# Massachusetts Water Resources Authority effluent outfall monitoring plan:

## Phase II post-discharge monitoring

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The Massachusetts Executive Office of Environmental Affairs organized an Outfall Monitoring Task force to provide advice, guidance, and oversight for monitoring of the MWRA effluent outfall in Massachusetts Bay. The membership (as of May 1997) of the Task Force is:

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# 1.0 INTRODUCTION

The Massachusetts Water Resources Authority (MWRA) is responsible for the construction and operation of a new sewage effluent outfall from the Deer Island Wastewater Treatment Plant. The new outfall will be located in Massachusetts Bay approximately 15 km from the Deer Island Plant in a water depth of 32 m (Figure 1-1). Improved effluent treatment, cessation of sludge discharge (accomplished in December of 1991), and moving the wastewater discharge from within the confines of Boston Harbor are expected to result in a significant improvement in water and sediment quality within the Harbor area without causing harm to the environment of Massachusetts and Cape Cod Bays (EPA 1988). Operation of the new outfall, originally scheduled for July 1995, has been delayed until 1998 (Table 1-1).

The MWRA is required to monitor for environmental impacts of the new outfall. The new outfall will be regulated through a permit issued by the U.S. Environmental Protection Agency and the Massachusetts Department of Environmental Protection under the National Pollutant Discharge Elimination System (NPDES). The EPA Supplemental Environmental Impact Statement (SEIS) (EPA 1988) requires monitoring for compliance with that NPDES permit, for assessing impact of the discharge beyond that which was identified in the SEIS as acceptable, and for collecting data useful for outfall management considerations. An amendment to the 1986 court order requiring the MWRA to upgrade their treatment facilities and effluent discharge outfall expanded on the data needs for outfall management (MWRA 1990). Included in this agreement was MWRA's commitment to implement "long term biological and chemical monitoring to describe existing conditions and evaluate the impacts of the treatment facility discharge." The information gained through these studies was to provide the fundamental understanding of the variability and ecological functioning of the Massachusetts Bay system.

Under the monitoring approach developed and adopted by MWRA and the Outfall Monitoring Task Force (OMTF) established by the Massachusetts Executive Office of Environmental Affairs (EOEA) to oversee the monitoring program, areas of concern (public, scientific, and regulatory) were identified following guidance for coastal monitoring included in NRC (1990). Using this information, a draft Phase I baseline monitoring plan was developed (MWRA 1991), reviewed, and accepted by EOEA with revisions (Pederson 1992). This plan described and discussed the ecological and other potential responses (perturbations) that were of concern (Table 1-2) and the field and laboratory studies that were necessary to acquire data to address these concerns. Details of the field and analytical program conducted under Phase I are described in a series of Combined Work/Quality Assurance Project Plans (Butler et al. 1995, Bowen et al. 1997, Blake and Hilbig 1995, Mitchell et al. 1995) with subsequent program revisions as data became available and in response to other recommendations (Hunt and Steinhauer 1994a,b; Hunt et al. 1994, McCarthy et al. 1996a,b,c).

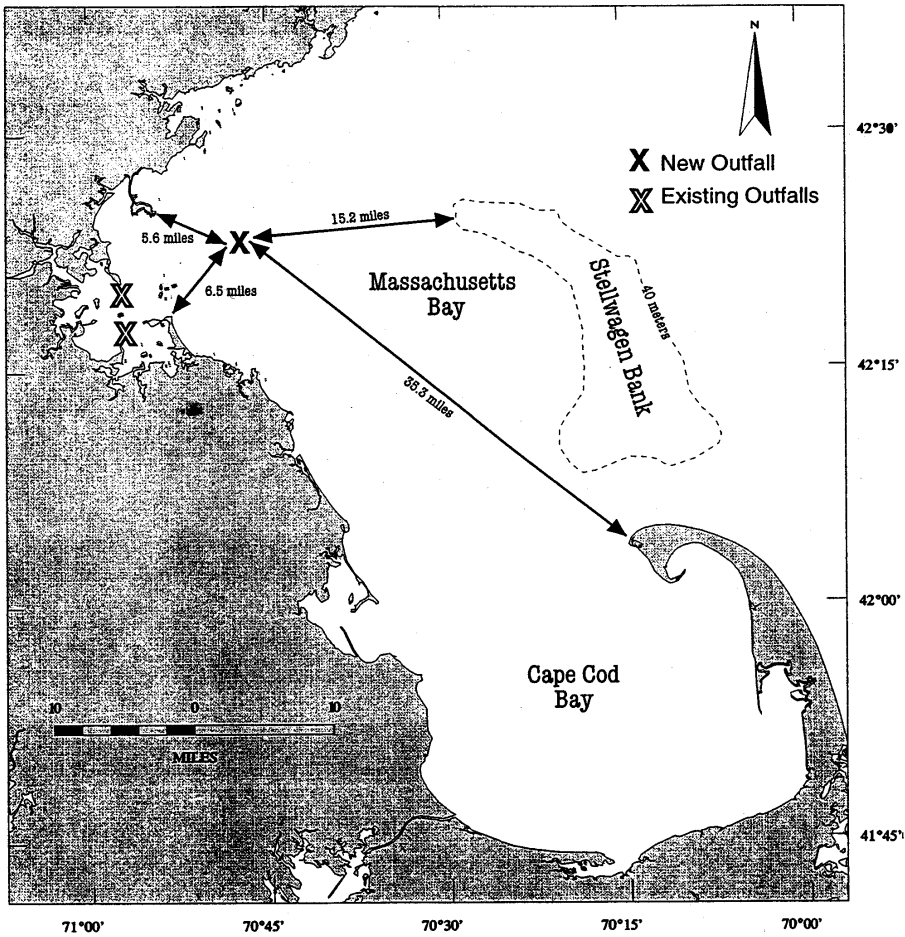


***FIGURE 1-1***
*Distances of the new outfall from selected sensitive areas in Massachusetts and Cape Cod Bays. The exisiting outfalls are near Deer Island and the more southerly Nut Island. The new outfall is 9.5 miles from Deer Island.*

**TABLE 1-1**

**Schedule of Treatment Upgrades and Monitoring**

| Year | Operation |
|---|---|
| 1991 | The Phase I Outfall Monitoring Plan formulated the monitoring hypotheses to be tested. Sludge discharge into Boston Harbor ceased in December. |
| 1992 | Baseline monitoring initiated. |
| 1995 | New primary treatment facility on Deer Island became operational in January. Draft Contingency Plan developed. |
| 1997 | MWRA revised the Contingency Plan (2/97) in response to comments. Draft NPDES permit for relocated discharge will be presented for comment. South systems flows may be sent to Deer Island via the completed (10/97) inter-island tunnel. |
| 1997 to 1999 | Secondary treatment batteries will become operational on Deer Island in phases. (7/97 for battery A, 12/97 for battery B, 12/99 for Battery C; each battery is 160 MGD). |
| 1998 | When the outfall is relocated (scheduled for 10/98), the monitoring program changes in name from Phase I (baseline) to Phase II (post-discharge), though there is consistency in the monitoring effort. |
| 2001 | Review first 3 years of post-discharge monitoring results to evaluate the impacts of the outfall relocation, the level of monitoring effort, and the appropriateness of monitoring hypotheses and Contingency Plan provisions. |

**TABLE 1-2**

**Summary of Trigger Parameters**

| Monitoring Area | Trigger Parameter |
|---|---|
| Effluent | Total Suspended Solids |
| | Biochemical Oxygen Demand |
| | Pathogenic Indicator Bacteria |
| | Nitrogen Loading |
| | Toxic Metals and Organic Chemicals |
| | Toxicity Testing |
| | Floatable |
| | Oil and Grease |
| | Plant Compliance with Permit Limits |
| Water Column | Dissolved Oxygen Concentration |
| | Dissolved Oxygen Respiration Rate |
| | Chlorophyll |
| | Nuisance and Noxious Algae |
| | Zooplankton |
| | Diffuser Mixing |
| Benthos | Benthic Community Structure |
| | Sediment Oxygen |
| | Sediment Toxic Metal and Organic Chemicals |
| Fish and Shellfish | Mercury and PCBs in Flounder, Lobster, and Mussels |
| | Lead in Mussels |
| | Lipophilic Toxic Contamination |
| | Liver Disease in Flounder |

The original discharge into Massachusetts Bay was planned for 1995. This is now projected for October of 1998. This has allowed collection of 6 years of baseline data, from 1992 to 1998, rather than the original 3 years required.

This report is the Post-Discharge Monitoring Plan (hereafter just referred to as the Monitoring Plan) for 1999 to 2001. The major emphasis is on the vicinity of the future outfall, with additional effort in Cape Cod and Massachusetts Bay. Improvements in Boston Harbor are also monitored by the MWRA but will not be covered in this report due to the difference in monitoring objectives. This Monitoring Plan describes the proposed monitoring effort and is complemented by two companion documents: the Outfall Monitoring Overview (e.g. Galya et al. 1996) describes the results of studies implemented under the Monitoring Plan, and the Contingency Plan (MWRA 1997) describes the response to exceedances of monitoring hypotheses. The Contingency Plan (MWRA 1997) lists thresholds (Caution and Warning Levels) which were developed to protect the environment and public health. The Contingency Plan also describes the various management actions that MWRA will undertake when thresholds are exceeded. Examples of management actions include additional monitoring, development of response plans and performance of engineering feasibility studies. The Contingency Plan provides more detailed discussion of the potential management actions.

## 1.1 Objectives for Post-Discharge Monitoring

The primary objectives of the Monitoring Plan are:

Objective 1: Test for compliance with NPDES permit requirements

Objective 2: Test whether the impact of the discharge on the environment is within the bounds projected by the SEIS

Objective 3: Test whether change within the system exceeds the Contingency Plan thresholds.

The MWRA effluent outfall will be regulated through a NPDES permit. It has to monitor regularly to test for compliance with the permit requirements. For example, the permit win specify allowable limits of carbonaceous Biochemical Oxygen Demand (cBOD) and Total Suspended Solids (TSS) in the effluent based on expected performance. Monitoring for these parameters allows MWRA to check for treatment performance, pinpoint areas of concern and correct for problems if they exist. MWRA win submit Monthly Discharge Monitoring Reports (DMR) and report exceedance of permit limits if they occur.

The EPA SEIS (with concurrent opinion from the National Marine Fisheries Service, NMFS) determined that there would not be significant water quality or biological impacts associated with the outfall. The Monitoring Plan tests for various water quality, sedimentary and biological parameters to ensure that impacts from the discharge is within the bounds projected by the SEIS.

The Contingency Plan was first recommended by the NMFS. It specifies numerical or qualitative thresholds which can suggest that effluent quality and/or environmental conditions may be changing or might be likely to change in the future. In the event that one of these thresholds is exceeded, the Contingency Plan sets into motion a process to confirm the threshold exceedance, to determine the causes and significance of the exceedance, and, if the suggested changes are attributable to the effluent outfall, to identify the response that will be taken to return the trigger parameter to a level which is at or below the relevant threshold. There is some overlap of Objective 3 with Objectives 1 and 2. The NPDES permit requirements are now a subset of Contingency Plan thresholds.

The Massachusetts Executive Office of Environmental Affairs (EOEA) and the U.S. EPA established the outfall monitoring task force (OMTF) to oversee and make recommendations on the Monitoring Plan, as well as to provide guidance in interpretation and evaluation of collected data. The task force is comprised of members from the scientific community as well as from state agencies (Department of Environmental Protection; Division of Marine Fisheries; Massachusetts Coastal Zone Management), federal agencies (National Marine Fisheries Service, U.S. Army Corps of Engineers, U.S. Environmental Protection Agency), and regional representatives (Boston Wastewater Advisory Committee; Save the Harbor/Save the Bay; Safer Water in Massachusetts; Cape Cod Commission; Center for Coastal Studies). MWRA and their consultants are non-voting participants. The current chairperson of the OMTF is Dr. Jerry Schubel, president of the New England Aquarium.

## 1.2 Components of the Monitoring Plan

The Monitoring Plan is organized around the general subject headings of effluent, water column, benthic, as well as fish and shellfish monitoring. Each of these subjects will be discussed in more detail in subsequent sections and is organized as follows:

- Overview of current baseline studies and important findings
- Contingency Plan trigger parameters and threshold levels
- Post-discharge Monitoring Plan components
- Data evaluation and comparison to thresholds

It should be noted that the effort described in the Monitoring Plan is more comprehensive than that necessary to just address the Contingency Plan thresholds. This is because there is extensive interaction among water quality and ecological parameters and natural variability in a complex environmental system such as Massachusetts Bay. The additional information collected is necessary in order to gain a more complete understanding of the system, and provide data that will be used to explain any changes in the system, and whether MWRA' s discharge contributed to the change.

The Post-Discharge Phase II monitoring will require rapid evaluation of data in relation to the trigger parameters. Biological and chemical data related to the thresholds will be examined individually ahead of the data report schedules. MWRA will require early notification from the laboratories when Caution and Warning Levels are exceeded.

## 1.3 Contingency Plan Thresholds

The ideal Monitoring Plan requires (1) a determination of what changes are significant and (2) establishment of an appropriate sampling and analysis plan. The issue lies with the relationship (or non relationship) between biological importance and the statistical significance of a given result. Parkhurst (1985) stated that "deciding on the degree of biological importance requires subjective scientific judgement, which some workers would rather not face." The Contingency Plan thresholds are based on expected permit limits, observations from the baseline monitoring, national water quality criteria and state standards, and in some cases, best professional judgement. A formal analysis of risk to the environment or human health if a trigger parameter is exceeded has not been performed.

