in the containers into which they transferred immediately upon subsampling from the grab, with their original labels. Information recorded on these labels includes collection date, survey location, station number, sample type, and replicate number. A chain-of-custody form with identifying information for each archived sample is posted on the outside of the freezer.

Chain of Custody Record

Project Name: Boston Harbor and Massachusetts Bay Monitoring Program
Project Number:
Client: Massachusetts Water Resources Authority

Sample Type: *Clostridium*/Sediment

Destination: SAIC Environmental Testing Laboratory, Narragansett, R.I.

Station	Replicate	Date of Collection	Number and Size of Whirlpaks	Shipped: date and initials	Received: date and initials

Figure 5. Sample Chain-of-Custody Form.

14. CALIBRATION AND PREVENTIVE MAINTENANCE

The SAIC service center (Newport, RI) has established rigorous procedures for maintenance of electronic equipment to ensure the consistent collection and processing of high-quality data. The navigation system and the REMOTS® camera system and image analysis system are part of this control process, the main components of which are summarized below.

- **Equipment Activity History (EAH).** The EAH records the make, model, serial number, and description of each piece of equipment along with the dates that the equipment is used, calibrated, and repaired and the purchase or transfer date.
- **Calibration, Maintenance, Repair Record (CMR).** A CMR sheet is maintained for each piece of equipment with calibration, maintenance and repair sheets attached as these activities occur.
- **Calibration Procedure.** This documents the procedure to be used for the calibration of instruments in-house (e.g., computer image analysis system) and provides a record of the procedure that is used when instruments are calibrated by outside businesses (e.g., current meters).
- **Calibration Sheet.** This sheet forms the record of the calibration by providing a space for each of the calibration results. The sheet also serves to verify the procedure was followed by requiring a signoff for each step in the calibration procedure. Instrument calibrations must be performed following approved procedures and with calibration sheets returned to the CMR file, whether the calibration is performed in-house or at a remote facility.
- **Service Procedure.** A service and maintenance procedure is available for each type of equipment and includes, as applicable, laboratory preparation or field service procedures.
- **Service Sheet.** This sheet forms the record of servicing or maintenance and includes a signoff line for each of the steps in the procedure.
- **Equipment Inventory.** The equipment inventory is maintained by the service center. It lists all types and quantities of equipment available and its status (e.g., operational, calibration due, and repair needed).
- **Equipment Schedule.** The equipment schedule is maintained by the service center as a source of equipment availability and dates of planned use.
- **Spares Inventory.** The program spares inventory is maintained by the program office and shows both the company spares for this program and the Government-Funded Equipment spare as appropriate. Quantity, source and shelf life are included.
- **Repair Log.** This log is included in the CMR for each repair that is performed and serves to document the type of repair and the date of the repair. Review of the CMRs for each type of equipment establishes the mean time before failure and mean time to repair.

Navigation Equipment

The SAIC PINSS can incorporate a variety of positioning systems (e.g., GPS, LORAN-C). SAIC proprietary software analyzes all positioning information and determines the best fit for current vessel position. This software provides a procedure for in-the-field (real-time) calibration of all positioning systems integrated into PINSS.

At the start of each survey day, the LORAN-C was calibrated to the GPS signal. Calibration factors were entered into the PINSS and recorded in the field log. This procedure allowed for corrections of the daily fluctuations in the LORAN-C signal and for signal variability expected over a wide survey area. Proper calibration of the LORAN-C allows stations to be reoccupied to within 25 m.

REMOTS® Image Analysis System

All Ektachrome HC100 color REMOTS® photographs are analyzed with the SAIC REMOTS® image analysis system. The image analysis system is calibrated with a "scale-slide" before digitally recording the REMOTS® photographs as color image files on computer disk. Calibration factors are recorded with each image file and are incorporated into the analysis of each slide.

Subcontractor Equipment

Calibration and preventive maintenance of all equipment used by subcontractors for sample analysis is conducted in accordance with manufacturers' recommendations.

15. DOCUMENTATION, DATA REDUCTION, AND REPORTING

Data are initially recorded either automatically onto computer disk from a data acquisition instrument or system or manually into a bound notebook or onto a special-purpose data sheet. Data sheets are used for results of infaunal enumeration (Figure 6), REMOTS® image analysis (Figure 7), grain size determination (Figure 8), *C. perfringens* spore concentration (Figure 9), and TOC analysis (Figure 10). Manual entries are made in ink and corrections are initialed, dated, and explained. Data from laboratory analyses will be entered into an electronic spreadsheet for reduction.

