Briefing for OMSAP workshop on ambient monitoring revisions
March 31-April 1, 2003

Massachusetts Water Resources Authority

Environmental Quality Department
Report 2003-ms-083

Information Briefing to Outfall Monitoring Science Advisory Panel

To: Dr. Andrew Solow, Chair OMSAP
From: Dr. Andrea Rex, Director, Environmental Quality, MWRA
Cc: OMSAP, IAAC, PIAC
Date: March 21, 2003
Subject: Briefing materials for review of effluent, fish and shellfish, sediment contamination and hard-bottom community monitoring

MWRA is in the process of reviewing its outfall monitoring program, using the process described in its NPDES discharge permit. As the Outfall Monitoring Science Advisory Panel requested, a two-day workshop has been scheduled for March 31 and April 1, 2003 to review the Outfall Ambient Monitoring Plan. The monitoring areas for review include effluent, fish and shellfish, sediment contamination, and hard-bottom communities. Briefing materials for each of these four monitoring areas, together with an introduction, are attached. MWRA is preparing a CD of appendices that include related synthesis reports and additional data. The CD will be available on MWRA's website, or can be obtained on disk from MWRA on request.

A second two-day workshop to review water column monitoring is scheduled for June 18 and 19, 2003, and a later one-day workshop will be scheduled to review benthic community monitoring.

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I INTRODUCTION

Since 1985, MWRA has worked to minimize the effects of wastewater discharge on the marine environment by ending the discharge of sludge and inadequately treated effluent into Boston Harbor, reducing pollutants at their source, improving wastewater treatment to modern standards, and providing increased dilution. Concerns about potential effects of moving the effluent outfall from the harbor to Massachusetts Bay have been recognized by MWRA and by the joint permit for the outfall issued by the U.S. Environmental Protection Agency (EPA) and the Massachusetts Department of Environmental Protection (MADEP).

MWRA is committed to ensuring good treatment and to conduct monitoring necessary to ensure that environmental impact of the discharge is minimal. This commitment is formalized in MWRA's discharge permit, which requires MWRA to monitor the effluent and the ambient receiving waters for compliance with permit limits and in accordance with the monitoring plan (MWRA 1991, 1997a). EPA and MADEP have established an independent panel of scientists, the Outfall Monitoring Science Advisory Panel (OMSAP), to review monitoring data and provide advice on key scientific issues related to the permit. The monitoring plan can be modified, under OMSAP's guidance, to incorporate new scientific information and improved understanding resulting from the monitoring.

In the current fiscal year, MWRA will spend over $5 million on effluent monitoring and environmental studies of Massachusetts Bay.

Table I-A. Breakdown of July 2002-June 2003 permit-required monitoring costs by project area

Project area	MWRA cost	Cost-share
Effluent	$330,000	$79,000
Outfall	$3,702,000	$895,000
water column	1,835,000	595,000
benthos	1,155,000	300,000
fish/shellfish	368,000	
pathogens	344,000	
Model	$136,000	$52,000
Permit reporting and management	$900,000	
Total	$5,068,000	$1,026,000

MWRA's outfall monitoring program (MWRA, 1991, 1997a) was originally designed to determine the effects on Massachusetts Bay of five years of discharge of primary-treated effluent followed by continued discharge of secondary-treated effluent. The expected contaminant loads from the discharge (EPA, 1988) were based on very imprecise estimates. Because of concern about the effects of a primary treated discharge on dissolved oxygen, organic loading to the sea floor, and accumulation of toxic contaminants, the monitoring program was quite comprehensive. Due to outfall construction delays, the secondary treatment plant was completed before offshore discharge started. In addition, effluent flow is lower than had been estimated, meaning more of the flow receives secondary treatment. Finally, measured toxic contaminant concentrations are lower than had been assumed in outfall siting studies even for full secondary treatment (see Table I-B.) There are now more than two years of post-discharge monitoring to compare with baseline conditions; monitoring results to date document minimal environmental effect. Thus it is appropriate to revisit the monitoring program, as recommended by the National Research Council (NRC, 1990), and refocus it on the potential for long-term chronic effects. Ongoing effluent monitoring will remain the core of the monitoring program.

Table I-B: Projected Supplemental Environmental Impact Statement (SEIS) Contaminant Loadings (EPA, 1988) *vs.* Measured Loadings (pounds/day)

	SEIS projection (average day, year 2020)	2000 actual (relatively low percentage secondary)	2002 actual (high percentage secondary)
Flow (million gallons/day)	390	381	336
Percent of flow receiving secondary treatment	100	85	96
Cadmium	4.2	0.4	0.2
Chromium	21.2	5.1	3.8
Copper	72	60.1	40.3
Lead	29.9	<10.4	<5.5
Mercury	1.3	0.11	0.07
Nickel	53.8	10.7	8.3
Silver	1.8	1.9	1.2
Zinc	207.9	124.8	84.7
total DDT	0.033	0.005	0.004
total PCB	0.3	0.02	0.006

The monitoring task areas under discussion at the March 31-April 1, 2003 OMSAP workshop include effluent, fish and shellfish, sediment chemistry, and hard-bottom community monitoring. For each area, this briefing package includes a brief summary of the monitoring approach, a description of key results, and MWRA recommendations for monitoring plan modifications.

No modifications are being recommended to effluent monitoring at this time. Recommended changes to the fish and shellfish monitoring are in frequency of sampling, and, for flounder, deletion of two sampling stations. Sediment chemistry monitoring would include more integration of results from grab samples, sediment cores, and sediment traps, with most stations having the full suite of contaminants analyzed every third year rather than every year. Recommended changes to the hard-bottom study are to drop one or more of the highly variable stations and to add a more distant reference station.

References

EPA. 1988. Boston Harbor Wastewater Conveyance System. Supplemental Environmental Impact Statement (SEIS). Boston: Environmental Protection Agency Region 1.

MWRA. 1991. Massachusetts Water Resources Authority effluent outfall monitoring plan: Phase I baseline studies. Boston: Massachusetts Water Resources Authority. Report ENQUAD ms-02. 95p.

MWRA. 1997a. Massachusetts Water Resources Authority effluent outfall monitoring plan: Phase II post discharge monitoring. Boston: Massachusetts Water Resources Authority. Report ENQUAD ms-44. 61p.

NRC. 1990. Managing Troubled Waters: The Role of Marine Monitoring. National Research Council. National Academy Press, Washington, DC. 125pp.

II MWRA EFFLUENT MONITORING

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II-1 Ensuring Effluent Quality: Pollution Prevention and Wastewater Treatment

The most important part of protecting Massachusetts Bay from pollution is ensuring that the final treated effluent is as clean as possible. MWRA accomplishes this through a vigorous pretreatment program and pollution prevention initiatives that minimize toxic contaminants entering the waste stream, and by maintaining and operating the treatment plant well. The MWRA toxic reduction and control program sets and enforces limits on the types and amounts of pollutants that industries can discharge into the sewer system. This has the important effect of minimizing contaminants in effluent and in the sludge that is removed during secondary treatment, enabling beneficial re-use of treated sludge.

Secondary treatment further reduces the concentrations of contaminants of concern (except nutrients) that are in the effluent that is ultimately discharged to Massachusetts Bay.

To prevent accidental discharge of pollutants to the system, MWRA has implemented best management practice plans for the Deer Island plant, its headworks facilities, the combined sewer overflow facilities, and the sludge pelletizing plant. Best management practices include daily visual inspections and immediate corrective response. Effectiveness of BMP measures are assessed by non-facility staff.

The extensive monitoring required in MWRA's stringent discharge permit, and the additional monitoring required in the Ambient Monitoring Plan and the Contingency Plan demonstrate how well the flow is treated.

MWRA is not proposing modifications to the effluent requirements in the Ambient Monitoring Plan at this time. Effluent monitoring data are presented here in detail because these results show that the plant is performing as well or better than anticipated in initial environmental impact studies during the treatment plant's design phase, and because the quality of the effluent provides a foundation for changes that MWRA will propose in the fish and shellfish and sediment contamination monitoring.

Pollution prevention

Details of MWRA's pollution prevention program are in the "*Massachusetts Water Resources Authority Industrial Waste Report, No. 18 October 2002*" on the web at http://www.mwra.com/sewer/html/trac_indust02.pdf. In addition to regulation of industrial discharges, MWRA's recent initiatives include programs for source reduction of mercury from dental facilities and household hazardous waste education programs. The report shows that in FY02 (ending June, 2002) there was no evidence of interference with treatment by toxic contaminants at the Deer Island Treatment Plant (DITP); sludge pellets met EPA Type 1 sludge criteria and met Massachusetts DEP criteria for Type 1 sludge except for molybdenum. In

August, 2002 however, a high-sulfate industrial discharge to DITP did cause an upset of the secondary treatment process, discussed further below in section II-3.

Table II-1.A summarizes levels of influent organic and metal contaminants to the Deer Island Treatment Plant, which have remained at low levels since the early 1990's.

Table II-1.A Influent contaminant loadings

Constituent	Loading (lbs/day)	
	2001	2002
Arsenic	2.4	2.2
Chromium	15.0	10.0
Copper	188	172
Lead	37.2	25.3
Mercury	0.67	0.48
Nickel	14.4	11.0
Silver	4.9	3.9
Zinc	321	294
VOA	532	485
Pesticides	0.040	0.043
Phthalates[1]	58.9	64.1
Total phenols	104	120
PAHs[2]	28.5	26.5

[1] **Phthalates:**
BIS(2-ETHYLHEXYL)PHTHALATE
BUTYL BENZYL PHTHALATE
DI-N-BUTYLPHTHALATE
DI-N-OCTYLPHTHALATE
DIETHYL PHTHALATE
DIMETHYL PHTHALATE

[2] **PAH's** are estimated based on 9 samples and include
2-METHYLNAPHTHALENE
ACENAPHTHENE
ACENAPHTHYLENE
ANTHRACENE
BENZO(A)ANTHRACENE
BENZO(A)PYRENE
BENZO(B)FLUORANTHENE
BENZO(GHI)PERYLENE
BENZO(K)FLUORANTHENE
CHRYSENE
DIBENZO(A,H)ANTHRACENE
DIBENZOFURAN
FLUORANTHENE
FLUORENE
INDENO(1,2,3-CD)PYRENE
NAPHTHALENE
PHENANTHRENE
PYRENE

Effects of Secondary Treatment

Biological secondary treatment effectively removes the remaining contaminants except for nutrients. Figure II-1A shows how the proportion of flows receiving secondary treatment increased as construction on the DITP progressed; the final battery of secondary treatment was completed in the spring of 2001 (mid FY2001). Figure II-1.B shows how solids discharges from MWRA sources including Deer Island and Nut Island treatment plants and sludge decreased by 80% since the beginning of the Boston Harbor project and Figure II-1.C illustrates how biochemical oxygen-demanding constituents also dramatically declined.

Figure II-1.A MWRA primary and secondary treated flows 1990-2002

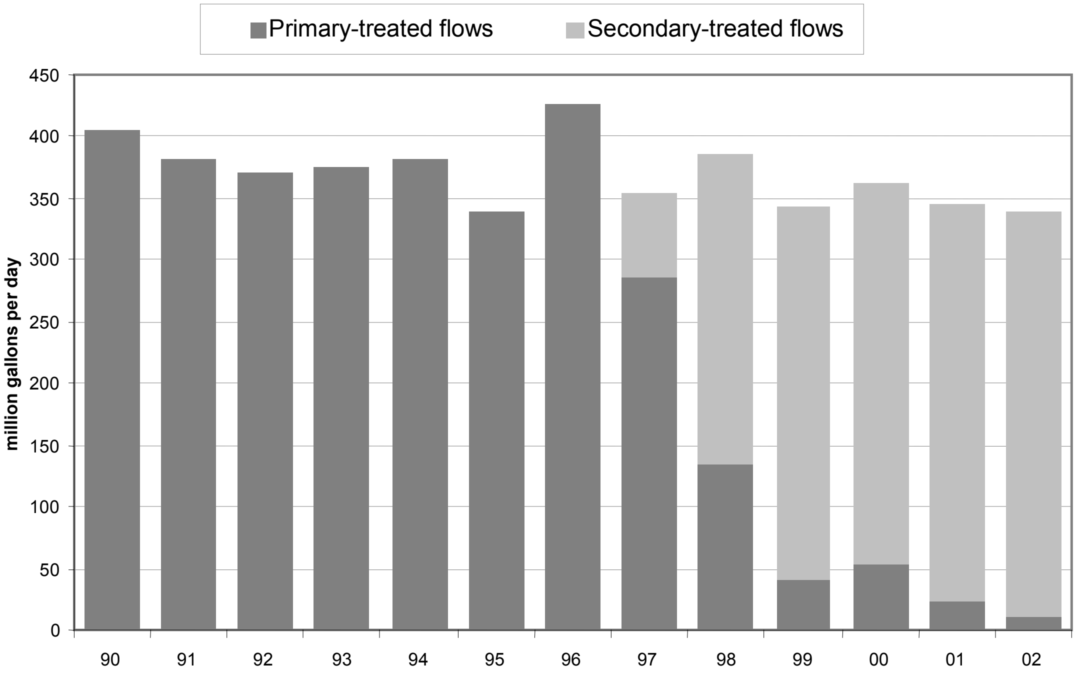


Figure II-1.B MWRA solids discharges 1988-2002

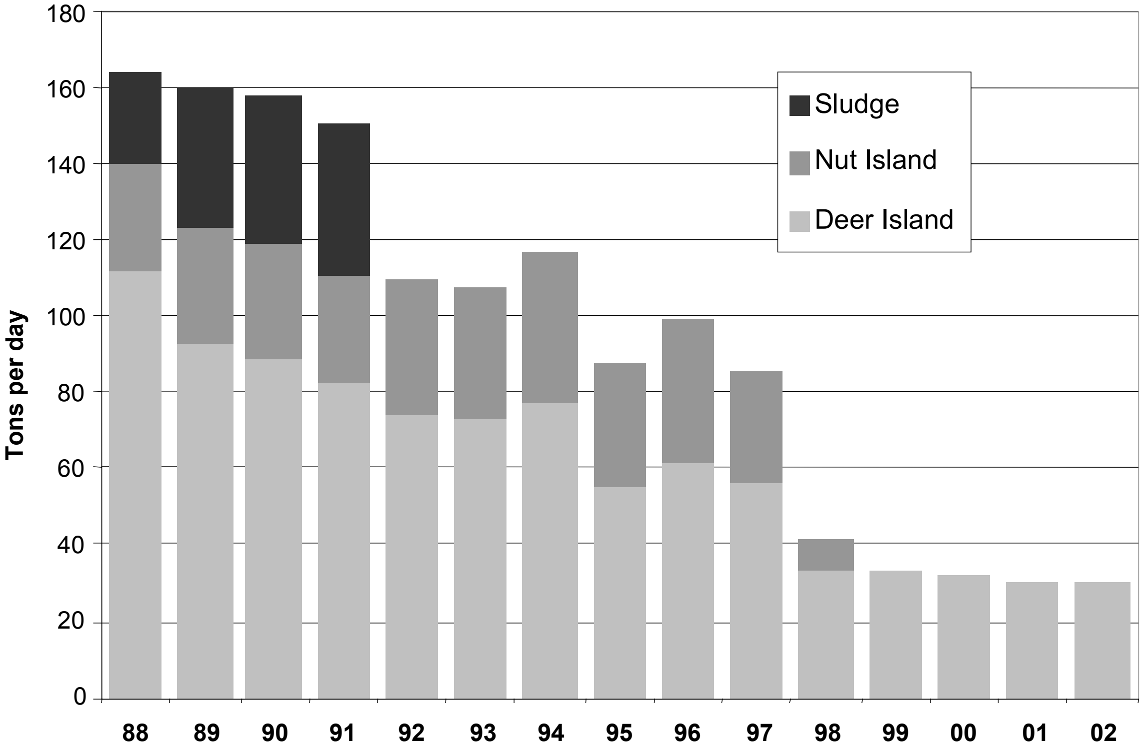


Figure II-1.C Biochemical Oxygen Demand in MWRA Discharges
1994-2002

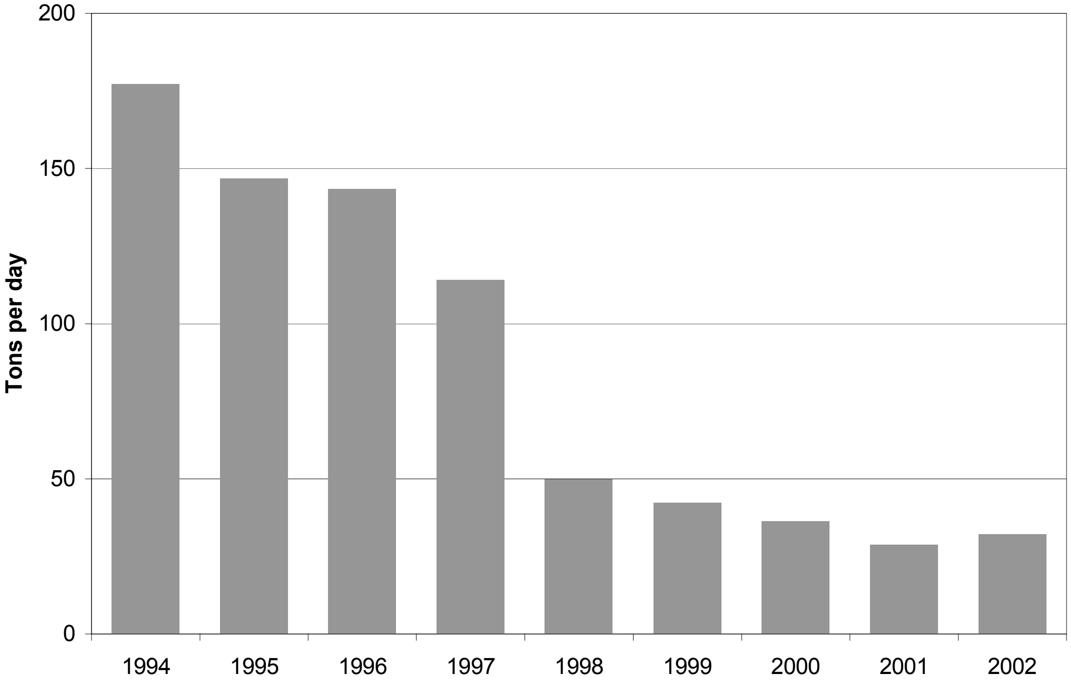


Table II-1.B shows that the percent of flow receiving activated sludge secondary treatment since FY1999 has increased. The percent of flow receiving secondary treatment varies with rainfall; the more it rains, the smaller the proportion of flow receiving secondary treatment. Thus, 88% of flow received secondary treatment in FY2001, a wet period, and 98% of flow received secondary treatment in FY2002, a dry period. Note, however that TSS and BOD removal were high in both those years.

Table II-1.B TSS and BOD removal efficiencies

MWRA Fiscal Year (July-June)	TSS removal (%)	BOD or cBOD removal (%)	Percent of flow receiving secondary treatment
FY1999	87	80	86
FY 2000	89	83	89
FY 2001	91	89	88
FY2002	92	90	98

Operation and Maintenance Requirements in Permit

MWRA's discharge permit requires that MWRA submit an operation and maintenance plan to regulatory agencies, and report on the results of the implementation of that plan annually. The most recent report is on the web at: http://www.mwra.com/harbor/pdf/omstatus02.pdf

The report summarizes operation and maintenance activities at the treatment plant, conveyance facilities and pipelines, and the sludge pelletizing facilities.

II-2 Tracking effluent quality: Monitoring requirements

MWRA's effluent monitoring requirements are laid out in three different areas of the permit: standard discharge monitoring requirements reported to regulatory agencies monthly in the National Polluant Discharge Elimination Program (NPDES) Discharge Monitoring Reports (DMRs), additional requirements in the outfall Contingency Plan, and requirements in the Ambient Monitoring Plan.

Monitoring questions

In the Ambient Monitoring Plan (AMP), the monitoring questions on effluent quality address whether MWRA is meeting its permit limits, thus the monitoring to answer these questions will continue. The questions in the AMP are:

1. Do effluent pathogens exceed permit limits?
2. Does acute or chronic toxicity of effluent exceed permit limits?
3. Do effluent contaminant concentrations exceed permit limits?
4. Do conventional pollutants in the effluent exceed permit limits?

Additional effluent monitoring requirements in the Monitoring Plan and the Contingency Plan beyond those in the NPDES DMR monitoring address emerging issues that the Outfall Monitoring Task Force saw as concerns, for example nutrient loading, newer pathogen indicators, and non-standard low-detection methods for measuring contaminants in the effluent. The tables in Section II-2 list the effluent parameters measured for the different types of permit requirements, and Section II-3 presents results of effluent monitoring.

Permit discharge monitoring requirements

These requirements, shown in Table II-A, are typical for wastewater treatment permits, and are not subject to modification under the Ambient Monitoring Plan provisions of the permit. Some of the parameters have limits and some are "report only."

Table II-2.A MWRA permit-required DMR monitoring for Deer Island Treatment Plant effluent

Parameter	Sample Type	Frequency	Limit
Flow	Flow meter	Continuous	report only
Flow dry day	Flow meter	Continuous	436 MGD annual average
cBOD	24-hr composite	1/day	40 mg/L weekly 25 mg/L monthly
TSS	24-hr composite	1/day	45 mg/L weekly 30 mg/l monthly
pH	Grab	1/day	not <6 or >8
Fecal coliform bacteria	Grab	3/day	14,000 col/100ml
Total residual chlorine	Grab	3/day	631ug/L daily 456 ug/L monthly
PCB, Aroclors	24-hr composite	1/month	0.045 ng/L
Toxicity LC50	24-hr composite	2/month	50%
Toxicity C-NOEC	24-hr composite	2/month	1.5%
Settleable solids	Grab	1/day	Report
Chlorides (influent only)	Grab	1/day	
Mercury	24-hr composite	1/month	
Chlordane	24-hr composite	1/month	
4,4' – DDT	24-hr composite	1/month	
Dieldrin	24-hr composite	1/month	
Heptachlor	24-hr composite	1/month	
Ammonia-nitrogen	24-hr composite	1/month	
Total Kjeldahl nitrogen	24-hr composite	1/month	
Total nitrate	24-hr composite	1/month	
Total nitrite	24-hr composite	1/month	
Cyanide, total	Grab	1/month	
Copper, total	24-hr composite	1/month	
Total arsenic	24-hr composite	1/month	
Hexachlorobenzene	24-hr composite	1/month	
Aldrin	24-hr composite	1/month	
Heptachlor epoxide	24-hr composite	1/month	
Total PCBs	24-hr composite	1/month	
Volatile organic compounds	Grab	1/month	

Monitoring requirements in the Contingency Plan

All of the DMR effluent monitoring limits have Contingency Plan thresholds; the Warning Level thresholds are the permit limitations. The Contingency Plan specifies additional thresholds for the parameters in Table II-2.B.

Table II-2.B Parameters reported as required in the Contingency Plan

Parameter	Sample type	Frequency
Plant performance	not applicable	annual
Annual nitrogen load	composite	annual (based on 5 samples/month)
Floatables (being developed)	7-day composite	1/month
Oil and Grease	grab	weekly

Monitoring requirements in Ambient Monitoring Plan.

The Ambient Monitoring Plan details requirements (Table II-2.C) beyond those included in ordinary discharge monitoring. More frequent and additional nutrient measurements are required, and non-standard low-detection limit methods are used to measure toxic contaminants.

Table II-2.C Ambient Monitoring Plan parameters for effluent

Parameter	Sample type	Frequency
Nutrients		
Total Kjeldahl nitrogen	composite	weekly
Ammonia	composite	weekly
Nitrate	composite	weekly
Nitrite	composite	weekly
Total phosphorus	composite	weekly
Total phosphate	composite	weekly
Acid base neutrals	composite	bimonthly
Volatile Organic Compounds	grab	bimonthly
Low detection limit analyses		
Cadmium	24-hr composite	weekly
Copper	24-hr composite	weekly
Chromium	24-hr composite	weekly
Mercury	24-hr composite	weekly
Lead	24-hr composite	weekly
Molybdenum	24-hr composite	weekly
Nickel	24-hr composite	weekly
Silver	24-hr composite	weekly
Zinc	24-hr composite	weekly
17 chlorinated pesticides	24-hr composite	weekly
Extended list of PAHs	24-hr composite	weekly
LABs	24-hr composite	weekly
20 PCB congeners	24-hr composite	weekly

Special studies outlined in Ambient Monitoring Plan.
The Ambient Monitoring Plan calls for an evaluation of indicators of human pathogens, but does not explicitly define how MWRA must carry out this evaluation. MWRA has collected data for two projects that address this requirement:

- Anthropogenic viruses and viral indicators in DITP influent and effluent
- *Enterococcus* in DITP influent and effluent

The Ambient Monitoring Plan also calls for an evaluation of effluent tracers. MWRA is co-sponsoring, with Sea Grant, a University of Massachusetts and Tufts University study of endocrine disruptors in Deer Island influent and effluent, in Boston Harbor, and around the new outfall site (these data are not yet available). MWRA's investigators have also measured sulfur and nitrogen isotope patterns in effluent to help determine if nitrogen isotopes may be a useful tracer in evaluating a zone of effect of the effluent. MWRA evaluates proposals to study emerging potential effluent tracers on an ongoing basis as new scientific developments occur. Another special study with the Woods Hole Oceanographic Institution is examining the utility of a gel membrane sensor to detect what proportion of copper in the effluent is bioavailable (data not yet available).

II-3. Effluent Monitoring Results

This section presents results from all the types of effluent monitoring done by MWRA, including the more "routine" effluent monitoring, and more specialized testing required in the Contingency Plan and Ambient Monitoring Plan. Table II-3.A shows how Deer Island effluent quality has changed for "conventional pollutants." (Note that flows from DITP increased in FY99 when the Nut Island Treatment Plant was closed and south system flows transferred to DITP).

Table II-3.A Deer Island effluent characterization, FY94-FY02 (July 1993-June 2002)

Parameter	FY94*	FY95*	FY96*	FY97*	FY98*	FY99	FY00	FY01	FY02
Average flow (MGD)	249	236	250	265.0	296.2	349.7	356	367.3	316.6
Average concentrations									
TSS (mg/L)	73.0	65.0	44.0	41.2	25.4	21.5	17.8	15.4	16.0
cBOD (mg/L)	ND	117.5	82.5	72.7	27.2	22.5	15.0	12.2	13.0
Settleable Solids (ml/L)	0.5	0.4	0.2	0.2	0.2	0.2	0.1	0.1	0.1
Total Kjeldahl Nitrogen (mg/L)	21.7	23.0	22.5	21.9	20.4	23.4	21.8	23.6	25.9
Ammonia Nitrogen (mg/L)	12.6	14.4	14.5	13.1	15.1	18.0	17.6	17.6	21.2
Nitrates (mg/L)	1.04	0.08	0.30	0.34	0.42	0.22	0.69	0.70	0.89
Nitrites (mg/L)	0.10	0.08	0.63	0.11	0.20	0.30	0.95	0.20	0.34
Orthophosphates (mg/L)	2.15	2.22	1.53	1.68	1.71	1.97	1.90	1.90	2.30
Total Phosphorus (mg/L)	2.92	3.35	3.42	2.90	2.77	2.93	3.00	2.80	3.10
Average loading (tons/day)									
TSS	52.1	45.3	27.0	28.7	16.8	14.2	26.5	23.6	21.1
cBOD	ND	114.5	87.1	82.4	32.6	34.0	23.8	19.4	16.9
Settleable Solids	0.4	0.3	0.1	0.1	0.1	0.1	0.1	0.2	0.1
Total Kjeldahl Nitrogen	22.5	22.6	23.4	24.3	25.2	34.2	32.4	36.1	34.2
Ammonia nitrogen	8.97	10.05	8.88	9.12	9.97	11.90	26.16	27.00	28.00
Nitrates	0.74	0.06	0.18	0.23	0.28	0.15	1.03	1.10	1.20
Nitrites	0.07	0.06	0.39	0.08	0.13	0.20	1.41	0.30	0.40
Orthophosphates	2.23	2.18	1.60	1.86	2.11	2.87	2.82	2.91	3.04
Total Phosphorus	3.03	3.30	3.57	3.20	3.42	4.27	4.46	4.29	4.09

*North System only. FY99 and later include South System data.

Permit discharge monitoring results: compliance with regulatory limits

Table II-3.B summarizes the results of effluent monitoring since the permit was effective. Details of monitoring results for individual tests follow.

Table II-3.B Summary of effluent monitoring results for DMR reporting

Parameter	Permit limits	Monitoring Results		
		Sep 6 – Dec 31 2000	2001	2002
Toxicity	Acute: effluent LC50<50% for shrimp and fish Chronic: effluent NOEC for fish survival and growth and sea urchin fertilization <1.5% effluent	No violations	One violation of chronic fish growth and one violation of sea urchin fertilization	No violations
Fecal coliform bacteria	<14,000 fecal coliforms/100 mL (monthly 90th percentile, weekly geometric mean, maximum daily geometric mean, and minimum of 3 consecutive samples)	No violations	One violation of daily geometric mean level	No violations
Total suspended solids	no more than 45 mg/L weekly 30 mg/L monthly	No violations	No violations	Two weekly violations One monthly violation
Carbonaceous biochemical oxygen demand	no more than 40 mg/L weekly, 25 mg/L monthly	No violations	No violations	No violations
Residual chlorine	no more than 631 ug/L daily, 456 ug/L monthly	One daily violation = 900 ug/L; before automated feedback for dechlorination	No violations	No violations
pH	not <6 or >8	One violation = 5.8, sampling artifact	No violations	No violations
PCBs as Aroclor	Aroclor= no more than 0.045 ng/L	No violations	No violations	No violations
Average dry day flow	Flow no more than 436 MGD annual average of dry days	Not applicable	No violations	No violations

Whole effluent toxicity. The MWRA tests effluent toxicity every month at DITP. Effluent toxicity provides an overall view of effluent quality, ensuring that the effluent does not adversely affect the environment. In 1989, the EPA found that the probable cause of most acute toxicity in DITP's waste stream was due to surfactants. Surfactants are most commonly used in household detergents to improve cleansing power. No acute toxicity could be attributed to metals or pesticides.

The MWRA permit requires four tests for effluent toxicity testing. 48-hr acute static toxicity tests using the mysid shrimp (*Americamysis bahia*) and the inland silverside fish (*Menidia beryllina*) measure the short-term lethal effects caused by the effluent. A chronic survival and growth test using *Menidia* and a chronic fertilization test using the sea urchin (*Arbacia* *punctulata*) both measure subtle toxic impacts over a longer period of time. The results of these tests for 2001 and 2002 are in Table II-3.C.

Table II-3.C Toxicity test results for Deer Island Treatment Plant effluent 2001 and 2002

	Acute toxicity LC50 (%) Permit limit minimum = 50%		Chronic toxicity NOEC (%) Permit limit minimum = 1.5%	
Month-year	*Menidia* (Inland silverside)	*Americamysis* (Mysid shrimp)	*Menidia* (Inland silverside) growth	*Arbacia* (Sea urchin) fertilization
January-01	100	100	50	1 (failure)
February-01	79.1	100	12.5	25
March-01	100	100	100	50
April-01	100	100	1 (failure)	100
May-01	100	100	50	25
June-01	76.3	100	50	50
July-01	75.2	100	50	25
August-01	87	100	25	6.25
September-01	82.4	100	25	100
October-01	69.5	100	6.25	50
November-01	63.1	100	25	100
December-01	68.3	70.7	50	*
January-02	97.7	95.6	50	25
February-02	100	100	50	100
March-02	100	100	25	100
April-02	100	100	100	25
May-02	100	100	50	50
June-02	72.2	100	50	100
July-02	68.3	100	50	100
August-02	68.3	100	50	50
September-02	100	100	50	50
October-02	100	100	50	100
November-02	64.9	100	50	100
December-02	100	100	50	100

*Not able to perform test due to lack of viable *Arbacia* gametes

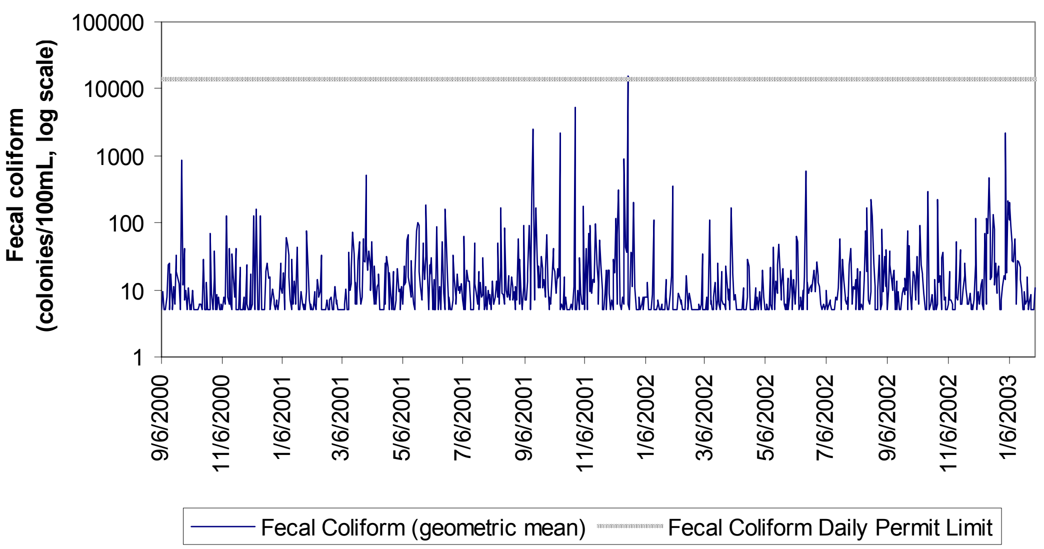
The LC50 (Lethal Concentration 50%) is the concentration of effluent in a sample that causes mortality to 50% of the test population during the duration of the test. The NOEC (No Observed Effect Concentration) is the concentration of effluent in a sample to which organisms are exposed in a life cycle or partial life cycle test that has no adverse effects. An NOEC limit of 1.5% means that 1.5% of the sample is effluent, and the remainder dilution water. Any acute LC50 below 50% or chronic NOEC below 1.5% would violate the NPDES limit.