The baseline monitoring has shown fairly large variations in the parameters being measured, as is expected in complex environmental systems. The statistical power of detecting change has been treated at various times by Hunt and Baptiste (1993) for fish and shellfish, Coats (1995) for sediment chemistry, and Hunt et al (1995) for water column. In general, detectable change can be as low as 10 to 20% for dissolved oxygen; 50 to 100% for fish and shellfish parameters, as well as some sediment chemicals; 100 to 200% for chlorophyll and dissolved inorganic nitrogen. The proposed Monitoring Plan should provide a high probability (80%) of detecting statistically significant change. Many of the Contingency Plan thresholds are greater than current baseline conditions (e.g. mercury levels in fish) such that statistically significant changes would be detected long before the threshold is approached.

# 2.0 EFFLUENT MONITORING

The major purpose of effluent monitoring is to test for compliance with NPDES permit limits. The NPDES permit limits for priority pollutants are expressed as concentrations in effluent; these are based on national water quality criteria, ambient conditions, and the projected outfall dilution. The actual outfall dilution will be tested under water column studies. Effluent monitoring will also provide accurate mass loads of various contaminants such that the fate, transport and risk of these contaminants in Massachusetts Bays can be better assessed, if necessary.

## 2.1 Overview of Phase I Baseline Studies

MWRA currently monitors the effluent from Deer Island and Nut Island treatment plants as well as the effluent from Combined Sewer Overflow (CSO) treatment facilities. Parameters are measured on a daily, weekly or monthly basis (e.g. BOD and TSS are monitored daily; nutrients are monitored weekly; priority pollutants are monitored monthly). MWRA 's Toxics Reduction And Control (TRAC) department is charged with the pre-treatment source reduction program and has conducted studies on the source of toxic contaminants into the system. In addition, MWRA has undertaken a fairly detailed effluent characterization study (DECS) starting from June of 1993, which has the following highlights:

- Two-24 hour composite effluent samples were collected per month, on two of the three days of the routine NPDES permit sample collection.
- Samples were analyzed for trace metals, PAHS, PCBs and pesticides using methods modified to achieve significantly lower detection levels than NPDES methods.
- The same nutrients measured in the water column program were characterized in the effluent. These include dissolved inorganic nitrogen compounds (ammonium, nitrite, nitrate), total dissolved nitrogen and particulate organic nitrogen, dissolved phosphate, total dissolved and particulate organic phosphorus, urea, dissolved silicate and biogenic silica, dissolved and particulate organic carbon.
- Special studies of removal efficiencies for the above analytes were performed at the MWRA pilot secondary treatment plant from 1993 to 1995.
- Special study of potential sewage tracers in effluent were evaluated, including linear alkyl benzenes (LAB), *Clostridium perfringens* spores and stable isotope ratios of sulfur and nitrogen.

### Important Findings

Effluent monitoring has demonstrated that, in general, improvements made at the MWRA system during the last few years have resulted in substantial improvements in wastewater effluent quality .The 1996 daily average concentration of BODS in Deer Island wastewater was 73 mg/l, with a range from 33 to 129 mg/l. The 1996 monthly average concentration of TSS in Deer Island wastewater was S2 mg/l, with a range of 24 to 133 mg/l. However, secondary treatment should lower both the BODS and TSS to below 30 mg/l in undiluted effluent. Typically, the carbonaceous BOD is less than BODS.

The total nitrogen load being discharged by MWRA in 1996 was estimated to be 12,692 tons, which slightly exceeded the Contingency Plan Caution Level. Figure 2-1 shows the total nitrogen load discharged from MWRA for the time period of 1990 to 1996.

The monitoring program demonstrated that substantial reductions have occurred in the loading of toxic contaminants. The pilot treatment studies demonstrated the efficacy for secondary treatment to further decrease the concentration of many toxic contaminants. MWRA anticipates that an approximately 100-fold dilution of the effluent will occur within a few tens to hundreds of meters of the future diffuser. This dilution will ensure that there is minimal risk to aquatic life.

The results of these effluent characterization studies have shown the importance of using proper laboratory analysis techniques with low detection limits. Toxic contaminant loads have been much better quantified, leading to the conclusion that earlier load estimates were too high.

## 2.2 Contingency Plan Trigger Parameters and Threshold Levels

Based on the results of these Phase I monitoring results, MWRA (1997) revised the Contingency Plan and linked potential management decisions to critical parameters. Trigger parameters and threshold levels applicable to the effluent are summarized in Table 2-1.

Many of the trigger parameters (such as TSS, cBOD) are based on U.S. EPA guidelines for secondary treatment and expected NPDES permit limits. However, the total nitrogen loading levels are based on the original 1988 SEIS determination, NOAA (1988) and the loadings that were assumed in the Massachusetts Bays Eutrophication Model (Hydroqual and Normandeau 1995). The Caution Level was derived as 90% of the Warning Level and rounded to 12,500. The threshold for floatables is based on best professional judgment. The threshold for plant performance is based on standards established by EPA and the Association of Metropolitan Sewerage Agencies to define preferred and acceptable operational achievement practices.

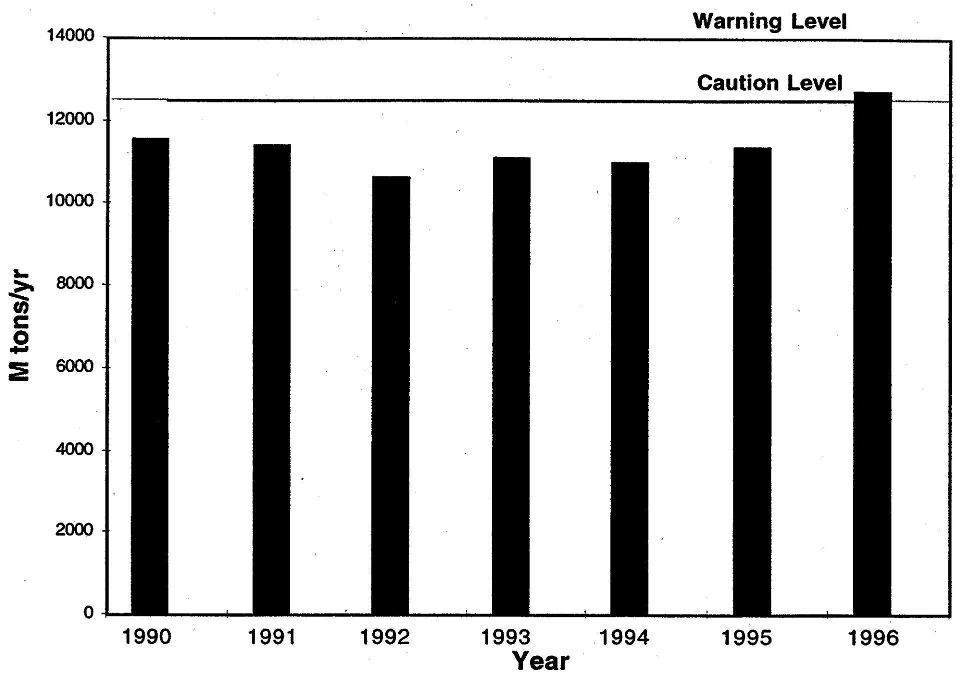


*FIGURE 2-1*
*Total nitrogen load discharged from the Deer Island and Nut Island treatment plants from 1990-1996.*

**TABLE 2-1**

**Trigger Parameters for Effluent**

| Parameter | Rationale for Trigger Parameters | Caution Level | Warning Level |
|---|---|---|---|
| Total nitrogen | - Potential for eutrophication based on water quality modeling and SEIS | 12,500 mtons/yr | 14,000 mtons/yr |
| Toxics | - Levels developed to meet water quality criteria and NPDES permit limits | | NPDES permit limits |
| Effluent Toxicity | - Direct measure of effluent toxicity<br>- Based on expected NPDES Permit limits | | Acute: LC50<50% for shrimp; chronic: NOEC for fish growth and sea urchin fertilization <1.5% effluent concentration at edge of mixing zone. |
| Carbonaceous BOD (cBOD) | - Provides measure of organic loading<br>- Expected secondary treatment performance | | 40 mg/l weekly<br>25 mg/l monthly |
| Fecal coliform | - Surrogate for pathogens<br>- Based on Massachusetts Water Quality Standards | | 14,000 fecal coliforms/100 ml daily at point of dechlorination |
| Total suspended solids (TSS) | - Provides measure of solids loading<br>- Expected NPDES permit limit | | 45 mg/l weekly<br>30 mg/l monthly |
| Floatables | - Aesthetic issue and may cause harm to marine life<br>- Expected removal | | 5 gal/day in final collection device |
| Oil and grease of petroleum origin | - Aesthetic issue<br>- Expected NPDES permit limits | | 15 mg/l weekly |
| Plant performance | - Expected plant performance | More than 5 violations of permit requirements per year | Operating in violation of the permit requirements more than 5% of the time over a year |

## 2.3 Phase II Monitoring Plan

The major purpose for Phase II post-discharge monitoring of wastewater effluent is to test for compliance with NPDES permit limits and other effluent thresholds, and to support evaluation of ambient monitoring data. The type of measurements, analytical methodology, sampling frequency and location planned for Phase II monitoring are described below.

### Nutrients

Total Kjeldahl nitrogen, ammonia, nitrate, nitrite, total phosphorus and phosphate - weekly composite.

### Toxic contaminants

#### Metals

Low-detection-limit analysis of heavy metals of concern: silver, cadmium, copper, chromium, mercury , lead, molybdenum, nickel, and zinc (The analyses incidentally yield data on arsenic, selenium, thallium, boron, beryllium, iron, and antimony) -weekly composite.

#### Organics

Low-detection-limit analysis of 17 persistent chlorinated pesticides, an extended list of PAHS, and 20 PCB congeners - weekly composite.
VOA (volatile organics) - bimonthly (every 2 months) grab.
ABN (acid-base-neutrals) - bimonthly composite.

**Toxicity:** Bioassay toxicity tests - quarterly composite.

**Other:** Total residual chlorine - 3 grabs/day. Cyanide - bimonthly grab**.**

### Organic material

cBOD (carbonaceous biochemical oxygen demand) - daily composite.

### Human pathogens

Pathogen indicators (total and fecal coliforms) -3 grabs/day.

### Solids

TSS (total suspended solids) - daily composite.

Settleable solids - daily grab.

### Floatables

Total petroleum hydrocarbons (oil and grease of petroleum origin) - weekly grab.
Floatables - weekly composite.

**Other data:**

pH - daily grab.
alkalinity - weekly composite.
LABs (linear alkyl benzenes) measured with PAHs above

### Special Studies

The detailed effluent characterization study (DECS) carried out by MWRA using methods modified to achieve significantly lower detection levels than traditional methods has shown the inadequacy of traditional NPDES laboratory analysis methodologies. This is particularly true for trace metals and PCBS. The OMTF has recommended in 1996 to cutting back to roughly quarterly sampling on the low detection level based on the extensive results from 1994 and 1995. The MWRA Deer Island Laboratory is preparing to perform these low detection level measurements to supplement regular NPDES monitoring.

Pilot treatment study will be considered for continuation to compare the performance of the secondary batteries as they come on line. Detailed nutrient characterization and the measurement of potential sewage tracers, such as LAB and isotopes of sulfur and nitrogen will be re-evaluated with respect to the establishment of a clear framework on how such data would actually be used to address management concerns and aid in the decision process. These will be dropped in future monitoring programs if they fail to provide useful information for addressing management concerns.

The use of fecal and total coliform bacteria as indicators for human pathogens will be evaluated and the use of viral indicators will be explored as special studies.

## 2.4 Data Evaluation and Comparison to Thresholds

The Phase II Monitoring Program will provide the information to address all of the effluent thresholds and more. In particular, total nitrogen loadings will be available on a monthly basis (with no more than one to two month's lag time) and projected for the year. Effluent toxicity data and priority pollutant concentrations will be available in a similar time frame (with perhaps longer lag times for some parameters depending on sample holding time requirements, and the sample turnaround time within the laboratory). Daily evaluation of plant performance is achieved by comparing measured parameters versus expected performance.

The MWRA treatment plant is transitioning from primary treatment (new primary treatment plant came on line in 1995) to secondary treatment (first battery to come on line in 1997) in phases, with full secondary treatment by 1999. Thus, the effluent will be a blend of primary and secondary treated wastewaters until 1999. Measured concentrations of various effluent parameters will be compared to the pilot treatment plant study results. Large discrepancies between predicted and observed removal efficiencies will be resolved.

### Data Analysis

Comparison of effluent monitoring results to threshold limits requires the calculation of weekly and monthly average values for several parameters. For conventional parameters, calculating the average concentration of a particular parameter is straightforward; the arithmetic mean is determined. However, when dealing with metals, pesticides, and organics, where very frequently the analytical results were below the method detection level, certain assumptions have to be made. The adoption of low detection limit methodologies will help overcome this weakness. Geometric means will be used in lieu of arithmetic means if it can be shown that the parameter follows a lognormal distribution. Time-average concentrations are flow-weighted in the case of priority pollutants (metals, cyanide, pesticides/PCBs, and organic compounds).

In addition, the flow through the wastewater treatment plant is not homogeneous. MWRA will evaluate the representativeness of different sampling locations.

### Data Reporting

MWRA plans to issue quarterly wastewater performance reports, with information relevant to the Contingency Plan, effluent quality, wastewater flow, treatment plant operations and maintenance as well as residuals processing. This ensures that pertinent information will be available to the various stakeholders, including the public, in a timely manner.

# 3.0 WATER COLUMN MONITORING

Potential water column issues due to the relocation of the outfall are associated with effects of the effluent organic material, nutrients, and toxic contaminants. Of these, changes in the nutrient balance in Massachusetts and Cape Cod Bays have the most potential for significant effects on the health of marine life in the Bay.

Organic material occurs naturally in water bodies and may also be introduced by wastewater effluents. Decomposition of organic material consumes dissolved oxygen (DO). Nutrients are necessary for the growth of all plants, aquatic and terrestrial. There is concern that the nutrients provided by the MWRA effluent (in particular nitrogen) could promote excessive algal blooms, (e.g. Kelly 1993). The excess algae could lead to conditions of low dissolved oxygen (DO) where sensitive organisms may suffocate.