Following completion of the data analysis, SAIC will submit the data collected as part of this program to MWRA for archiving in the central database. The spreadsheets developed by SAIC during the course of the program will up uploaded to PC ORACLE and submitted to MWRA on disk in ASCII format.

Project: MWRA OUTFALL MONITORING Project Number: 1-098-01-1091-000 Date:

Season: SUMMER Year: 1992 Station: Replicate:

Taxon:

Code	Species	No. Indiv.	Remarks	Init.	QC

Figure 6. Sample Data Sheet for Infaunal Taxonomy.

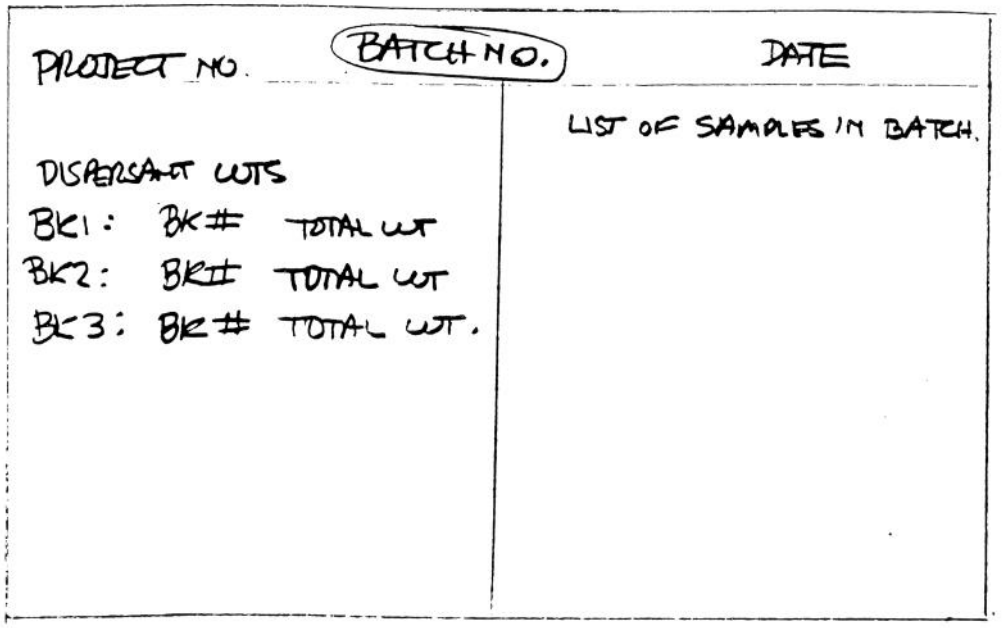
SAIC REMOTS DATASHEET

```
   Station . . . . mwra        Time . . . 0912        Date . . . . . 051592
   Number  . . . . T3          Frame  . . 6           Initials . . . RWW
   Replicate . . . c           Roll . . . 5           Plan view  . . NO
-------------------------------------------------------------------------
PENETRATION
   Maximum . . . . 20.40 cm    Boundary roughness . .  0.88 cm
   Minimum . . . . 19.52 cm    Roughness type . . . .  Biological
   Average . . . . 19.96 cm
-------------------------------------------------------------------------
GRAIN SIZE
   Mode . . .    3 to 4 phi    Range . . . . .  3 to > 4 phi
-------------------------------------------------------------------------
APPARENT RPD
   Minimum . . . .  1.92 cm    Width . . . 13.92 cm
   Maximum . . . .  2.96 cm    Area  . . . 33.96 cm2
   Average . . . .  2.44 cm
-------------------------------------------------------------------------
REDOX REBOUND LAYER
   Top . . . . . .  0.00 cm    Bottom  . .  0.00 cm   Width  . .  0.00 cm
-------------------------------------------------------------------------
MUD CLASTS
   Number  . . . .  5          Size  . . .  0.36 cm   Status . .  Reduced
-------------------------------------------------------------------------
METHANE
   Minimum . . . .  0.00 cm    Number  . .  0
   Maximum . . . .  0.00 cm    Size  . . .  0.00 cm
   Average . . . .  0.00 cm
-------------------------------------------------------------------------
DREDGED MATERIAL
   Depth . . . . .  0.00 cm
-------------------------------------------------------------------------
COMMENTS
   Form comments:
   -0              -0              -0              -0
   -0              -0              -0              -0
   -0              -0              -0              -0
   -0              -Amphipods      -0              -0

   Add measure . .  0.00 cm    Comment: x

   General comment:
       extreme reworking, amphi tubes, sml feeding voids
-------------------------------------------------------------------------
BIOLOGICAL
   Successional stage . . . . . Stage I
   Low DO present . . . . . . . NO
   Organism Sediment Index  . . 5
=========================================================================
```

Figure 7. Sample Data Sheet for REMOTS® Image Analysis. Data are from the MWRA Spring 1992 Survey.