There have been two toxicity test failures since the outfall began operating. In January 2001, the chronic sea urchin fertilization test failed, likely because the test organisms were in sub-optimal condition. This test result is discussed in detail in the notification to EPA and DEP in MWRA's repository libraries and on the web at: http://www.mwra.com/harbor/pdf/px022301.pdf.

In April 2001, the inland silverside fish chronic growth test failed, but this result is likely to have been due to variability in the fish rather than to toxicity of the effluent. Detailed descriptions of these test results are discussed in detail in the notification to EPA and DEP in MWRA's repository libraries and on the web at: http://www.mwra.com/harbor/pdf/px051801.pdf.

Fecal coliform. For fecal coliform, the daily geometric mean of three samples per day has a discharge limit of 14,000 colonies/100mL. Figure II-3.A shows average daily fecal coliform since the NPDES permit became effective in September 2001. There has been one permit violation of fecal coliform, on December 18, 2001, when the daily geometric mean for fecal coliform was 15,597 colonies/100mL. The cause of this violation was a brief drop in total chlorine residual in the disinfection basin due to increased plant flow. With less chlorine and greater wastewater volume, the effectiveness of disinfection fell, leaving greater numbers of fecal coliform bacteria in the effluent. Excepting the one permit violation noted above, the results for Deer Island have been well below the limit, for the monthly geometric means and for the additional limits for fecal coliform of not more than three consecutive samples measuring over 14,000 colonies/100mL and no more than 10% of the samples in a month measuring over 14,000 colonies/100 mL. These three limits were not approached.

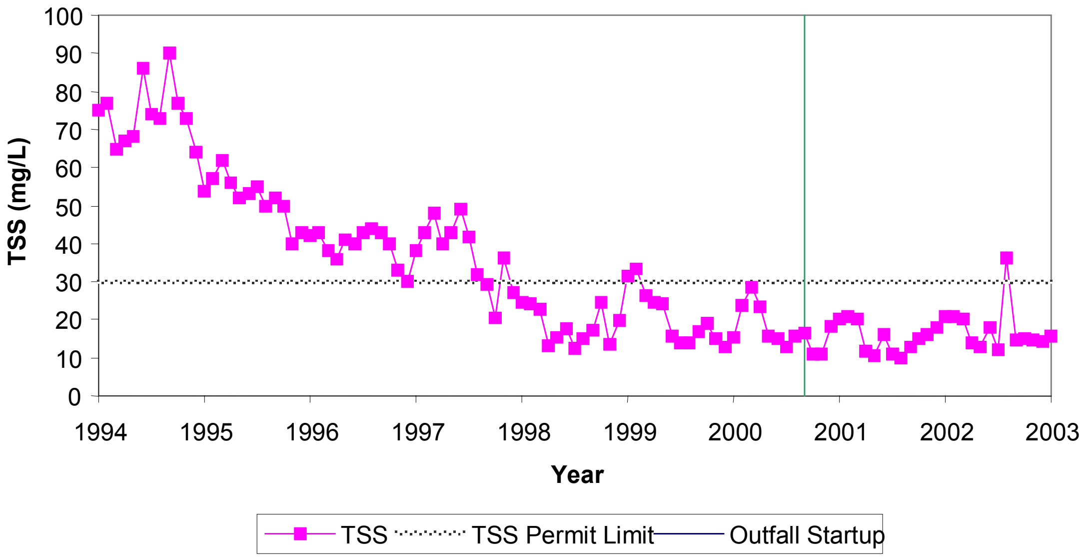
Figure II-3.A Effluent Daily Average Fecal Coliform, Deer Island
September 6, 2000-January 31, 2003



Total suspended solids and carbonaceous biochemical oxygen demand. For total suspended solids (TSS) and carbonaceous biochemical oxygen demand (cBOD), the permit limits monthly and weekly average concentrations. Figures II-3.B and II-3.C show that the monthly averages for TSS and cBOD generally were well below the regulatory discharge limits of 25 mg/L for cBOD and 30 mg/L for TSS for monthly average concentration. Both parameters have improved markedly from the historical trends before secondary treatment began in 1997.

In August, 2002, TSS exceeded the permit limitations (and by definition exceeded the Contingency Plan warning level thresholds) for weekly and monthly values. The high TSS in August, 2002 were caused by an "upset" of the secondary treatment plant process: high sulfate industrial waste discharged to the plant during an experiment caused an overgrowth of filamentous bacteria which prevented effective secondary treatment. See http://www.mwra.com/harbor/pdf/200208tpx.pdf for a detailed explanation of this exceedance and how it was handled at the treatment plant to minimize potential impacts. Note that there was no exceedance of BOD during that time period, reflecting the fact that secondary treatment, although compromised, was still removing oxygen-demanding constituents.

Figure II-3.B Effluent Monthly Average TSS, Deer Island
January 1994-January 2003



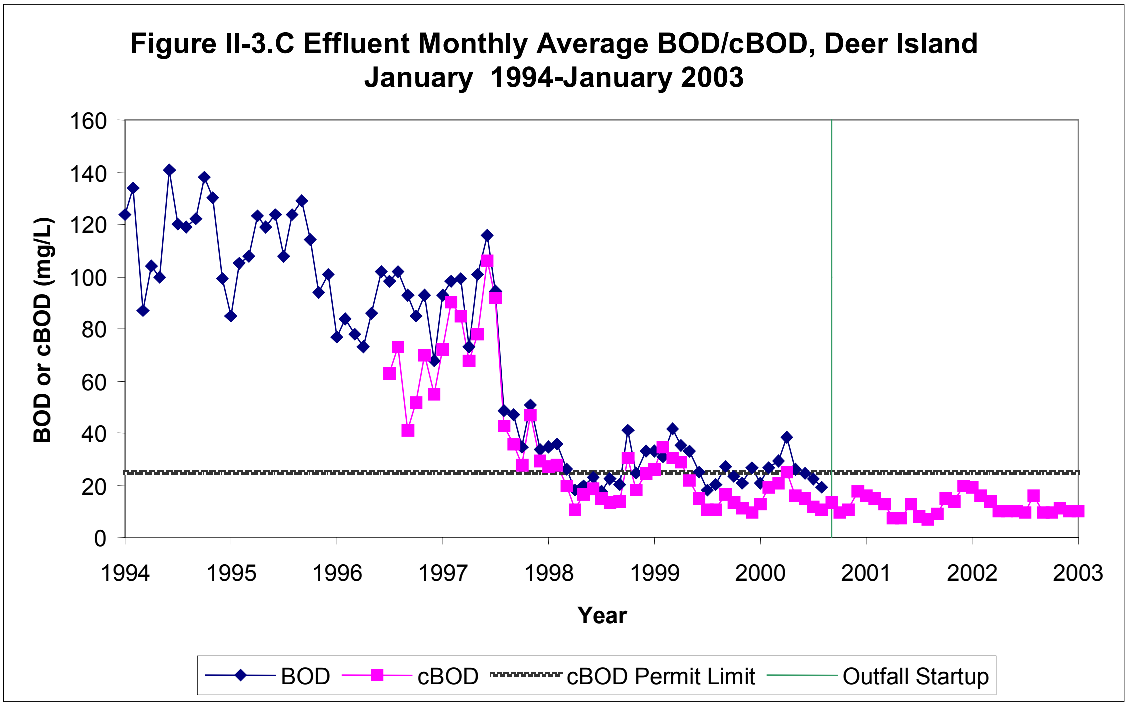


Figure II-3.C Effluent Monthly Average BOD/cBOD, Deer Island
January 1994-January 2003

Total chlorine residual. Figure II-3.D shows how the chlorine residual in the effluent discharged from Deer Island has dropped dramatically since 1997. Chlorine is necessary for effective disinfection of the wastewater, but because it can have toxic effects on marine life it is

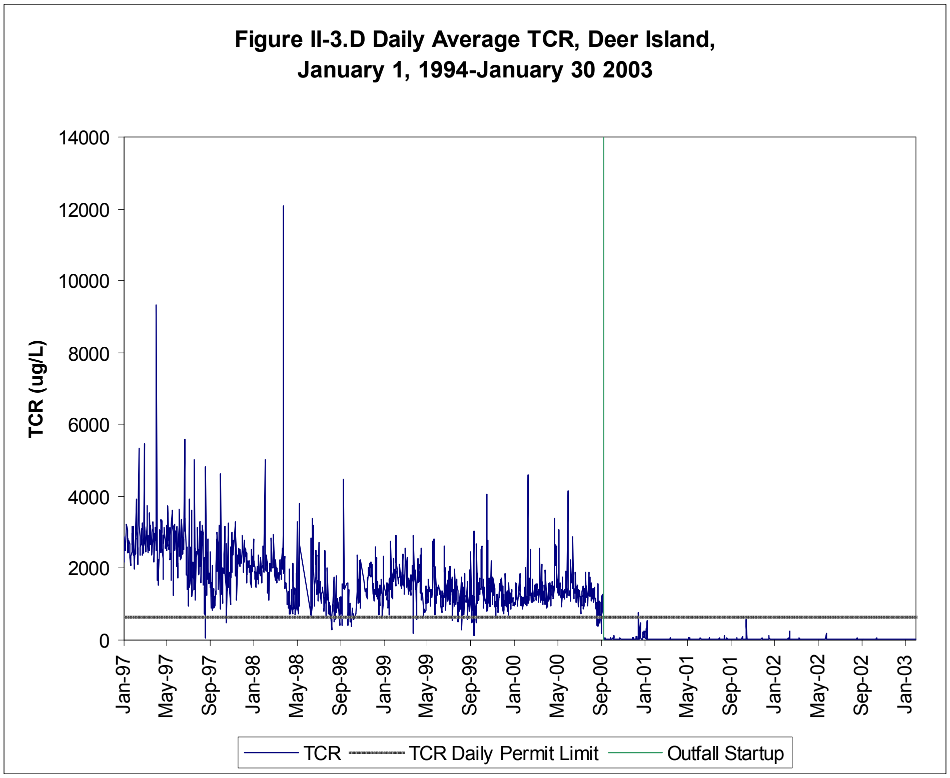
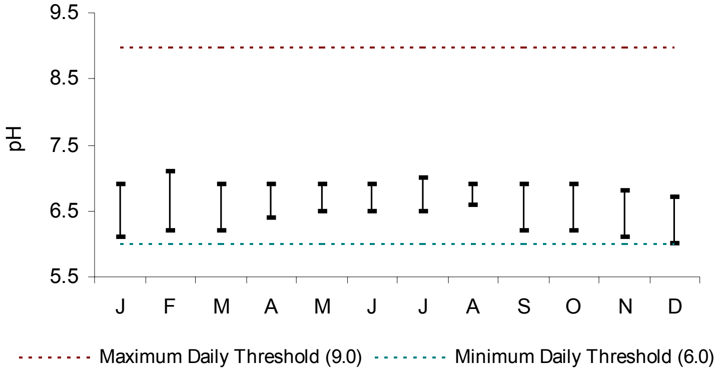


Figure II-3.D Daily Average TCR, Deer Island,
January 1, 1994-January 30 2003

desirable to minimize the amount of chlorine remaining in the final effluent after treatment. As secondary treatment came on line, beginning in mid-1997, the amount of chlorine necessary for effective disinfection decreased. Then, when the new outfall began operating in September 2000, dechlorination also began, greatly reducing the chlorine residual.

pH. DITP effluent tends to be acidic because the pure oxygen used in secondary treatment causes the production of relatively large amounts of CO_2, which when dissolved in the wastewater, increases its acidity. The CO_2 off-gasses as the effluent tumbles down the shaft from the treatment plant to the outfall tunnel. There was a single pH violation early in the operation of the outfall, because the sampling method was not allowing for a period of off-gassing. Since the sampling method was adjusted, pH measurements have been within permit limits. Figure II-3.E shows the range by month for daily pH for 2002.

Figure II-3.E pH in Deer Island Effluent, 2002



Aroclors. These PCBs have never been detected in MWRA effluent by EPA standard methods. However, PCBs are detected as part of the Ambient Monitoring Plan sampling, when specialized low-level detection methods are used; see Table II-3.F, and further discussion below.

Dry Day Flow. Average dry day flow has been well within permit limits (Figure II-3.F).

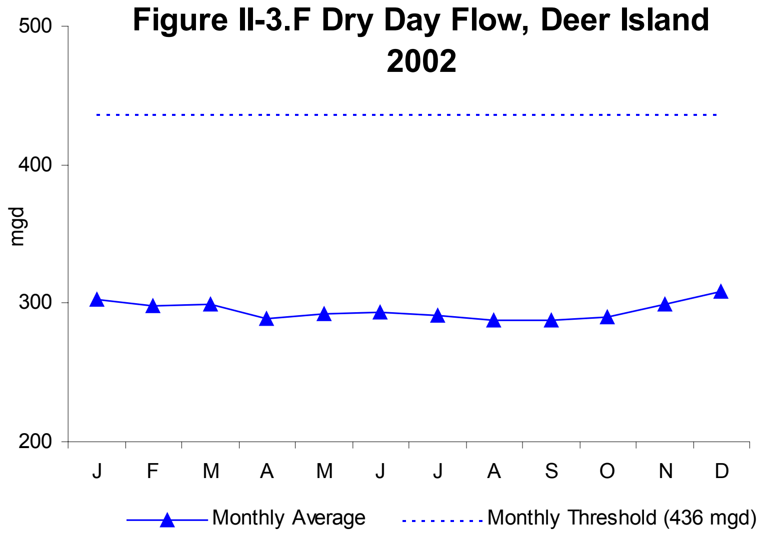
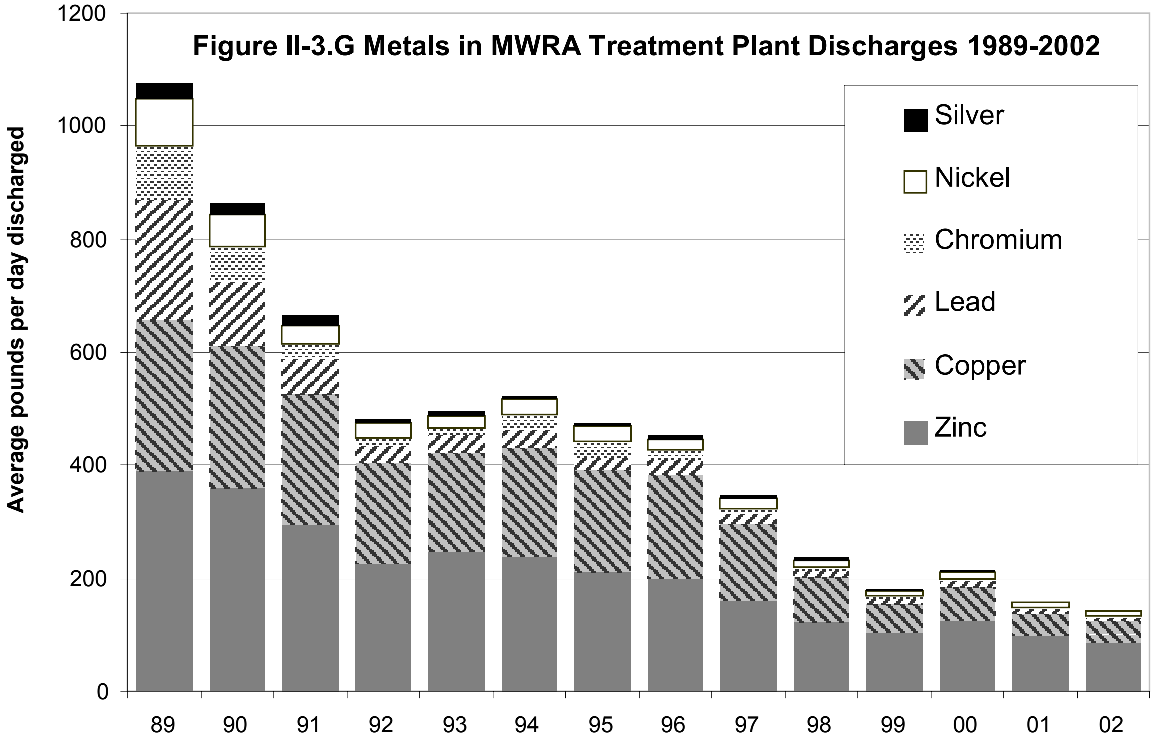


Figure II-3.F Dry Day Flow, Deer Island 2002

Priority pollutants (metals) in MWRA discharges. MWRA has no numerical limits for most priority pollutants, but must report on test results. Figure II-3.G shows how metals in MWRA effluent have dropped over time. Further discussion of priority pollutant results follows in the discussion of results of the low-detection level sampling required by the Ambient Monitoring Plan.

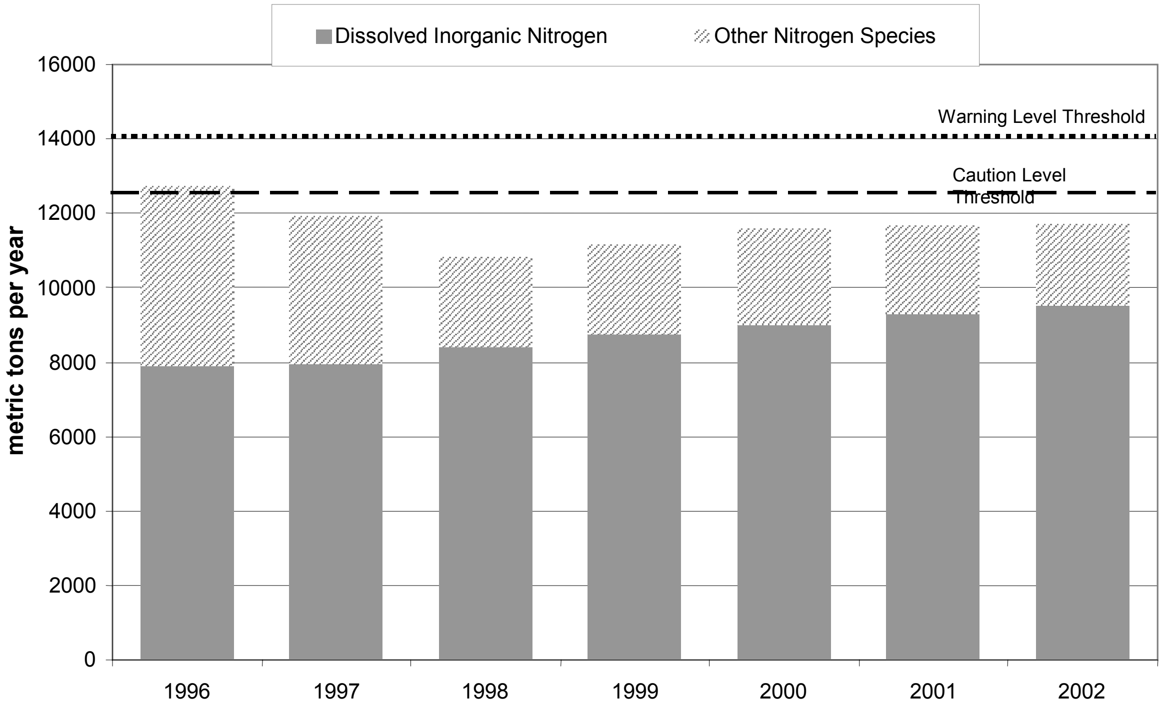


Contingency Plan Results

Plant performance. This Contingency Plan threshold assesses overall treatment plant performance; the Deer Island Treatment Plant meets the threshold if there are fewer than 5 permit violations in a year, thus qualifying for the American Metropolitan Sewerage Association's "Silver Award." DITP received the Silver Award in 2001, and is applying for the award for 2002, having had fewer than 5 violations.

Total nitrogen load. The total nitrogen load from MWRA treatment facilities has remained stable and below the Contingency Plan Caution Level threshold of 12,500 metric tons/year. (The Warning Level threshold is 14,000 metric tons/year.) Figure II-3.H shows that in 1996, before secondary treatment, total nitrogen would have exceeded the Caution Level threshold. Nitrogen levels have remained below 12,000 metric tons since secondary treatment began in 1997. The amount of dissolved inorganic nitrogen has increased since 1996, as anticipated, because secondary treatment converts organic nitrogen to inorganic nitrogen (ammonia + nitrate/nitrite).

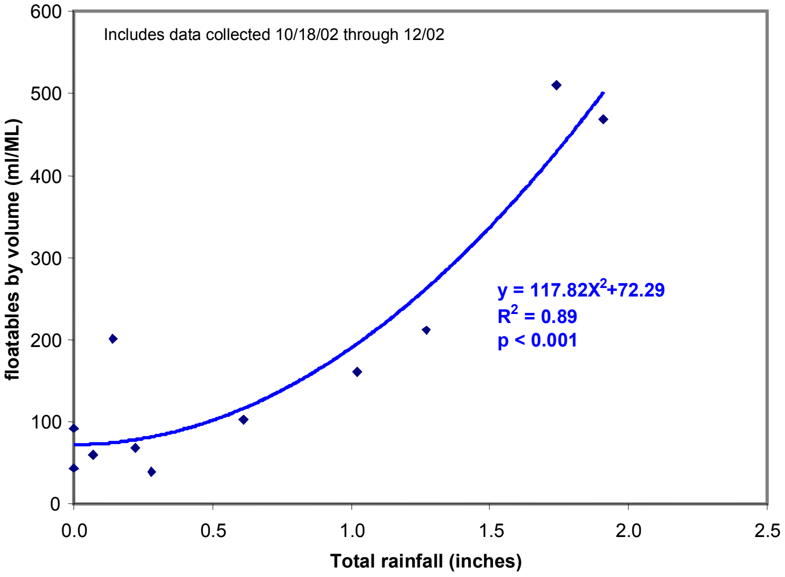
Figure II-3.H. MWRA Treatment Plant Nitrogen Discharges 1996-2002



Floatables. MWRA has designed and constructed a floatables sampling device which screens small bits of solid matter from the final effluent. The floatables threshold is still being developed. Although the sampling and measurement methods are still being refined, preliminary data indicate that:

- the floatables sampling device is working well, and gives a representative sample of what is discharged in the effluent;
- visual observations confirm that most of the material is broken into small pieces, less than an inch in diameter;
- floatables of special concern (condoms, plastic bags) are very rarely found;
- the average amount of floatables discharged is 11 gallons or 12 kg per 100 mgd;
- approximately 86% of this material (by weight) is degradable, and 14% is non-degradable
- thus, on average, about six gallons of non-degradable floatables are discharged per day;
- volume and weight of total floatables are highly and consistently correlated during normal plant operations; and
- the proportion of floatables in the effluent increases with rainfall events, and can be described by a polynomial equation, as shown in **Figure II-3.I**. (When DITP reaches its maximum pumping capacity of 1,200 mgd, the amount of flow, and presumably floatables reaches a maximum.)

Figure II-3.I Effluent floatables are a function of rain



Oil and Grease. A second measure of effluent quality in the Contingency Plan is oil and grease, measured as petroleum hydrocarbons (PHC). As shown in Figure II-3.J, and Table II-3.D PHC has averaged less than 0.2 mg/L, well below the 15 mg/L threshold.

Figure II-3.J Petroleum Hydrocarbons in DITP effluent

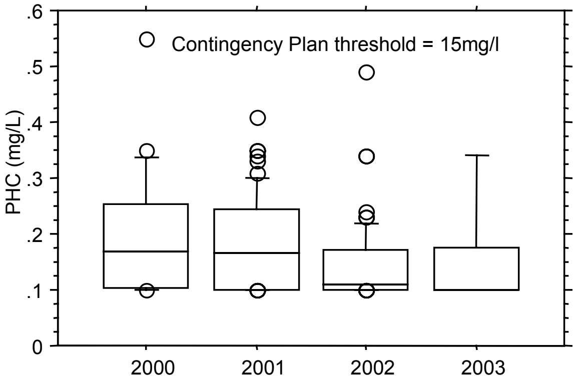


Table II-3.D Petroleum Hydrocarbons in DITP effluent, descriptive statistics (mg/L)

	All years	2000	2001	2002	2003
Mean	.167	.201	.181	.144	.152
Std. Dev.	.085	.116	.083	.070	.105
Std. Error	.007	.027	.010	.009	.047
Count	153	19	64	65	5
Minimum	.100	.100	.100	.100	.100
Maximum	.550	.550	.410	.490	.340

Ambient Monitoring Plan Results: Detailed effluent characterization study, using low detection limit methods.

Metals

Low detection limit effluent monitoring for metals is conducting using NPDES approved methods, based on inductively coupled plasma atomic emission spectrometry (ICP) or graphite furnace atomic absorption spectrometry (GFAA).

Priority pollutant concentrations in Deer Island effluent are very low. Table II-3.E compares concentrations of priority pollutant metals in DITP effluent to water quality criteria.

Table II-3.E. Comparison of Deer Island Treatment Plant effluent to water quality criteria FY02 (July 2001-June 2002)

Acute	Total Recoverable Maximum (ug/L)	Total Dissolved Maximum (ug/L)	Dilution	Estimated Concentration in ZID	Acute Criteria*** (ug/L)	Times Detected
Arsenic	0.4	0.4	50	0.008	69	0 of 23
Copper	22.2	18.4	50	0.37	4.8	87 of 107
Lead	4.3	4.1	50	0.082	210	5 of 75
Mercury	0.053	0.045	50	0.0009	1.8	74 of 88
Nickel	5.38	5.33	50	0.11	74	76 of 76
Silver	1.06	0.901	50	0.018	1.9	72 of 75
Zinc	51.2	48.4	50	0.97	90	75 of 75

Chronic	Total Recoverable Average (ug/L)	Total Dissolved Average (ug/L)	Dilution	Estimated Concentration in ZID	Chronic Criteria*** (ug/L)	Times Detected
Arsenic	0.4	0.4	70	0.006	36	0 of 23
Copper	12.6	10.5	70	0.15	3.1	87 of 107
Lead	1.38	1.31	70	0.019	8.1	5 of 75
Mercury	0.0181	0.0154	70	0.00023	0.94	74 of 88
Nickel	2.7	2.7	70	0.038	8.2	76 of 76
Silver	0.309	*	70	*	**	72 of 75
Zinc	27.7	26.2	70	0.37	81	75 of 75

ZID: Zone of Initial Dilution
* No applicable conversion factor
** No applicable criteria
*** Criteria from National Recommended Water Quality Criteria for Priority Toxic Pollutants, Federal Register, December 10, 1998
Total Dissolved Max Conc (Col D) = Total Recoverable Max Conc (Col C) * Criteria Maximum Concentration (CMC, see below)
Total Dissolved Avg Conc (Col D) = Total Recoverable Average Conc (Col C) * Criteria Continuous Concentration (CCC, see below)

Conversion factors for "Acute" and "Chronic"

	CMC	CCC
As	1	1
Cu	0.83	0.83
Pb	0.951	0.951
Hg	0.85	0.85
Ni	0.99	0.99
Ag	0.85	*
Zn	0.946	0.946

Federal Register 12/10/98, 98-30272

The majority of priority pollutant parameters were below detection levels. Those that were detected had relatively low concentrations. All of the maximum values measured, except for copper, met acute receiving water quality criteria in effluent *before dilution*. All the average values, except for copper, met the chronic receiving water criteria in the effluent *before dilution*. The water quality criteria apply *after* initial dilution (at the outfall, the acute initial dilution is approximately 50:1, chronic is 70:1). Attachment S in the NPDES permit gives calculation details for estimating the receiving water concentrations based on effluent concentrations.

Organic Contaminants

Low detection limit effluent monitoring for organic contaminants includes pesticides, polychlorinated biphenyls (PCBs), polyaromatic hydrocarbons (PAH), semivolatile organics (ABN), and volatile organics (VOA). The analytical methods for organics are derived from the EPA methods approved for the NPDES program, but modified to achieve increased sensitivity. In particular, selected ion monitoring (SIM) gas chromatography / mass spectrometry (GC/MS) is used to increase the sensitivity of the PAH method.

Twenty-four hour composite samples of Deer Island Treatment Plant (DITP) effluent are collected at least weekly and tested for most organic parameters. Due to their volatility, VOA samples collected as grab samples in samples twice a month.

DITP effluent results for organic parameters for FY02 are summarized in Table II-3.E with all concentrations in parts-per-trillion (ng/L).

Volatile Organic contaminants. (VOA). Six of 43 VOA parameters were detected in 25 grab samples. Detected contaminants were at low parts-per-billion (μg/L) concentrations, and none of these contaminants have water quality criteria for toxicity to marine life. The maximum observed value for tetrachloroethene slightly exceeded the 10^{-6} human health criteria for this compound *before dilution* of the effluent.

Semivolatile Organics (ABN). Only one ABN parameter was detected, in one of 25 samples collected during FY02. Bis(2-ethylhexyl)phthalate (BEHP) was detected in a sample collected 14-Sep-2001 at 14 μg/L. This exceeds the 10^{-6} human health criteria for BEHP (5.9 μg/L) by about a factor of two *before dilution* of the effluent.

Table II-3.E. Comparison of Deer Island Treatment Plant effluent to water quality criteria FY02 (July 2001-June 2002)

Component	N of samples Detected	Maximum of samples detected (ng/L)	Mean of samples detected (ng/L)	Acute Criteria ** (ng/L)	Chronic Criteria **	Human Health Criteria** (ng/L)
Acetone	23 of 25	28,000	8,040	B	B	B
Carbon Disulfide	1 of 25	5,610	5,610	B	B	B
Chloroform	24 of 25	8,580	6,170	B	B	470,000
Methylene Chloride	9 of 25	5,890	3,570	B	B	1,600,000
Tetrachloroethene	20 of 25	12,800	5,480	B	B	8,850
Toluene	1 of 25	2,810	2,810	B	B	200,000,000
Bis(2-ethylhexyl)phthalate	1 of 25	14,000	14,000	B	B	5,900
Total NOAA PAH	52 of 52	1,274	285	B	B	B
Chrysene	52 of 52	67.9	17.5	B	B	49
Phenanthrene	52 of 52	226	26.8	B	B	B
Chlordane	48 of 62	58.2	4.67	90	4	2.2
04,4'-DDT	7 of 62	1.49	0.58	30	1	0.59
Lindane	51 of 62	9.7	2.06	160	B	63
Heptachlor	6 of 62	6.27	2.87	90	4	0.21
Total DDT	40 of 62	4.27	1.33	B	B	B
Total PCB	42 of 59	5.72	1.30	B	30	0.17

B - No applicable criteria

** National Recommended Water Quality Criteria for Priority Toxic Pollutants, Federal Register, December 10, 1998

Polycyclic aromatic hydrocarbons (PAH). Certain individual PAHs are routinely detected in DITP effluent samples at sub-parts-per-billion concentrations. These results are summarized in Table II-3.E as "Total NOAA PAH" because this is the grouping used in the Contingency Plan threshold for mussels. The NOAA PAH are 24 individual PAH components. None of these have water quality for toxicity to marine life, but seven of the 24 have been listed as probable human carcinogens and are assigned a value of 49 ng/L as 10^{-6} human health criteria (HHC). The average measured concentrations for all seven of these compounds were below the HHC during FY02, with mean measured concentrations ranging from 10% to 40% of the HHC *before dilution*. Chrysene, which had the highest measured single sample concentration amongst the seven for the year, is listed as an example in Table II-3.E. Phenanthrene, which had the highest measured single sample concentration amongst the other 17 PAH, is also listed as an example in Table II-3.E.