Adding effluent to the marine environment could change the relative levels of different nutrients so that undesirable algae dominate or are present along with useful algae. The undesirable algae could have impacts on the marine food web and ecology or human health.

The toxic contaminants discharged by the MWRA effluent are projected to be at extremely low concentrations. The impacts will probably not be seen directly in the water column but may be observed in sediments and bioaccumulate through fish and shellfish. This will be discussed in Sections 4 and 5.

## 3.1 Overview of Phase I Baseline Studies

Bigelow Laboratory for Ocean Sciences conducted a series of six surveys in 1989-1990 to collect a suite of environmental data from Massachusetts Bay. Hydrographic measurements (temperature, salinity) were taken along with nutrients (dissolved nitrate, nitrite, ammonium, silicate and phosphate), dissolved oxygen, chlorophyll-a, and particulate organic carbon (POC) and nitrogen (PON). In addition, primary production was measured, as well as phytoplankton community structure and zooplankton volume.

Water column monitoring was expanded in 1992, focussing on a nearfield area, a 120 square kilometer area (an area roughly the size of Boston Harbor) centered on the future outfall. The nearfield area included 21 stations and was sampled 14 to 16 times per year from 1992 to 1994. This expanded monitoring also included 25 to 31 farfield stations covering Massachusetts and Cape Cod Bays and Boston Harbor. These farfield stations were sampled six times per year from 1992 to 1994.

For 1995-97 the water column monitoring design was slightly modified following review to include 17 nearfield stations sampled 17 times per year. The farfield monitoring includes 26 stations sampled 6 times per year. *In situ* hydrographic parameters are measured at each station and samples are collected for analysis of dissolved inorganic nutrients. At a subset of the stations, samples are collected for analysis of dissolved organic carbon, nitrogen, and phosphorus; particulate carbon, nitrogen, and phosphorus; total suspended solids; and chlorophyll-a (filtered samples) and phaeopigments and identification and enumeration of phytoplankton and zooplankton. $^{14}C$ primary production has been measured in both the nearfield and the farfield, with current emphasis on two nearfield stations and one farfield station adjacent to Deer Island. Water column respiration has been measured at the productivity stations and at one offshore station.

### Important Findings

Water column monitoring has shown Massachusetts Bay to be a complex and highly variable system. Much of what occurs in the system is controlled by its seasonal physical characteristics. Massachusetts Bay undergoes an annual progression from a vertically mixed water mass during late fall to spring, to a strongly stratified system in summer (during June to October). While mild stratification may occur in the spring due to freshwater inputs to the system, temperature is primarily responsible for the summer stratification.

Water column nutrient concentrations reach annual maxima in the winter. As light increases during late winter (February-March), a strong seasonal phytoplankton bloom typically develops which occasionally depletes nutrients throughout the water column. This late winter bloom may be followed by a second event in late April, particularly if the first bloom is not strong and sufficient nutrients remain. The baseline data indicate that nitrogen is typically the limiting nutrient in the system.

As the seasonal thermocline sets up, a strong density barrier is formed which prevents vertical mixing, and dissolved nutrient concentrations in the surface layer diminish due to phytoplankton uptake. The depth of the thermocline typically is at 15 to 20 meters in the nearfield (about half way to the sea floor). Periodic upwelling and mixing events, which occur during the stratified period, release nutrients from below the pycnocline into the surface waters, enhancing summertime phytoplankton productivity. As the surface layer begins to cool and sink in the fall, the water column mixes and nutrients trapped in the bottom layer are released to the surface. This nutrient release typically produces a fall phytoplankton bloom that can exceed the spring event in terms of chlorophyll biomass and productivity.

The thermocline also creates a barrier to oxygen diffusion from the atmosphere. As a result, dissolved oxygen (DO) concentrations in the bottom water typically decline throughout the stratified period. The relative magnitude of the DO depression is dependent upon several factors:

- initial DO concentration at the onset of stratification;
- bottom water temperature;
- duration of stratification;
- availability (and quality) of carbon substrate to fuel respiration; and
- the occurrence of periodic perturbations (mixing, horizontal advection) to the water column which may resupply oxygen to bottom waters.

The rate of DO decline during the stratified period has been relatively uniform throughout the baseline monitoring years, however, two baseline years (1994 and 1995) had significantly lower minimum DO concentrations. These two years both had higher bottom water temperatures as well as lower initial concentrations, and appeared to have been subjected to a lesser degree of periodic alteration of stratification.

The conceptual models, which have evolved from the synthesis of baseline data, have supported the development and refinement of threshold parameters to be used for post-relocation evaluations. These are discussed in the following section.

## 3.2 Contingency Plan Trigger Parameters and Threshold Levels

Based on the results of the Phase I baseline studies, MWRA (1997) revised the Contingency Plan and linked potential management decisions to critical parameters. The levels applicable to the water column are summarized in Table 3-1. These are discussed further below. Seasons are defined for the table as follows: spring, January to April; summer, May to August and fall, September to December.

Dissolved Oxygen Concentration and Saturation

Aquatic animals are sensitive to the concentration of DO in the water column. Low levels of DO can have negative impacts on marine life. Because of the importance of DO, the state has set a water quality standard that DO should not fall below 6 mg/l and 75% of saturation in Massachusetts bay. MWRA is using these standards as the basis for Caution and Warning Levels for bottom waters in the nearfield and Stellwagen Basin. During the five year baseline period (1992 to 1996), the DO saturation Caution or Warning level have been violated on several occasions (four times in the nearfield, five times in Stellwagen). The applicability of the current DO threshold levels should be re-evaluated.

Dissolved Oxygen Depletion Rate

The average baseline DO depletion rate measured from 1992 to 1996 is about -0.026 mg/l/day. A 1.5-fold increase in the DO depletion rate would trigger exceedance of a Caution Level. An increase could be related to increased respiration of discharged organic matter or of algae stimulated by discharged nutrients, or to decreased ventilation of bottom waters.

**TABLE 3-1**

**Trigger Parameters for Water Column**

| Parameter | Rationale for Threshold Level | Caution Level | Warning Level |
|---|---|---|---|
| Dissolved oxygen in bottom waters of nearfield and Stellwagen basin (ppm or saturation level) | • Measures potential for hypoxia, or low DO impacts<br>• Level based on Massachusetts Water Quality Standards | Monthly mean < 6.5 mg/l or 80% of saturation for any one month during stratification (June - Oct.) | Monthly mean < 6 mg/l or 75% of saturation for any one month during stratification (June - Oct.) |
| Oxygen depletion rate in nearfield bottom (mg/L/day) | • Measures short-term and long-term rate of DO depletion and potential for future hypoxia<br>• Level based on prediction in SEIS for the potential for hypoxia | Monthly depletion rate > 1.5X baseline during stratification (June - October), -0.040 mg/L/day | Monthly depletion rate > 2X baseline during stratification (June - October), -0.053 mg/L/day |
| Chlorophyll in nearfield (μg/L) | • Measures the algal biomass and provides indication of eutrophication state<br>• Level based on appreciable change from baseline conditions | Annual mean > 1.5X baseline, 2.80 μg/L Seasonal mean conceneration exceeds 95th percentile of baseline distribution.<br>Spring: 2.71 μg/L<br>Summer: 2.27 μg/L<br>Fall: 4.44 μg/L | Annual mean > 2X baseline, 3.74 μg/L |
| Paralytic shellfish poisoning in farfield | • Measures the impact of undesirable algae | New incidence | None |
| Nuisance algae in nearfield (cells/L) | • Measures and evaluates increases in undesirable algae concentration<br>• Level based on change from baseline conditions | *Alexandrium tamarense* season mean population densities exceeds 95th percentile of baseline mean.<br>Spring: 2.34 cells/L<br>Summer: 26.1 cells/L<br>Fall: 7.57 cells/L | None |

**TABLE 3-1 (Cont'd)**

**Trigger Parameters for Water Column**

| Parameter | Rationale for Threshold Level | Caution Level | Warning Level |
|---|---|---|---|
| Zooplankton assemblage in nearfield region | • Measures potential change in zooplankton community structure<br>• Level based on qualitative indications | Nearfield assemblage shifts from a transitional community towards an inshore community (*Acartia, Eurytemora, Centropages hamatus*) with fewer representatives from an offshore community (*Calanus, Pseudocalanus, Centropages typicus, Oithona*) | |
| Initial dilution | • Measures the performance of the actual outfall<br>• Level based on comparison between design and actual dilution | | Less than that set by NPDES permit |

Chlorophyll

Adding effluent to the marine environment could change the amounts of nutrients or the relative levels of different nutrients so that excessive or prolonged algal blooms could occur. Chlorophyll is the most common measure of algal biomass. Since baseline concentrations of chlorophyll-a average about 2-3 ~g/l, the Caution and Warming Levels were set at 3 to 4 ~g/l based on peer review comments to the OMTF . The levels are well below the chlorophyll-a level of 20 g/l which is mentioned as a eutrophication threshold in the National Oceanographic and Atmospheric Administration' s Estuarine Eutrophication survey (NOAA 1997). In addition to annual means, seasonal thresholds for chlorophyll were developed to better reflect the seasonal nature of algal blooms. All the discrete sampling depth samples of the nearfield from each season are averaged to produce a seasonal mean for that year. The seasonal means for the baseline period were assumed to follow a normal distribution such that the 95th percentile is directly related to the mean and standard deviation of the baseline seasonal means. Actual 95th percentile values are summarized in Table 3-1.

Nuisance and Noxious Algae

Nuisance and noxious algae occur naturally in Massachusetts and Cape Cod Bays annually albeit in small numbers. The 1996 Peer Review Workshop recommended the use of paralytic shellfish poisoning (PSP) at shellfish beds to set red tide caution levels.

The nuisance algae thresholds were developed from the baseline conditions. The Caution Levels were set as the 95th percentile of seasonal mean concentrations of the three target species of *Alexandrium tamarense, Nitzchia pungens and Phaeocystis pouchetii.*

Zooplankton

Zooplankton community composition in inshore regions of Massachusetts Bay differs from that in offshore regions. The nearfield region represents a transition between the two communities. The zooplankton species in inshore communities require the high concentration of nutrients found in Boston Harbor for rnaximal growth and reproduction. One concern is that changes in nutrient concentrations resulting from outfall relocation could result in changes in the nearfield zooplankton community.

Dilution

Since all evaluations of toxic impacts depend on concentration after initial mixing, the MWRA will measure the actual dilution of effluent by seawater around the new outfall to test predictions of effluent dilution.

## 3.3 Phase II Monitoring Plan

Because the post-discharge monitoring results will be compared to pre-discharge results, it is important that the methods used to collect the data are comparable and consistent. Thus the Phase II monitoring plan is similar to the Phase I monitoring plan. The monitoring includes 17 surveys per year focussed on the nearfield area (see Figures 3-1 for station locations) and 6 surveys per year covering the farfield area with stations in Massachusetts and Cape Cod Bays and Boston Harbor (see Figure 3-2). Each station has a designated set of analyses performed on samples collected at various depths (see Tables 3-2 and 3-3 for nearfield and farfield station designations and Table 3-4 for definition of analysis groups). Stations F23, NO4 and N18 are actually D+P+R stations, but historically displayed as D+P stations in Figure 3-1 for convenience of representation. Further details are provided below.

### 3.3.1 Nearfield

### Water Quality and Hydrography

Measurement: Dissolved ammonium, nitrate, nitrite, phosphate, and silicate; *in situ* temperature, salinity, dissolved oxygen, chlorophyll fluorescence, transmissometry , irradiance, depth of sensors, and altitude of sensors above seafloor .

Location: Discrete samples for nutrients at 21 stations (Figure 3-1) along rectangular cruise tracks at five depths: one surface sample, two rnid-depth samples that span the pycnocline when it exists, one rnid-depth sample at the chlorophyll maxima, and one bottom sample. Continuous vertical profiles of hydrographic measurements will be taken from surface to within 5 m of the bottom at each station.

Frequency: Seventeen surveys per year during weeks number 6, 9, 12, 14, 17, 20, 25, 27, 30, 32, 34, 36, 39, 41, 44, 48, and 51.

### Biology and Productivity

Measurement: Dissolved organic carbon, nitrogen, and phosphorus; particulate carbon, nitrogen, and phosphorus; total suspended solids; discrete chlorophyll-a (filtered samples) along with phaeopigments; dissolved oxygen; in situ relative fluorescence.

Location: Discrete samples at 7 stations (type A or D in Figure 3-1) at 2 to 5 depths (depending on the parameter) as presented in Tables 3-2 and 3-4.