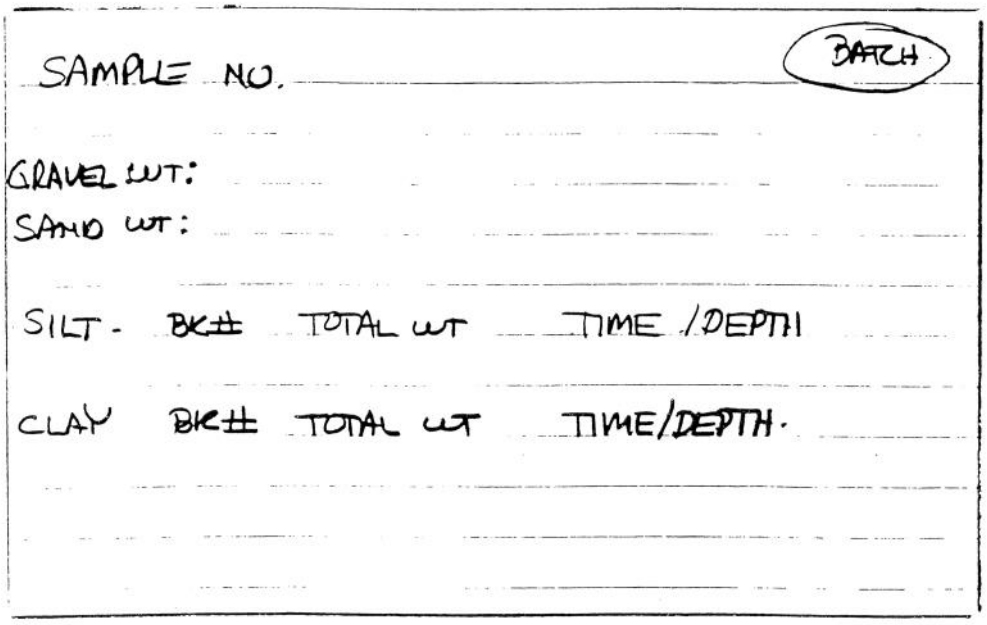


Figure 8. Sample Data Sheet for Grain Size Determination.

Microbiological Data Log

Sample number:_____
Sample type:_____
Date of collection:_____
Storage location and temperature:_____
Date and time of analysis:_____
Incubation start:_____
Incubation end:_____
Media choice:_____
Positive control:_____
Negative control:_____

DILUTION 10 _____
DILUTION 01 _____
DILUTION -1 _____
DILUTION -2 _____
DILUTION -3 _____
DILUTION -4 _____
DILUTION -5 _____

DENSITY OF CLOSTRIDIUM PERFRINGENS/100G | _____ |

Figure 9. Sample Data Sheet for *C. perfringens* Enumeration.

TOC / TIC DATA REPORT

Data Recorded by: ______________________ Data Validated by: ______________________

Date Entered: ______________________ Date Validated: ______________________

Location of Original Data: ____

Sample #	Lab ID #	Date of Analysis	TOC % Dry Weight	TIC % Dry Weight	Comments

Figure 10. Sample Data Sheet for TOC Analysis.

16. DATA VALIDATION

All data collected and analyzed under this Work/QA Plan are subject to 100% check for errors in transcription, calculation, or spreadsheet input. Data transferred manually from data sheets or logbooks to spreadsheets are printed out and proofread against the original entry. Calculations made manually are checked by a second staff member. Data generated by SAIC are validated by the appropriate Task Leader. Data generated by a subcontractor are verified by the subcontractor Subtask Leader; results reported to SAIC are reviewed by the Task Leader to ensure that they are complete, internally consistent, and technically reasonable.