Pesticides. A few individual pesticides are detected in DITP effluent at parts-per-trillion (ng/L) levels. Chlordane, lindane (gamma-BHC), 4,4'-DDD, and 4,4'-DDE were frequently detected during FY02. The maximum detected concentration of lindane was well below the acute water quality criteria and the average measured concentration was well below the HHC for this compound. The average detected concentration of 4,4'-DDT in seven samples that had detectable levels was slightly below the HHC *before dilution* as well.

Chlordane is measured as the sum of six individual components in MWRA effluent (cis- and trans-chlordane, cis- and trans-nonachlor, heptachlor and heptachlor epoxide). Some or all of these were detected in 48 of 62 effluent samples. The average measured concentration exceeded both the chronic water quality criteria and the 10^{-6} human health criteria before dilution.

Polychlorinated biphenyls (PCBs). The NPDES-approved methods for PCBs are based on detecting and quantifying the Aroclors, which are industrial mixtures of PCBs. There is no NPDES approved method for Total PCB or for individual PCB congeners. There are a total of 209 possible PCB congeners, but only about 140 congeners are found in the virgin industrial mixtures. Due to the multiplicity of possible sources, weathering, and possible biological transformation, detecting Aroclors is not reliable as a measure of the Total PCB content of DITP effluent.

MWRA developed a method for determining 67 individual PCB congeners based on dual-column gas chromatography with electron capture detection (GC/ECD). This method is capable of detecting sub-parts-per-trillion (ng/L) levels of these congeners. Samples are tested using the 67-congener list on a monthly basis, and for a shorter list of congeners that matches those analyzed in the tissue and sediment samples on a weekly basis.

PCBs as Aroclors is the only organic contaminant that has a numeric discharge limit in the DITP NPDES permit. The limit is 0.045 ng/L based on the human health criterion and the expected amount of effluent dilution. Aroclors have not been detected in a DITP effluent sample since the current NPDES permit went into effect. However, the 1998 revised water quality criteria are intended to be compared to a sum of congeners or homologues. The average concentration of PCB congeners detected exceeds the HHC value before dilution of the effluent. Some recent high-resolution gas chromatography/high-resolution mass spectrometry (HRGC/HRMS) data indicates that PCB data for the effluent may be strongly impacted by positive interferences. MWRA will be looking in to this issue further.

Trends in priority pollutants

The low-level detection analyses enable MWRA to detect trends, for example Figures II-3.K and II-3.L show how mercury loadings and PAH loadings in MWRA effluent have decreased, respectively, as the proportion of effluent receiving secondary treatment has increased.

Low-detection level analyses for the pesticide chlordane (Figure II-3.M) show that the levels in DITP effluent, although low, increase during the summer, possibly indicating increased use or disposal of this banned chemical during the gardening season.

Figure II-3.K Mercury loading in DITP effluent as a function of secondary treatment

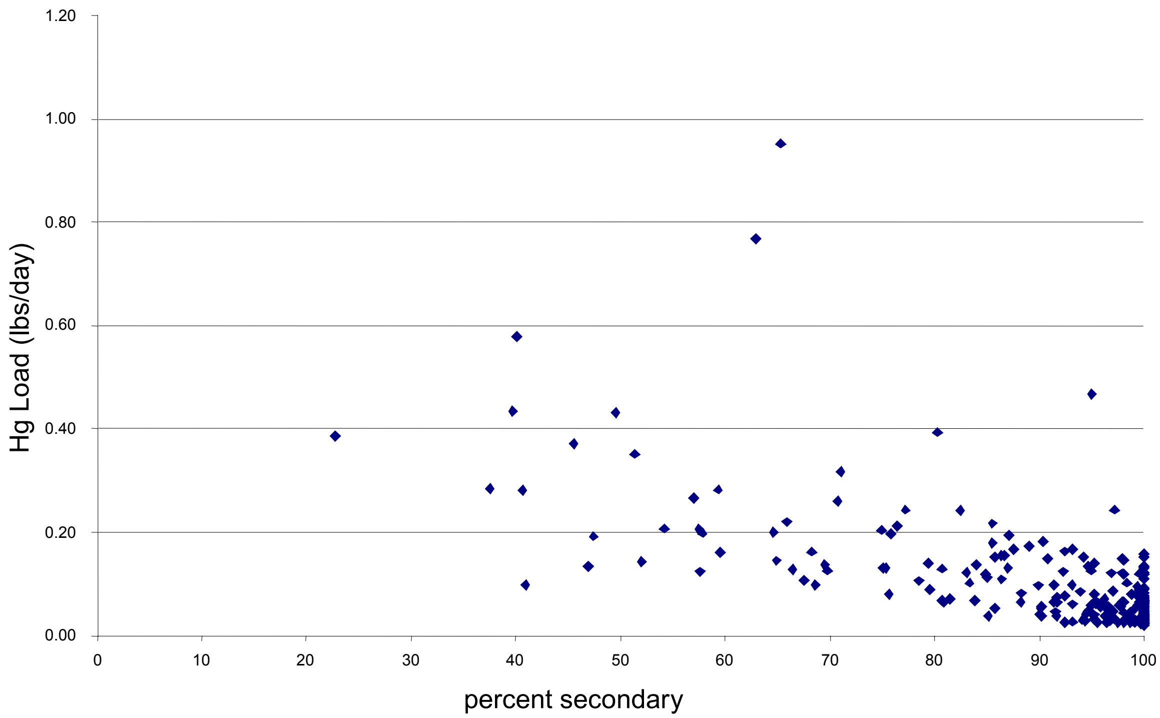


Figure II-3.L PAH loading in DITP effluent as a function of secondary treatment

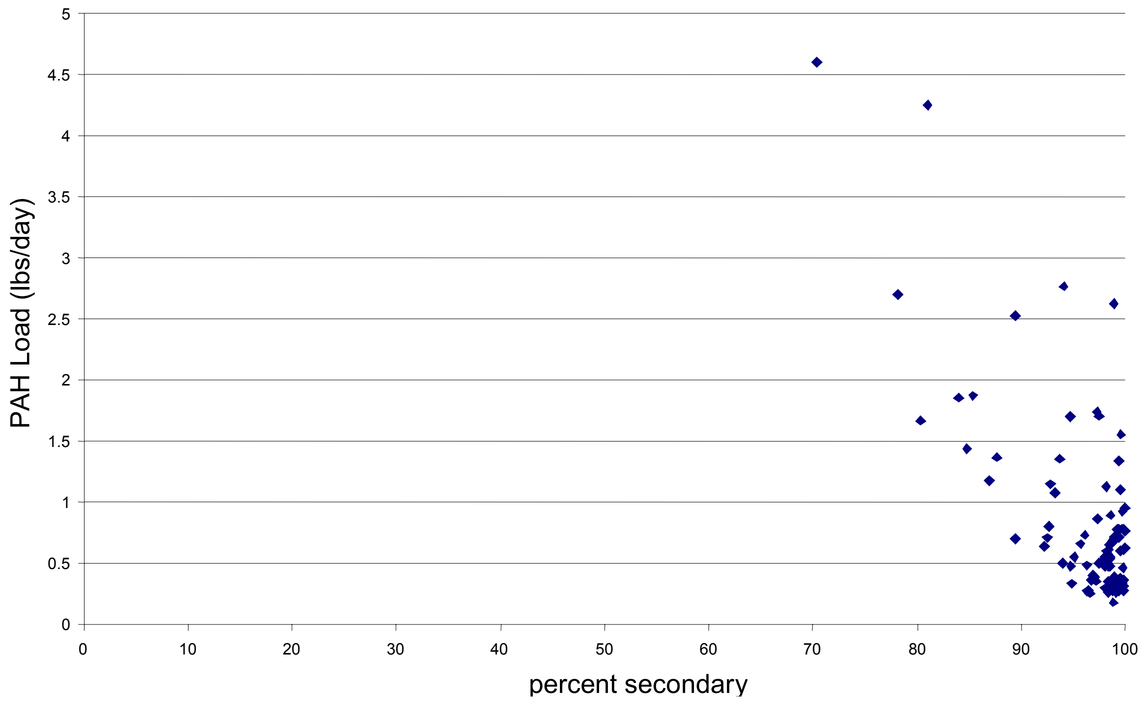
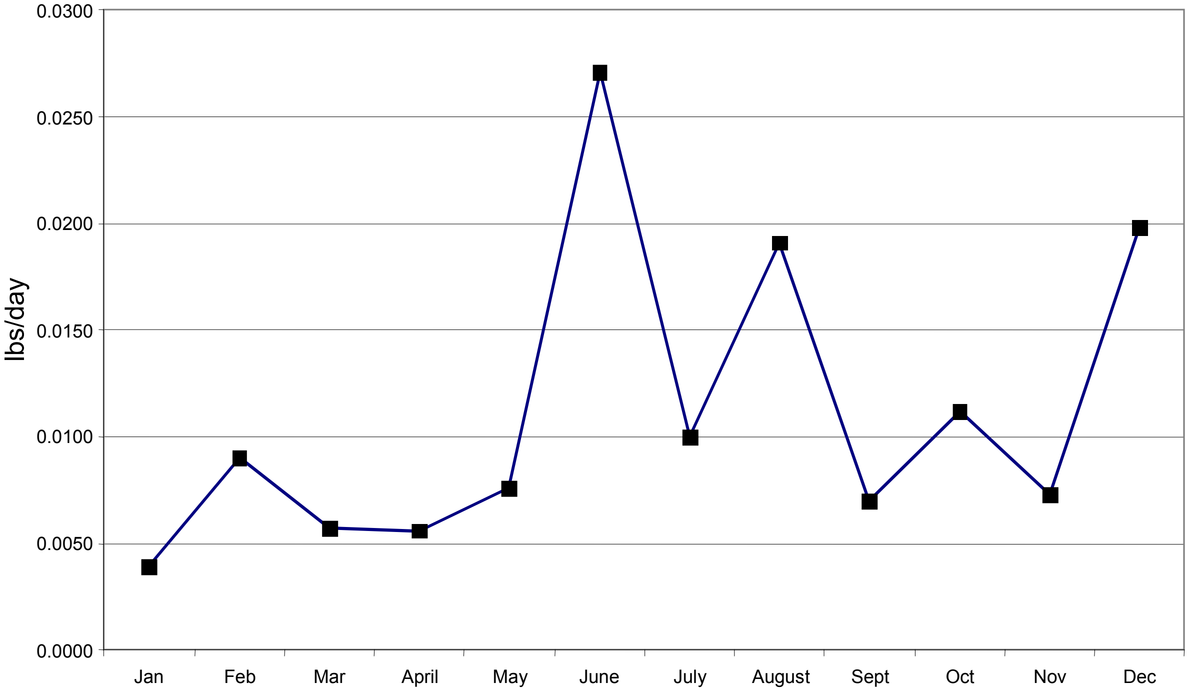


Figure II-3.M Chlordane loadings from DITP, 2002



Ambient Monitoring Plan: Special Effluent Studies

Pathogens and their indicators: *Enterococcus*, anthropogenic viruses and bacteriophage.

Massachusetts Water Quality Standards use fecal coliform bacteria counts as the indicator of the risk of human pathogens; therefore the Deer Island discharge must meet permit limits for fecal coliform. The Ambient Monitoring Plan calls for an evaluation of other indicators of human pathogens. Together with virologists at the University of New Hampshire, MWRA has conducted studies of the following pathogens: cultivatable enteroviruses including poliovirus, coxsackie virus and echovirus; adenovirus 40/41; rotavirus; and astrovirus. Samples are collected from influent and effluent to assess the presence of human pathogens in raw wastewater and the effectiveness of treatment on pathogen removal. Detailed descriptions of the methods used in this study are on the web at http://www.mwra.com/harbor/enquad/pdf/ms-073.pdf . In addition to the pathogens, MWRA studies four pathogen indicators: male-specific bacteriophage, somatic bacteriophage, and the indicator bacteria *Enterococcus* spp and fecal coliform. (MWRA also monitors the presence of pathogens and indicators in Boston Harbor and Massachusetts Bay, but this discussion is restricted to effluent monitoring.)

Bacteriophage have been suggested by some investigators as indicators that may better mimic the behavior of viral pathogens during treatment and in the environment than do bacterial indicators. Table II-3.G shows the units of measurement for each parameter, and the arithmetic and geometric mean values found in DITP wastewater at each stage of treatment.

Table II-3.G Changes in bacteria and virus counts in Deer Island wastewater through the treatment process.

	Arithmetic Mean Geometric Mean			
	Influent	Primary effluent	Secondary effluent	Chlorinated secondary effluent
Enterococcus	457,000	135,000	14,000	9
(Col/100mL)	500,000	205,000	24,300	88
Fecal Coliform	5,130,000	1,410,000	112,000	7
(Col/100mL)	5,550,000	3,350,000	175,000	12
Cultivatable Virus	13.2	6.3	4.9	2.75
(MPN/L)	37.93	54.26	7.26	3.88
Male Phage	246,000	11,500	6,460	10,000
(PFU/L)	408,000	103,000	56,000	75,700
Somatic Phage	60,300	3,390	4,680	2,090
(PFU/L)	82,100	42,800	34,400	14,100

These data are also shown as bar graphs with standard errors indicated in Figure II-3.N.

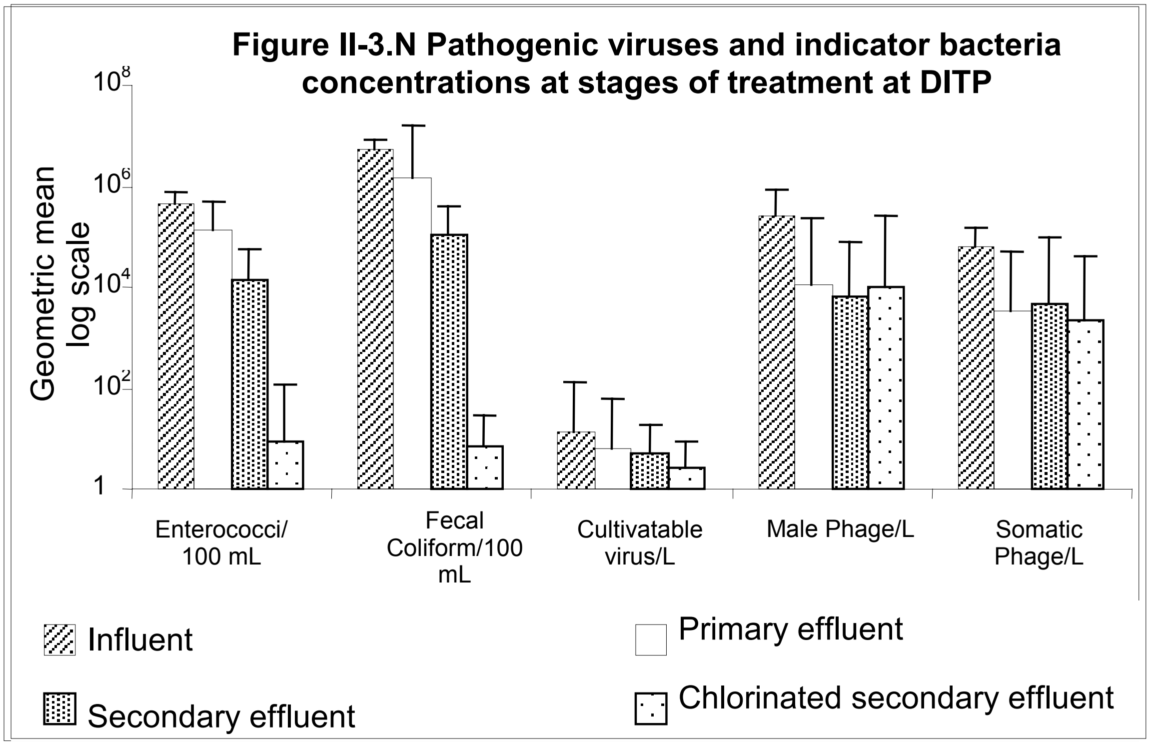
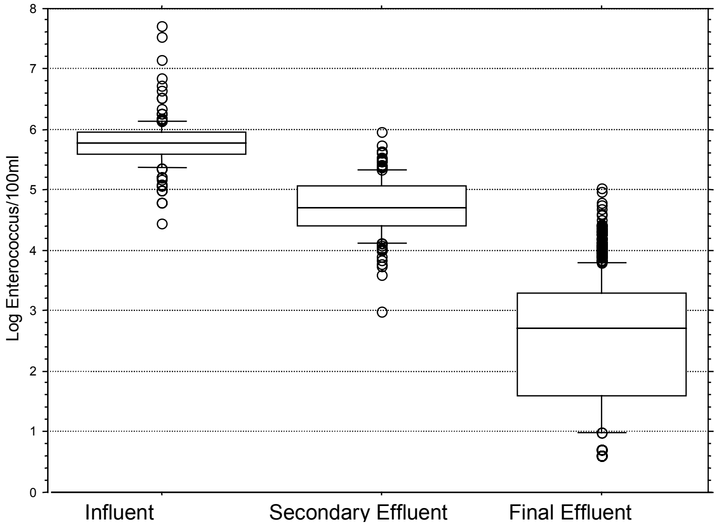


Figure II-3.N Pathogenic viruses and indicator bacteria concentrations at stages of treatment at DITP

These microorganisms differed in their responses to the three phases of treatment. The bacteria indicators fecal coliform and enterococci showed large and significant decreases in counts as treatment progressed: secondary treatment decreased average counts 10-fold, and disinfection of the effluent further decreased average counts 1,000-fold. For pathogenic cultivatable viruses, although the error bars overlap, the biggest difference in counts was after secondary treatment, with a relatively small effect of disinfection. For both the bacteriophages, the biggest change in numbers was after primary treatment, with little effect of either secondary treatment or disinfection. Again, the error bars overlap. These data suggest the indicator bacteria do not respond to treatment the same way the viral pathogens do, but that phages are not a better indicator of the presence of pathogenic viruses than are indicator bacteria.

Figure II-3.O shows results from all the *Enterococcus* samples in Deer Island wastewater collected after the new outfall went on-line. The box plots show frequency distributions of daily geometric means. Although *Enterococcus* are effectively reduced by secondary treatment and disinfection, about 10% of the samples exceed 10^4 col/100 ml. EPA recommends that *Enterococcus* be used to indicate the presence of human health risk in marine waters. In the future, Massachusetts may change its standard from fecal coliform to *Enterococcus* for marine waters. (The FDA shellfish program still requires the measurement of fecal coliform in monitoring shellfish-growing waters.) Although it is not possible to predict what a permit limit would be,[1] the box plot shows that at the present level of chlorination (which consistently results in low levels of fecal coliform) it is likely that about 10% of samples would exceed an *Enterococcus* criterion. Thus, future use of the *Enterococcus* indicator may necessitate higher levels of chlorination (and more sodium bisulfate for dechlorination).

Figure II-3.O. Deer Island Treatment Plant *Enterococcus* counts, September 5, 2000-December 31, 2002



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[1] If EPA criteria were applied in a manner comparable to the existing fecal coliform limit a criterion of 35 col/100 ml (which applies at a bathing beach), times a dilution factor of 70 would give a hypothetical 2,450 col/100 ml limit in effluent. If the EPA suggested criterion for “infrequent full body contact” of 500 col/100 ml were used, the hypothetical limit could be 35,000 col/100 ml. The existing permit limit for fecal coliform is 14,000 col/100 ml.

Reporting on effluent quality. Results of effluent monitoring required by MWRA's permit and Contingency Plan are reported to regulatory agencies, OMSAP, and the public rapidly and in a variety of communication vehicles. MWRA's routine monthly discharge monitoring reports are placed in repository libraries in Hyannis and at MWRA headquarters, and are published on MWRA's website at:http://www.mwra.com/harbor/html/ditp_performance.htm.
A unique requirement in MWRA's discharge permit is that all treatment plant permit violations are reported within five days to regulatory agencies, OMSAP and the public, and noticed on MWRA's website and in repository libraries. In addition, EPA maintains a listserve which actively notifies those on the list of a permit violation. Quarterly Contingency Plan effluent reports are posted on MWRA's web site at: http://www.mwra.com/harbor/pdf/cpqeff.pdf and are also placed in the repository libraries. Annual summary reports of NPDES compliance, that give detailed effluent quality data are available on MWRA's web site at: http://www.mwra.com/harbor/enquad/. Finally, the annual Outfall Monitoring Overview, published each year, summarizes effluent quality data and effluent Contingency Plan results. The most recent Outfall Monitoring Overview is available at repository libraries and on the web at http://www.mwra.com/harbor/enquad/pdf/2002-18.pdf.

II-4 Conclusions and Recommendations

MWRA's effluent monitoring is intensive and thorough. The "normal" conventional and priority pollutant constituents are measured frequently (for example, most facilities only measure whole effluent toxicity quarterly while DITP carries out these tests monthly). In addition, MWRA is on the "cutting edge" of effluent quality monitoring in several areas:

- low detection-limit measurements of toxic contaminants
- developing a sampling method for quantifying "floatables"
- measuring viral pathogens, bacteriophage and *Enterococcus.*

The results of effluent monitoring show that

1. DITP is operating as designed, and consistently meets permit limits and Contingency Plan thresholds.
2. Discharges of solids and BOD have decreased by 80%, compared to the old treatment plants.
3. Discharges of priority pollutants are well below SEIS predictions, and in most cases meet receiving water quality criteria even before dilution.
4. Low detection level effluent analyses of PAH, pesticides and PCBs help MWRA to define an effluent signature. Changes in the treatment plant performance are detectable over much shorter time scales than can be expected with sediment and tissue monitoring. Characteristic ratios of various PAH components, PCB congeners and pesticide components should also help to separate the MWRA contribution from other sources of these parameters to Massachusetts Bay over time.
5. Total nitrogen discharges have decreased slightly, and the amount of dissolved inorganic nitrogen species has increased about 10% as expected with secondary treatment
6. Pathogenic viruses are detectable in final effluent, but at very low numbers: secondary treatment effectively removes pathogens.

MWRA has found that the ability to detect trace levels of contaminants in its effluent aids in the interpretation of other ambient monitoring data, especially for evaluation of fish and shellfish data and toxicity testing. The pattern of certain organic contaminants can help determine whether MWRA effluent might be a source of contamination found in the environment. The effluent data provide valuable feedback to the treatment plant operators and the pollution prevention team. MWRA is recommending no changes to the Ambient Monitoring Plan Effluent Monitoring projects at this time.

References

Butler E, Higgins M, Chiapella J and Sung W. 1997. Deer Island effluent characterization studies: January 1995-December 1995. Boston: Massachusetts Water Resources Authority. Report 1997-03. 91 p.

Breiteneicher D, Delaney B and Pierre-Louis A. 2000. Pollution Prevention Plan: households and permitted industries in the Massachusetts Water Resources Authority service area. Boston: Massachusetts Water Resources Authority. Report ms-063. 18 p.

Darling S and Wu D. 2001. NPDES compliance summary report, fiscal year 2001. Boston: Massachusetts Water Resources Authority. Report 2001-08. 196 p.

Leone CH. 2000. Annual Report on Infiltration and Inflow - FY2000. Boston: Massachusetts Water Resources Authority. Report ms-062. 27 p.

Margolin AB, Abramson SL, Gagnon C and Baptiste-Carpenter EM. 2002. Combined work/quality assurance plan (CW/QAPP) for anthropogenic virus survey: 2002-2005. Boston: Massachusetts Water Resources Authority. Report ms-073. 54 p.

McCarthy S, Mitchell DF and Keay KE. 1996. Summary of MWRA effluent, fish and shellfish workshop: May 24, 1996. Boston: Massachusetts Water Resources Authority. Report ms-041. 128 p.

MWRA 2002. Massachusetts Water Resources Authority Industrial Waste Report, No. 18 October 2002

MWRA 2002. Massachusetts Water Resources Authority Annual Report on Operation and Maintenance July 2001-July 2002. October 2002.

MWRA. 2001. Massachusetts Water Resources Authority Contingency Plan Revision 1. Boston: Massachusetts Water Resources Authority. Report ms-071. 47 p.

MWRA. 1997. Massachusetts Water Resources Authority effluent outfall monitoring plan: Phase II post discharge monitoring. Boston: Massachusetts Water Resources Authority. Report ms-044. 61 p.

MWRA. 1991. Massachusetts Water Resources Authority effluent outfall monitoring plan phase I: baseline studies. Boston: Massachusetts Water Resources Authority. Report ms-002. 95 p.

Pawlowski C, Keay KE, Graham E, Taylor DI, Rex AC and Connor MS. 1996. The state of Boston Harbor 1995: the new treatment plant makes its mark. Boston: Massachusetts Water Resources Authority. Report 1996-06. 22 p.

Shea D. 1994. Appendix A to Report 93-18 "Annual review of toxic contaminants discharged by MWRA: 1993". Boston: Massachusetts Water Resources Authority. Report ms-023. 59 p.

Sung W and Higgins M. 1998. Deer Island effluent characterization studies: January 1997-October 1997. Boston: Massachusetts Water Resources Authority. Report 1998-06. 77 p.

Uhler AD and West DE. 1994. Deer Island effluent characterization June -November, 1993. Boston: Massachusetts Water Resources Authority. Report 1994-04. 46 p.

Werme C and Hunt C. 2002. 2001 Outfall monitoring overview. Boston: Massachusetts Water Resources Authority. Report 2002-18. 84 p.

Wu D. 2003. NPDES compliance summary report, fiscal year 2002. Boston: Massachusetts Water Resources Authority. Report Draft.

III FISH AND SHELLFISH

Maury Hall, Lisa Lefkowitz, Michael Moore

III-1 Background

Commercial and recreational fishing are important parts of the regional identity and economy of Massachusetts. Concerns have been expressed that the relocation of sewage effluent into the relatively clean waters of Massachusetts Bay could adversely affect the health of the local marine ecosystem or result in the chemical contamination of commercial fisheries, rendering them unfit for human consumption. Because many toxic contaminants adhere to particles, animals that live on the bottom, in contact with sediments, and animals that eat bottom-dwelling organisms were thought to be most vulnerable. Shellfish that feed by filtering suspended matter from large volumes of water are considered excellent indicators of the potential for the bioaccumulation of toxic contaminants. These shellfish are themselves resource species and are prey to other fisheries species. Consumption of these animals by predators could result in transferring contaminants up the food chain and ultimately to humans.

III-2 Monitoring Design

The monitoring program focuses on three indicator species: winter flounder, lobster, and blue mussel (Figures III-2.A and III-2.B). Winter flounder and lobster are important resource species in the region. The blue mussel is also a fishery species and is commonly employed as a biomonitoring organism.

Figure III-2.A Sampling areas for mussel and flounder monitoring. (See text for sample locations of individual species.)

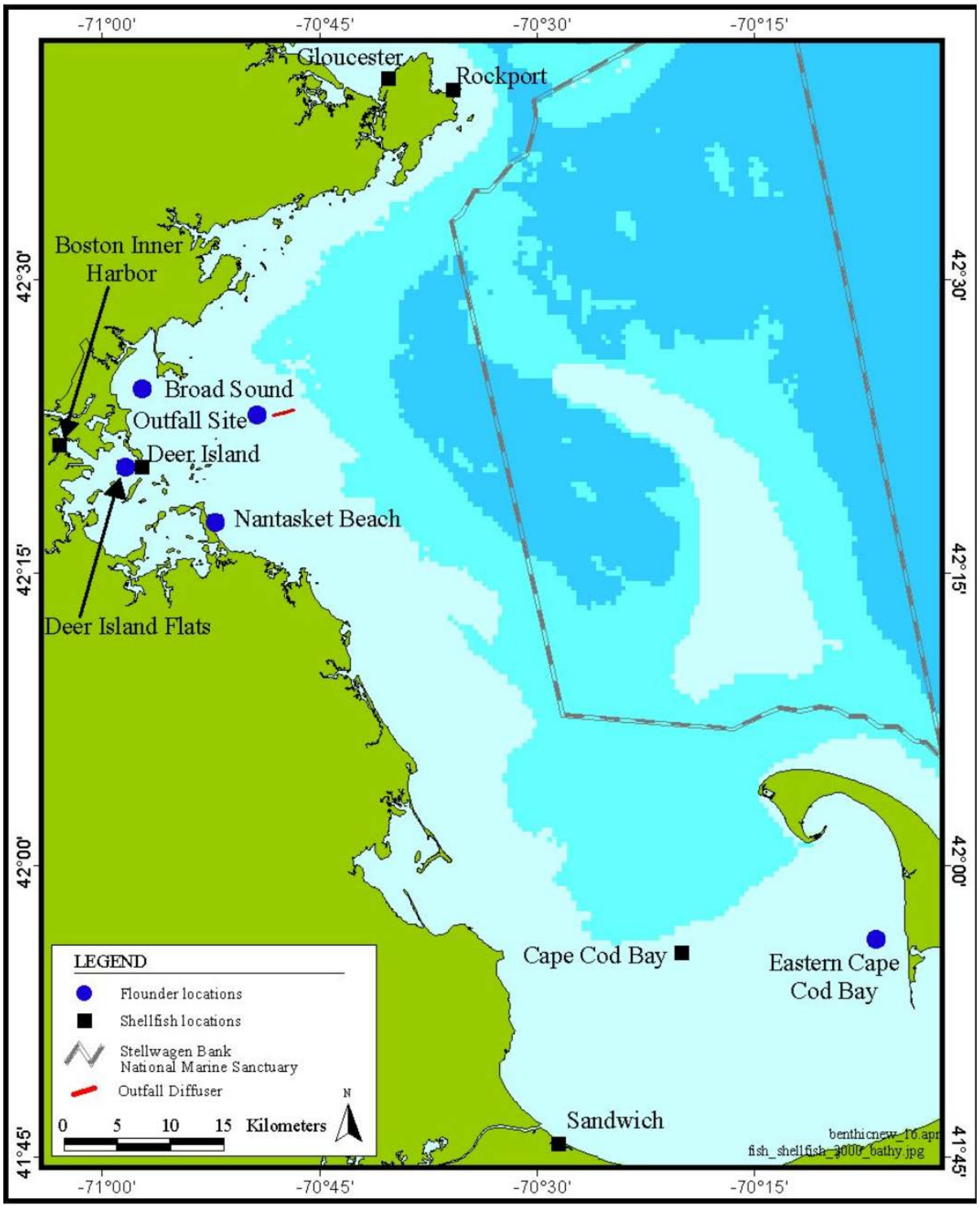
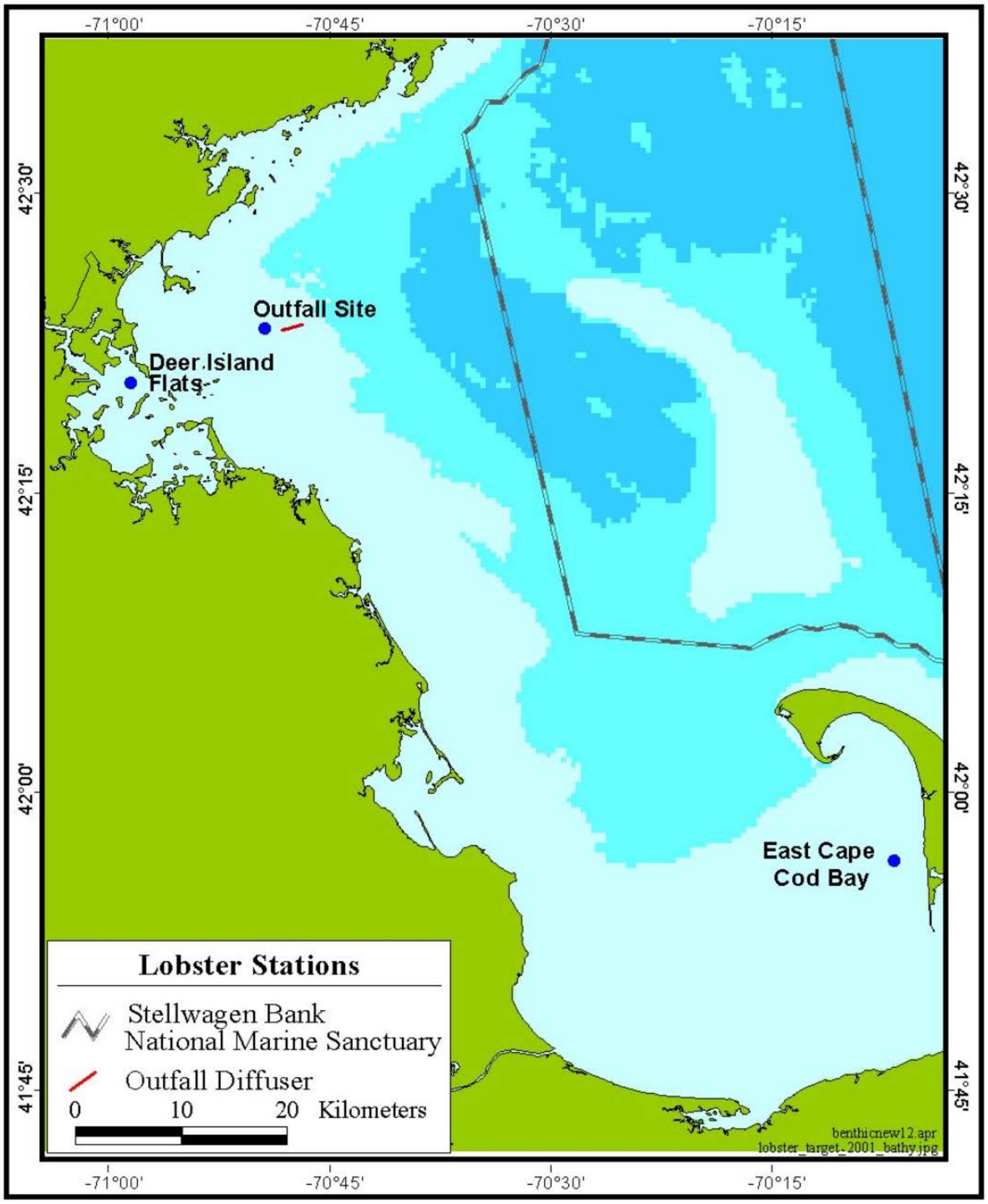


Figure III-2.B Sampling areas for lobster monitoring.