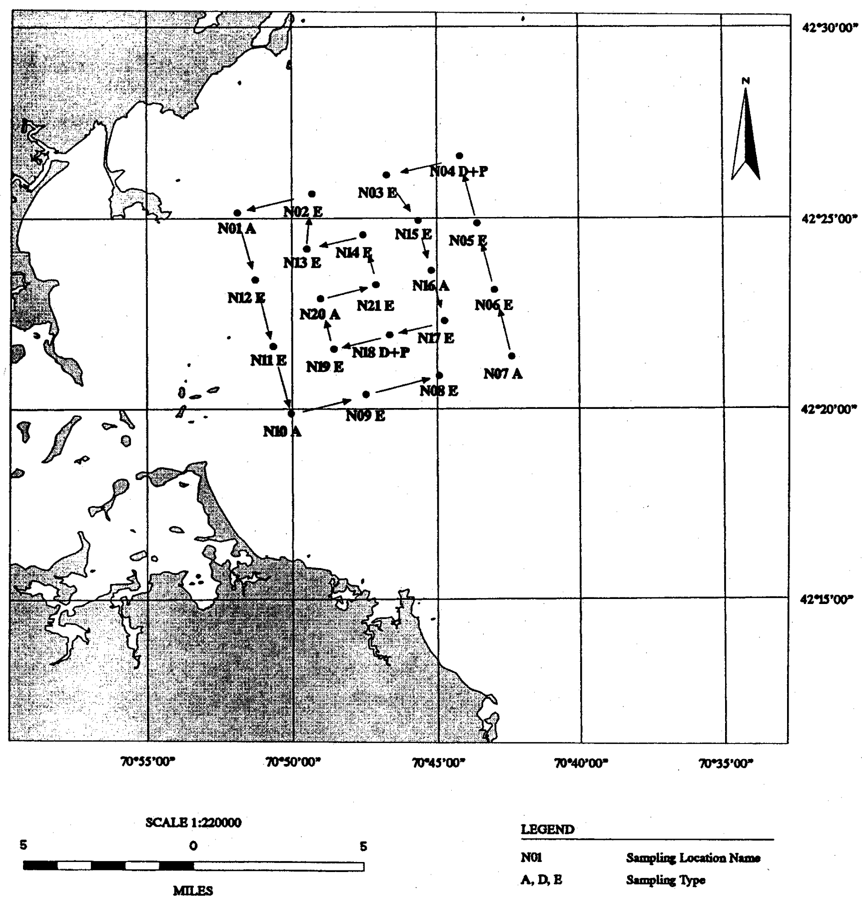


***FIGURE 3-1***
*Nearfield Stations.*
*Arrows Denote Potential Survey Track.*

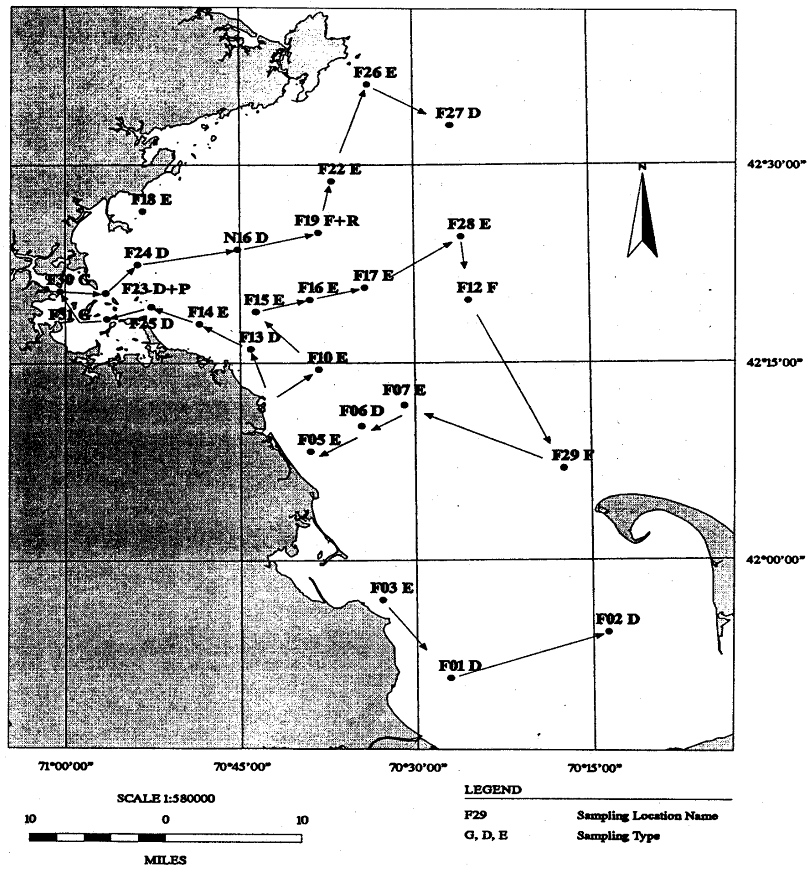


*FIGURE 3-2*
*Farfield Stations.*
*Arrows Denote Potential Survey Track.*

## TABLE 3-2

### Analysis Group for Each Station and Depth, Nearfield Survey

| Station Name | N01 | N02 | N03 | N04 | N05 | N06 | N07 | N08 | N09 | N10 | N11 | N12 | N13 | N14 | N15 | N16 | N17 | N18 | N19 | N20 | N21 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Station Type | A | E | E | D+P+R | E | E | A | E | E | A | E | E | E | E | E | A | E | D+P+R | E | A | E |
| **Nearfield Stations** | | | | | | | | | | | | | | | | | | | | | |
| Surface | G3 | G8 | G8 | G1 + P + R | G8 | G8 | G3 | G8 | G8 | G3 | G8 | G8 | G8 | G8 | G8 | G3 | G8 | G1 + P + R | G8 | G3 | G8 |
| Mid-surface | G5 | G8 | G8 | G5 + P | G8 | G8 | G5 | G8 | G8 | G5 | G8 | G8 | G8 | G8 | G8 | G5 | G8 | G5 + P | G8 | G5 | G8 |
| Middle | G3 | G8 | G8 | G2 + P + R | G8 | G8 | G3 | G8 | G8 | G3 | G8 | G8 | G8 | G8 | G8 | G3 | G8 | G2 + P + R | G8 | G3 | G8 |
| Mid-bottom | G5 | G8 | G8 | G5 + P | G8 | G8 | G5 | G8 | G8 | G5 | G8 | G8 | G8 | G8 | G8 | G5 | G8 | G5 + P | G8 | G5 | G8 |
| Bottom | G3 | G8 | G8 | G3 + P + R | G8 | G8 | G3 | G8 | G8 | G3 | G8 | G8 | G8 | G8 | G8 | G3 | G8 | G3 + P + R | G8 | G3 | G8 |

## TABLE 3-3

### Analysis Group for Each Station and Depth, Farfield Survey

| Station Name | F01 | F02 | F03 | F05 | F06 | F07 | F10 | F12 | F13 | F14 | F15 | F16 | F17 | F18 | F19 | F22 | F23 | F24 | F25 | F26 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Station Type | D | D | E | E | D | E | E | F | D | E | E | E | E | E | F+R | E | D+P+R | D | D | E |
| **Farfield Stations** | | | | | | | | | | | | | | | | | | | | |
| Surface | G1 | G1 | G8 | G8 | G1 | G8 | G8 | G7 | G1 | G8 | G8 | G8 | G8 | G8 | G7+R | G8 | G1+P+R | G1 | G1 | G8 |
| Mid-surface | G5 | G5 | G8 | G8 | G5 | G8 | G8 | G7 | G5 | G8 | G8 | G8 | G8 | G8 | G7 | G8 | G5+P | G5 | G5 | G8 |
| Mid-depth | G2 | G2 | G8 | G8 | G2 | G8 | G8 | G7 | G2 | G8 | G8 | G8 | G8 | G8 | G7+R | G8 | G2+P+R | G2 | G2 | G8 |
| Mid-bottom | G5 | G5 | G8 | G8 | G5 | G8 | G8 | G7 | G5 | G8 | G8 | G8 | G8 | G8 | G7 | G8 | G5+P | G5 | G5 | G8 |
| Bottom | G3 | G3 | G8 | G8 | G3 | G8 | G8 | G7 | G3 | G8 | G8 | G8 | G8 | G8 | G7+R | G8 | G3+P+R | G3 | G3 | G8 |

| Station Name | F27 | F28 | F29 | F30 | F31 | N16 |
|---|---|---|---|---|---|---|
| Station Type | D | E | F | G | G | D |
| Surface | G1 | G8 | G7 | G1 | G1 | G1 |
| Mid-surface | G5 | G8 | G7 | G0 | G0 | G5 |
| Mid-depth | G2 | G8 | G7 | G2 | G2 | G2 |
| Mid-bottom | G5 | G8 | G7 | G0 | G0 | G5 |
| Bottom | G3 | G8 | G7 | G3 | G3 | G3 |

**TABLE 3- 4**

**Chemical and Biological Analysis Performed in Each Analysis Group**

| Analysis | Analysis Group | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | G0 | G1 | G2 | G3 | G4 | G5 | G6 | G7 | G8 | G9 | P | R |
| Dissolved Inorganic Nutrients | | X | X | X | X | X | X | X | X | | | |
| Dissolved Organic Carbon | | X | X | X | | | | | | | | |
| Total Dissolved N & P | | X | X | X | | | | | | | | |
| Particulate C & N | | X | X | X | | | | | | | | |
| Particulate P | | X | X | X | | | | | | | | |
| Biogenic Silica | | X | X | X | | | | | | | | |
| Chlorophyll & Phaeopigments | | X | X | X | X | X | X | | | X | | |
| Total Suspended Solids | | X | X | X | X | | | | | X | | |
| Dissolved Oxygen | | X | X | X | X | X | | X | | X | | |
| Urea | | X | X | | | | | | | | | |
| All Phytoplankton | | X | X | | | | | | | | | |
| Screened Phytoplankton | | X | X | | | | | | | | | |
| Zooplankton | | X | | | | | | | | | | |
| Areal Productivity | | | | | | | | | | | X | |
| Respiration | | | | | | | | | | | | X |

Frequency: Seventeen surveys per year during weeks number 6, 9, 12, 14, 17, 20, 25, 27, 30, 32, 34, 36, 39, 41, 44, 48, and 51.

Measurement: Phytoplankton and zooplankton identification and enumeration, urea, $^{14}C$ primary productivity, and respiration.

Location: Discrete samples at 2 stations (type D Figure 3-1) at two depths for phytoplankton and urea (surface and mid-depth), zooplankton by net tow. Primary productivity and respiration measurements at stations N04 and N18.

Frequency: Seventeen surveys per year during weeks number 6,9, 12, 14, 17, 20,25, 27, 30, 32, 34, 36, 39,41,44,48, and 51.

### Dilution

The dilution performance of the outfall will be evaluated and compared with design and model results. Revised dilution ratios will be used to update the NPDES permit and allow for better fate and transport evaluation of contaminants of concern.

Measurement: Continuous monitoring of sewage tracers such as salinity and dye (rhodamine WT added to the effluent for the survey). Hydrographic measurements to establish the current and density stratification field. The details of these measurements remain to be developed along with the workplan.

Location: Rectangular tracks in a twenty five square km area centered on the middle of the future outfa1l.

Frequency: Four surveys after the outfall becomes operational spread out over the year to represent various seasons. Measurements will be carried out in a time frame to cover typical tidal variations.

## 3.3.2 Farfield

Data is collected from far-field stations to establish reference conditions and to determine if a region-wide trend is occurring.

### Water Quality and Hydrography

Measurement: Dissolved ammonium, nitrate, nitrite, phosphate, and silicate; *in situ* temperature, salinity, dissolved oxygen, chlorophyll fluorescence, transmissometry, irradiance, depth of sensors, and altitude of sensors above seafloor.

Location: Discrete samples for nutrients at 26 stations (Figure 3-2) at five depths: one surface sample, two mid-depth samples that span the pycnocline when it exists, one mid-depth sample at the chlorophyll maxima, and one bottom sample (three depths at the shallower harbor stations). Continuous vertical profiles of

hydrographic measurements will be taken from surface to within 5 m of the bottom at each station.

Frequency: Six surveys per year during weeks number 6, 9, 14, 25, 34, and 41.

### Biology and Productivity

Measurement: Dissolved organic carbon, nitrogen, and phosphorus; particulate carbon, nitrogen, and phosphorus; total suspended solids; discrete chlorophyll-a (filtered samples) along with phaeopigments; dissolved oxygen.

Location: Discrete samples at 11 stations (type G or D in Figure 3-2) at 3 to 5 depths (depending on the parameter) as presented in Tables 3-3 and 3-4.

Frequency: Six surveys per year during weeks number 6, 9, 14, 25, 34, and 41.

Measurement: Phytoplankton and zooplankton identification and enumeration, urea, $^{14}C$ primary productivity, and respiration.

Location: Discrete samples at 9 stations (type D, Figure 3-2) at two depths for phytoplankton and urea (surface and mid-depth), zooplankton by net tow. Primary productivity measurements at station F23 (Figure 3-2). Respiration measurements at stations FI9 and F23.

Frequency: Six surveys per year during weeks number 6, 9, 14, 25, 34, and 41.

### Paralytic shellfish poisoning

The monitoring of PSP in shellfish beds is managed by Massachusetts Department of Public Health.

## 3.3.3 Special Studies

### Water Circulation, Particle Fate and Plume Tracking

An understanding of how the effluent would be transported away from the outfall area after initial dilution is necessary for an assessment of the risk associated with various contaminants dissolved in the effluent. An understanding of how particles would be transported, coagulate and settle is also important because many toxic contaminants tend to be sorbed on the particulate phase. The MWRA has entered into an cooperative agreement with the U.S. Geological Survey (USGS) since 1991 to perform some of these studies. The USGS maintains a moored array near the future outfall site for continuous monitoring of currents, conductivity (salinity), temperature, fluorescence (chlorophyll), and transmittance (turbidity). In addition, a sediment trap is employed at the mooring. Additional moorings could be employed, along with the use of drogues and drifters to ascertain long term average transport and sedimentation patterns. At a minimum the current USGS mooring at the outfall site will be maintained.

Plume tracking surveys are performed to determine the location and chemical and biological characteristics of the effluent discharge plume leaving the outfall and mixing with ambient waters. Physical characteristics will also be monitored. Continuous sensor measurements of salinity (conductivity), temperature, DO, chlorophyll (fluorescence), TSS (via optical beam transmittance) and perhaps acoustic techniques will be performed along with discrete water sample measurements (for calibration).

Remote Sensing

Remote sensing via satellite imagery offers the opportunity to evaluate spatial variations in the system, and to provide information on changes within the system which occur between monitoring surveys. Parameters which are available from satellite imagery include sea surface temperature and chlorophyll (e.g. Ocean Color and Temperature Scanner, OCTS). This imagery is available in processed form off the Internet; the monitoring program will access this imagery and use it in the synthesis of water column monitoring results.