17. PERFORMANCE AND SYSTEMS AUDITS

The SAIC QA Officer for this project is Mr. Raymond Valente. Mr. Valente has no technical responsibilities on the project and thus functions as an independent auditor to ensure that work is conducted in accordance with this Work/QA Plan. Mr. Valente will conduct at least one such system audit during the course of the project. He will report his results to the Project Manager (Dr. James Blake) and to the SAIC Officer-in-Charge of this project (Dr. Joseph Germano).

Performance audits are the responsibility of the Program Manager and Task Leaders and will be conducted at their discretion to verify data accuracy. Subcontractor Subtask Leaders are responsible for audits of their own facilities.

Mr. Valente and Dr. Brigitte Hilbig conducted a site visit and system audit of Cove Corp. in 1991 as part of the Environmental Monitoring and Assessment Program (EMAP) near coastal program. The results of that audit demonstrated that Cove Corp. was rigorously following the QC Plan. Because of that successful audit, SAIC has high confidence in the subcontractor's commitment and quality and has no need to repeat the effort at this time.

18. Problem Identification/Corrective Action

All technical personnel (including subcontractors) share responsibility for identifying and resolving or helping to resolve problems encountered in the routine performance of their duties. Discrete, easily correctable problems are normally addressed through the established chain of command, with proper documentation. Dr. James Blake, SAIC's Program Manager, is responsible to MWRA and to SAIC management for overall conduct of all aspects of the project, including cost, schedule, and technical performance. As such, he is charged with identifying and resolving problems that have not been addressed at a lower level in a successful or timely way, affect multiple components of the project, necessitate changes in this Work/QA Plan, or require consultation with upper levels of SAIC management or with MWRA.

Problems identified by the QA Officer are reported as described in Section 17.

19. REPORTS

Reports to be delivered under this Work/QA Plan are a survey plan and survey report for the surveys in Boston Harbor and Massachusetts Bay, one report (draft and final) for Boston Harbor, and one report (draft and final) for Massachusetts and Cape Cod Bays.

The survey plan was submitted in advance of the field work. The survey report, submitted in September, contains an account of stations occupied, samples collected, problems encountered, and any significant observations or unexpected events in the field.

Separate reports will be prepared for the Boston Harbor and Massachusetts Bays surveys. The results of the sediment profiling, benthic biology, and sedimentary parameters will be integrated to provide a comprehensive picture of the benthic community structure. Each of the REMOTS® parameters and some of the biological parameters will be mapped in order to provide a visual representation of spatial patterns in the data.

Analysis of the benthic database will be initiated with an assessment of a suite of benthic community parameters, followed by an analysis of community patterns using cluster or similarity analysis and ordination. The community parameters will include species diversity calculations, species richness estimates (numbers of species per area), and species densities. The species composition of each station will also be determined with the rank order and percent contribution of each species indicated. These data will be important in addressing biological explanations for patterns indicated in cluster analysis and ordination. For cluster analysis, we use the Bray-Curtis Similarity Coefficient (Boesch, 1977) and NESS (Normalized Expected Species Shared) (Grassle and Smith, 1976) to compare similarities between stations and groups of stations. This type of analysis will readily sort stations into groups with differing degrees of similarity. Explanations for these differences may be readily apparent from inspection of the species lists or other benthic parameters. Ordination analysis using reciprocal averaging or correspondence analysis will be used. This technique begins with the results of the Bray-Curtis similarity analysis in both the normal and inverse modes. The technique can readily detect species or groups of species that are responsible for the observed clustering patterns or shifts in ordination space.

A related type of ordination analysis called multiple discriminant analysis (MDA) is recommended to determine whether groups of stations considered to be distinct on biological grounds are also distinct on physical and chemical grounds (Green and Vascotto, 1978). Physical parameters include sediment grain size (percent sand, silt, and clay), TOC, and various REMOTS® parameters including depth of the apparent RPD, surface boundary roughness, and the degree disturbance in the sediment caused by bioturbation. By using MDA, we will be able to determine if the patterns detected in the cluster analysis are associated with different levels of the physical parameters being measured simultaneously. If the chemistry samples now archived for analysis under a separate contract have been analyzed, it would also be useful to consider the results of the organic and metal analyses. MDA is available in most statistical packages for PCs (e.g., SYSTAT) and is relatively easy to manipulate.