Winter Flounder

Winter flounder live on and eat food from the ocean bottom, often lying buried in the sediments with only their eyes exposed. Consequently, flounder can be exposed to contaminants directly, through contact with the sediments, or indirectly, by ingesting contaminated prey. Fifty flounder are collected annually from each of five locations: Deer Island Flats, Broad Sound, off Nantasket Beach, the outfall site, and eastern Cape Cod Bay. Age, weight, length, and external condition (*e.g.* presence of fin rot) are determined for each fish. Each liver is examined to quantify types of vacuolation (centrotubular (CHV), tubular, and focal, representing increasing severity), macrophage aggregation, biliary duct proliferation, and neoplasia or tumors. Neoplasia and vacuolation have been associated with chronic contaminant exposure.

Chemical analyses of winter flounder tissues from Deer Island Flats, the outfall site, and Cape Cod Bay have been made annually, while tissue analyses of flounder from Nantasket Beach and Broad Sound are made every two years. Chemical analyses are done on 15 fish per site, aggregated into 3 composites of five fish each. Separate analyses are done on fillets and on livers. Fillets and livers are analyzed for PCBs, pesticides, mercury, and lipids. Liver samples are also analyzed for PAHs, lead, silver, cadmium, chromium, copper, nickel, and zinc.

Lobster

Lobsters live on a variety of sea-floor environments within the region, including mud, sand, gravel, and rock outcrops. Commercial lobstermen collect lobsters for the monitoring program, with on-board scientists verifying the sampling locations. Lobsters are taken from Deer Island Flats, near the outfall site, and eastern Cape Cod Bay to determine specimen health and tissue contaminant burden. Chemical analyses are performed on three composites of five animals each. Meat (from the tail and claw) and hepatopancreas are analyzed for lipids, PCBs, pesticides, and mercury. Hepatopancreas samples are also analyzed for PAHs, lead, silver, cadmium, chromium, copper, nickel, and zinc.

Blue Mussel

Like other filter feeders, blue mussels process large volumes of water and can concentrate toxic metals and organic compounds in their tissues. Mussels can be readily maintained in fixed cages, so they are convenient monitoring tools. Mussels are collected from clean reference sites (*i.e.* Rockport, Gloucester, and Sandwich, Massachusetts and in 2002 Harpswell, Maine). They are then put in cages and deployed in replicate arrays at up to four sites, including Boston Inner Harbor, Deer Island, the outfall site, and Cape Cod Bay. After a minimum deployment of 40 days or a preferred deployment of 60 days, chemical analyses are performed on composite samples of mussel tissue. Generally, four to eight composite samples are analyzed at each site. A composite consists of ten mussels for organic contaminant analysis and five for metals analysis. Analytes include PCBs, pesticides, PAHs, lipids, mercury, and lead.

III-3 Monitoring Results

Winter Flounder

Contingency plan thresholds have been established as an alert to unexpected or unacceptable changes after the onset of offshore effluent discharge. For flounder, thresholds were set based on allowable FDA concentrations of mercury and PCBs in edible tissue, on a doubling of the baseline average of lipid normalized dieldrin, total DDTs, and total chlordanes in edible tissue, and on the pre-diversion average of the incidence of centrotubular hydropic vacuolation (CHV) in livers from flounder collected in the vicinity of the old Deer Island effluent and sludge discharge site. Table III-3.A shows that no thresholds have been exceeded and that results from each of the two years since the outfall came on line have generally been well below the baseline average. Trend plots of all contaminants can be found in the appendices.

Table III-3.A. Contingency plan baseline, threshold, and 2001 and 2002 values for fish and shellfish monitoring

Parameter Type/ Location	Parameter	Baseline	Caution Level	Warning Level	2001 Results	2002 Results
Flounder tissue nearfield	PCB	0.033 ppm	1 ppm wet weight	1.6 ppm wet weight	0.027 ppm	0.024 ppm
	Mercury	0.074 ppm	0.5 ppm wet weight	0.8 ppm wet weight	0.08 ppm	0.065 ppm
	Chlordane	242 ppb/g lipid	484 ppb/g lipid	None	144 ppb/g lipid	73.7 ppb/g lipid
	Dieldrin	63.7 ppb/g lipid	127 ppb/g lipid	None	68.1 ppb/g lipid	10.6 ppb/g lipid
	DDT	775.9 ppb/g lipid	1552 ppb/g lipid	None	596 ppb/g lipid	254 ppb/g lipid
Flounder nearfield	Liver disease (CHV)	24.4%	44.9%	None	6%	24%
Lobster tissue nearfield	PCB	0.015 ppm	1 ppm wet weight	1.6 ppm wet weight	0.0097 ppm	.0086 ppm
	Mercury	0.148 ppm	0.5 ppm wet weight	0.8 ppm wet weight	0.15 ppm	0.13 ppm
	Chlordane	75 ppb/g lipid	150 ppb/g lipid	None	49.5 ppb/g lipid	48.1 ppb/g lipid
	Dieldrin	161 ppb/g lipid	322 ppb/g lipid	None	172 ppb/g lipid	132 ppb/g lipid
	DDT	341.3 ppb/g lipid	683 ppb/g lipid	None	305 ppb/g lipid	289 ppb/g lipid
Mussel tissue nearfield	PCB	0.011 ppm	1 ppm wet weight	1.6 ppm wet weight	0.0096 ppm	.0084 ppm
	Lead	0.415 ppm	2 ppm wet weight	3 ppm wet weight	0.24 ppm	.33 ppm
	Mercury	0.019 ppm	0.5 ppm wet weight	0.8 ppm wet weight	0.02 ppm	.023 ppm
	Chlordane	102.3 ppb/g lipid	205 ppb/g lipid	None	250 ppb/g lipid, caution level exceedance	210 ppb/g lipid, caution level exceedance
	Dieldrin	25 ppb/g lipid	50 ppb/g lipid	None	25.2 ppb/g lipid	25.6 ppb/g lipid
	DDT	241.7 ppb/g lipid	483 ppb/g lipid	None	205 ppb/g lipid	223 ppb/g lipid
	PAH	1080 ppb/g lipid	2160 ppb/g lipid	None	3020 ppb/g lipid, caution level exceedance	3140 ppb/g lipid, caution level exceedance

Similar to flounder meat, flounder livers of fish collected at the outfall site show no apparent contaminant increases as a result of the wastewater diversion (Figures III-3.A, III-3.B, III-3.C, and III-3.D. All trend plots are shown in the appendices.

Figure III-3.A Total PCB in Flounder Livers 1992-2002

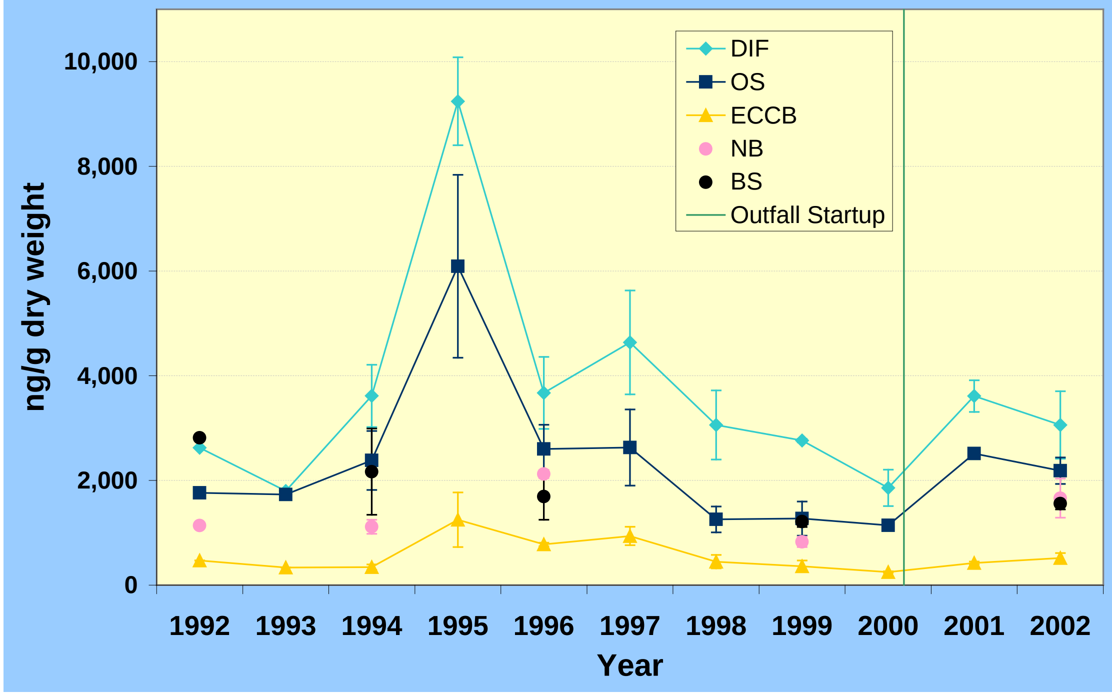
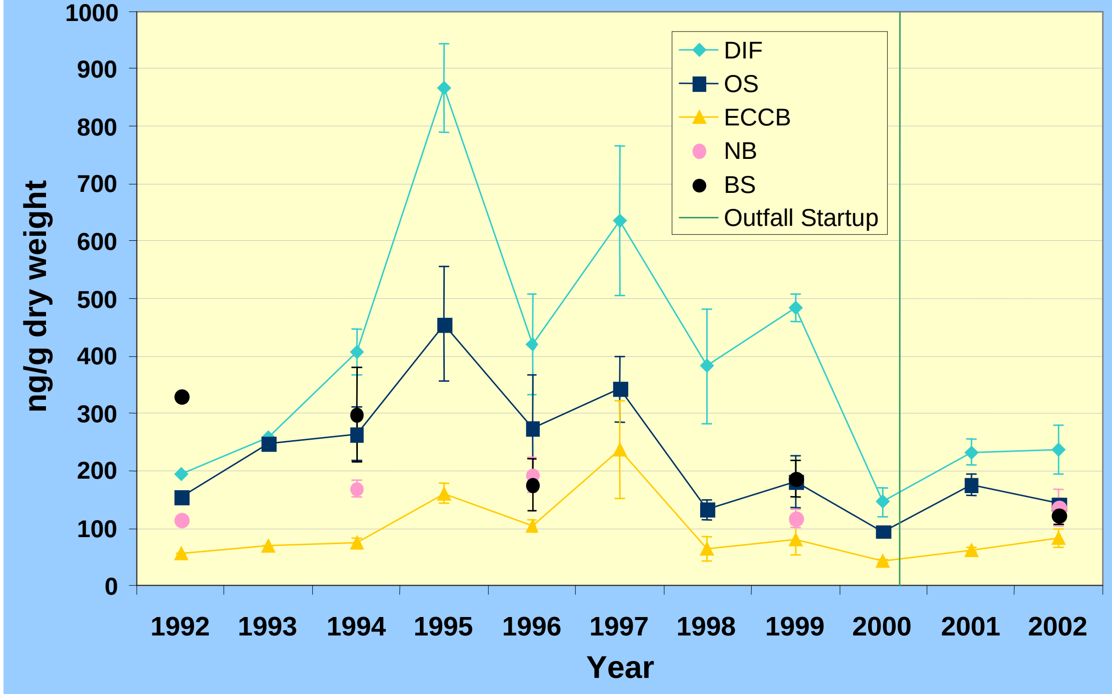


Figure III-3.B Total DDT in Flounder Livers 1992-2002



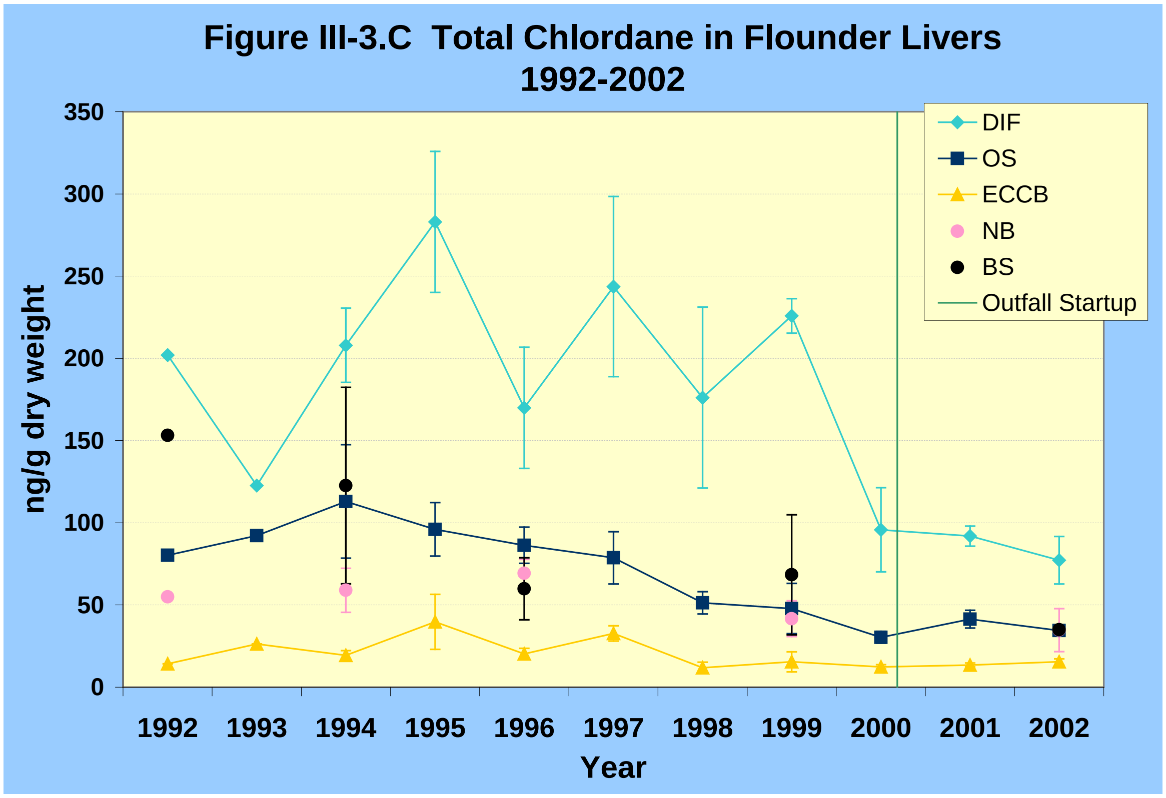


Figure III-3.C Total Chlordane in Flounder Livers 1992-2002
ng/g dry weight
0
50
100
150
200
250
300
350
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
Year
DIF
OS
ECCB
NB
BS
Outfall Startup

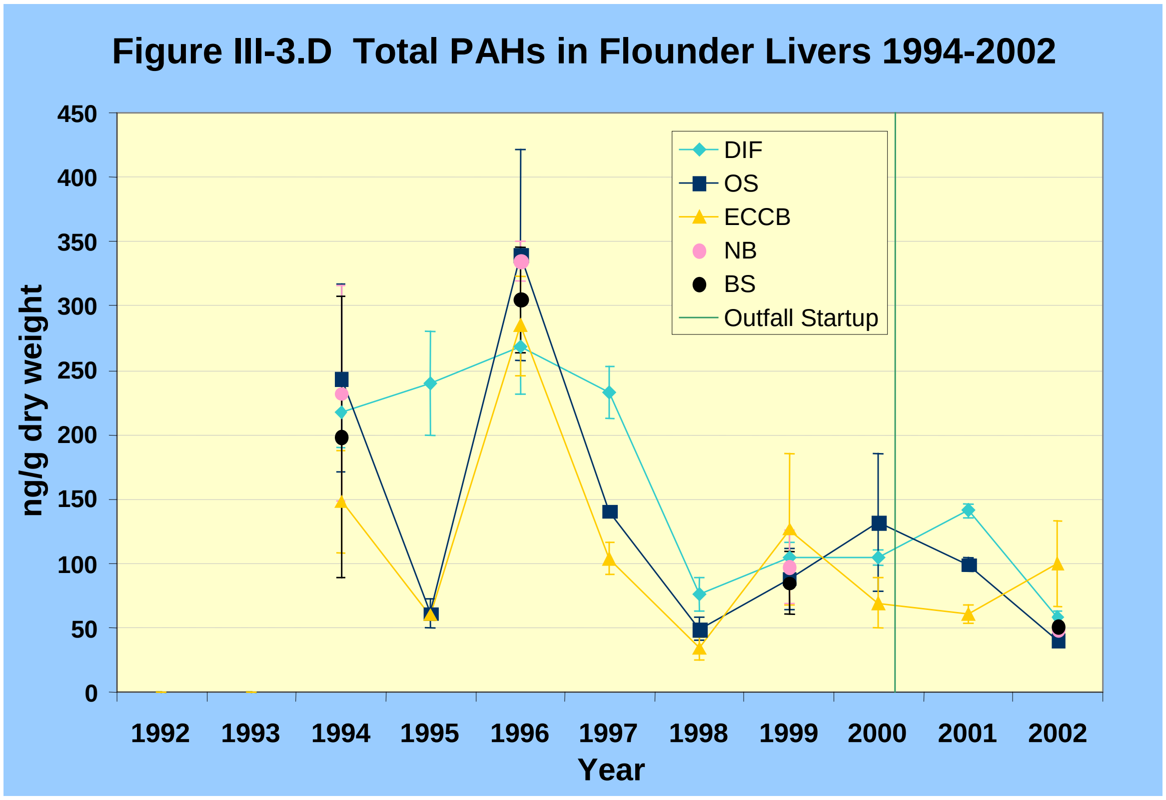


Figure III-3.D Total PAHs in Flounder Livers 1994-2002
ng/g dry weight
0
50
100
150
200
250
300
350
400
450
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
Year
DIF
OS
ECCB
NB
BS
Outfall Startup

A high incidence of liver disease in flounder from Boston Harbor was a major impetus behind the mandate to reduce the contaminant loading to the harbor.   The onset of liver disease is age related. Exposure over several years is required before hydropic vacuolations are clearly expressed in liver tissue (Figure III-3.E).   Plots of the incidence of CHV over time (Figure III-3.F) and CHV normalized to age (Figure III-3.G) indicate a tendency toward a lower CHV incidence since the early 90’s at most stations. Fish collected from Cape Cod Bay show no long-term trend. The incidence of neoplasia has been extremely low at all stations since the early 1990’s (Trend plot in the appendices).

Figure III-3.E   Proportion of winter flounder showing hydropic vacuolation for each age, for each station (1991 - 2000), except OS - post (2001 - 2002). N = 2,639

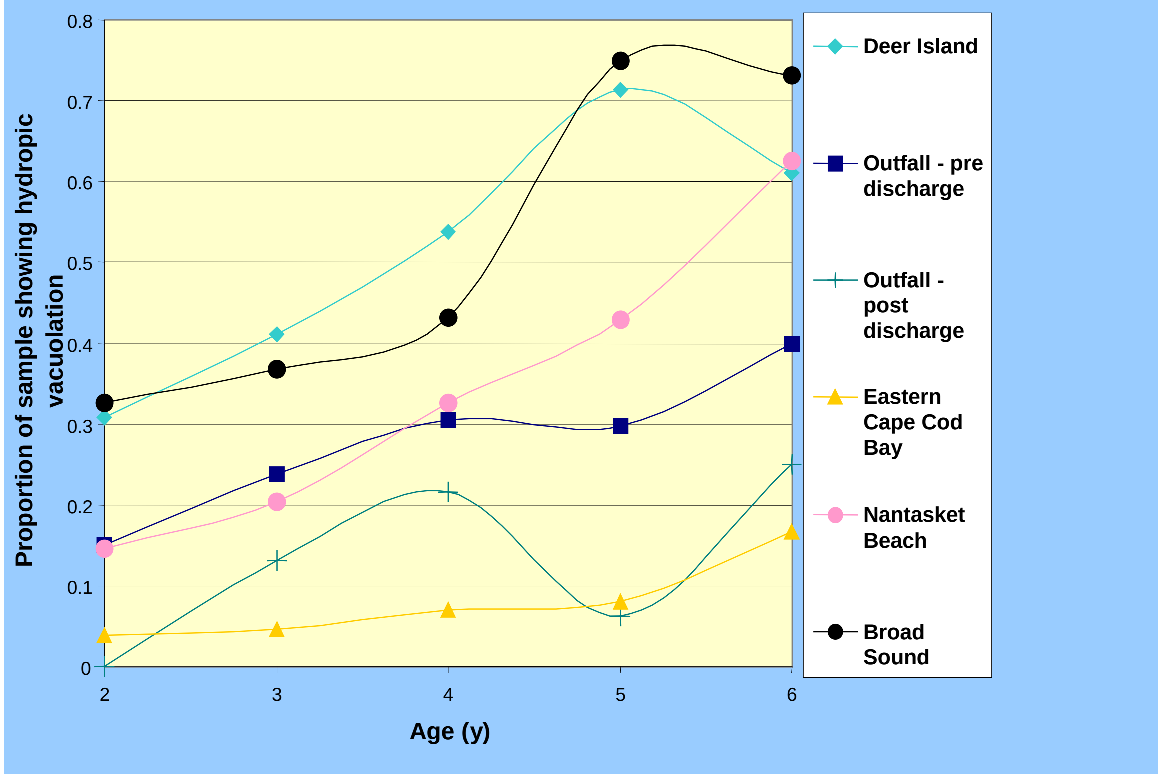


Figure III-3.F Incidence of CHV Over Time

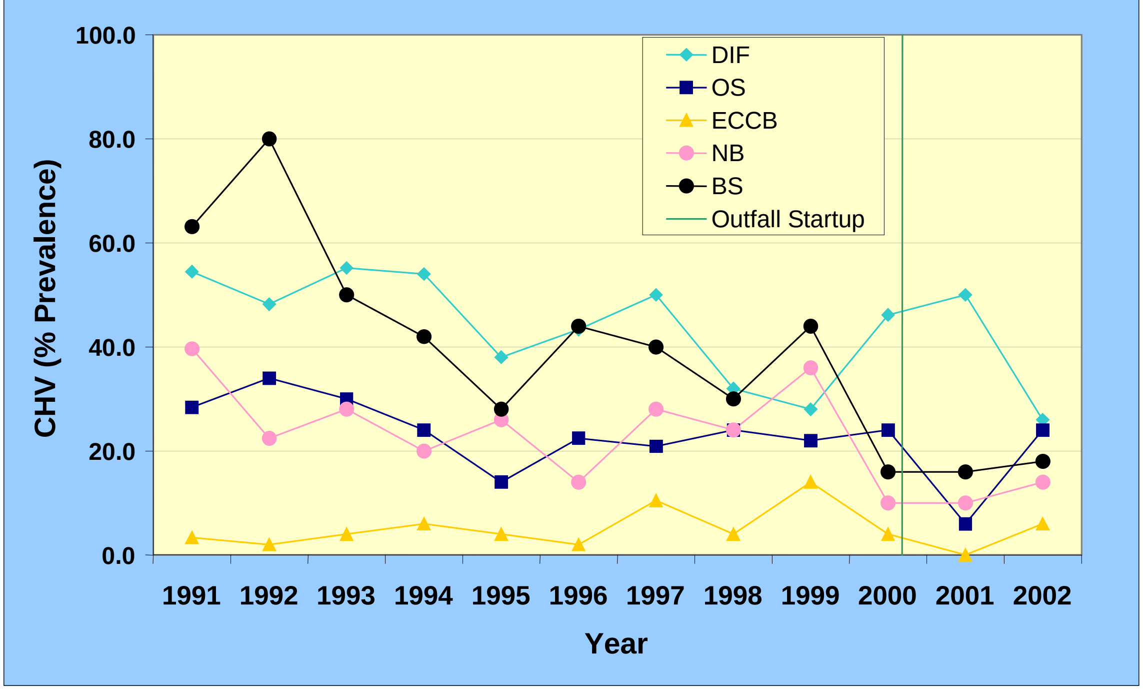
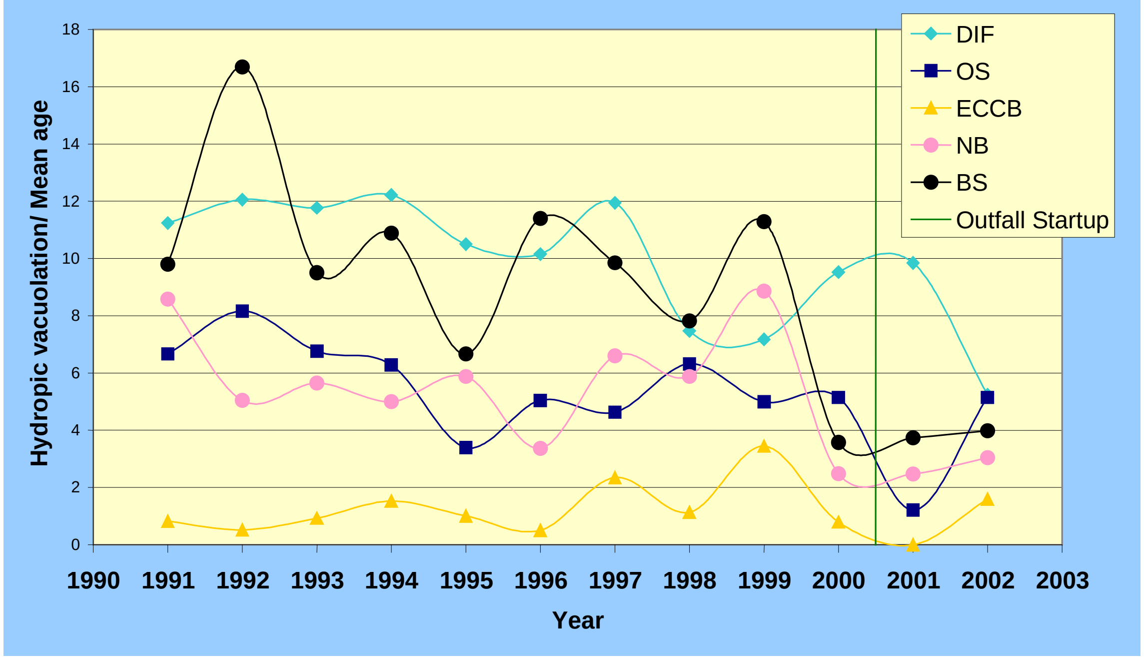


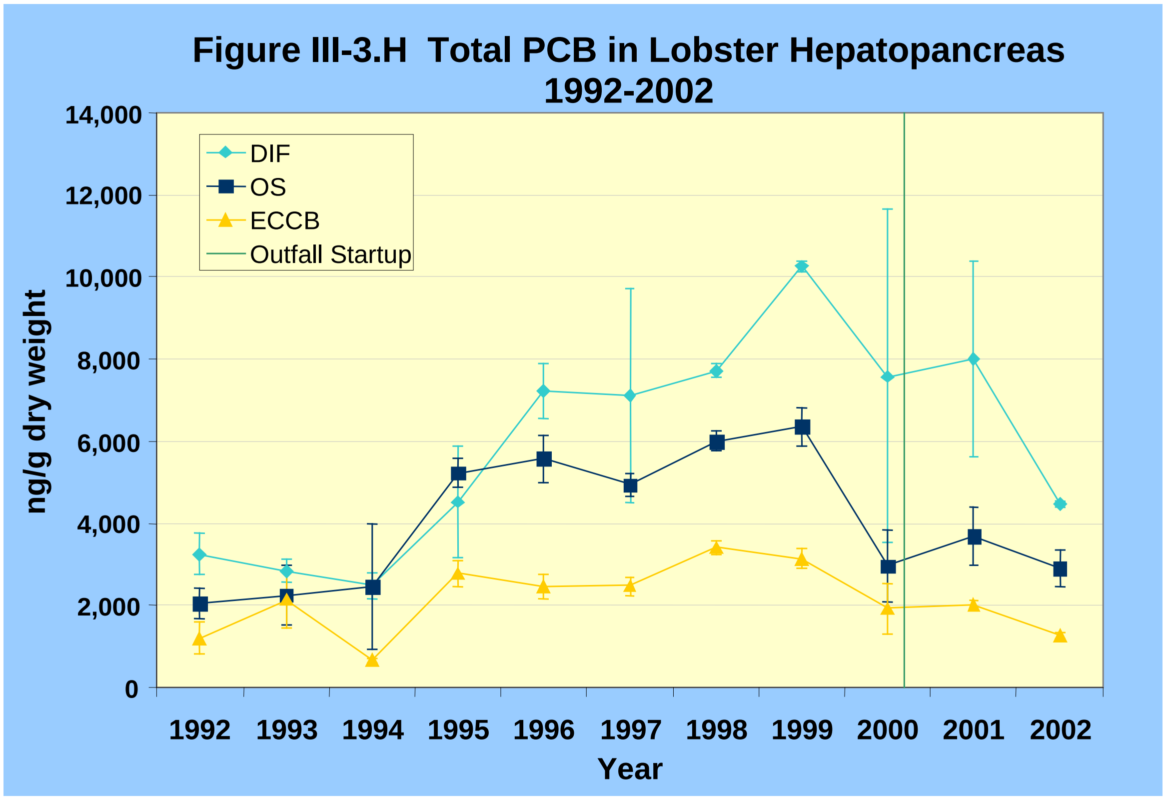
Figure III-3.G Hydropic vacuolation index (HV%/Age)
for each station in each year



Lobster

As for flounder, Table III-3.A (comparison with thresholds) shows that neither 2001 or 2002 results approached any Caution and Warning thresholds. In most cases results were below the baseline. Trend plots for all lobster meat contaminants are in the appendices.

Similarly, lobster hepatopancreas contaminant data show most 2001 and 2002 results are well within the baseline range (Figures III-3.H, III-3.I, III-3.J, and III-3.K).