### Primary productivity, Benthic nutrient flux, denitrification and oxygen demand

The relation between nutrient level, chlorophyll-a and primary production, as well as its impact on dissolved oxygen, are an important concern. Alternate methods for measuring primary productivity more efficiently are being explored.

An understanding of benthic nutrient flux is necessary for calculating a mass balance of nutrients, especially for nitrogen. The bottom water depletion of dissolved oxygen is due to both water borne oxygen demands (cBOD, respiration and decay of planktonic material) and sediment bound oxygen demand. A knowledge of both is necessary to understand the DO depletion rate. This is discussed in the Benthic Monitoring Section.

### Modeling

It has been recommended that the Bays Eutrophication Model (BEM) should be used to see whether DO conditions in 1992 to 1995 could be reproduced, and to be used for assessing future conditions. The original framework was ambitious in its design, with the ultimate goal to establish detailed cause and effect relations between nutrients, plankton growth and the subsequent impact on dissolved oxygen. The ability of such models for making predictions should be realistically assessed and re-evaluated, in particular whether deterministic models are applicable to complex environmental systems.

### Shoreline Pathogen Monitoring

It was recommended that shellfish bed monitoring for pathogens be integrated into the overall monitoring program (in conjunction with the Division of Marine Fisheries). This recommendation is under development.

## 3.4 Data Evaluation and Comparison to Thresholds

Post-discharge monitoring of the water column is similar to the baseline monitoring. The suite of measurements will provide all the necessary information for threshold comparisons (chlorophyll, DO, phytoplankton and zooplankton). Other measurements are made which serve as supporting information for interpreting the threshold parameters. Furthermore, the sampling provides data suitable for input to the Bays Eutrophication Model.

Dissolved Oxygen Concentration and Saturation

The concentration of dissolved oxygen is bottom waters of individual samples in the nearfield and Stellwagen basin has on occasion gone below the threshold values of 6 mg/l and 75% saturation during the baseline monitoring period. The factors that determine minimum DO are 1) the initial DO concentration before it starts to decline; 2) water temperature; 3) the total time of decline and; 4) the occurrence of mixing events. These items are closely linked to the onset stratification and the tinting of the fall overturn. Violation of the DO threshold during the baseline period indicates that low DO excursions of bottom waters in Massachusetts Bay occur naturally. This issue will require consideration during evaluation of post-discharge DO data.

Dissolved Oxvgen Depletion Rate

The DO depletion rate in bottom waters of the Nearfield and in Stellwagen Basin are of special concern. The numerous DO measurements over time will allow for calculations of the DO depletion rate, which will then be compared to the threshold levels. Standard linear regression of DO concentration versus time will be performed with collection data to calculate the DO depletion rate. This will be compared directly with the mean DO depletion rate measured in the baseline period (with the appropriate multipliers, e.g. 1.5 x for Caution Level).

Chlorophyll

Chlorophyll concentrations will be available from the nearfield and farfield surveys. These chlorophyll measurements will be aggregated by time and space to provide suitable values for comparison to the threshold levels. For example, mean seasonal chlorophyll concentrations in surface waters in the nearfield will be calculated and compared to the 95th percentile of the seasonal average concentration from the baseline period. Annual average chlorophyll from ship surveys in the nearfield area will also be calculated and compared to the threshold values. Additional measurements of chlorophyll are available from satellite imagery and from an instrument deployed on the long term USGS Mooring near the future outfall site.

Nuisance and Noxious Algae

Water samples are collected for identification and enumeration of phytoplankton. Special attention will be given to the three target species *Alexandrium tamarense, Nitzchia pungens and Phaeocystis pouchetii.* The Caution Level relates to the 95th percentile of the seasonal mean concentrations.

Zooplankton

The phytoplankton net tows described above will also provide samples for zooplankton identification and enumeration. These cell data will allow for a characterization of the community structure in both the nearfield and the farfield. This will be used to determine whether the nearfield region is becoming more like the inshore region rather its present status of being a transition between inshore and offshore regions.

Dilution

The special dilution studies will provide the information necessary for calculating the actual outfall dilution and comparison against designed dilutions. This information could be used along with effluent monitoring information for permit evaluation. The available effluent loading information can be used along with the measured dilution and plume tracking studies to further evaluate the long-term fate and transport of various parameters of concern (e.g. nutrients).

### Data Reporting

MWRA will develop a reporting schedule with the objective to expedite communication of threshold parameter results. For the water column monitoring, these include chlorophyll, oxygen, and nuisance phytoplankton species. Both chlorophyll and oxygen are monitored by *in situ* sensors which are post-calibrated using analytical results from discrete samples. The expedited reporting for these parameters will be:

- 1 week turnaround time (TAT) after each survey for a tabular summary of preliminary sensor un-calibrated results (e.g. Temperature, Salinity, DO, fluorescence, etc), to be accompanied by any supporting information regarding sensor offset, drift, or maintenance activity (membrane change) which may affect relative sensor output;

- 3 week TAT for a tabular summary of DO and chlorophyll analytical results to confirm preliminary sensor results, which will coincide with submittal of the survey report:

- two months (following last survey of each period) for periodic data reports, which are submitted five times per year.

MWRA will also require expedited reporting for nuisance phytoplankton taxa. Since the seasonal occurrences of the three taxa which have been identified as nuisance species *(Phaeocystis pouchetii, Alexandrium tamarense, and Pseudo-nitzschia multiseries)* vary widely, and together encompass almost the entire annual monitoring period, this reporting will be performed on a routine basis for each survey.

To achieve the objective of nuisance phytoplankton reporting, an extra screened phytoplankton sample will be collected at nearfield station N18 during each of the 17 nearfield surveys. This sample will be collected at the chlorophyll maxiinum depth. This approach will provide the best representation of the potential presence of nuisance taxa in the photic zone.

The extra screened sample will be qualitatively examined immediately upon receipt by the plankton subcontractor. The subcontractor will determine whether the nuisance taxa are present in the sample and estimate their density .In addition, the subcontractor will identify the dominant form of other taxa present. These results will be communicated with the plankton task manager, and, in the event that nuisance species are encountered, forward the results to the MWRA Water Column Task Manager. The results will also be included with the survey summary provided within one week of the survey's completion. Complete reporting of quantitative taxonomic analyses will be submitted within two months (following the last survey of each period) in the periodic plankton reports submitted five times per year.

# 4.0 BENTHIC MONITORING

One of the primary concerns with wastewater discharge into marine environments is organic enrichment of the seafloor, resulting in poorly oxygenated muds supporting impoverished communities of opportunistic colonizers which are pollution tolerant. Another concern is the build-up of toxic contaminants in the sediments that can be bioaccumulated by benthic organisms and eventually fish and shellfish that are commercially important. These concerns are justified in terms of sludge discharge (such as Boston Harbor prior to 1992 or the New York Bight) or primary treated effluent discharge (such as Los Angeles Hyperion plant prior to upgrade to secondary treatment) where particle loads are still relatively high. Effective dilution of the new outfall in Massachusetts Bay will help ensure only minor impact on the benthos within a relatively narrow zone around the diffuser.

## 4.1 Overview of Phase I Baseline Studies

The Benthic Monitoring Program was initiated in 1992 to focus on soft sediments near the site of the new outfal1 (the nearfield) with its line of 55 diffusers as well as selected sentinel stations in various parts of Massachusetts Bay and Cape Cod Bay (the farfield). It initially included 10 special stations at farfield locations sampled for biology in May 1992 as part of a USGS/MWRA survey, 20 stations in the nearfield sampled in August 1992, and 12 stations in the farfield also sampled in August 1992. However, achieving a good monitoring design for the nearfield area has been difficult due to the heterogeneity of habitats and paucity of muddy sites, and the sampling protocol was modified several times to find the best approach. Regardless of these changes, the baseline program should permit a full assessment of natural processes in the nearfield prior to the initiation of sewage disposal operations in 1998. Based upon the data through 1994, the nearfield was redefined for benthic monitoring as a 2-krn area around the outfall in which changes are most likely to occur once the outfall goes on line. The remainder of the original nearfield, and some of the nearshore farfield stations, have .since been termed midfield (see Table 4-1). Stations FF10, FF12 and FF13 are now midfield stations, but their designations have not been changed. See Figures 4-1, 4-2 for the location of these stations.

Twice since 1992, the spatial array of stations sampled with grab samples was integrated with the sediment profile camera to allow mapping of physical and biological patterns in Massachusetts Bay.

## Important Findings

In Western Massachusetts Bay, including the vicinity of the future effluent outfall, relic glacial topography and infrequent physical disturbances control sediment deposition in the near and midfield. This sedimentary regime results in a complex mosaic of sediment types in the mid- and nearfield, with small

**TABLE 4-1**

**Revised Station Grouping after Coats (1995)**

| Station Grouping | Distance from Outfall | Stations |
|---|---|---|
| nearfield<br>(diffuser-induced changes are expected) | 0-2 km | NF13, NF14, NF15, NF17, NF18, NRF19, NF23, NF24 |
| midfield<br>(diffuser-induced changes are less likely) | 2-8 km | MF2, MF4, MF5, MF7, MF8, MF9, MF10, MF12, MF16, MF20, MF21, MF22, FF10, FF12, FF13 |
| farfield<br>(diffuser-induced changes are highly unlikely) | >8 km | FF1A, FF4, FF5, FF6, FF7, FF9, FF11, FF14 |
| **The original grouping by Coats for the midfield was 2-7 km from the outfall, this has been modified to 2-8 km in this plan.** | | |