In order to understand the REMOTS® and benthic data from a historical perspective, the report will consider each of the previous sets of samples collected as part of the MWRA monitoring in Boston Harbor. Results will be interpreted from the point of view of detecting natural seasonal and year-to-

year trends as well as patterns that might be related to the abatement of sludge disposal in the Harbor. For Massachusetts Bay, the summer 1992 samples are the first to be collected as part of the Outfall Monitoring Program and represent the initial baseline. However, some of the stations can be considered from a historical perspective in that stations sampled as part of the STFP (Secondary Treatment Facilities Plan) in 1987 and 1988 have been reoccupied. Further, a set of farfield samples were taken at 10 of the 12 stations in the spring of 1992. It will be of interest to compare the 1992 and 1987-1988 benthic results because seasonal samples taken during the STFP effort suggested that benthic communities were relatively consistent over the one-year effort at the different stations (Blake *et al.*, 1987, 1988). The presence or absence of the same benthic communities in 1992 will be important in evaluating how the soft-bottom benthos can be best interpreted as an indicator for long-term monitoring.

Due dates for submission of the drafts of these two reports will be established as part of Work Order No 3, but it is expected that they would be delivered at the beginning of 1993. After receipt of comments from MWRA, SAIC will revise the reports within 30 days. In addition to a bound copy of the final report, SAIC will deliver one unbound copy with all original graphics and an IBM-compatible disk with all text files in WordPerfect 5.1 format.

20. REFERENCES

Bisson, J.W. and V.J. Cabelli. 1979. Membrane filter enumeration method for *Clostridium perfringens*. Appl. Environ. Microbiol. 37:55-66.

Blake, J.A., E.M. Baptiste, R.E. Ruff, B. Hilbig, B. Brown, R. Etter, and P. Nimeskern. 1987. Soft-bottom benthos of Massachusetts Bay. Marine Ecology and Water Quality Field Studies for Outfall Siting. Deer Island Secondary Treatment Facilities Plan. Report Submitted to Camp Dresser and McKee, Inc., for the Massachusetts Water Resources Authority.

Blake, J.A., R.E. Ruff, and N.J. Maciolek. 1988. Soft-bottom benthos from Stations B2 and D2 collected in February 1988. Marine Ecology and Water Quality Field Studies for Outfall Siting. Deer Island Secondary Treatment Facilities Plan. Supplemental Report Submitted to Camp Dresser and McKee, Inc., for the Massachusetts Water Resources Authority.

Boesch, D.F. 1977. Application of numerical classification in ecological investigations of water pollution. U.S. Department of Commerce, NTIS PB-269 604. EPA-60013-77-033.

Bothner, M.H., C.M. Parmenter, D.C. Twichell, C.F. Polloni, and H.J. Knebel. 1991. A geologic map of the sea floor in western Massachusetts Bay, constructed from digital sidescan sonar images, photography, and sediment samples. USGS Digital Data Series. U.S. Geological Survey.

Emerson, D.J. and V.J. Cabelli. 1982. Extraction of *Clostridium perfringens* spores from bottom sediment samples. Appl. Environ. Microbiol. 44:1144-1149.

EPA. 1984. Guidance for preparation of combined Work/Quality Assurance Project Plans for Environmental Monitoring. U.S. Environmental Protection Agency, Office of Water Regulations and Standards, Washington, DC.

Folk, R.L. 1974. Petrology of Sedimentary Rocks. Hemphill Publishing Co., Austin, TX.

Grassle, J.F., and W.L. Smith. 1976. A similarity measure sensitive to the contribution of rare species and its use in investigation of variation in marine benthic communities. Oecologia 25:13-22.

Green, R.H., and G.L. Vascotto. 1978. A method for the analysis of environmental factors controlling patterns of species composition in aquatic communities. Water Research 12:583-590.

MWRA. 1991. Massachusetts Water Resources Authority effluent outfall monitoring plan phase I: Baseline studies. MWRA Enviro. Quality Dept. November 1991. Massachusetts Water Resources Authority, Boston, MA.

Rhoads, D.C., and J.D. Germano. 1982. Characterization of benthic processes using sediment profile imaging: An efficient method of Remote Ecological Monitoring Of The Seafloor (REMOTS® System). Mar. Ecol. Prog. Ser. 8: 115-128.

Rhoads, D.C., and J.D. Germano. 1986. Interpreting long-term changes in benthic community structure: A new protocol. Hydrobiologia 142: 291-308.

SAIC. 1987a. REMOTS® survey of Broad Sound, Massachusetts Bay. SAIC-87/7511&141. Science Applications International Corporation, Newport, RI.