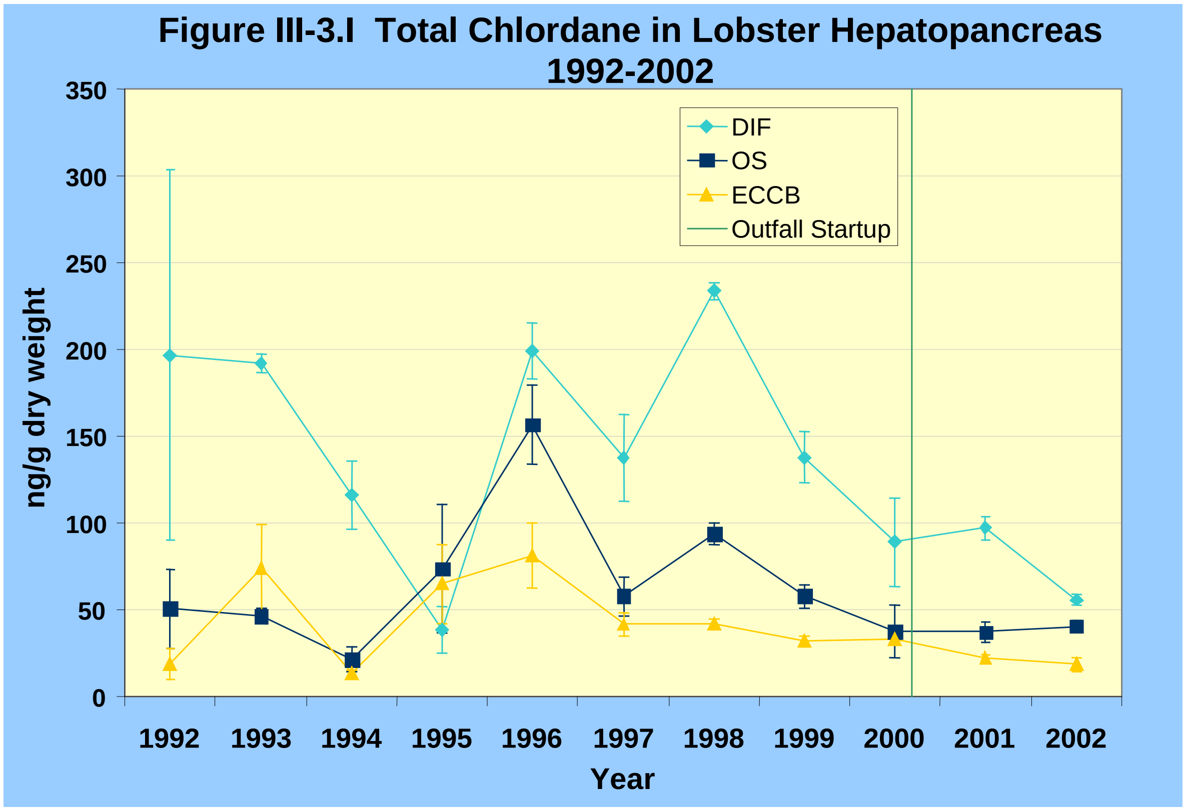


Figure III-3.I Total Chlordane in Lobster Hepatopancreas 1992-2002

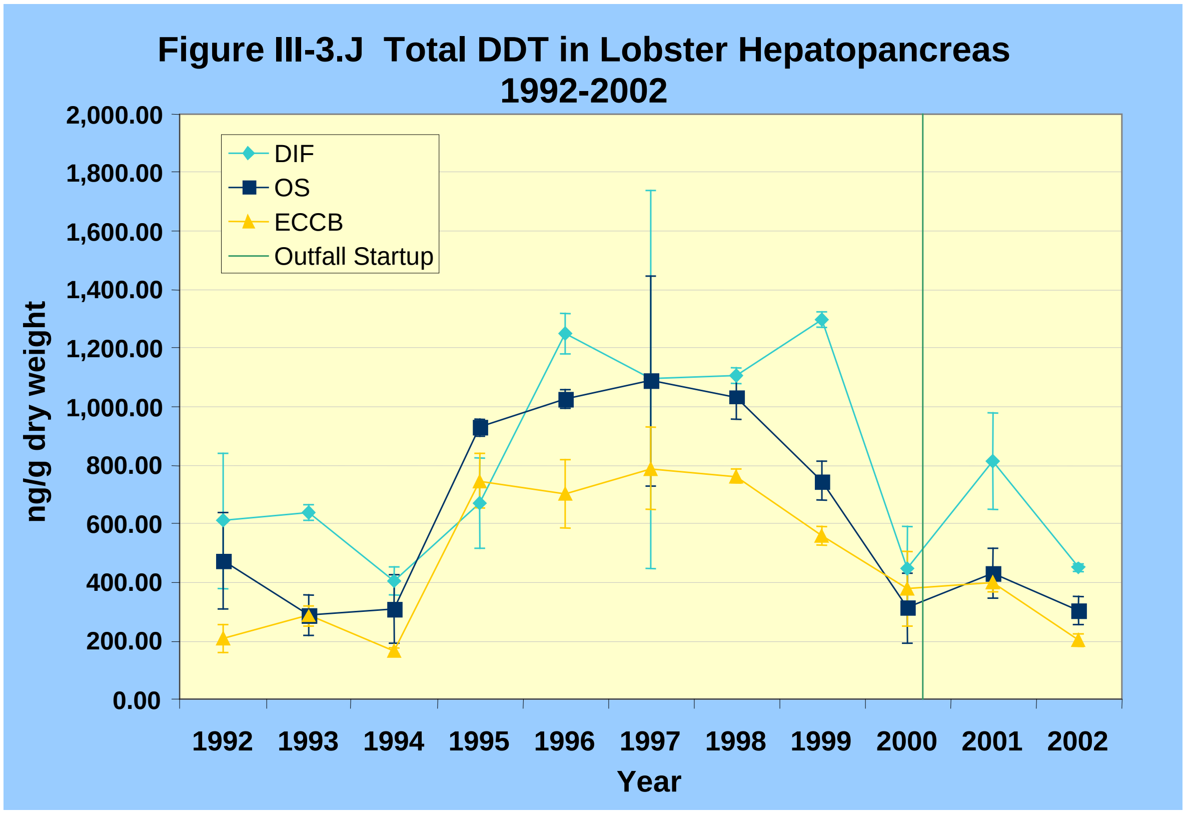


Figure III-3.J Total DDT in Lobster Hepatopancreas 1992-2002

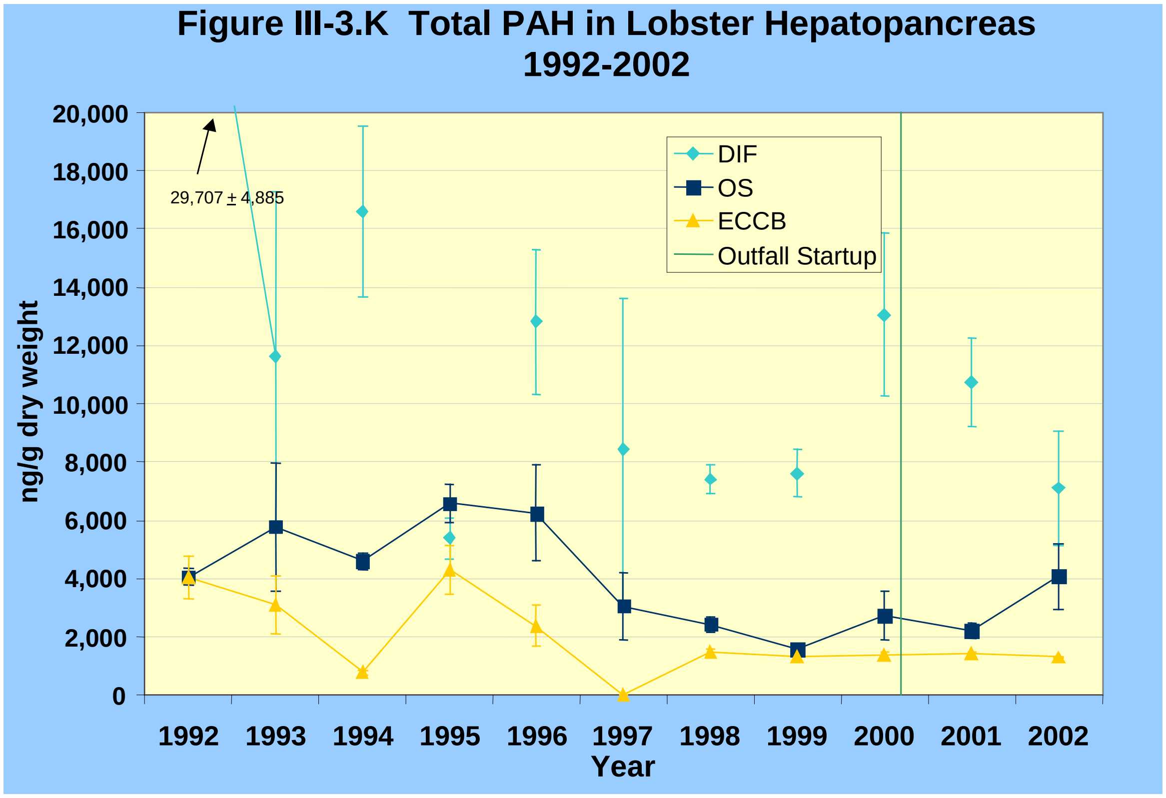


Figure III-3.K Total PAH in Lobster Hepatopancreas 1992-2002

Trend plots for silver and copper in lobster hepatopancreas (Figures III-3.L and III-3.M) indicate an increasing trend since the early 1990's. The cause of the apparent increase is not known. However, because it predates the diversion and is also observed at Deer Island Flats, it does not appear to be caused by the effluent diversion.

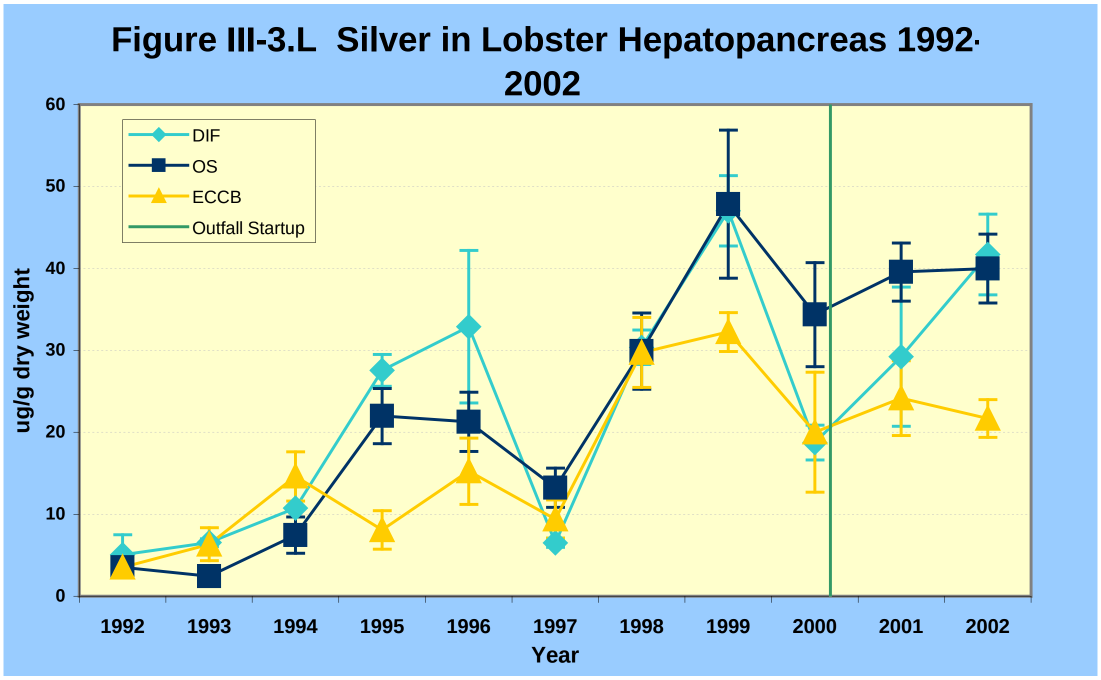
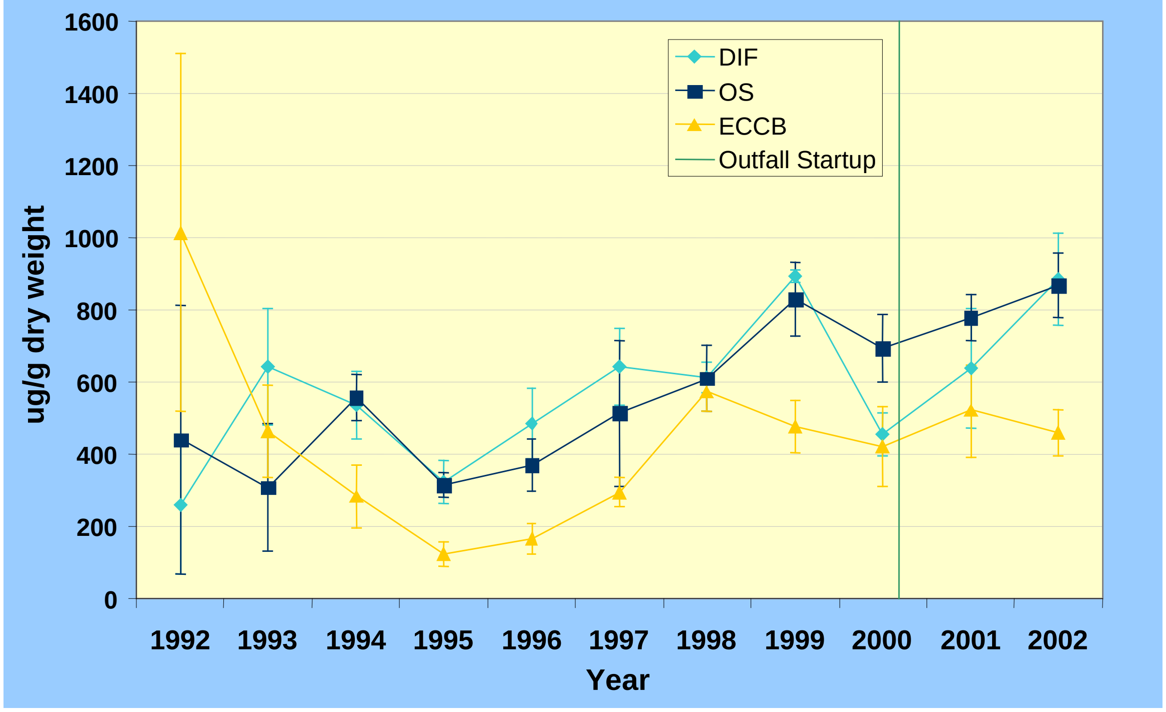


Figure III-3.L Silver in Lobster Hepatopancreas 1992-2002

Figure III-3.M Copper in Lobster Hepatopancreas 1992-2002



Blue Mussel

With the exception of chlordanes and PAHs 2001 and 2002 results were well below threshold levels and at or below baseline values**.** (Table III-3.A, Figures III-3.N, III-3.O, and III-3.P). See appendix for plots of all parameters.

Figure III-3.N Total PAHs in Mussels 1991-2002

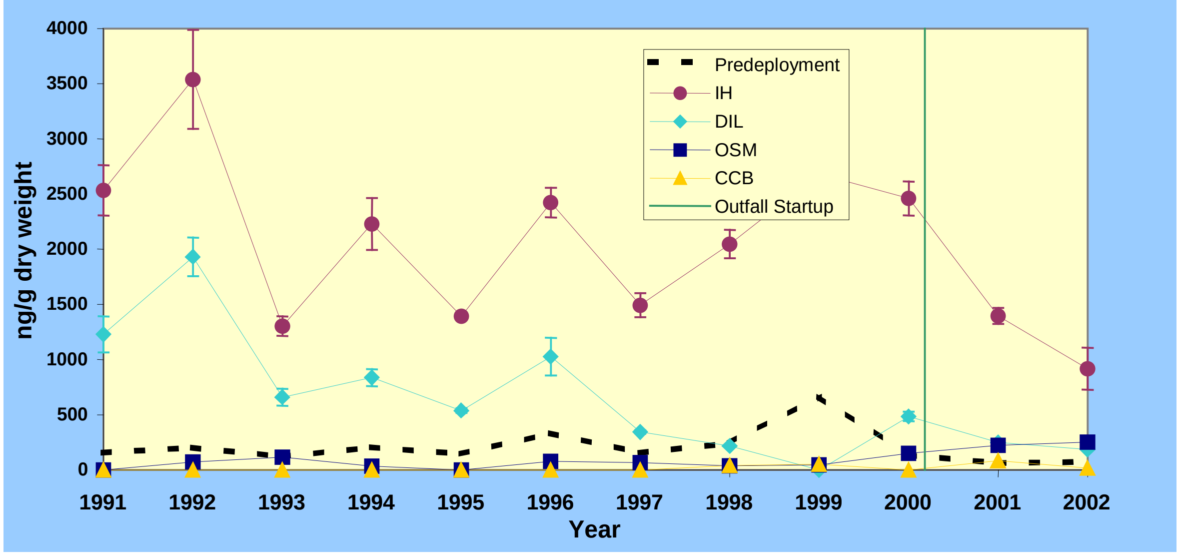


Figure III-3.O Total Chlordane in Mussels 1991-2002

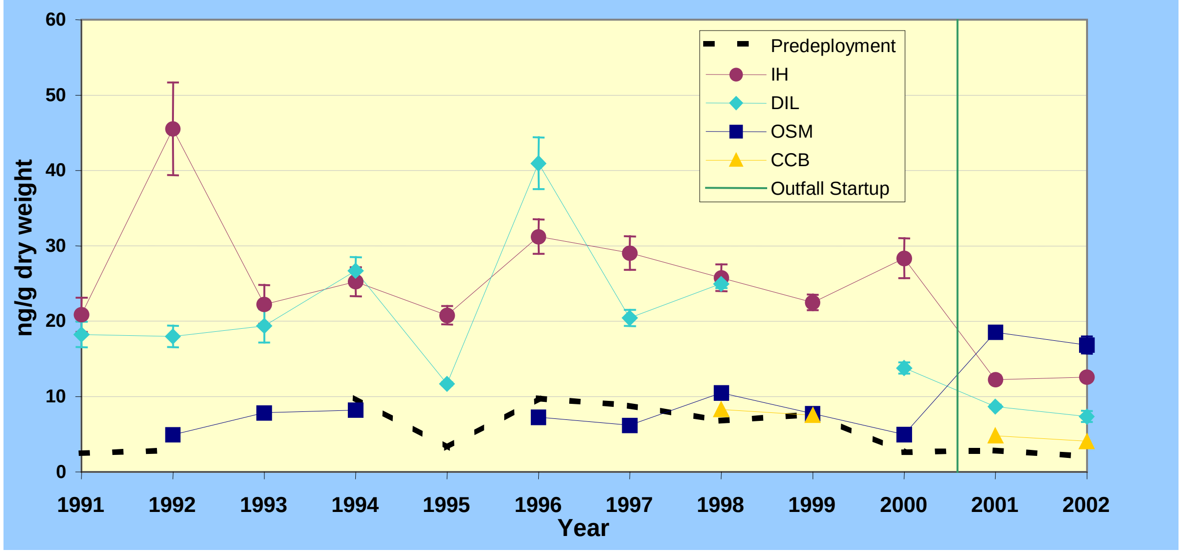
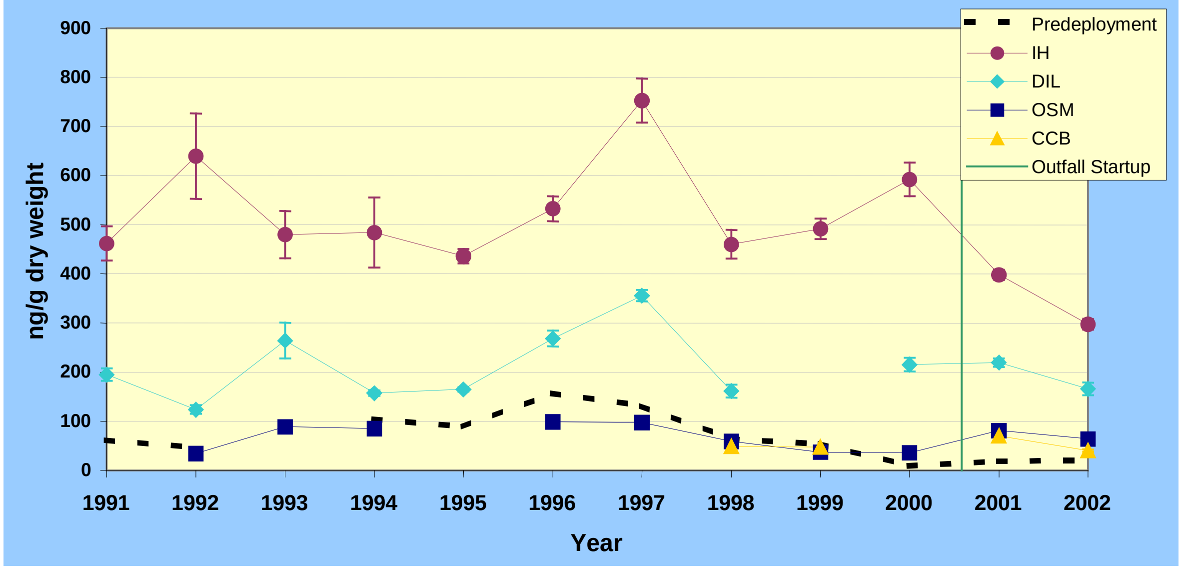


Figure III-3.P Total PCB in Mussels 1991-2002



Hunt *et al.* 2002 and Lefkovitz *et al.* 2002 discuss the 2001 mussel contingency plan exceedances in detail. They concluded that using more recent data on the bioavailibility of PAHs and chlordanes in MWRA effluent to mussels placed within the outfall mixing zone allows reasonably good predictions of the observed mussel concentrations. Hunt *et al.* 2002 also provides an analysis as to whether the observed mussel concentrations pose or suggest an environmental risk. They conclude that they do not. A recent OMSAP focus group on the 2002 exceedances reached the same conclusion.

III-4 PROPOSED CHANGES TO THE MONITORING

The monitoring plan poses several questions relating to the fish and shellfish monitoring. They are:

1. Has the level of contaminants in the tissues of fish and shellfish around the outfall changed since discharge began?
2. Do the levels of contaminants in the edible tissue of fish and shellfish around the outfall represent a risk to human health?
3. Are the contaminant levels in fish and shellfish different between outfall, Boston Harbor, and a reference site?
4. Has the incidence of disease and/or abnormalities in fish and shellfish changed?

The monitoring results of the first two post-diversion years indicate that there have been no short-term changes in flounder health, flounder contaminant body burdens, or in lobster contaminant body burden at the outfall site. With the exception of PAHs and chlordanes, mussels have not shown any changes compared to baseline conditions. The increases in PAHs and chlordanes do not pose a risk to human health or an environmental concern at this time. Therefore, the answer to questions 1, 2, and 4 is that after two years of monitoring we see no adverse changes or changes which pose a threat to human health. The answer to question 3 was established early in the monitoring program – there have always been differences in contaminant levels between the outfall, Deer Island Flats, and reference areas.

While there have been no short-term changes observed, monitoring should continue to establish that there are no long term changes. A longer-term monitoring program should be modeled after the Status and Trends Mussel Watch Program, where individual stations are monitored every several years.

Since liver histopathology provides a clear indication of contaminant impacts on animal health we plan to continue annual monitoring of flounder liver histopathology at the three core sites; the outfall site, Deer Island Flats, and Cape Cod Bay.

We propose the following changes to fish and shellfish monitoring:

- For flounder, mussels and lobster: The present sampling schedule measures tissue contaminant levels in all three species every year. We propose to change the schedule to rotate tissue chemistry analyses among the three species every year. Mussels would be monitored in 2003, lobster in 2004, and flounder in 2005. The present level of effluent monitoring, as well as a targeted MWRA and USGS benthic monitoring program will provide the supporting data to indicate the potential for adverse trends for any of the three species.

- For flounder: Since the flounder collection sites of Broad Sound and Nantasket Beach were never considered anything other than “control” sites, we recommend dropping these sites after the 2003 field season, as the Deer Island and Cape Cod Bay sites provide adequate controls for measuring outfall effects. Over the course of the monitoring program tissue chemistry from these two sites has only been measured every two to three years (see figures in flounder section as well as in appendix). Data from all five sites are in the process of being analyzed and incorporated in a paper for publication (Moore *et al.,* in prep).

References

Hunt, C., S. Abramson, L. Lefkovitz, J. Neff, G. Durell, K. Keay, and M. Hall. 2002. Evaluation of 2001 Mussel Tissue Contaminant Threshold Exceedance. MWRA. ENQUAD Report 2002-05. 48 p.

Lefkovitz, L., S. Abramson, R. Hillman, M. Moore, J. Field. 2002. 2001 Annual Fish and Shellfish Report. MWRA. ENQUAD Report 2002-14. 175 p.

IV SEDIMENT CONTAMINANT MONITORING

Kenneth E. Keay, Carlton D. Hunt, and Suh Yuen Liang

IV-1 Background

The sea floor of Massachusetts and Cape Cod bays was originally shaped by the glaciers, which sculpted the bottom and deposited debris, forming knolls, banks, and other features. Within Massachusetts Bay, the sea floor ranges from mud in depositional basins to coarse sand, gravel, and bedrock on topographic highs. The area around the outfall is marked by underwater drumlins, which are elongated hills about 10 meters high, with crests covered by gravel and boulders. Between these drumlins are small depositional depressions. The major regional long-term sinks for fine-grained sediments include Boston Harbor, Cape Cod Bay, and Stellwagen Basin (USGS 1997, 1998).

Sediment transport in the region occurs primarily during storms. Typically, waves during storms with winds from the northeast resuspend sediments, which are transported by shallow currents from western Massachusetts Bay toward Cape Cod Bay and by deeper currents to Stellwagen Basin, where they are likely to remain. Cape Cod Bay is partially sheltered from large waves by the arm of Cape Cod, and storm waves are rarely large enough to resuspend sediments in Stellwagen Basin, which is the deepest feature in the region.

Environmental Concerns Within Boston Harbor, studies of the sediments have documented recovery following the cessation of sludge discharge, improvements to CSO systems, and improved sewage effluent treatment (Bothner *et al*. 1998, Lefkovitz *et al*. 1998, Kropp *et al*. 2002). However, relocating the outfall raised concerns about potential effects of the relocated discharge on the offshore sea floor. These concerns focused on three issues: eutrophication and related low levels of dissolved oxygen, accumulation of toxic contaminants in depositional areas, and smothering of animals by particulate matter. This briefing deals primarily with the second issue, accumulation of potentially toxic contaminants. Section V of this briefing package evaluates the hardbottom special study, while the soft-sediment benthic community concerns and monitoring will be discussed at a later workshop.

Although the Deer Island Treatment Plant was designed to keep effluent contaminant concentrations low, EPA’s 1988 Environmental Impact Statement (EPA, 1988) predicted small increases in contaminant concentrations in nearby sediments. One factor in these predicted increases was the expectation that the outfall would be discharging primary-treated effluent for five years. However, construction delays meant that the outfall did not come on-line until after the effluent was receiving secondary treatment, which effectively removes these chemical contaminants. In addition, early projections of contaminant loadings from secondary effluent were very high (see Table I-B in the Introduction). The effluent monitoring data shown in Section II confirm that the DITP discharges very low amounts of chemical contaminants compared to the primary-treated discharge to Boston Harbor. In fact, for many constituents, water quality criteria are met in the effluent even before dilution. Thus, the relatively intense temporal and spatial scales of the sediment contaminant monitoring in the Ambient Monitoring Plan (MWRA 1991, 1997), were designed to measure impacts from contaminant loadings that turned out to be much lower than projected. As the monitoring results presented here show, two years of post-discharge sampling have found no evidence of acute outfall-related impacts on sediment contamination, which were the original concerns. MWRA believes that it can address the remaining concerns with a more cost-effective program.

IV-2 Monitoring Design

Sediment contaminant monitoring was designed to address the questions in Table IV-2.A; this briefing addresses 27, 37, &38. Question 29, which addresses whether changes in benthic communities correspond to changes in contaminant concentrations, was most recently addressed for baseline data in Section 5.2.8 of Kropp *et al*. (2001). We will address that question using data through 2002 in the summer workshop, when we discuss benthic community monitoring.

Table IV-2.A. Questions addressed by sediment contaminant studies, including the status reported in the briefing package for the September 24, 2002 OMSAP meeting.

#	Question (from monitoring plan, MWRA 1991)	Status
27	Have the concentrations of contaminants in sediments changed?	Answered (acute) shift focus to chronic
29[1]	Are any benthic community changes correlated with changes in levels of toxic contaminants (or sewage tracers) in sediments?	Answered for baseline
37	What is the level of sewage contamination and its spatial distribution in Massachusetts and Cape Cod Bays sediments before discharge through the new outfall?	Answered
38[2]	Has the level of sewage contamination or its spatial distribution in Massachusetts and Cape Cod Bays sediments changed after discharge through the new outfall?	Answered for nearfield and for dissolved constituents. Not answered for farfield sediment toxic ontaminants.

The core of the monitoring consists of annual, mid-August sampling of sediments at 31 stations throughout Massachusetts and Cape Cod Bays (Figs. IV-2.A, IV-2.B). Replicate field samples are collected at all farfield stations and at stations NF12, NF17, and NF24; single samples are collected at remaining nearfield stations. Samples are analyzed for contaminant concentrations and other chemistry parameters in sediments (Table IV-2.B). Details of MWRA's benthic monitoring can be found in the project work plan (Williams *et al*. 2002). Results of MWRA's benthic monitoring have been presented in a series of annual interpretive reports, e.g. Blake *et al*. (1998), Kropp *et al*. (2001, 2002).

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[1] Recommend dropping this question. It is redundant with questions 26 and 27, and rather than guiding the monitoring design represents an evaluation that could be performed if changes were observed in the benthos or in contaminants.

[2] Drop, redundant with #7 (dissolved toxic contaminants), #8 (pathogens) , #11 and # 18 (nutrients), #27 (sediment contaminants).

Figure IV-2.A. Locations of nearfield soft-bottom stations, including stations sampled by nearfield contaminant special study (NCSS) and USGS.

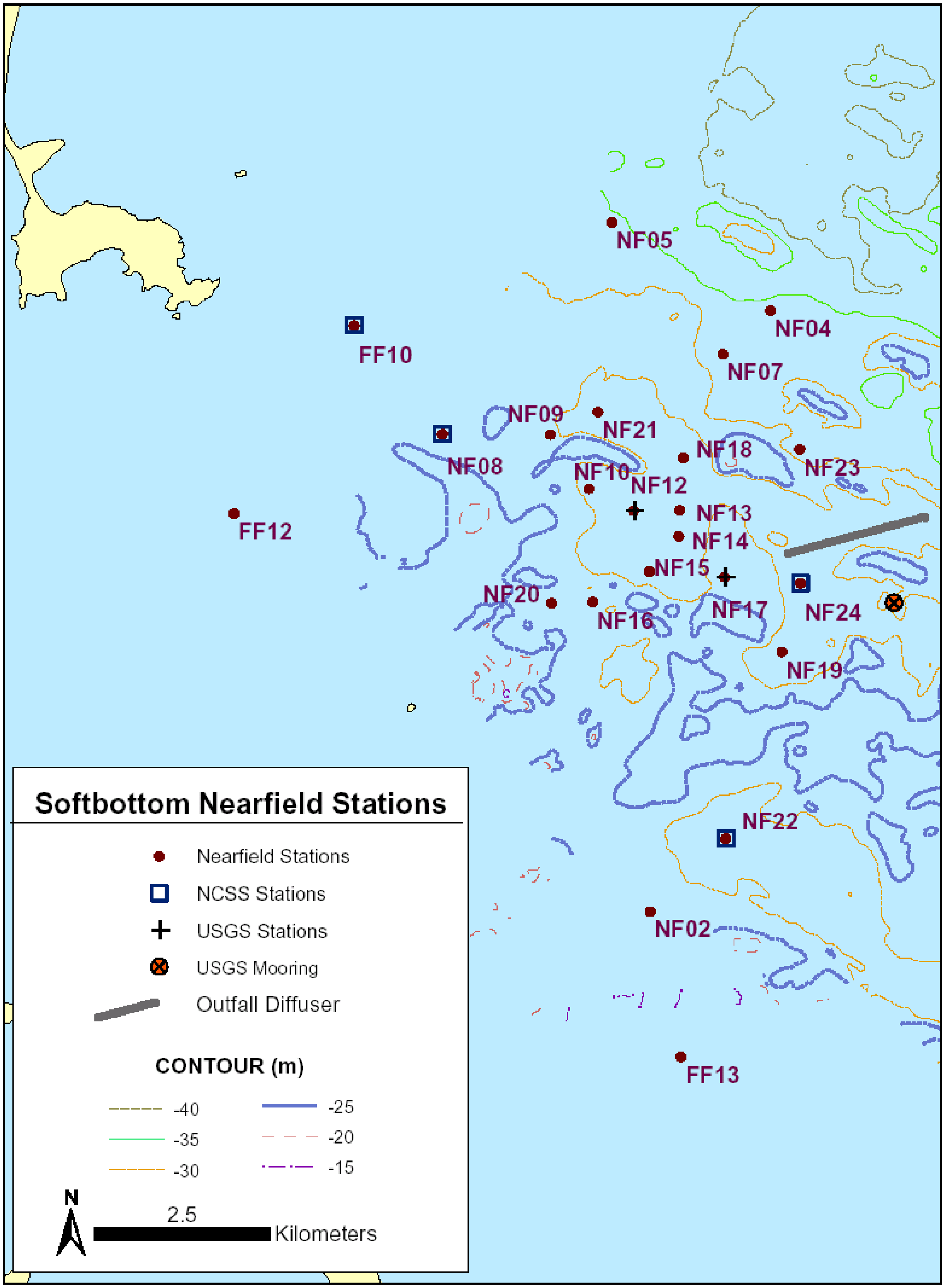


Figure IV-2.B. Locations of farfield soft-bottom stations

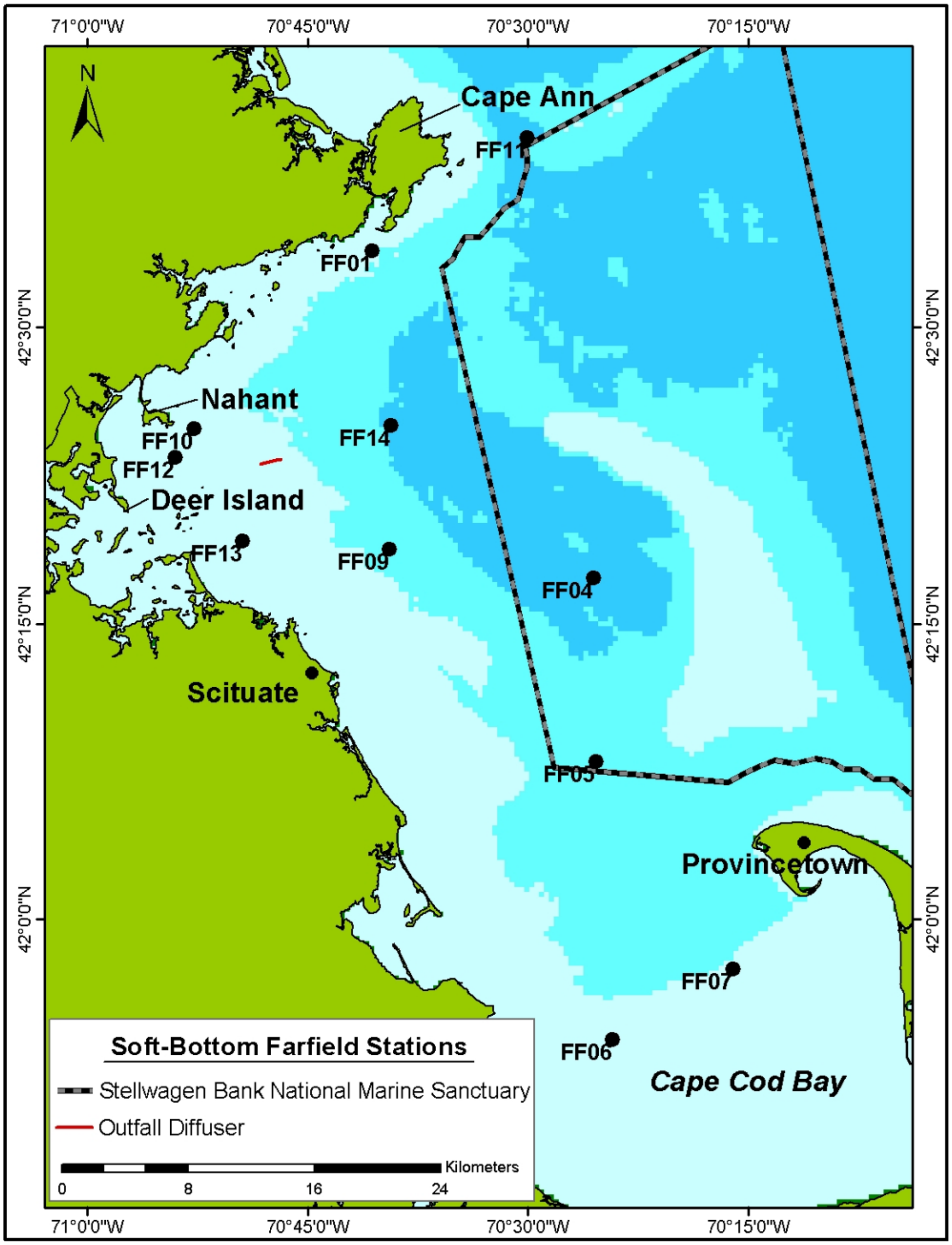


Table IV-2.B. Parameters measured during nearfield and farfield sediment contaminant monitoring.