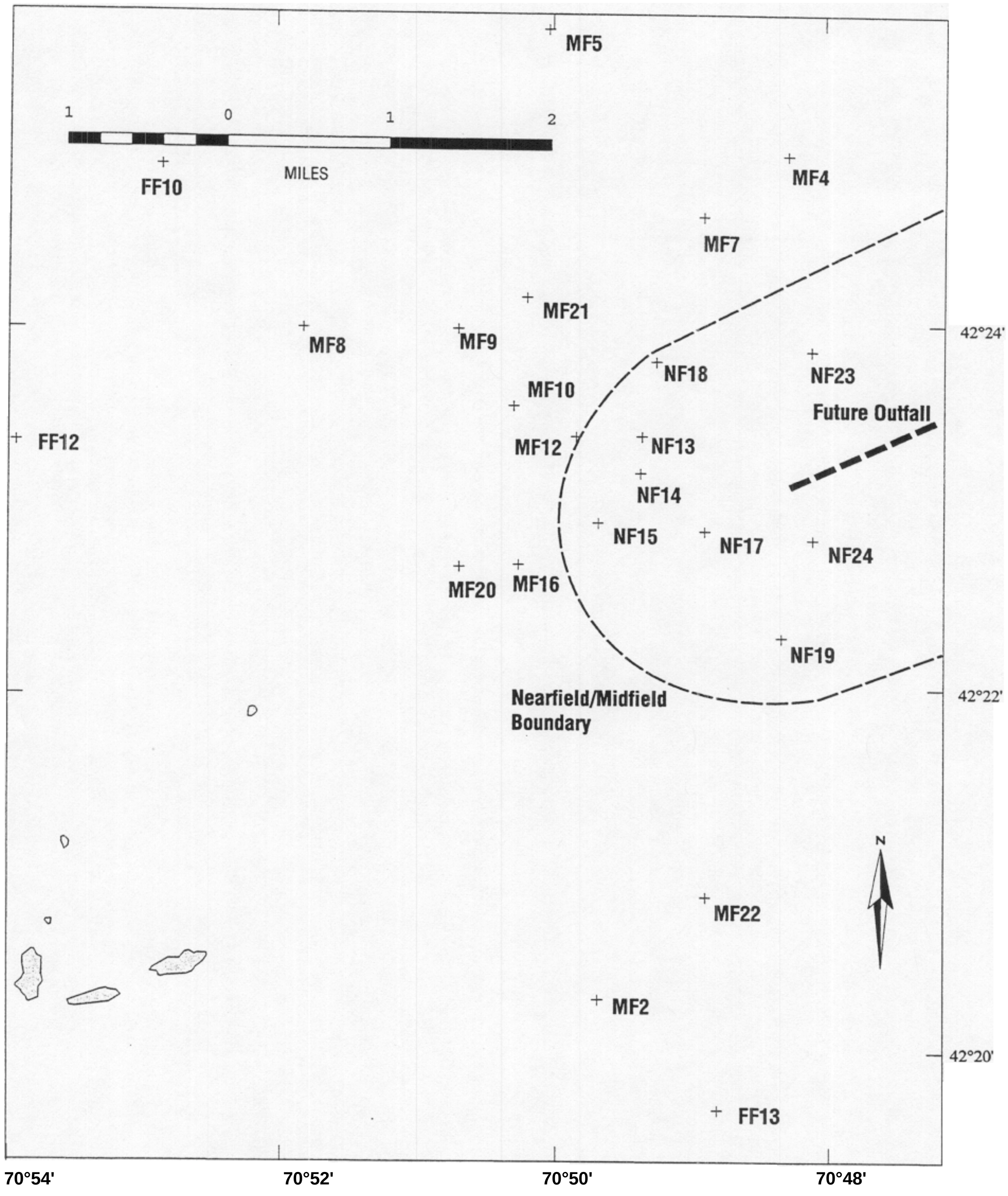


***FIGURE 4-1***

*Nearfield and Midfield Soft Bottom Stations.*

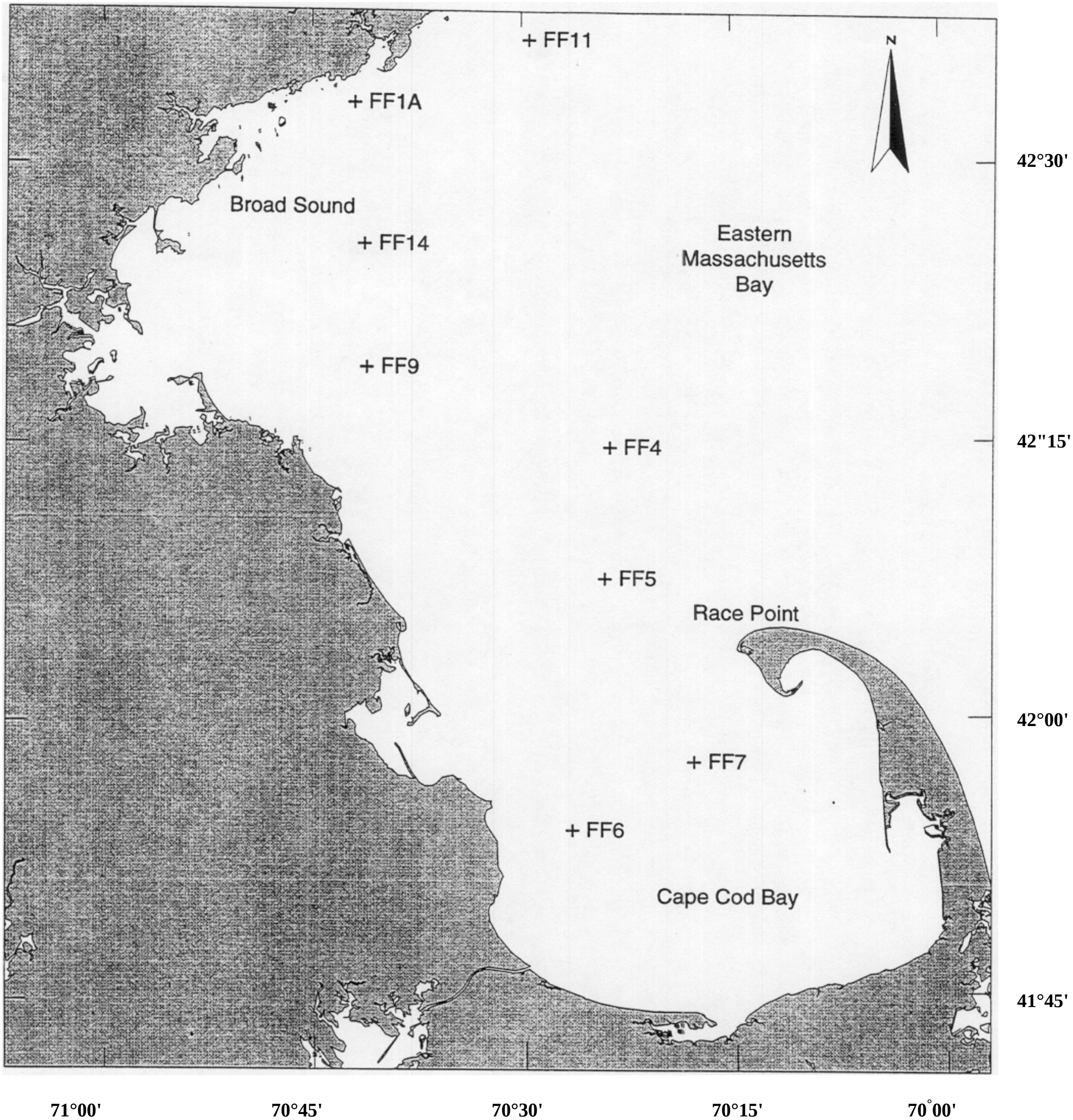


*FIGURE* **4-2**
*Station Locations for Grab Samples, Farfield.*

patches, about 100 to 1,000 m in diameter, of muddy depositional sediments interspersed with sandier patches and separated by expanses of erosional gravels, cobbles, and boulder-strewn submerged drumlins.

The presence of layered sediments, such as sand over mud, as well as changes in surficial grain size at some sites between years, has suggested active, storm-induced sediment transport.

The structure of the benthic communities in the near- and midfield is largely determined by sediment grain size. These structures have been observed in the area since inception of this program, with slight changes reflecting the shifting of sediments. Benthic community structure in the farfield is mostly influenced by water depth and also by location (Massachusetts Bay versus Cape Cod Bay). Species diversity and species composition have been varying over time, and likely have been a reflection of natural events such as larval settlement. The dominant benthic species at the future outfall site in 1995 was also abundant in 1987, but not in 1992 through 1994.

In 1994 and again in 1995, serni-quantitative video surveys were conducted in the hard-bottom areas adjacent to the new outfall to complement the soft-bottom studies. These two surveys have shown that location on the drumlins, depth. substratum type, and habitat relief all appear to playa role in determining the structure of benthic communities inhabiting hard-bottom areas in the vicinity of the future outfall. Benthic communities inhabiting drumlin tops are dominated by red algae, whereas the drumlin flanks and topographic lows are characterized by encrusting or attached fauna.

In 1995, organic contaminant concentrations in sediments were generally low and did not exceed any of the thresholds. Nearfield mean metal concentrations for all trace metals were below the ER-M sediment criteria. Mercury concentrations were relatively high at two individual stations, with the one at NF24 (1.69 ~g/g) exceeding the ER-M value of 0.71 ~g/g.

## 4.2 Contingency Plan Trigger Parameters and Threshold Levels

Based on the results of the Phase I Baseline Monitoring results, MWRA (1997) revised the Contingency Plan and linked potential management decisions to critical parameters. The levels applicable to the benthic environment are summarized in Table 4-2.

**TABLE 4-2**

**Trigger Parameters for the Benthic Environment**

| Parameter | Rationale for Threshold Parameters | Caution Level | Warning Level |
|---|---|---|---|
| Redox potential discontinuity in nearfield sediments | - Measures decrease in oxygen content in sediment environment | RPD depth declines by half. The threshold value is under development, average is about 3.5 cm in 1995 | |
| Toxic contaminants in nearfield sediments | - Measures potential for toxic effects on benthic marine life<br>- Thresholds based on national sediment quality criteria | 90% of EPA sediment criteria where available.<br>90% of NOAA ER-M or PEL, whichever is lower for a given contaminant | |
| Community structure (diversity, species composition, and species abundance) in outfall midfield area | - Provides measure of benthic community health | Species diversity, composition, and relative abundance patterns measured in the mid-field appreciably depart from those measured during the baseline monitoring period, after factoring out the effect of storms on sediment texture. Specific diversity threshold values are being developed. | |
| Species composition in the midfield (2-8 km from outfall): appearance of opportunistic species not encountered during baseline monitoring | - indicates changes in sedimentary environment | 25% shift of community toward opportunists | 50% shift of community toward opportunist's |

## 4.3 Phase II Monitoring Plan

### Soft-bottom benthos in the nearfield and farfield

Measurements: Benthic species composition and abundance as retained on 0.3 mrn sieves; chemical constituents including PAHS, LABS, PCBS, pesticides, metals, TOC; sediment grain size; *Clostridium perfringens* spore counts in the 0 to 2 cm depth fraction; and sediment profile images for measurement of RPD depth, and other physical and biological parameters.

Replication: In order to permit statistical comparisons between stations and years,. replication has been built into the sampling design. For the benthic biology samples, three replicate 0.04 m2 grab samples are collected at each of the farfield stations, nearfield stations NF17 and NF24 and midfield stations MF12, FF10, FF12, and FF13. The mix of replicated and non-replicated samples in the nearfield and midfield brings the total number of samples to 12 and 23 in each of these areas, respectively. According to Coats (1995), these 12 replicates can be treated as independent observations to provide sufficient statistical power to detect smaller scale changes in benthic parameters (e.g., 8% change in the Shannon-Wiener index, H' in the pooled midfield stations).

Location: Eight stations in the nearfield and 15 stations in the midfield. Eight stations in the farfield.

Frequency: One sampling per year (August) for all parameters. The OMTF has indicated that the measurement frequency for contaminants should be revisited after approximately two years of discharge monitoring data are available, and that a long-term sediment contaminant sampling frequency on the order of every 3-5 years should then be appropriate except organic and metal constituents which are to be sampled at 2-3 year intervals depending upon recommendation of the OMTF.

### Special study of hard-bottom benthos in the nearfield

Measurements: Benthic hard-bottom species composition as determined by 35-mm photography and video analysis; topography and sediment cover.

Location: Eight transacts along drumlins and other topographic features in the vicinity of the outfall to a distance of 2 mi (=3.2 km) north and south. See Figure 4-3 for suggested transect locations.

Frequency: One sampling per year (June to August timeframe ).

### Special studies on benthic nutrient flux

Benthic flux measurements have provided important information on bounds of the sediment denitrification rate, as well as the contribution of sediment oxygen demand to overall bottom water DO depletion rates.

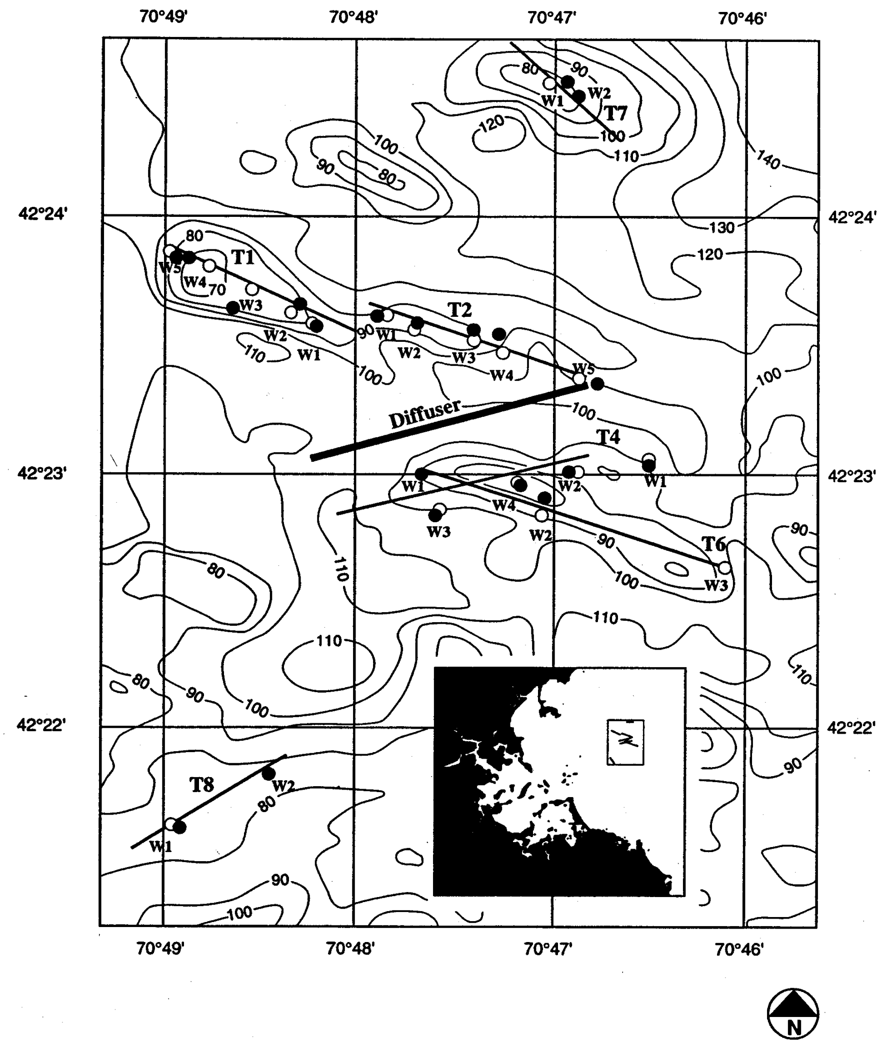


***FIGURE 4-3***
*Transect locations for nearfield hard-bottom video survey.*
*Open circles are 1995 stations; filled circles are 1996 stations.*

Measurements: Temperature, salinity and DO of the bottom water at each station when surveyed. Two cores per station will be incubated and measured for ammonia, nitrate & nitrite, urea, phosphate, silica and DO in the overlying water of those two cores per station every 2-8 hours. Total carbon dioxide will be measured at the beginning and end of the incubation. In addition, undisturbed sediment cores will be obtained from each station and measured for profiles of porewater ammonia, nitrate & nitrite, urea, phosphate, silicate, dissolved sulfides, pH, alkalinity and redox potential in at least 10 depths per station. Surficial sediments from each station will also be analyzed for total organic carbon, total nitrogen and grain size.

Location: See Figure 4-4 for location of benthic flux sampling locations.

Frequency: Four surveys each year during March, May, July, August and October.

### Special studies on sediment transport

In addition, the USGS maintains an active research program to study the transport of sediments in Massachusetts Bay.

## 4.4 Data Evaluation and Comparison to Thresholds

Coats (1995) developed a complex multivariate approach to test for change in the nearfield benthic communities. He also demonstrated that pooling of replicated and non replicated contaminant data within the nearfield and midfield provides sufficient statistical power to detect any increases in contaminant concentration well before concentrations of concern are reached. However, some caution needs to be exercised because there may be a bias in pooling multiple samples from one site with non-replicated samples that are more widely distributed among sediment types.

The multivariate analysis developed by Coats (1995) for detecting change in nearfield and midfield benthic communities from baseline variation shows promise as a sensitive indicator of change in species diversity and composition, but suffers from shortcomings that limit its application as a rapid response threshold. First, it is theoretically quite complicated, and is fully interpretable only to specialists in numerical ecology. Second, before the requisite analyses can be run, extensive checks must be carried out to ensure full comparability between a year's species identifications and the baseline data set. Occasional changes in the understanding of individual groups of organisms can lead to what were formerly thought to be 2 species lumped into a single group, or to the reverse situation, with a single taxon split into 2 new species. Multivariate analyses similar to those developed by Coats (1995) are particularly sensitive to the effects of this kind of change. Reconciling the implications of such changes to a multi-year data set can often required weeks, as appropriate taxonomic authorities must sometimes be consulted.