SAIC. 1987b. REMOTS® survey of Broad Sound, Massachusetts Bay, Cruise 2: The adventure continues...SAIC-87/7536&163. Science Applications International Corporation, Newport, RI.

SAIC. 1990. REMOTS® sediment-profile photography surveys of Boston Harbor, Dorchester, Quincy, Hingham, and Hull Bays, June 1989 and May 1990. SAIC Report No. SAIC-90/7578&236.

SAIC. 1992. REMOTS® sediment-profile photography survey of Boston Harbor, Dorchester, Quincy, Hingham, and Hull Bays. SAIC Report No. SAIC-92/266. Science Applications International Corporation, Woods Hole, MA.

APPENDIX A

PROCEDURE FOR GRAIN-SIZE ANALYSIS

SUMMARY PROCEDURE TO MEASURE WEIGHT PERCENT GRAVEL, SAND, SILT AND CLAY

1. Uniquely numbered 50 ml beakers are washed, rinsed, and oven dried. They are weighed to 0.1 mg on an analytical balance three separate times. Weights are averaged to obtain a working weight for each beaker. Beaker weight table is maintained in sediment laboratory.

2. A dispersing solution of approximately 0.5 percent sodium metaphospate is used to prevent flocculation of clay particles during analysis. The solution is prepared by dissolving approximately 100 g of sodium metaphosphate into 20 l of deionized water. Triplicate 25 ml aliquots are taken from each batch into preweighed beakers, oven dried, weighed on an analytical balance, and averaged.

3. Samples are refrigerated or stored in iced coolers until sample processing. Sample is homogenized and split using best available means to obtain sample for analysis that will contain approximately 30 grams dry weight mud and/or 70 grams dry weight sand.

4. Sample aliquot is mixed with approximately 200 ml of dispersing solution and allowed to sit overnight.

5. Sample is wet-seived through a 64 micron seive to separate gravel/sand from silt/clay using less than 800 ml of deionized water.

6. Sand/gravel fraction is rinsed into a beaker from seive. Water is decanted, and sample is rinsed with tap water, decanted, and placed in drying oven (95 deg) overnight.

7. Silt/clay fraction is washed into 1000 ml graduated cylinder and topped off to exactly 1000 ml using dispersing solution.

8. Temperature of cylinder is measured, and monitored at 4 hour intervals.

9. Cylinder is mixed with stirring paddle for 2 minutes to fully homogenize sample. Timer is started when mixing ends (settling begins).

10. 25 ml aliquots are removed from the cylinder at specific times and depths to correspond with the settling rates of silt and clay. Settling rates are calculated using Stokes Law, following the methods of Folk, 1974. The formula,

$$T = \frac{D}{1500 \times A \times d^{**2}}$$

is used, where T is time in minutes, D is depth of pipette in cm,

d**2 is particle diameter in mm, and A is a constant dependent upon the viscosity of water (a function of temperature), force of gravity, and density of particles.

11. The 25 ml aliquots are placed in pre-washed, pre-weighed 50 ml beakers and dried in 95 deg C oven overnight. The samples are removed and weighed to 0.1 mg on an analytical balance.

12. Dried sand/gravel fraction is mixed and dry seived through a 2 mm seive. Material retained on seive, and material retained on pán is weighed to 0.1 mg.

13. All weights are entered to LOTUS routine for calculations.

Dispersant weights are calculated as follows:

$$\frac{\text{Total wt - beaker wt}}{\text{25 ml aliquot}} \times 1000 \text{ ml/l} = \text{Dispersant wt (g/l)}$$

Sample weights are determined by subtracting beaker weight from beaker + sample weight, and scaled to weight per litre by multiplying by 40.

Silt fraction is determined by subtracting clay weight from total mud weight.

Sand and gravel weights are determined by subtracting weighing boat weights from sample.

Results are presented at Gravel:Sand:Silt:Clay percentages, and as Sand:Silt:Clay percentages.

14. Precision will be measured by triplicate analysis of 10 percent of samples, and expressed as the percent coefficient of variation (%CV), calculated as

$$\%CV = sd/\bar{x} \times 100\%$$

Analyses of sand, silt, and clay fractions will show less than 20% CV to be acceptable. There is no limit on gravel variation, as its natural variability is high. If the sample has less than 5% weight percent of sand, silt, or clay fractions, this criteria is not utilized. If these criteria are not met, techniques will be evaluated and, if necessary, samples reanalyzed.