Parameter	Parameter	Parameter
Polycyclic Aromatic Compounds	**Polychlorinated Biphenyls**	**Metals**
Naphthalene	Cl2(8)	Al Aluminum
C_1-Naphthalenes	Cl3(18)	Cd Cadmium
C_2-Naphthalenes	Cl3(28)	Cr Chromium
C_3-Naphthalenes	Cl4(44)	Cu Copper
Acenaphthylene	Cl4(52)	Fe Iron
Acenaphthene	Cl4(66)	Pb Lead
Biphenyl	Cl4(77)	Hg Mercury
Dibenzofuran	Cl5(101)	Ni Nickel
Fluorene	Cl5(105)	Ag Silver
C_1-Fluorenes	Cl5(118)	Zn Zinc
C_2-Fluorenes	Cl5(126)	
C_3-Fluorenes	Cl6(128)	**Physical Sediment Parameters/Sewage Tracers**
Dibenzothiophene	Cl6(138)	
C_1-Dibenzothiophenes	Cl6(153)	Grain Size
C_2-Dibenzothiophenes	Cl7(170)	Gravel
C_3-Dibenzothiophenes	Cl7(180)	Sand
Phenanthrene	Cl7(187)	Silt
Anthracene	Cl8(195)	Clay
C_1-Phenanthrenes/Anthracenes	Cl9(206)	phi<-1
C_2-Phenanthrenes/Anthracenes	Cl10(209)	!1<phi<0
C_3-Phenanthrenes/Anthracenes		0<phi<1
C_4-Phenanthrenes/Anthracenes	**Chlorinated Pesticides**	1<phi<2
Fluoranthene	Aldrin	2<phi<3
Pyrene	Dieldrin	3<phi<4
C_1-Fluoranthenes/Pyrenes	Endrin	4<phi<8 (silt)
Benz(a)anthracene	Hexachlorobenzene	phi>8 (clay)
Chrysene	Lindane	Total Organic Carbon
C_1-Chrysenes	Mirex	*Clostridium perfringens*
C_2-Chrysenes	2,4-DDD	Linear Alkyl Benzenes
C_3-Chrysenes	2,4-DDE	Phenyl decanes (C_{10})
C_4-Chrysenes	2,4-DDT	Phenyl undecanes (C_{11})
Benzo(b)fluoranthene	4,4-DDD	Phenyl dodecanes (C_{12})
Benzo(k)fluoranthene	4,4-DDE	Phenyl tridecanes (C_{13})
Benzo(e)pyrene	4,4-DDT	Phenyl tetradecanes (C_{14})
Benzo(a)pyrene	DDMU	
Perylene	Cis-chlordane	
Indeno(1,2,3-c,d)pyrene	Heptachlor	
Dibenzo(a,h)anthracene	Heptachlorepoxide	
Benzo(g,h,i)perylene	Trans nonachlor	
Benzothiazole		

In spring 1996, the Outfall Monitoring Task Force determined that the baseline for sediment contaminant analyses was adequate, and that contaminant analyses could stop until the outfall came online. At the time, outfall startup was expected by 1999. In 1999, MWRA again sampled all sediment stations for contaminants, ensuring we would have contaminant data from late in the baseline for comparison to discharge monitoring results.

Sediment contamination special studies This annual monitoring has been complemented by two special studies. The first is an ongoing collaboration between MWRA and the U.S. Geological Survey, and investigates sediment contaminants and sediment transport in the Bays. Since 1989 USGS has taken sediment cores three times a year from two stations, one sandy (NF17) and one muddy (NF12), near the Massachusetts Bay outfall (USGS 1997b; Figure IV-2.A) These stations have been occupied by MWRA's monitoring since 1992. USGS also uses a mooring in the nearfield to collect hydrographic data and samples of suspended matter that deposits in sediment traps. Suspended matter samples are analyzed for metals, grain size, TOC, and effluent tracers.

The second special study was a 2-year program of more frequent sampling at stations FF10, NF08, NF22, and NF24. Following outfall startup, triplicate samples were collected at each station in February/March, August, and October. The data from this study were intended to provide early indications of rapid organic carbon and/or contaminant build-up, should those occur.

IV-3 Monitoring Results

This section presents recent results which typify the findings of the monitoring. Results for other parameters are included in an appendix to this briefing, which will be made available electronically prior to the workshop.

Baseline sampling at nearfield stations documented that the area around the outfall is composed of heterogeneous sediments that have received historic inputs of contaminants from Boston Harbor and other sources. Contaminant concentrations in the nearfield track the silt-clay fraction of the sediments; muddier stations tend to have more organic carbon and higher concentrations of contaminants (Figs. IV-3.A, IV-3.B). In a principal components analysis of nearfield sediment data from 1992 through 2001 (the first year of discharge), more than 2/3 of the variability in the entire dataset was explained by the first principal component, which was associated with the observed sand-mud gradient. (Kropp *et al*. 2002 Sec. 4.3.1).

Figure IV-3.A. Total PCB (top) and Copper (bottom) for each nearfield station compared to the range seen during baseline. Stations are in order of increasing mean TOC concentration (dashed line in sub-plot). Baseline station mean values for TOC and percent fines, plotted by station, are shown in the sub-plot.

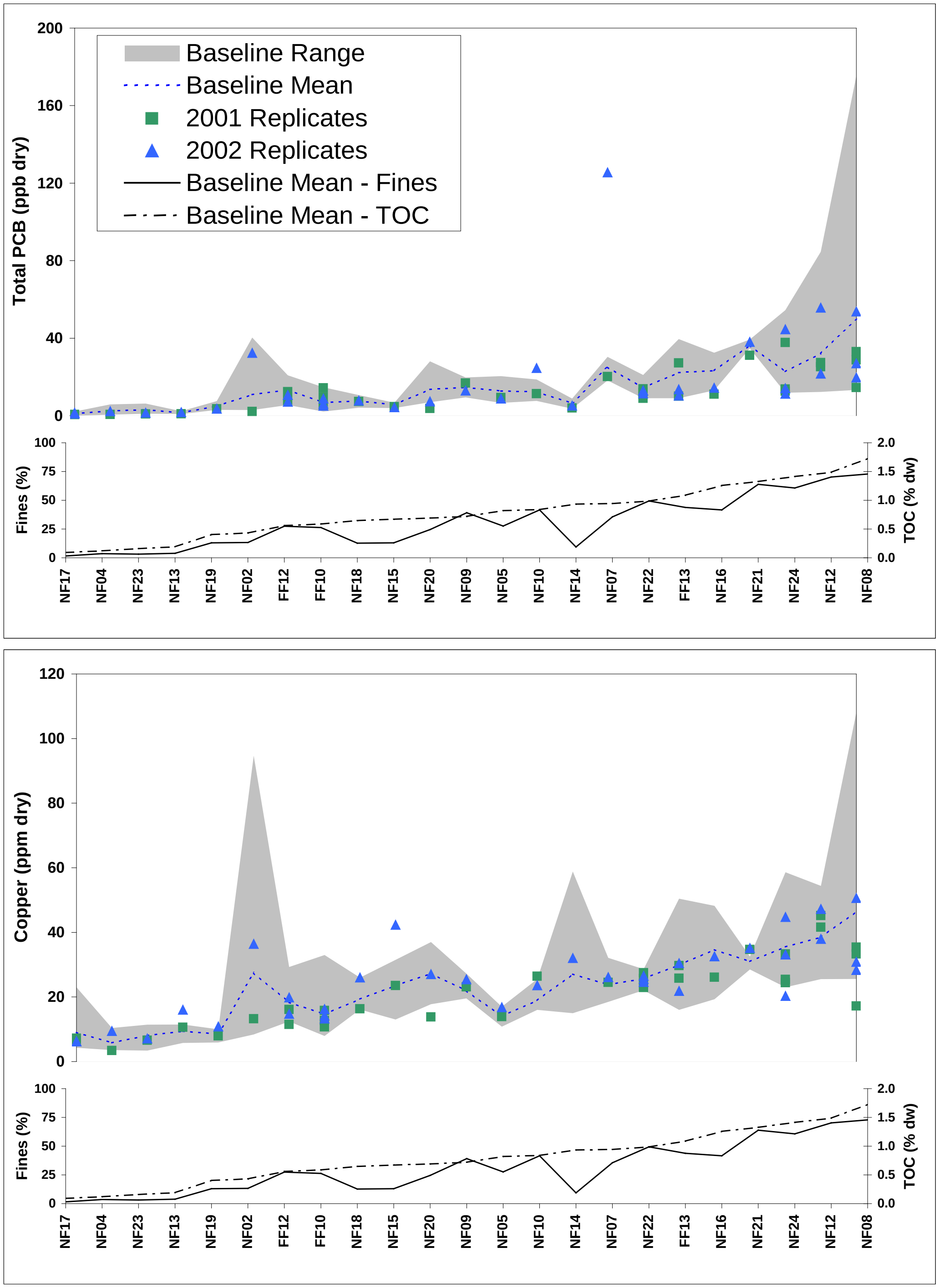
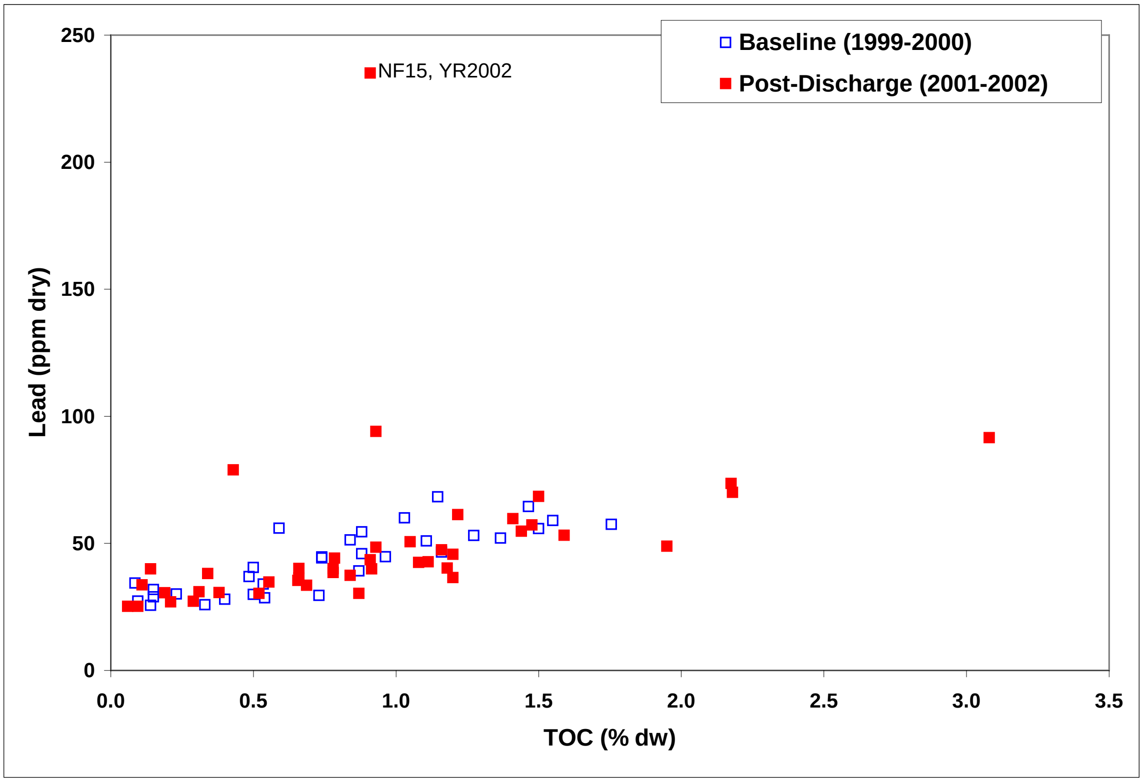
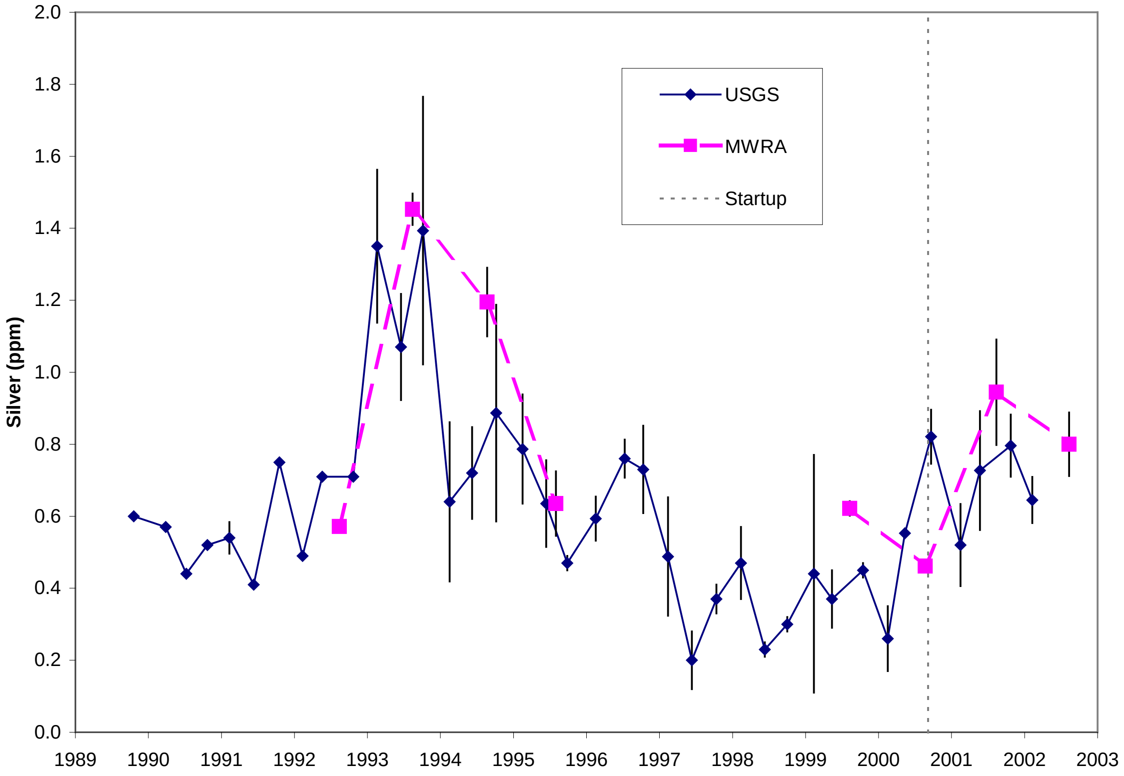


Figure IV-3.B. Scatterplot of Total Organic Carbon versus lead concentrations in nearfield sediments for the last 2 years of baseline (1999 and 2000) and the first 2 years of discharge (2001 and 2002).



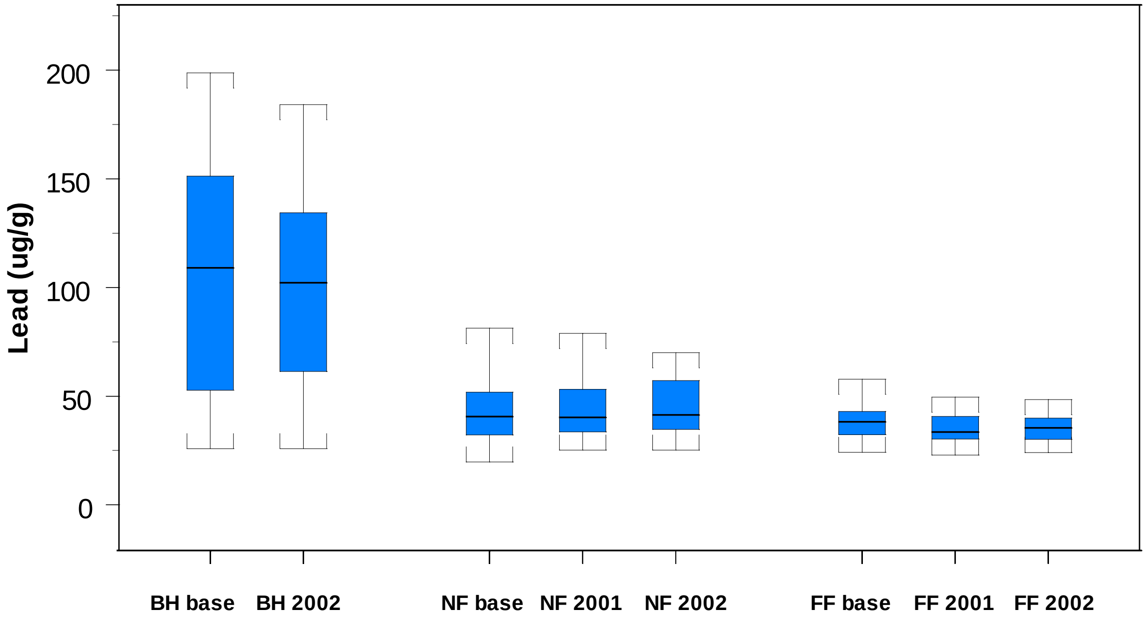
Storm-driven transport of fine sediments and the contaminants they carry is another major factor determining concentrations of contaminants in nearfield sediments. The largest such event yet observed followed the major northeast storm of December 11-16, 1992 (Bothner *et al*. 2002). Sediment concentrations of silver at station NF12 peaked in both USGS and MWRA samples collected after that storm (Figure IV-3.C) which caused sustained wave heights in excess of 7m in the vicinity. Suspended sediment and turbidity measurements from the hydrographic mooring also document the importance of storms to sediment and contaminant transport in the nearfield (Bothner *et al*. 2002, Butman *et al*. 2002).

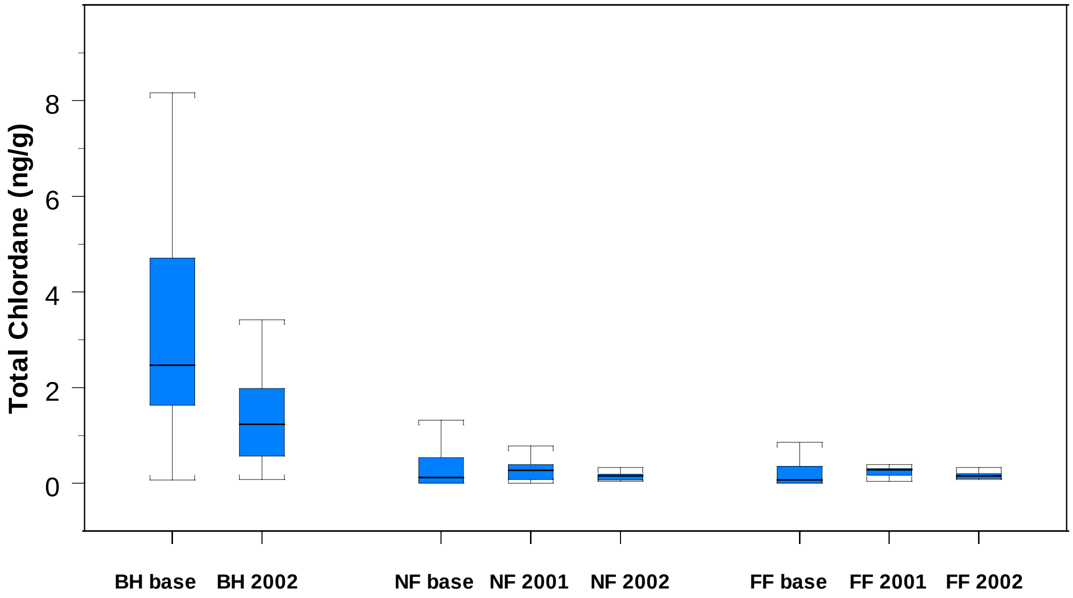
Figure IV-3.C. Silver concentration in surficial sediments at mud station NF12, 1989-2002. USGS data are the mean(+/- s.d.) of 5 mm thick surficial samples, MWRA data are mean and range of 2 cm samples.



The USGS research has documented that the regional long-term depositional sinks for fine sediments and their associated contaminants are in Stellwagen Basin and in deeper portions of Cape Cod Bay, with a gradient of highest contaminant concentrations in Boston Harbor; much lower concentrations in western Massachusetts Bay (near MWRA's outfall), in Stellwagen Basin and in Cape Cod Bay; and the lowest concentrations north and east of the Bays system (Bothner *et al*. 1993 , USGS 1997a). MWRA monitoring results support these findings(e.g. Figure IV-3.D)

Figure IV-3.D. Boxplots showing the distribution of lead and total chlordanes from MWRA monitoring in Boston Harbor (BH), nearfield (NF) and farfield (FF) sediments. Harbor baseline data are from studies in 1994 (Durell 1995), 1997 (Blake *et al.* 1998) and 1998 (Lefkovitz *et al*. 1999). Nearfield and farfield baseline data are from August surveys of all sites in 1992-1995 and 1999, and a subset of nearfield stations in 2000.





Discharge effects monitoring results Contaminant concentrations in the nearfield have not shown rapid increases since outfall startup. Average concentrations in the nearfield are far below the Contingency Plan thresholds (Table IV-3.A). Results indicate an effluent signal has been detected in the most sensitive sewage tracers measured, *i.e.* silver and *Clostridium perfringens* spores. The signal is subtle and there is no generalized increase in contaminants in nearby sediments.

Table IV-3.A. 2002 results for Contingency Plan thresholds for sediment contaminants.

Contaminant	range over baseline	threshold	2001 value	2002 value[3]
PAHs (ng/g dry weight)				
Acenaphthene	23-41.3	500	35	46
Acenaphthylene	38.3-58.4	640	48	83
Anthracene	114.1-171	1100	165	264
benz(a)anthracene	221.4-302	1600	277	362
benzo(a)pyrene	223.6-287	1600	283	300
Chrysene	217.3-288	2800	278	362
dibenzo(a,h)anthracene	30.5-42	260	47	59
Fluoranthene	465-592	5100	581	821
Fluorene	37.9-60.9	540	52	75
Naphthalene	53.5-83.2	2100	86	103
Phenanthrene	296.4-405	1500	422	630
Pyrene	440.3-540	2600	538	847
sum HMWPAH	2986.4-3754	9600	3644	4816
sum LMWPAH	1420.1-2004	3160	1683	2138
total PAH	4482.5-5726	44792	5327	6954
Other organic contam. (ng/g)				
p,p'-DDE	0.28-1.25	27	0.5	0.6
total DDT	2.59-5.27	46.1	3	2.3
total PCB	10.4-28.6	180	13	18
Metals (ug/g dry weight)				
Cadmium	0.09-0.23	9.6	0.1	0.09
Chromium	61.9-86.8	370	75	79
Copper	19.2-27.6	270	24	25
Lead	42.9-47.2	218	46	51
Mercury	0.2-0.29	0.71	0.27	0.20
Nickel	15.5-18.5	51.6	18	17
Silver	0.47-0.71	3.7	0.5	0.49
Zinc	56.6-69.7	410	60	64

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[3] The apparent elevation in PAH concentrations in 2002 results from an anomalous sample from station FF10 which may have contained coal tar or furnace ash, and had extremely high concentrsations of many PAH analytes and TPAH concentrations of 66,900 ppb. Two other August 2002 samples from the site each had TPAH concentrations of <4,000 ppb, and three sediment contaminant special study samples from the site in October 2002 had concentrations < 5,400 ppb, within the baseline range at this site (Figure IV-3.G). Without this sample, the 2002 nearfield mean for total PAHs, for example, would be 5,191 ppb, approximately the same as in 2001

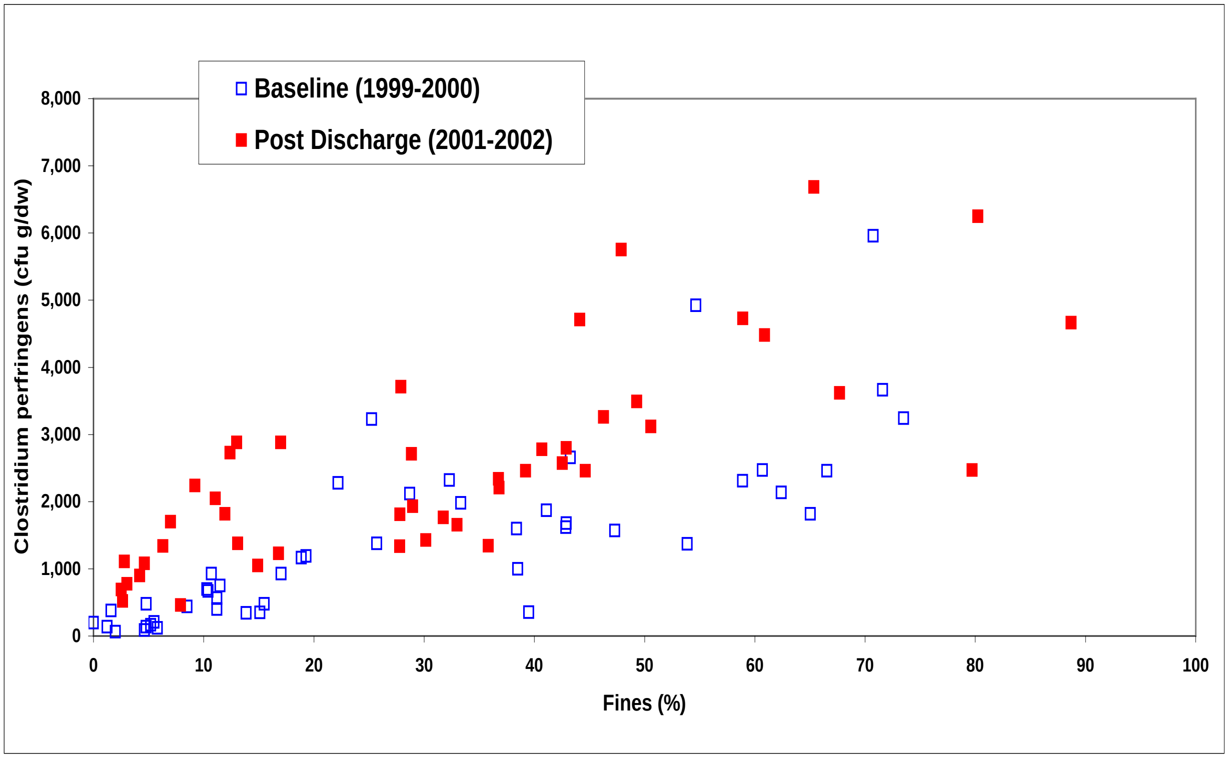
USGS researchers have found silver to be an excellent tracer of effluent particulates (Bothner et al. 1993, 2002). As seen in Figure IV-3.C, silver concentrations at NF12 decreased after the December 1992 northeast storm, stabilizing after 1997. While levels following outfall startup appeared slightly higher than those in 1999 and early 2000, silver concentrations at the site in 2001 were not significantly different from those observed in 1997-2000 (Bothner *et al*. 2002.) A similar result was obtained for an analysis of *Clostridium perfringens* spore counts, another tracer of effluent particulates.

Analyses of material collected in sediment traps located near the outfall provided a more sensitive signal. Both silver and *C. perfringens* in sediment trap samples from the first several months of outfall discharge showed significant increases over concentrations observed in the first 8 months of 2000, prior to outfall relocation. Both tracers were significantly elevated compared to levels observed at the site when DITP was discharging secondary-treated effluent to Boston Harbor. However, concentrations of both silver and *C. perfringens* in the sediment traps were within the range observed there prior to 1998, when DITP was discharging primary-treated effluent into Boston Harbor; those tracers were transported to the outfall site (Bothner *et al*. 2002). Thus, for these particle borne effluent tracers, the local effect of transferring the discharge from BostonHarbor to Massachusetts Bay is mitigated by the additional removal of solids and contaminants accomplished by secondary treatment.

Attachment IV-I to this briefing (Dahlen *et al*. 2003) contains an evaluation of MWRA’s core sediment contaminant monitoring data from 1992-2002. To summarize that evaluation, of all parameters monitored, only *Clostridium perfringens* spores show a convincing increase in nearby sediments since offshore discharge began in September 2000. *C. perfringens* spore counts showed a general decline in nearfield sediments during baseline monitoring (Kropp *et al*. 2001), so the increase is only discernable when the comparison is restricted to the late baseline (1999 and 2000) data. (Figs. IV-3.E, Figure IV-3.F).

A principal components analysis of the 1992-2002 August data showed that more than 2/3 the variability in the sediment grain size, TOC, and contaminant data is associated with the sand/silt gradient in the nearfield. No substantial departures are seen in the PCA sample weightings compared to baseline data to indicate that stations are becoming more contaminated (Dahlen *et al*. 2003).