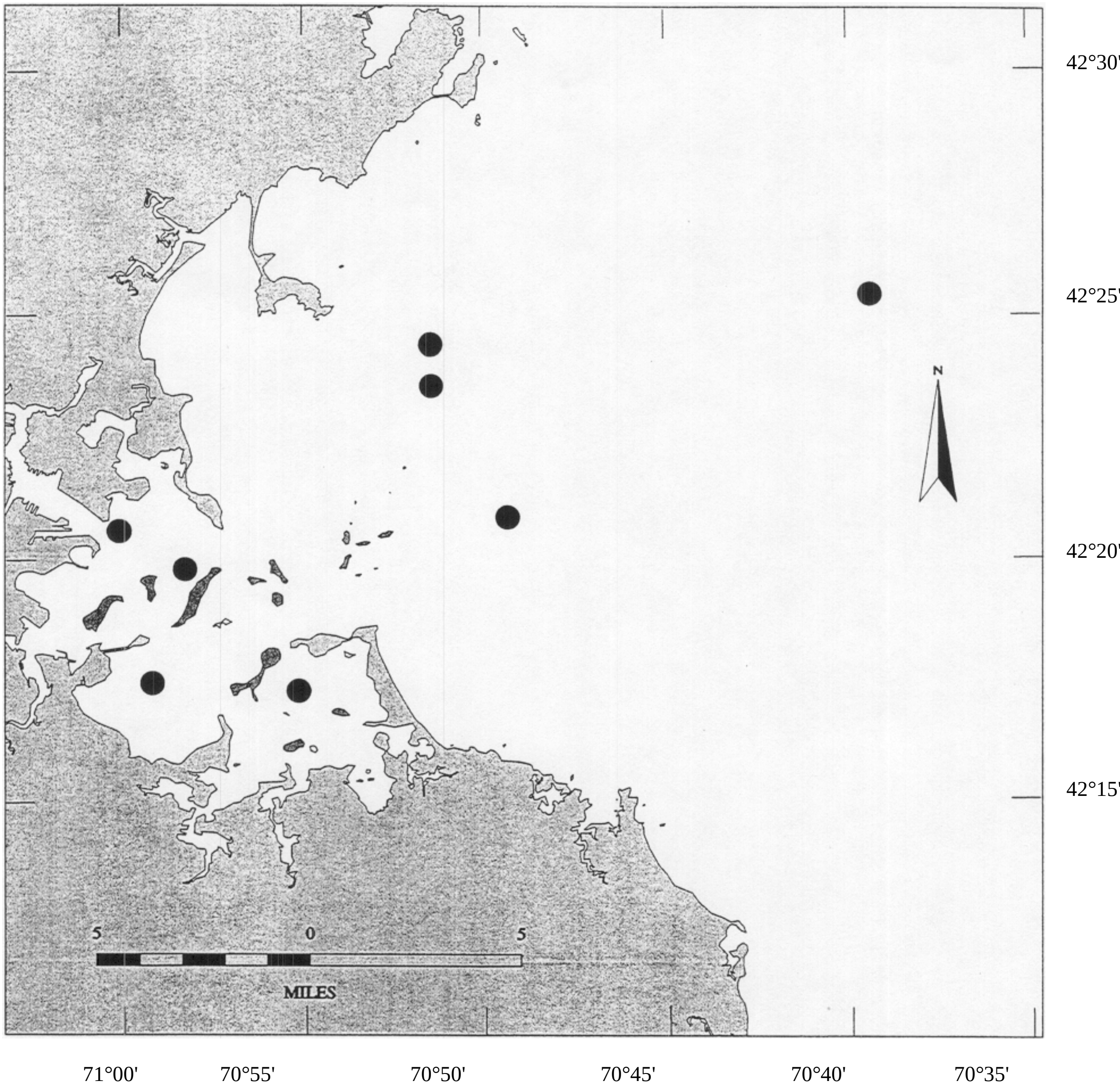


***FIGURE 4-4***
***Benthic Nutrient Flux Sampling Locations.***

Taken together, these shortcomings suggest that multivariate analyses similar to or derived from that of Coats (1995) are best used as confirmatory and/or interpretive analyses, with initial threshold testing carried out using parameters more readily understood by non-specialists, and less sensitive to minor changes in species identifications.

### Soft-bottom Benthos/Benthic Diversity

A suite of parameters was developed by ecologists in the past 50 years to summarize patterns of species richness, species diversity, abundance, and dominance. However, to date none have shown broad applicability as stand-alone indicators of change in sediment communities. Investigations to refine rapid response trigger parameters for threshold testing are ongoing, and revisions to the parameters described below will be submitted for OM1F review in early Spring 1998.

Data generated by these analyses will be compared with the baseline results to ensure that no appreciable impact has occurred. In the case of the soft-bottom benthos, the nearfield has been divided into a nearfield that is within 2 km of the discharge and a midfield that extends outside of the 2 km discharge radius to a distance of 8 km. An additional three farfield stations (each with three replicates) are also located in the midfield area.

Water quality model predictions of organic carbon deposition to the seafloor (Hydroqual and Normandeau, 1995) suggest that some faunal changes are likely within 2 km of the outfall, but not in the midfield. Therefore, while changes in near-field stations will be monitored, trigger levels apply to the midfield stations outside the 2-km boundary.

Currently, the most promising diversity parameter for threshold testing appears to be species diversity calculated with the Hurlbert rarefaction method at a sample size of 100 individuals. Ongoing threshold development efforts include deriving related measures of species evenness. Other diversity metrics, for example, the Shannon Wiener information function (H') and Pielou's evenness (J'*)* will continue to be calculated, but will probably not be primary thresholds.

Measures of species diversity cannot stand alone as indicators of community change, as the identities of the species present plays no role in their calculation. In other words, identical diversities might be calculated from 2 samples that share no species. Since changes in the types of species found in sediments (known as a community's composition) are frequent responses to pollution, diversity thresholds need to be coupled with a community composition threshold.

The establishment of trigger parameters for changes in species composition is difficult because there could be a range of natural changes possible depending upon the degree of perturbation on the community.

Caution levels might include the appearance of species in dominance lists that were not previously encountered at those stations or groups of stations. Warning levels might include the total dominance of these species coupled with a corresponding decrease in species diversity .For example, the common estuarine polychaete *Polydora cornuta* is a common indicator species in Boston Harbor, yet is rare in Massachusetts Bay. The appearance of *P. cornuta* at a midfield station might be interpreted as a shift to a stressed community because the species is normally found in situations where the RPD is shallow, species diversity is low, and organic loading is high. Likewise, the appearance of dense assemblage of amphipods, such as now occur in Boston Harbor, might be indicative of an altered sedimentary regime. Any such changes in faunal composition will need to be closely compared with the species diversity and sedimentary data in order to explain and understand the processes that have led to change. Suggested Caution (20%) and Warning (50%) Levels are presented in Table 4-2.

The hard-bottom study was established by OM1F as a supplemental study, not intended to duplicate the intensity (and ultimately the sensitivity) of the soft-bottom monitoring. Therefore, no thresholds have been established for this component. The hard-bottom program will focus on interpreting effects of the discharge within the outfall nearfield. Monitoring results (consisting of video and 35-mm slides) in the different habitat types will be compared against the baseline results. The video tapes will be viewed to provide information on the uniformity of the environment. Large, clearly identifiable organisms will be enumerated. Slides will be projected and analyzed for sea-floor characteristics and organisms. Most recognizable taxa will be recorded, counted and normalized to mean number of individuals per slide. Data from each waypoint will be pooled and examined by hierarchical classification. This consists of a pairwise comparison of the species composition of all waypoints using the percent similarity coefficient. Changes in species composition and increased sediment drape on the rocks may be evidence of impact. See Figure 4-3 for the location of the hard-bottom survey transects.

**Toxic Chemicals** in **Sediments**

The very low contaminant concentrations found in secondary effluent means that loading of contaminants from the future discharge will be small compared to the amounts already present in the environment (Mitchell, et al., 1997). Therefore, sediment-bound contaminant concentrations are not expected to change over short time scales (months to a year) as a result of the discharge, although moderate short-term fluctuations have been documented associated with major storm events (Bothner, et al., 1993). Nonetheless, concerns over short-term build-up of contaminants were sufficient for the OMTF to determine that during the first 2 to 3 years after discharge begin, all nearfield, midfield, and farfield stations should be sampled annually, and that a small, 3 to 4 station 2-year special study focussing on even shorter time scales (every 4 months) be designed to supplement the annual sampling and the USGS sediment transport study.

The OMTF has indicated that the measurement frequency for contaminants should be revisited after approximately two years of discharge monitoring data are available, and that a long-term sediment contaminant sampling frequency on the order of every 3 to 5 years should then be appropriate.

An OMTF subcommittee that evaluated the sediment contaminant program in April 1997 recommended that previously suggested contaminant thresholds (see, for example, MWRA, 1995) be modified as follows: Where EP A has recommended draft sediment quality criteria, a Caution threshold will be established at 90% of that level. Where criteria are not available, Caution Levels will be established for individual compounds at either 90% of the Effects Range-Medium Levels published in Long et al., (1995) or at the Probable Effects Levels established in MacDonald (1993). The subcommittee recommended that no Warning Level thresholds be established at this time.

The subcommittee recommended against the addition of sediment toxicity bioassays to the routine monitoring, however suggesting that such measurements may be useful supplementary measurements if contaminant thresholds are reached. A recent study in the area demonstrated no clear link between contaminant concentrations, measurements of sediment toxicity , and the apparent health of the benthic communities sampled (Hyland and Costa, 1995).

## Sediment Profile Image Analysis/RPD Depth

Sediment profile image analysis will provide an accurate estimate of the apparent depth of the redox potential discontinuity level (RPD) in sediments. The SPI camera also provides detail of surface benthic boundary features, sediment layering, grain size, methane, and various biological parameters including bioturbation and presence/absence of tube mats. An organism/sediment index can be generated, that when coupled with dissolved oxygen and *Clostridium pe1fringens* data can estimate the relative health of the seabed. A reduction in the depth of the RPD is an indication that water column dissolved oxygen is decreasing. Shallow RPDs will result in hydrogen sulfide production and possibly methane production. Deep RPDs are indicative of healthy conditions. The 1995 RPD by sediment profile image studies showed a range of 1.8 cm to greater than 6.2 cm, with a mean value of 3.5 cm.

In a monitoring program where short-term results may be crucial for identifying problems with sediment quality, the SPI camera offers the possibility of rapid data return. If necessary, the 35mm slides can be examined with a "quick-look" method that can be used to provide evidence of Caution Levels within 24 hours of sampling.

# 5.0 FISH AND SHELLFISH MONITORING

MWRA has continued to conduct a biomonitoring program for fish and shellfish, which supports evaluation of the future effluent outfall in Massachusetts Bay. The goal of the biomonitoring program is to obtain baseline data that may be used to assess the potential environmental impact (i.e., protection of human health and biological resources) of the effluent discharge on Massachusetts Bay, and to evaluate the facility's compliance with threshold values.

The specific objective of the fish and shellfish monitoring program to date has been to define the baseline condition of three indicator species: winter flounder (*Pleuronectes americanus* ), Northern lobster (*Homarus americanus),* and blue mussel (*Mytilus edulis).* These three indicator species are used to evaluate environmental impacts to: bottom-dwelling fish (winter flounder); surface-dwelling macroinvertebrates (lobster); and water-column filter-feeder (blue mussel). Body burdens of certain pesticides (DDT , aldrin/dieldrin, chlordane, heptachlor, etc.), PCBS, lead, and mercury were compared to FDA Action limits and monitoring program warning limits to evaluate potential risk or trends. Finally, the results were evaluated for their ability to answer the underlying monitoring hypotheses.

## 5.1 Overview of Phase I Baseline Studies

Earlier bioaccumulation studies by MWRA have utilized blue mussels and analyzed for PAHS, selected pesticides, PCBS, lead, copper and zinc. The current baseline fish and shellfish monitoring program added more metals, mercury in particular (see Table 5-1). As shown on Figure 5-1, specimens were collected from sites in Boston Harbor (Deer Island Plats, off *Discovery* ), Massachusetts Bay (Future Outfall Site, Nantasket Beach, Broad Sound), and Eastern Cape Cod Bay. Baseline conditions were characterized in terms of biological parameters (length, weight, biological condition); the presence/absence of disease (both internal and external); and concentrations of organic and inorganic compounds in various tissues. These tissues included: for the winter flounder -liver and filet; for the northern lobster -hepatopancreas and tail meat; and for the blue mussel -soft tissue. The monitored parameters were examined for spatial trends between stations and interannual variations from previous monitoring data. Since the mussels are incubated *in situ* in caged arrays, the predeployment mussels serve as experimental controls. Table 5-1 summarizes the chemical analyses performed for fish and shellfish.

Gross deformities, parasites or visually apparent diseases are noted for both collected flounder and lobster. In addition, histological measurements in flounders are used (in particular, liver lesions) as a measure of their general health, which in turn reflect on the ecological status of their general environs.