Figure IV-3.E. Scatterplot of *Clostridium perfringens* and percent fines using nearfield data from the two years before and after the new outfall came on-line (top) or data from all years (1992-2002) (bottom). (Source: Battelle)



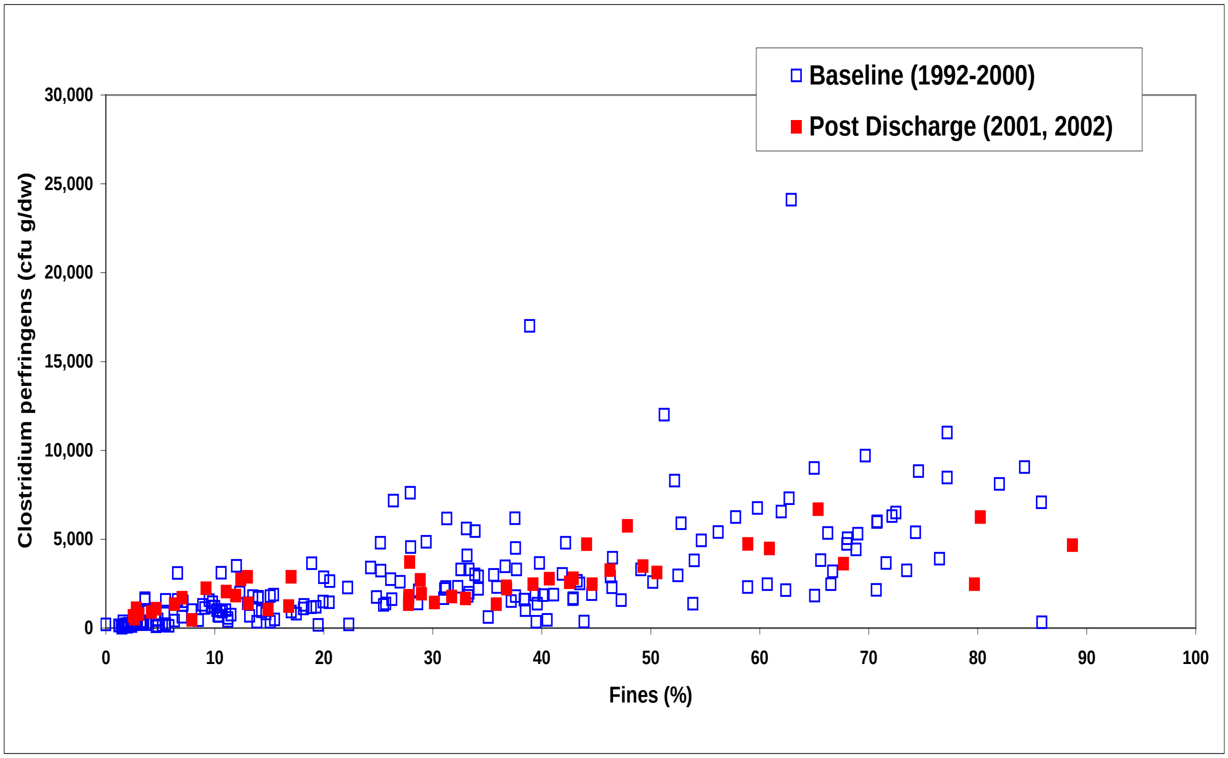
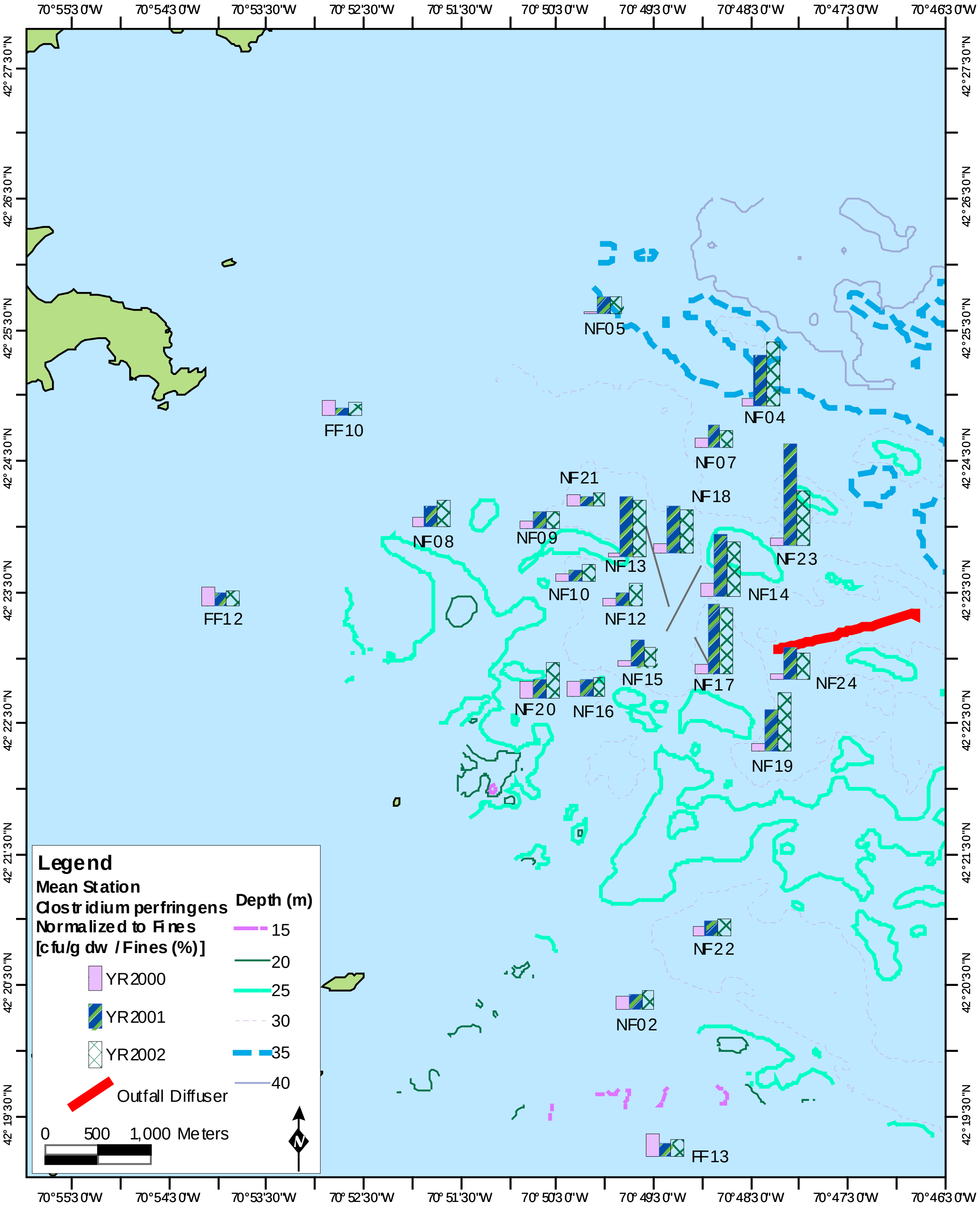


Figure IV-3.F. Nearfield mean concentrations of *Clostridium perfringens* (normalized to percent fines) in nearfield sediments, collected in August 2000, 2001 and 2002. (Source Battelle). The scale ranges from 12 to 700 spores/%silt-clay.



The October 2002 results of MWRA's 2-year sediment contaminant special study were recently completed; raw data do not reflect rapid increases in contaminants since startup (Figure IV-3.G).More detailed evaluations will be included in the forthcoming synthesis report.

IV-4 Future monitoring

The Ambient Monitoring Plan states:

> "The OMTF has indicated that the measurement frequency should be revisited after approximately two years of discharge monitoring data are available, and that a long-term contaminant sampling frequency on the order of every 3-5 years should then be appropriate" (MWRA 1997 p 4-13) .

MWRA proposes current changes to sediment contaminant monitoring that are cost-effective and protective:

1. Continue to collect and analyze sediment contaminant samples in duplicate from stations NF12 and NF17 at least annually through 2005. MWRA anticipates that this sampling will be carried out as part of the USGS/MWRA cooperative study.
2. Continue to analyze available sediment trap samples for tracers of effluent solids (e.g. silver, Clostridium) through 2005.
3. Review core and sediment trap data from the USGS/MWRA cooperative special study or its successor after the 2005 field season to determine if additional work is warranted.
4. Decrease the scheduled frequency of contaminant analyses at other nearfield and all farfield stations to every third year, beginning immediately. Except at NF12 and NF17, analyses would not be scheduled for 2003 and 2004, and would occur again in 2005. In 2005 contaminant samples would be collected at the same stations as benthic community samples[4].
5. Continue to collect and analyze sediment samples for grain size, Total Organic Carbon (TOC), and spores of *Clostridium perfringens* at all benthic community sampling stations during the annual August surveys.

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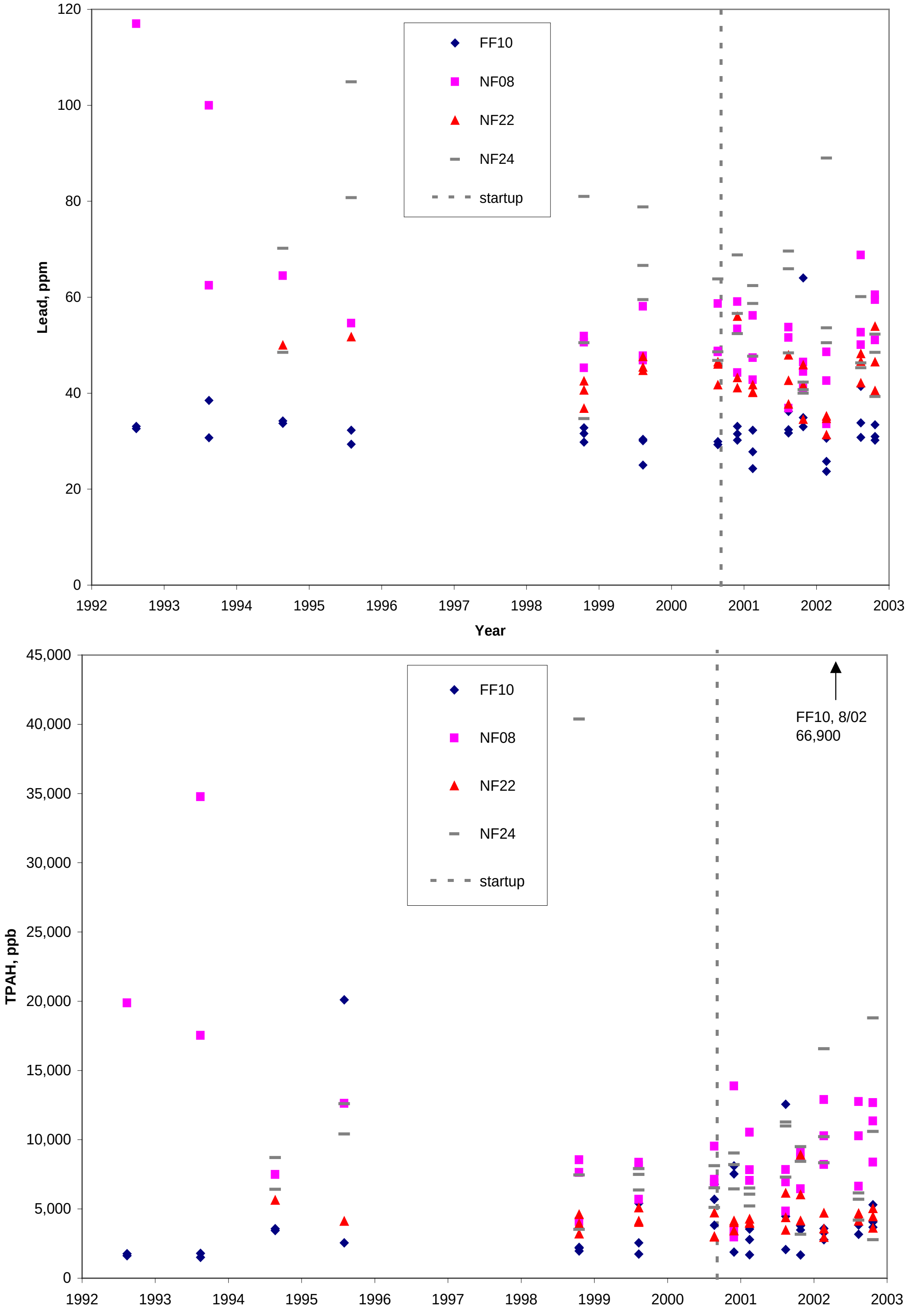
[4] MWRA's proposal for soft-benthic community monitoring is still being developed, and will be presented at a future OMSAP workshop. Changes under consideration for monitoring in 2004 and beyond include reductions in the numbers of stations. Any station reductions proposed at that time would affect both infaunal and contaminant sampling.

Figure IV.3.G Timeseries of lead (top) and total PAH (bottom) data from contaminant special study stations, 1992-2002.(Source MWRA).



Justification

Chemical concentrations in sediments are strongly influenced by grain size and TOC, which influence the redox condition with depth in the sediments. Sediment oxidation in turn influences contaminant retention in sediments, especially metals. In a system like Massachusetts Bay with a relatively constant input term (source(s)) and stable grain size and TOC levels in the sediments, one would not expect substantial changes in contaminant levels in sediments. If any of these forcing functions were to change appreciably, one could expect to see the chemical concentrations change.

The research and monitoring carried out to date documents that:

1. The input of contaminants from MWRA to the Massachusetts Bay system now is lower than in the early 1990s, is expected to be relatively constant over time from the outfall, and is well characterized (Section II).

2. Grain size and TOC in the sediments are generally consistent among years and relatively stable except during major storm events, which can winnow the fines out of the sediments.

3. Neither TOC nor sediment RPD have shown major changes in nearfield sediments since outfall startup (Figs IV-4.A, IV-4.B)

4. Contaminant concentrations have been relatively stable at the nearfield and farfield stations over the past 10 years, and are substantially lower than in Boston Harbor.

5. Sensitive tracers of the outfall are showing detectable but small responses to the diversion in the nearfield, within the baseline range but above conditions observed during late baseline.

6. Contaminants are not showing substantial changes two years after the diversion, thus neither inputs nor factors influencing deposition are being altered in a dramatic way by the discharge.

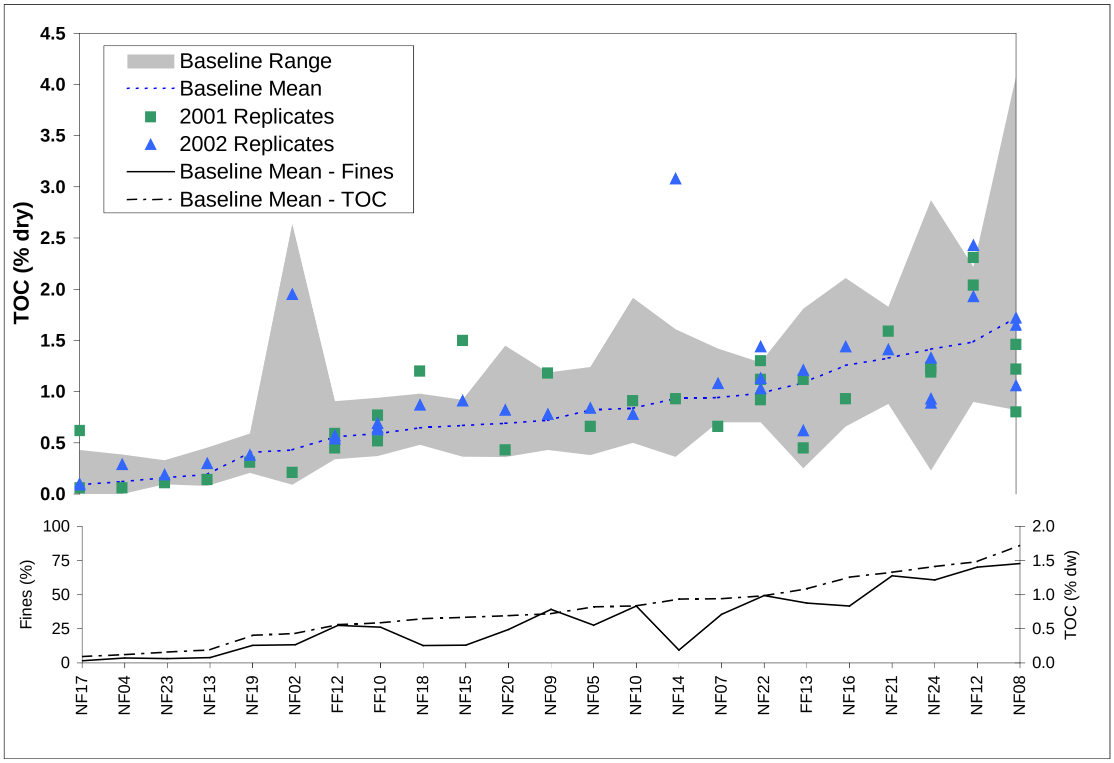
7. Given the continuing low inputs and evidence of relatively slow outfall-induced changes in contaminants even in Boston Harbor, where major decreases in inputs have occurred in the past 10 years, we do not expect rapid changes offshore.

8. The shortest time frame in which we might see outfall-related increases in sediment contaminants is several years, given the low loading and known variability in the sediments. Detection of effluent-related increases in contaminant concentrations is not likely even at the nearby stations where small increases in *Clostridium perfringens* has been observed. This is consistent with projections made in Coats (1995) based on a box model of sediments within 2 km of the outfall. The present effluent quality is equal to or better than the 1995 projections.

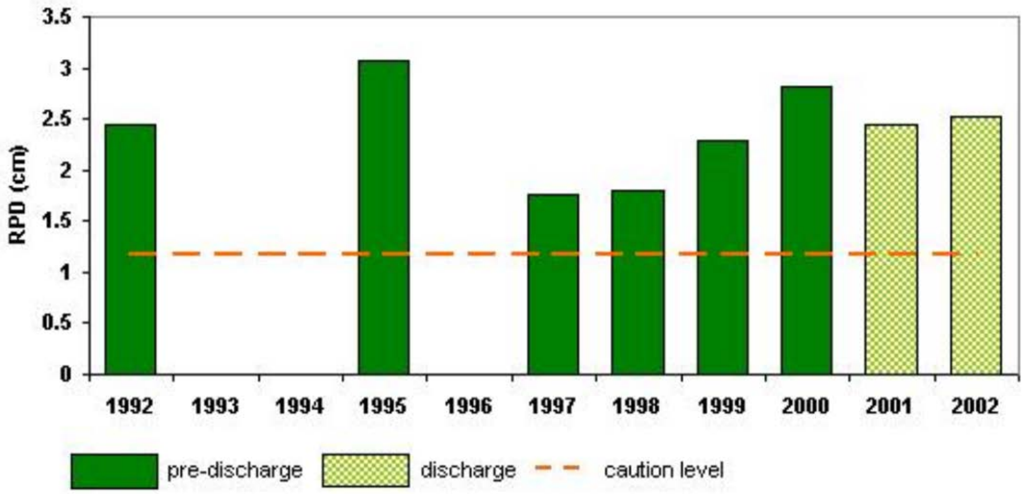
9. The proposed sampling for contaminants in nearfield and farfield sediments every third year would be environmentally protective, based on the measured rate of change.

10. Additional environmental protection is built into our proposal through our ongoing effluent contaminant monitoring. Effluent monitoring will be buttressed buttressed by our proposal to continue annual contaminant measurements at 2 stations, continue metals and tracer analyses in sediment trap samples, and continue annual grain size, TOC, *Clostridium perfringens* , and RPD measurements at all stations. Those data will allow identification of unexpected conditions that could be associated with increased sediment contaminant concentrations, for example increased deposition of effluent-derived particulates or shallower RPDs.

Figure IV-4.A. Total Organic Carbon for each nearfield station compared to the range seen during baseline. Stations are in order of increasing mean TOC concentration (dashed line in sub-plot). Baseline station mean values for TOC and percent fines, plotted by station, are shown in the sub-plot. (Source Battelle).



IV-4.B. Mean Apparent Redox Potential Discontinuity (RPD) for nearfield sediments, 1992-2002, as measured by sediment profile imaging. (Source, MWRA).



References

Blake JA, Williams IP, Gallagher ED, Hecker B, Rhoads DC and Arnofsy PL. 1998. Massachusetts Bay outfall monitoring program: benthic biology and sedimentology baseline monitoring for 1997 and retrospective analysis of the 1992-1997 database. Boston: Massachusetts Water Resources Authority. Report 1998-16. 221 p.

Bothner, MH, Buchholtz ten Brink, M, and Manheim, FT, 1998, Metal concentrations in surface sediments of Boston Harbor - changes with time: Marine Environmental Research, v. 45, No. 2, p. 127-155.

Bothner, MH, Buchholtz ten Brink, M, Parmenter, CM, d'Angelo, WM, and Doughten, MW, 1993, The distribution of silver and other metals in sediments from Massachusetts and Cape Cod Bays: U.S. Geological Survey Open-File report 93-725. 31 pp.

Bothner, MH, Casso MA, Rendigs RR, and Lamothe PJ. 2002. The effect of the new Massachusetts Bay sewer outfall on the concentrations of metals and bacterial spores in nearby bottom and suspended sediments. Marine Pollution Bulletin v. 44, No. 2, p1063-1070.

Butman B, Bothner MH, Lightsom FL, Gutierrez BT, Alexander PS, Martini MA, and Strahle WS. 2002. Long-term Oceanographic Observations in Western Massachusetts Bay Offshore of Boston, Massachusetts: Data Report for 1989-2000. U.S. Geological Survey Digital Data Series DDS-74. DVD-ROM

Dahlen, DT, Hunt, CD, and Emsbo-Mattingly, S. 2003. Sediment Contaminant Briefing Package for OMSAP. Attachment I to this chapter. 13 pp.

Durell GS. 1995. Concentrations of contaminants in Dorchester Bay and Boston Harbor sediments collected in the vicinity of CSO discharges and comparison to 1990 concentrations. Boston: Massachusetts Water Resources Authority. Report 1995-14. 128 p.

EPA. 1988. Boston Harbor Wastewater Conveyance System. Supplemental Environmental Impact Statement (SEIS). Boston: Environmental Protection Agency Region 1.

Kropp RK, Diaz R, Hecker B, Dahlen D, Boyle JD, Abramson SL and Emsbo-Mattingly S. 2001. 2000 outfall benthic monitoring report. Boston: Massachusetts Water Resources Authority. Report 2001-11. 148 p.

Kropp RK, Diaz RJ, Hecker B, Dahlen DT, Boyle JD, Abramson SL and Emsbo-Mattingly S. 2002. 2001 Outfall Benthic Monitoring Report. Boston: Massachusetts Water Resources Authority. Report 2002-15. 137 p.

Lefkovitz L, Dahlen DT, Hunt CD and Ellis BD. 1999. 1998 CSO sediment study synthesis report. Boston: Massachusetts Water Resources Authority. Report 1999-12. 68 p.

MWRA. 1991. Massachusetts Water Resources Authority effluent outfall monitoring plan phase I: baseline studies. Boston: Massachusetts Water Resources Authority. Report ms-002. 95 p.

MWRA. 1997. Massachusetts Water Resources Authority effluent outfall monitoring plan: Phase II post discharge monitoring. Boston: Massachusetts Water Resources Authority. Report ms-044. 61 p.

USGS. 1997a. Predicting the long-term fate of sediments and contaminants in Massachusetts Bay. Woods Hole: U.S. Geological Survey. USGS Fact Sheet FS-172-97. 6p.

USGS 1997b. Metals concentrations in sediments of Boston Harbor and Massachusetts Bay document environmental change. Woods Hole: U.S. Geological Survey. USGS Fact Sheet 150-97. 4p.

USGS. 1998. Mapping the sea floor and biological habitats of the Stellwagen Bank National Marine Sanctuary region. Woods Hole: U.S. Geological Survey. USGS Fact Sheet 078-98. 2p.

Williams IP, Maciolek NJ, Boyle JD, Dahlen DT and Baptiste-Carpenter EM. 2002. Combined work/quality assurance plan for benthic monitoring: 2002-2005. Boston: Massachusetts Water Resources Authority. Report ms-076. 109 p.

ATTACHMENT 1

MWRA Task Order 29 Task 29.07
Sediment Contaminant Briefing Package for OMSAP
By Deirdre T. Dahlen, Carlton D. Hunt, and Stephen Emsbo-Mattingly

Methods

Sediment grain size, total organic carbon (TOC), sewage tracer, organic contaminants and metals data collected from 1992 to 2002 (August surveys only) were evaluated to determine what, if any, changes to the Massachusetts and Cape Cod bay systems are apparent as a result of the new outfall coming on-line in September 2000.

Sediment data were evaluated using a variety of graphical and statistical techniques to support data assessments. Data presented in this briefing package include:

- **Range Plots** – Histogram plots showing the baseline range and post-discharge data for a given station and parameter.
- **Nearfield and Regional Maps -** Station mean concentrations of *Clostridium perfringens* (normalized to percent fines) from 2000 to 2002 at nearfield and regional locations.
- **Scatter Plots** – XY scatter plots showing the correlation between bulk sediment parameters (percent fines, TOC and percent clay) and selected organic contaminants (total PAH, total PCB, total LAB) and metals (Hg, Ag, Pb, Cu) in the nearfield, using station mean values (August surveys only)
- **PCA** – Pursuant to guidance from Ken Keay (MWRA) and the Battelle project team, the updated MWRA sediment data set (1992-2002) was subjected to a principal components analysis (PCA) using the Nearfield Baseline Model as described in the 2001 Outfall Benthic Monitoring Report (2001 Report). Selected samples were excluded from the PCA because one or more parameters were missing. The stations were grouped in the PCA figures according to the magnitude of change in *Clostridium perfringens* (CPERF) abundance; i.e., stations with the greatest increase were presented in Figure 1a, stations with less pronounced change were presented in Figure 1b, and stations with decreasing abundances were presented in Figure 1c. The calculated values used to group these stations are presented in Table 1.

Data terms referenced throughout this briefing package include:

- **Nearfield -** refers to all nearfield stations plus farfield stations FF10, FF12, and FF13
- **Regional -** refers to all farfield stations, plus traditionally replicated nearfield stations NF12, NF17, and NF24
- **Station Mean** – average of all station replicates for a given parameter and sampling year
- **Baseline Mean** – average of data for a given station and parameter over the baseline period (1992-2000), sampled during August surveys only
- **Baseline Range** – range in data (minimum and maximum values) for a given station and parameter over the baseline period (1992-2000), using station replicates data, August surveys only

Results

The PCA results demonstrated similar changes in the sediments as described in the 2001 Outfall Benthic Report (Kropp *et al.*, 2002)[1]. None of the stations exhibited a notable increase in TPEST, TCHLOR, TLAB, TPCB, TDDT, Cd and Ag. Most of the 2001 and 2002 data fell within the general distribution of samples collected during the baseline period (1992-2000). Sediment samples from the remaining stations trended away from the upper right corner of each station plot and indicated decreasing levels of these anthropogenic toxins. Clearly, the activation of the diffuser did not cause an increase in these substances of environmental concern. By contrast, the trend, if any, in the activated diffuser period was a modest increase in fines (e.g., NF02, NF04, NF14, NF18, NF21, and NF23). While the stations with elevated CPERF resided most closely to the diffuser pipe, the compositional effects of increased CPERF and Fines appeared limited given the close proximity of the 2001 and 2002 data to the grouping of baseline data by station. This limited effect indicated that the changes in CPERF and Fines were modest with respect to the overall variability of the sediment data set.

Results from the range plots, updated to include 2002 data, also demonstrated similar changes in the sediments as described in the 2001 Outfall Benthic Report. While local increases in selected parameters were observed[2], results from the range plots showed that most of the 2001 and 2002 data fall within the general distribution of samples collected during the baseline period [representative parameters shown in Figures 2 and 3; full compilation of range plots provided in Appendices A (nearfield locations) and B (regional locations)]. These data suggest that activation of the new outfall is not causing an increase in contaminants of environmental concern to the Massachusetts and Cape Cod bay systems.

In contrast, station mean values for *Clostridium perfringens* abundances (normalized either to percent fines or percent clay) increased in 2001 and 2002, thereby breaking away from the trend toward decreasing abundances observed in the nearfield system since 1998. While *Clostridium perfringens* abundances (normalized to percent fines) increased in 2001 and 2002 at nearly all nearfield stations, the greatest increases generally occurred at those stations located within 2-km of the western end of the new outfall (diffuser 55; Figure 4). These findings suggest that effluent discharge from the new outfall is having, as expected, a localized, but modest, effect on nearby sediments.

Excluding regional stations located close to the outfall (i.e., NF12, NF17 and NF24), 2001 and 2002 abundances of *Clostridium perfringens* (normalized to percent fines) showed no such increase at regional locations (Figure 5). This strongly indicates the effluent discharged from the new outfall is not having an effect on regional sediments. Interestingly, abundances of *Clostridium perfringens* (normalized to percent fines) decreased slightly in 2001 and 2002, at regional stations located near Boston Harbor (i.e., FF10, FF12 and FF13) (Figure 5). This suggests that diversion of the effluent discharge to the new outfall is having a positive influence on the near harbor sediments.

Results from the correlation analyses showed that the major factors influencing the concentration of contaminants and sewage tracers in the nearfield were primarily related to grain size factors suggestive of different sediment depositional environments (representative parameters presented in Appendix C). Further, the increase in *Clostridium perfringens* abundances observed in 2001 and 2002 are clearly evident when the correlation analysis is performed using data from two years before and after the new outfall came on-line (1999-2002) (Figure 6 top). The correlation between *Clostridium perfringens* and bulk sediment properties using data from all years (1992-2002) does not show the clear increase of

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[1] Kropp RK, Diaz R, Hecker B, Dahlen D, Boyle JD, Abramson SL, Emsbo-Mattingly S. 2002. **2001 Outfall Benthic Monitoring Report**. Boston: Massachusetts Water Resources Authority. Report ENQUAD 2002-15. 137 pages plus appendices.

[2] Examples include TOC at NF14 in 2002; total PCB at NF07 in 2002; Hg at FF12, NF10 and NF21 in 2001; Pb at NF14 and NF15 in 2001 and 2002.

Clostridium perfringens (Figure 6 bottom). This can be attributed to system changes in *Clostridium perfringens* from early in the program to the late 1990s, which resulted from a variety of factors including various MWRA facility upgrades. Therefore, data presented here most represents the system after it responded to these early improvements and shows conditions observed in the two years before diversion of effluent discharge to the new outfall.

Last, the correspondence between percent fines across years (2000-2002) was evaluated to confirm the modest increase in percent fines observed from the PCA. The evaluation showed a clear indication of more fine-grained material building up since 2000 (Figure 7). For example, increases in percent fines were observed in 2001 at stations FF10, NF16, NF22, NF21 and NF12 (Figure 7 top). Percent fines increased yet again in 2002 at stations NF02 and NF20 (Figure 7 middle). Increases in percent fines at other nearfield stations (e.g., NF04, NF14, NF18 and NF23) were apparent, but generally small.

Conclusions

The PCA and detailed *Clostridium perfringens* analyses both showed small to modest changes to the nearfield system since activation of the new outfall. For PCA, the greatest compositional changes between the baseline and activated diffuser periods occurred at stations NF02, NF04, NF14, NF18, NF21, and NF23, which were primarily caused by changes in the amount of fine grained sediments at selected locations. For *Clostridium perfringens*, there was a general increase in abundances across the entire nearfield, with largest increases observed at those stations located within 2-km of the western end of the diffuser.

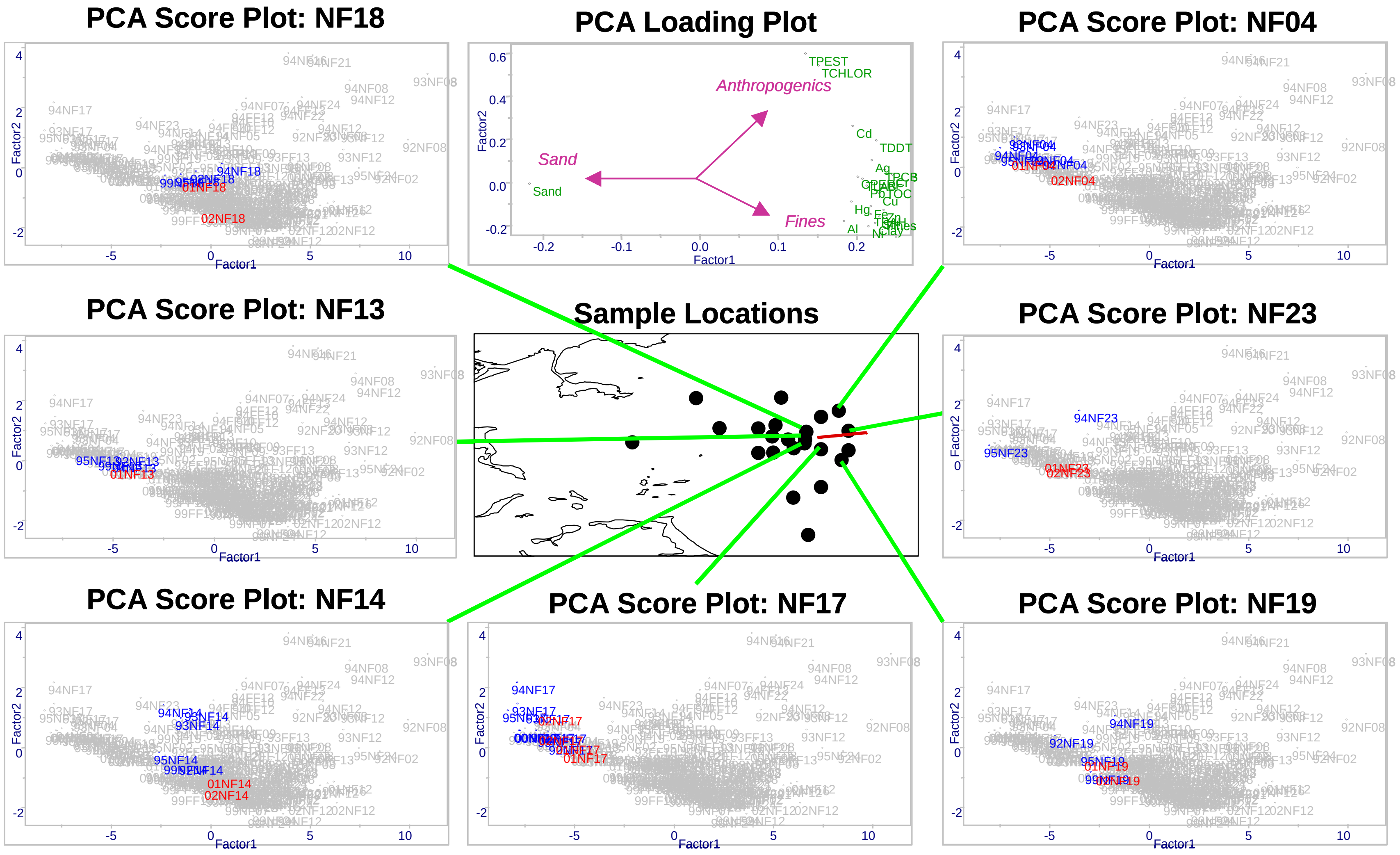
While there is clearly an increase in *Clostridium perfringens*, no such widespread increases were observed in organic contaminant or metals concentrations, suggesting that activation of the outfall is not having a measurable effect on nearby sediments. Thus, *Clostridium perfringens* is an excellent indicator of the early response to diversion of the effluent discharge.