## TABLE 5-1

### Chemistry Analyses for Fish and Shellfish Monitoring

| Organism | Number (Type of Samples) | Parameters |
|---|---|---|
| Flounder | 9 or 15 composites (fillet)* | Mercury<br>PCB<br>Chlorinated pesticides<br>Lipids |
| Flounder | 9 or 15 composites (liver)* | Trace metals<br>PCB<br>PAH<br>Chlorinated pesticides<br>Lipids |
| Lobster | 9 composites (meat) | Mercury<br>PCB<br>Chlorinated pesticides<br>Lipids |
| Lobster | 9 composites (hepatopancreas) | Trace metals<br>PCB<br>PAH<br>Chlorinated pesticides<br>Lipids |
| Mussel | 20 composites (soft meat) | Mercury<br>Lead<br>PCB<br>PAH<br>Chlorinated pesticides<br>Lipids |

**1 = Chemical analyses of flounder and lobster meat are conducted on three composite samples per stations. Composites are comprised of the pooled biological material from 5 individual specimens. For flounder, three monitoring stations were occupied in 1995 and 1997, by inclusion of the Nantasket Beach and Broad Sound five were occupied in 1996 (yielding 15 samples)**

**2 = Chemical analyses of mussel tissue is conducted on five composite samples per station (at 3 monitoring stations + 1 predeployment station). Composite are comprised of the pooled biological material from 10 individual specimen.**

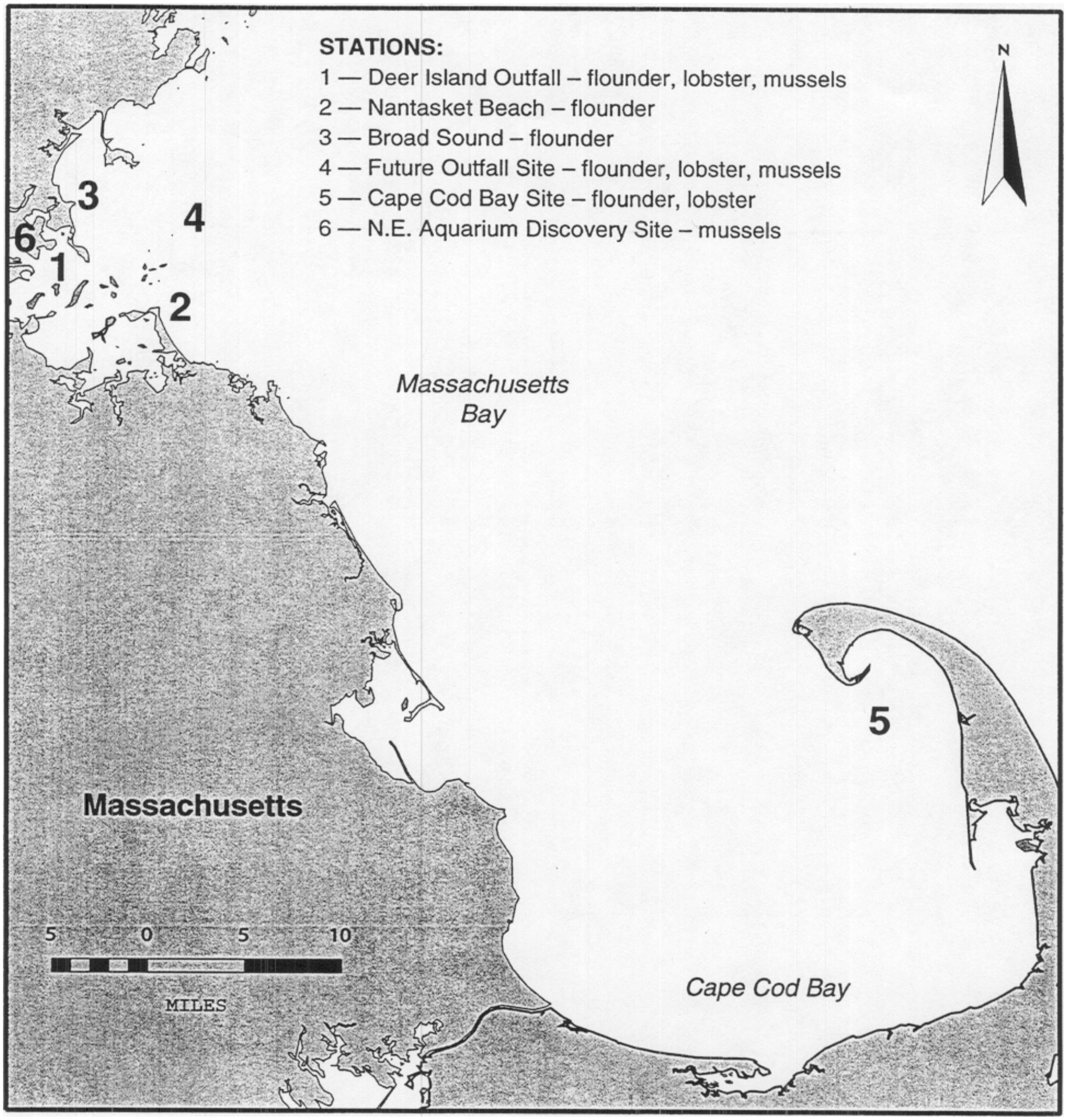


***FIGURE 5-1***
*Sampling Stations for Winter Flounder, Lobster and Mussels during 1996.*

## Important Findings

The baseline fish and shellfish monitoring program has shown that contaminant concentrations are generally higher in flounder from Boston Harbor than from the future outfall site. Contaminant concentrations at the future outfall site are generally higher than similar measurements from a site in Cape Cod Bay. However, the highest 1995 mercury concentrations were present in flounder from the future outfall site. The 1995 data indicated significantly increased concentrations of DDT and PCBs over values from previous years. Liver lesions are present in flounder from all sites though the frequency of lesions has been decreasing from year to year. In lobster, the highest organic contaminant concentrations in 1995 were present at the future outfall site. Metal concentrations in lobster were lowest in Cape Cod Bay and similar at other sites, except for mercury which was highest at the future outfall site. Fish and shellfish contaminant concentrations have been consistently well below levels that might cause any concern because of human consumption.

The 1995 findings are consistent with results from earlier baseline years, which reported elevated levels of some toxic contaminants in the lobster hepatopancreas (commonly referred to as the "tomalley"). This finding has been observed in coastal Massachusetts waters for some time and was the basis for a Massachusetts Department of Public Health advisory on the consumption of tomalley issued in 1988.

## 5.2 Contingency Plan Trigger Parameters and Threshold Levels

Based on results from the baseline studies, MWRA (1997) revised the Contingency Plan and linked potential management decisions to the critical parameters. The trigger parameters and threshold levels applicable to Fish and Shellfish are summarized in Table 5-2. The threshold values for edible tissue body burdens are more conservative than federal Food and Drug Administration (FDA) limits based on human health risk.

## 5.3 Phase II Monitoring Plan

The Phase II Post-discharge Monitoring Plan will be consistent with monitoring conducted during Phase I Baseline Studies. The basic premises remain the same -that of protection of human health for fish and shellfish consumption and maintenance of the ecological health of the benthic communities. The details of the Phase n Monitoring Plan are considered below. See Figure 5-1 for the location of the sampling stations.

**TABLE 5-2**

**Trigger Parameters for Fish and Shellfish**

| Parameter | Rationale for Threshold Levels | Caution Level | Warning Level |
|---|---|---|---|
| Mercury in fish and shellfish tissue near outfall | - Human health FDA limit | 0.5 μg/g wet weight | 0.8 μg/g wet weight |
| Total PCB in fish and shellfish tissue near outfall | - Human health FDA limit | 1 μg/g wet weight | 1.6 μg/g wet weight |
| Lead in mussel near outfall | - Human health FDA limit | 2 μg/g wet weight | 3 μg/g wet weight |
| Lipid normalized toxics in fish tissue near outfall | - Indicator for ecological and human health | 2X baseline | |
| Liver disease incidence in flounder | - Indicator for ecological health | Greater than average harbor prevalence from 1991 to 1997 | |

**Flounder and lobster**

Measurements: PCB, pesticides, mercury and lipids in flounder fillet, and lobster meat. PCB, PAH, trace metals, pesticides, and lipids for flounder liver, and lobster hepatopancreas. Histological analysis for flounder liver. Animal size, mass, and dry/lipid weight will also be recorded.

Location: For flounder, Deer Island flats, Future Outfall Site and East Cape Cod Bay, Nantasket Beach and Broad Sound Sites sampled every year for histology with the Nantasket Beach and Broad Sound fish being analyzed for chemical constituents every other year. For lobster, the Deer Island flats, Future Otufall Site and East Cape Core Bay Sites are sampled every year.

Frequency: Once a year during April for flounder and July-August for lobster. Biological material from fifteen specimens from each station are pooled to form three composite samples of 5 individuals each for chemical analysis. Fifty histological sections to be made per station for flounder liver.

### Mussels

Measurements: PAH, PCB, pesticides, mercury and lead.

Location: Outside the mixing zone near the Future Outfall Site, In-Harbor reference site (Discovery Site).

Frequency: Caged mussels in replicate arrays (with > 50 mussels each) deployed at mid-depth or below the pycnocline. Deployment will be for 60 days during June through August. Biological material from 50 mussels from a station as pooled to form five composite sample (10 specimens per sample) for chemical analyses.

### Special Studies

Currently there are no special studies to be conducted for Fish and Shellfish Monitoring under the Phase n Monitoring Plan. Such studies will be considered on a case-by-case basis, such as in the event that threshold values are repeatedly exceeded.

## 5.4 Data Evaluation and Comparison to Threshold Values

Data evaluation and comparison to threshold values are conducted for two types of trigger parameters. The first is based on comparison of contaminant levels to risk-based Caution and Warning Levels (Section 5.4. I) and the second is based on relative increases in indicator parameter (Section 5.4.2). A summary of the data sources and comparison for evaluation of the trigger parameters is contained in Table 5-3.

**TABLE 5-3**

**Data Sources and Comparison for Trigger Parameter Threshold Values**

| Parameter | Data Source | Comparison |
|---|---|---|
| **A. Contaminants in Fish and Shellfish** | | |
| 1. Mercury in fish and shellfish meat near future outfall site | Data: | Wet weight mercury concentration of composite flounder fillet or lobster tail/claw meat from future outfall site. |
| | Reported In: | MWRA Annual Fish and Shellfish Report. |
| | Comparison: | • Mean tissue concentration vs. Caution Level and/or Warning Level |
| 2. Total PCB in fish and shellfish meat near future outfall site | Data: | Wet weight total PCB concentration of composite flounder fillet or lobster tail/claw meat from future outfall site. |
| | Reported In: | MWRA Annual Fish and Shellfish Report. |
| | Comparison: | • Mean tissue concentration vs. Caution Level and/or Warning Level |
| 3. Lead in mussel near future outfall site | Data: | Wet weight lead concentration of caged mussels from future outfall site. |
| | Reported In: | MWRA Annual Fish and Shellfish Report. |
| | Comparison: | • Mean tissue concentration vs. Caution Level and/or Warning Level |

## TABLE 5-3 (Cont'd)

### Data Sources and Comparison for Trigger Parameter Threshold Values

| Parameter | Data Source | Comparison |
| --- | --- | --- |
| **B. Ecological Health Parameter** | | |
| 4. Lipid-normalized toxics in fish and shellfish tissue near future outfall site | Data: | Lipid-normalized PAHs, PCBs/pesticides, and mercury in founder liver and lobster hepatopancreas from future outfall site |
| | Reported In: | MWRA Annual Fish and Shellfish Report |
| | Comparison: | • Mean tissue concentration vs. mean "baseline" concentration |
| 5. Liver disease incidence in flounder | Data: | Prevalence of centrotubular hydropic vacuolation (CHV) in founder liver at future outfall site. |
| | Reported In: | MWRA Annual Fish and Shellfish Report. |
| | Comparison: | • Mean prevalence of CHV vs. 1991-1997 baseline conditions in harbor. |

### 5.4.1 Contaminant Concentrations in Fish and Shellfish

The thresholds for fish and shellfish include the Caution Level and Warning Level for mercury and PCBs in fish and lobster edible tissue and for lead in mussels. Exceedance of the Caution Level by the mean of composite samples collected near the outfall should be noted but no further action would probably be required, unless an increasing trend appeared to be developing. Exceedance of the Warning Level by the mean of the composite samples could lead to further analysis such as revalidating lab results or running additional replicate analyses (if tissue is available). Further elaboration of contingency plans for repeated exceedances of the Caution Level or Warning Level have yet to be established. However, based on current trends (described in Section 2.1), there is no reason to anticipate that environmental conditions will change following diversion to cause an exceedance of the Caution Level or Warning Level for the monitored species.

### 5.4.2 Ecological Health Indicators

In addition to the parameters which are used to evaluate potential human health risk, there are parameters which are used as indicators of overall fish -and shellfish community health (Ecological Indicator Parameters). Unlike the contaminant threshold parameters discussed in Section 5.4.1, these thresholds are triggered by relative rapid increase in parameter. These thresholds include a relative increase (i.e., 2X the baseline level) of lipid-normalized toxics in the fish and shellfish edible tissues or the incidence of liver lesion in flounder liver. The use of the relative increase criterion provides a pragmatic trigger for investigating a rapid increase in the amount of tissue burdens or histopathological lesions. While the increase, in itself, may not result in an adverse impact to the fish or shellfish communities, it does provide a measurable indication of potential deterioration in water or sediment quality that may need further investigation. It should be recognized, however. that these trigger parameters have indirect application to human health concerns as well.

Application of a statistical comparison or evaluation of these Ecological Indicator Parameters in Phase II may require further discussion as to what constitutes "baseline' conditions (i.e., does this only apply to years 1991-1997?). For example, it has not been determined whether the mean, maximum, or range of values best constitutes the baseline. Summation and analysis of the current baseline data (i.e., 1991-96 data sets) for the individual monitoring parameters has indicated that a significant increase is detectable to a level below the Caution Level. A simple metric of statistical change (a one-tested T-test at 5% significance) can be used to indicate significant change at levels below an exceedance of the Caution Level. This potentially allows refinement of the monitoring program in the following year, if necessary, to modify or increase monitoring effort for that parameter. In addition, some type of trend analysis (i.e., multivariate analysis) with comparison of the temporal and spatial results will potentially be useful.

Comparison of the histopathology results is straight forward due to the large sample size (50 per station). In this case, a comparison of the mean prevalence of hepatocellular hydropic vacuolation to the mean and standard deviation of the "baseline" years could be used to evaluate whether the year's results is significantly higher (e.g., one-tailed t-test or nonparametric equivalent).

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