Results from the PCA and detailed *Clostridium perfringens* analyses suggest that when contaminants are measured, sampling include at a minimum the following stations: NF02, NF04, NF14, NF18, NF21, NF23, NF17, NF07, NF20, FF10, FF12, and FF13. This station grouping encompasses:

1) Stations with greatest compositional changes identified from the PCA;
2) Representative stations with modest to high increases in *Clostridium perfringens* abundances observed since 2000;
3) Stations that will help geographically bracket compositional changes in the nearfield sediments; and
4) Stations that show early signs of positive influence from effluent diversion.

These 12 stations represent 50% of the nearfield sediment chemistry sample collection and measurement effort under the 1997 Outfall Monitoring Plan. Further reduction in effort is appropriate by decreasing the sampling frequency.

Figure 1a. Comparison of nearfield sediments from the baseline period (1992-2000) and activated diffuser period (2001-2002) using PCA. The greatest increase in CPERF abundances occurred at these stations. Principal components 1 and 2 represented 69% and 6% of the variability in the baseline period, respectively. Score plots are replicated to demonstrate the relative spatial and temporal composition of all nearfield samples. Location specific baseline and activated diffuser data are colored in blue and red, respectively.


PCA Score Plot: NF18

PCA Loading Plot

PCA Score Plot: NF04

PCA Score Plot: NF13

Sample Locations

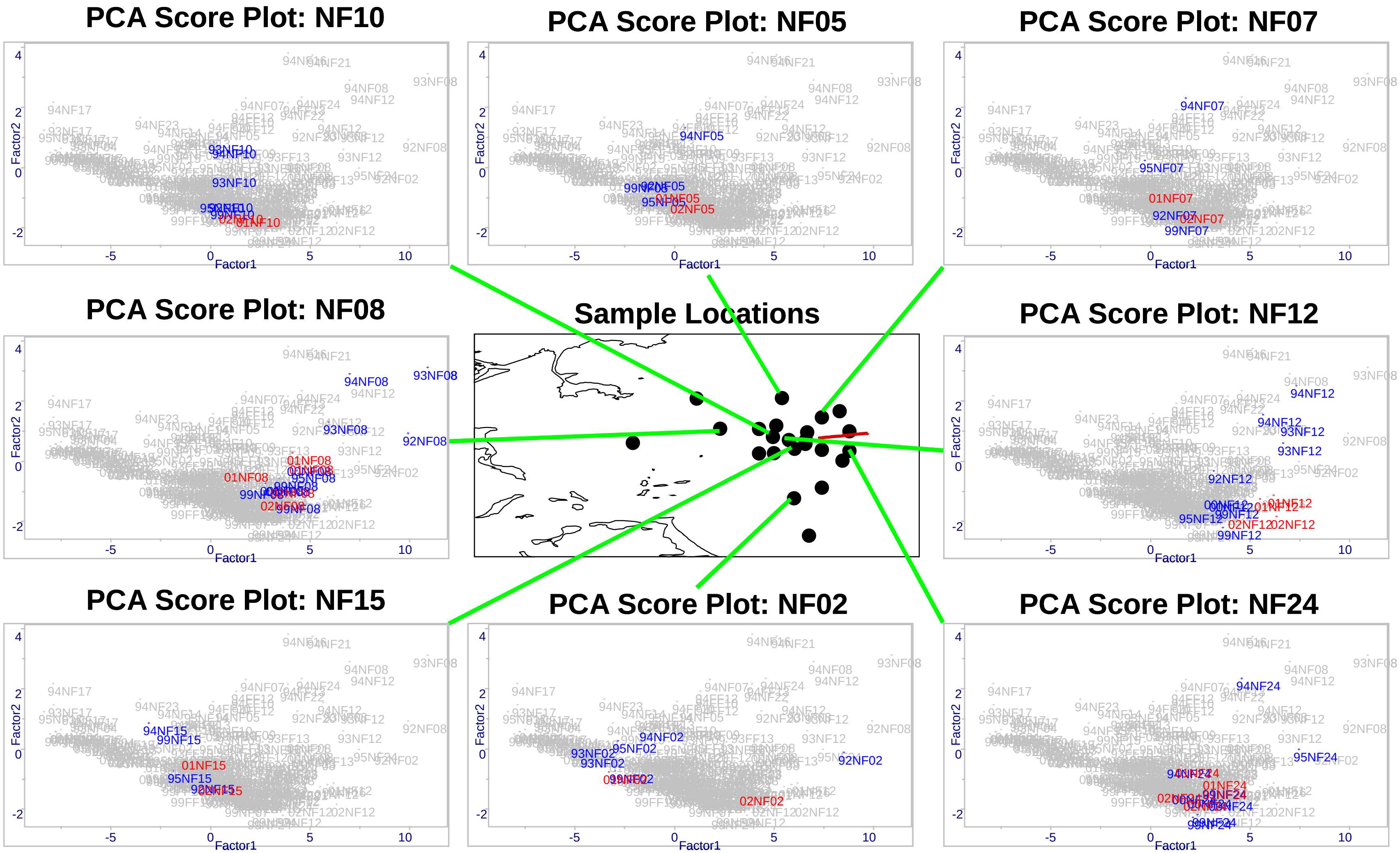
PCA Score Plot: NF23

PCA Score Plot: NF14

PCA Score Plot: NF17

PCA Score Plot: NF19

Figure 1b. Comparison of nearfield sediments from the baseline period (1992-2000) and activated diffuser period (2001-2002) using PCA. Moderate changes in CPERF abundances occurred at these stations. Principal components 1 and 2 represented 69% and 6% of the variability in the baseline period, respectively. Score plots are replicated to demonstrate the relative spatial and temporal composition of all nearfield samples. Location specific baseline and activated diffuser data are colored in blue and red, respectively.



PCA Score Plot: NF10

PCA Score Plot: NF05

PCA Score Plot: NF07

PCA Score Plot: NF08

Sample Locations

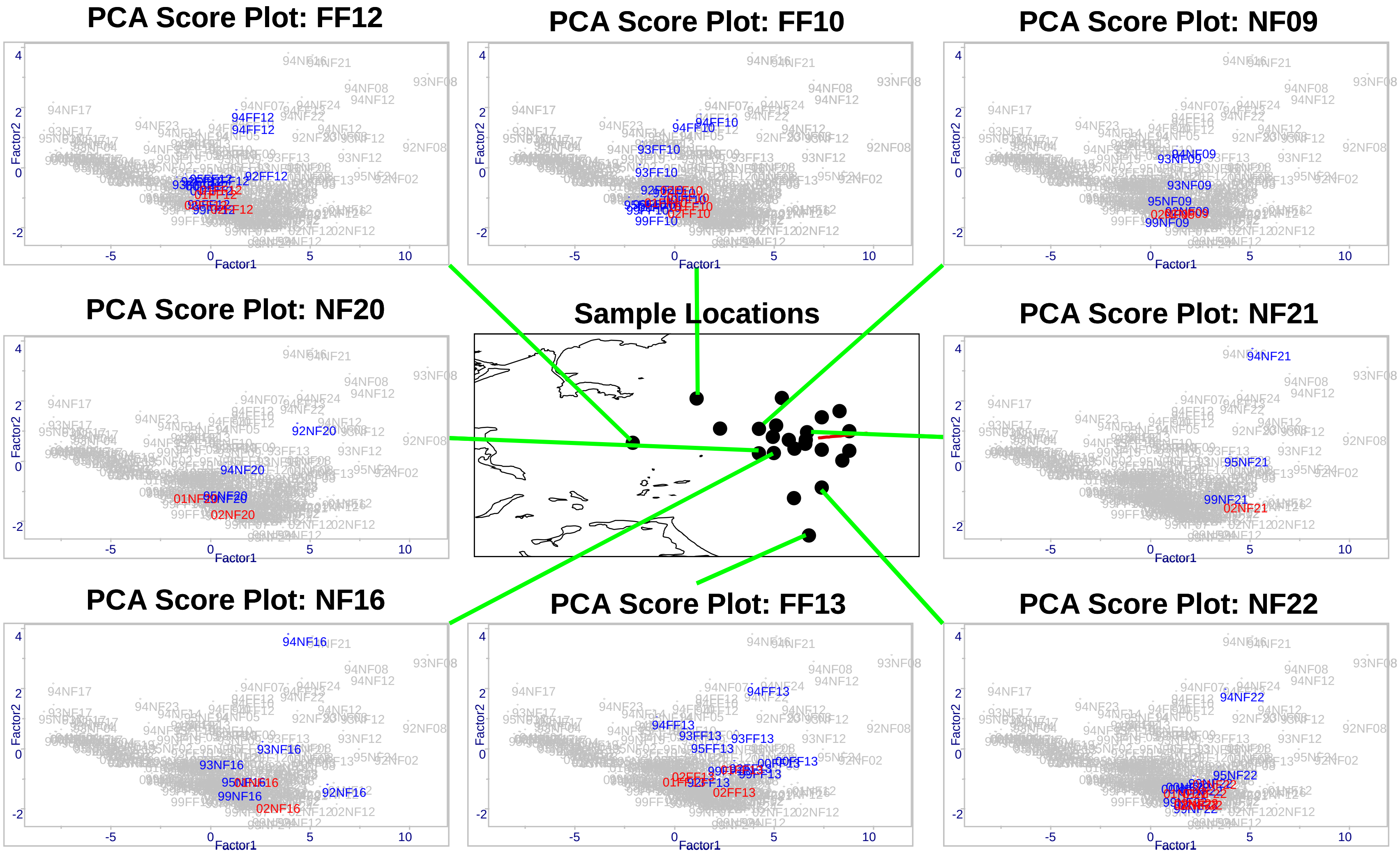
PCA Score Plot: NF12

PCA Score Plot: NF15

PCA Score Plot: NF02

PCA Score Plot: NF24

Figure 1c. Comparison of nearfield sediments from the baseline period (1992-2000) and activated diffuser period (2001-2002) using PCA. The greatest decrease in CPERF abundances occurred at these stations. Principal components 1 and 2 represented 69% and 6% of the variability in the baseline period, respectively. Score plots are replicated to demonstrate the relative spatial and temporal composition of all nearfield samples. Location specific baseline and activated diffuser data are colored in blue and red, respectively.



PCA Score Plot: FF12

PCA Score Plot: FF10

PCA Score Plot: NF09

PCA Score Plot: NF20

Sample Locations

PCA Score Plot: NF21

PCA Score Plot: NF16

PCA Score Plot: FF13

PCA Score Plot: NF22

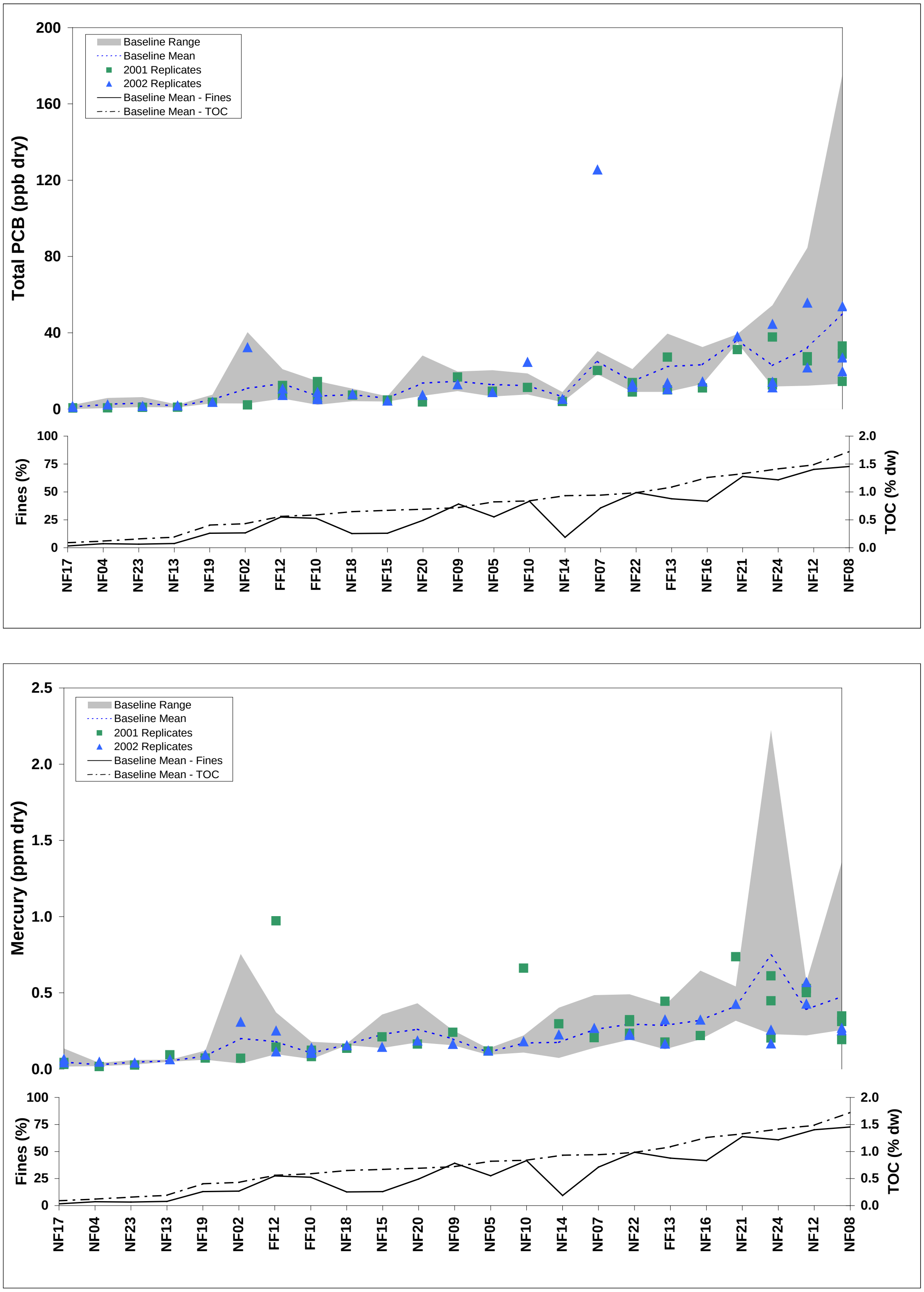
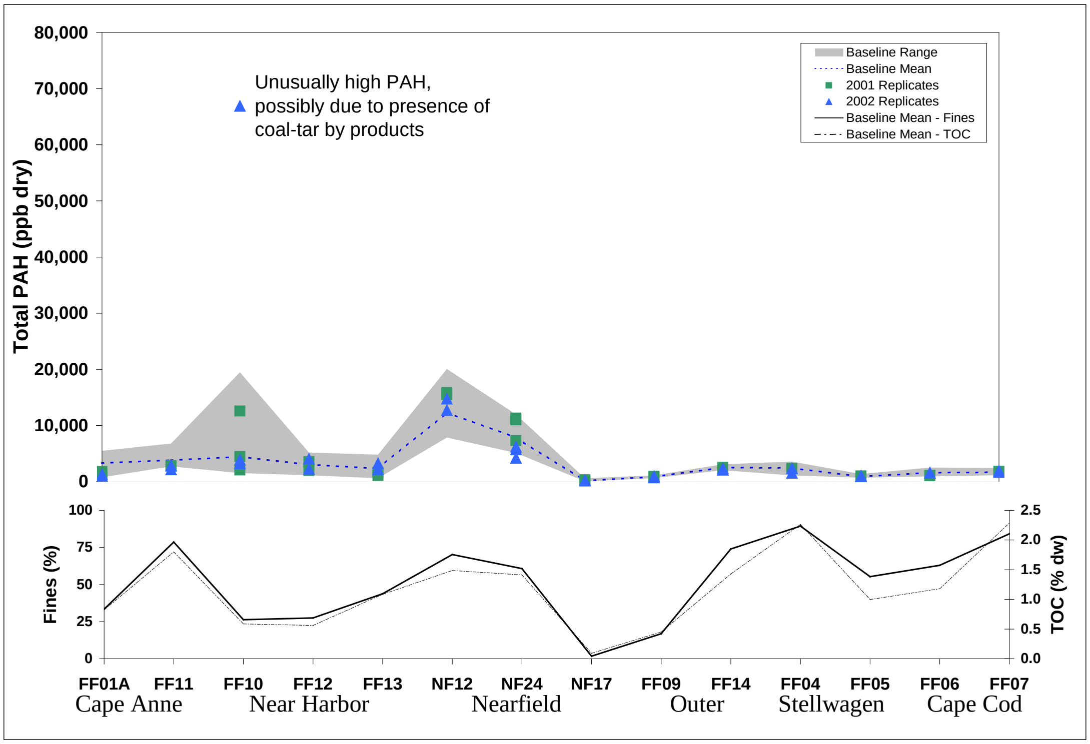


Figure 2. Representative parameters (total PCB, mercury) for each nearfield station sampled in 2001 (squares), 2002 (triangles) and the range of values occurring during the baseline period (gray band). The baseline mean values are indicated (dashed line within gray band). Stations are presented in order of increasing mean TOC concentration (dashed line in sub-plot). Baseline station mean values for TOC and percent fines, plotted by station, are shown in the sub-plot.



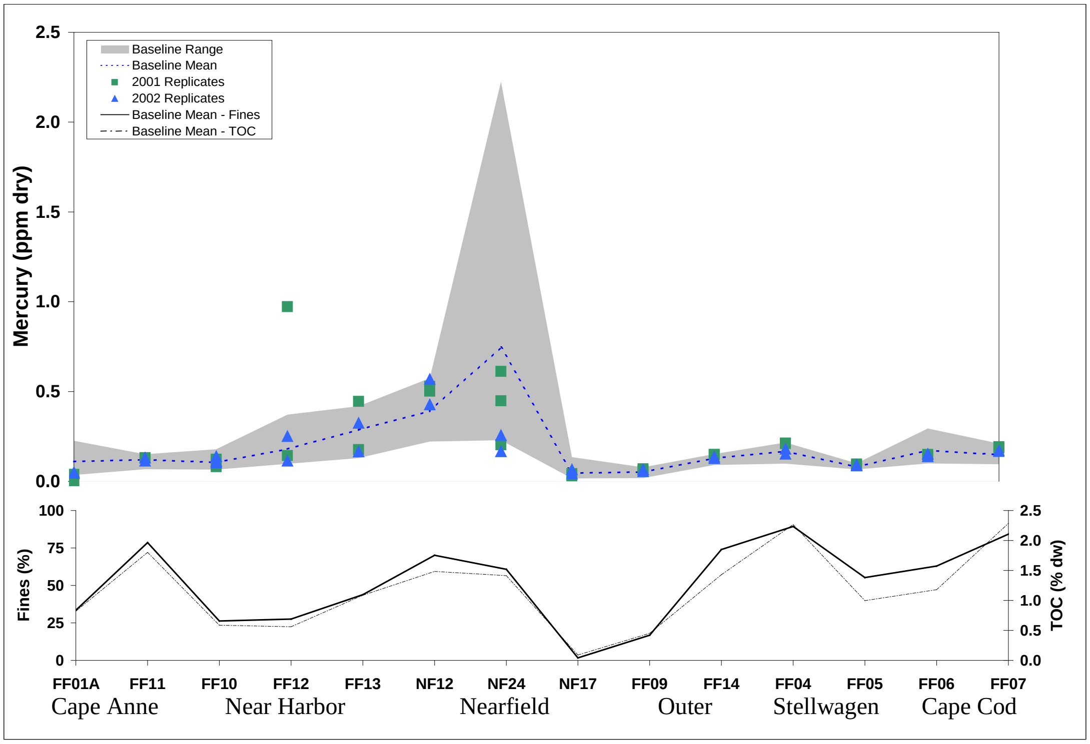


Figure 3. Representative parameters (total PAH, mercury) for each regional station sampled in 2001 (squares), 2002 (triangles) and the range of values occurring during the baseline period (gray band). The baseline mean values are indicated (dashed line within gray band). Stations are presented in order of location relative to the outfall, from north to south. Baseline station mean values for TOC and percent fines, plotted by station, are shown in the sub-plot.

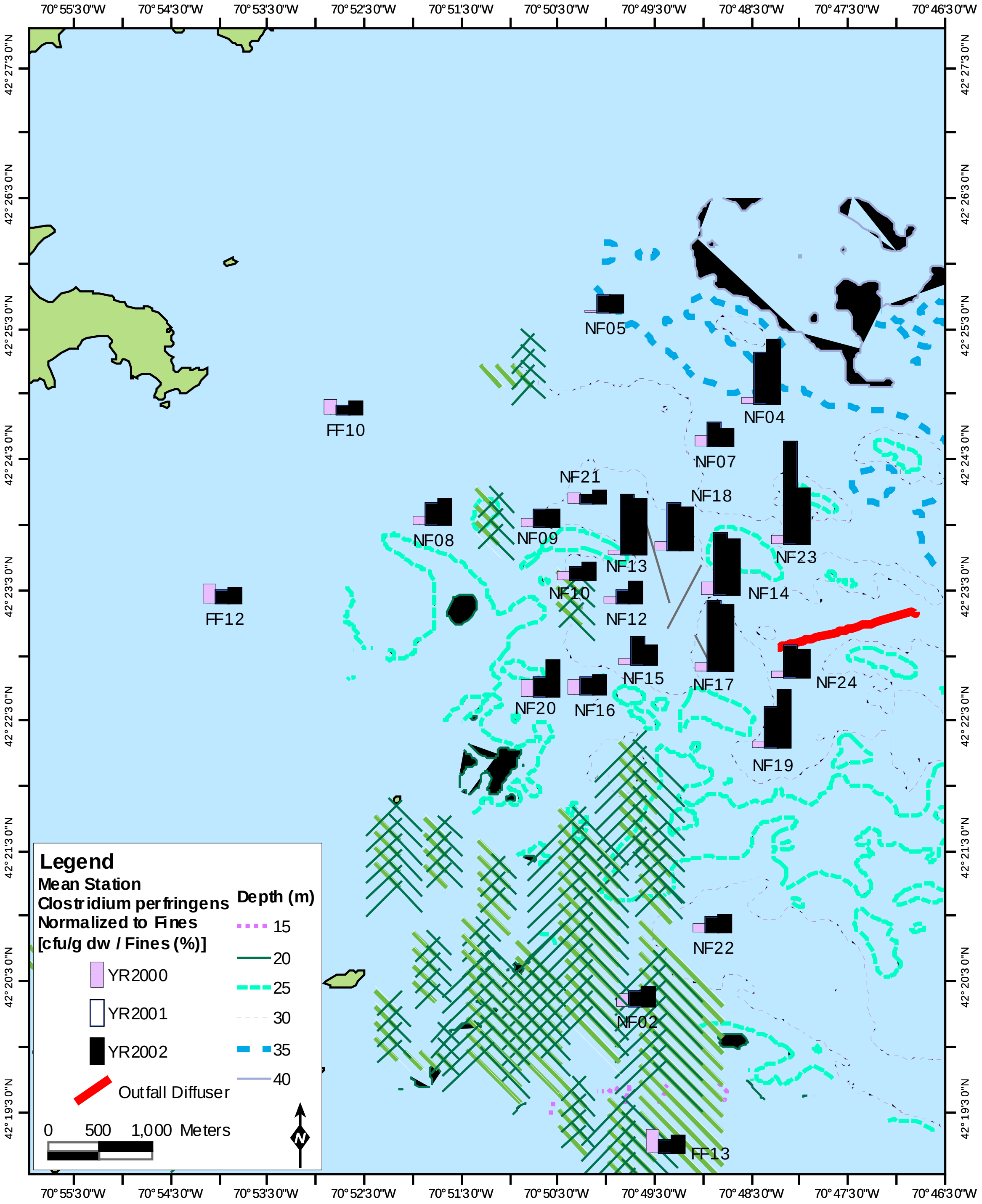


Figure 4. Station mean concentrations of *Clostridium perfringens* (normalized to percent fines) in nearfield sediments, collected in August 2000, 2001 and 2002.

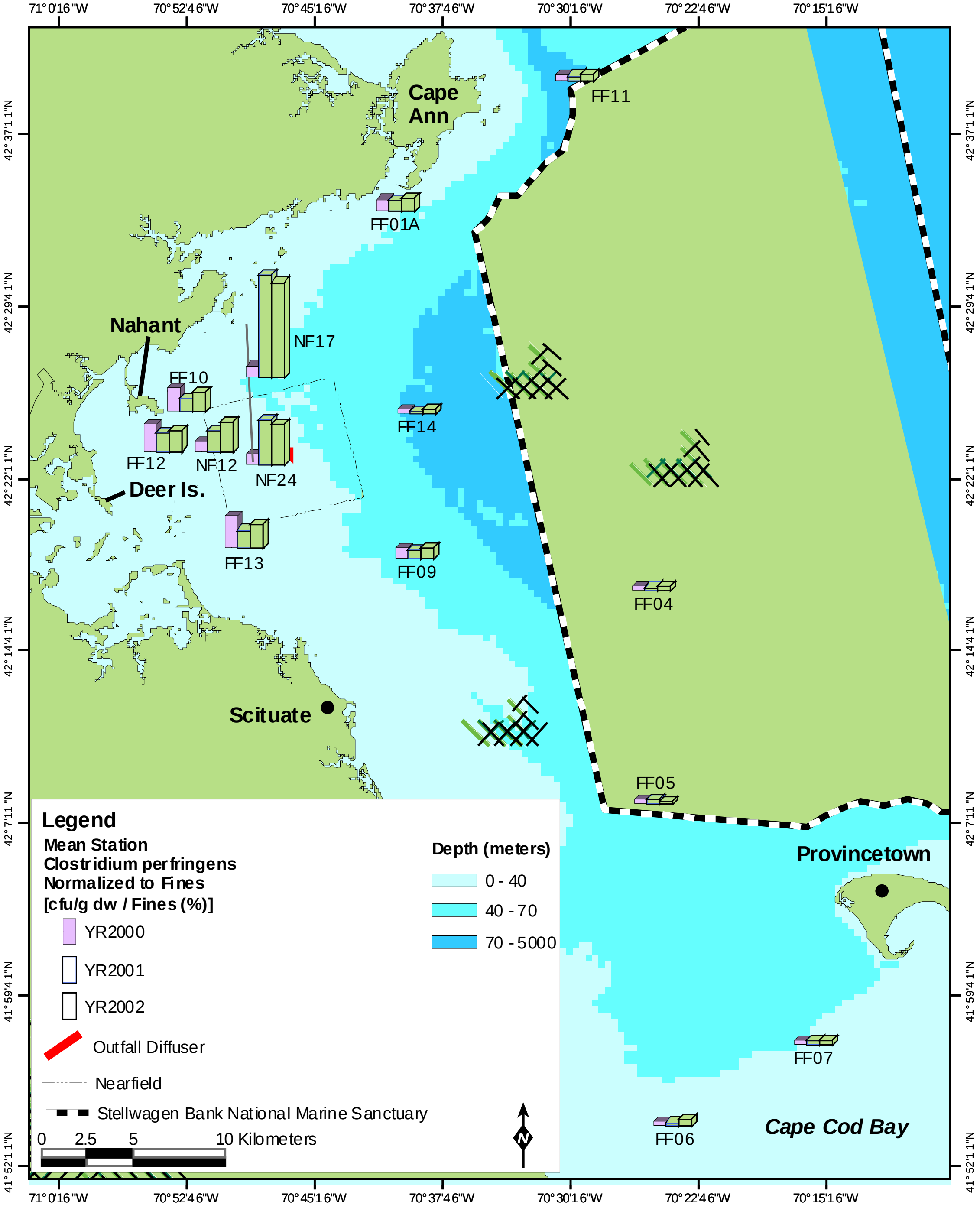
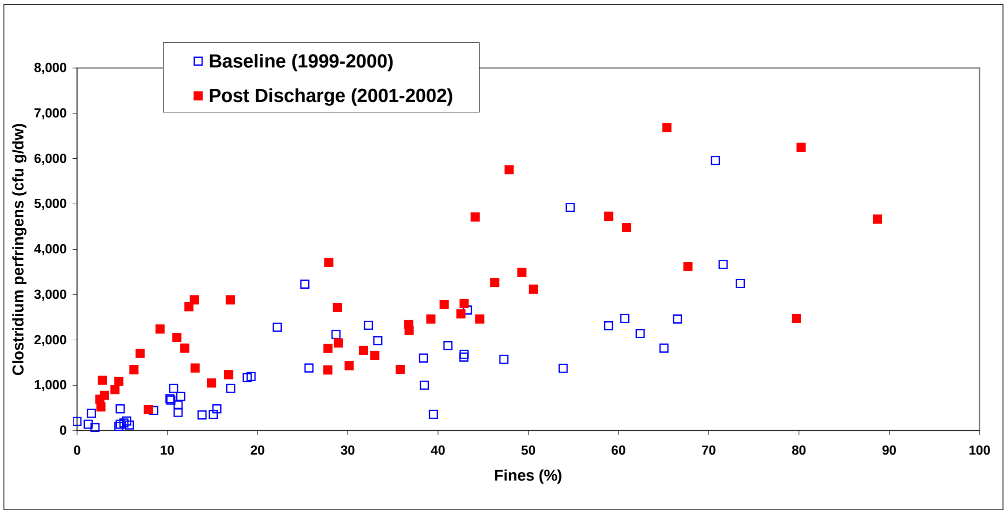


Figure 5. Station mean concentrations of *Clostridium perfringens* (normalized to percent fines) in regional sediments, collected in August 2000, 2001 and 2002.



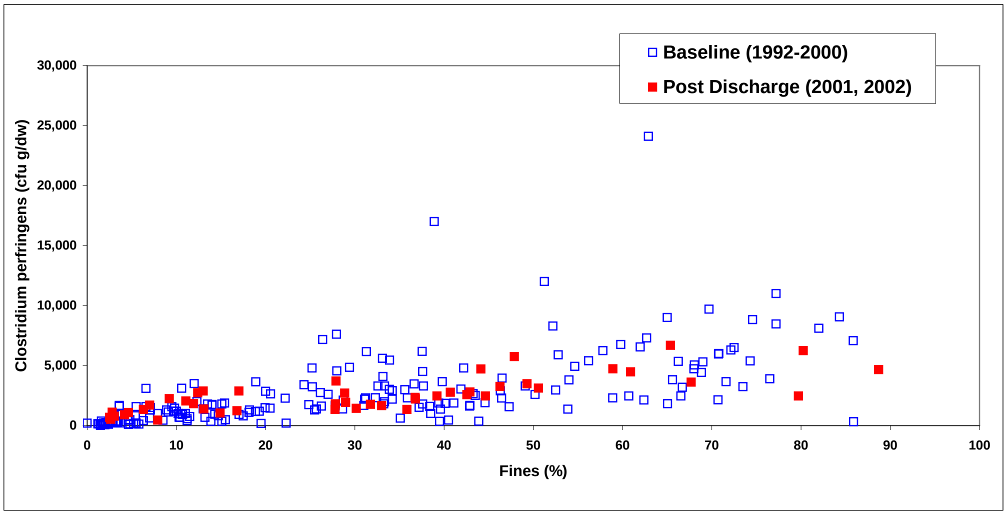


Figure 6. Correspondence between *Clostridium perfringens* and percent fines using data from the two years before and after the new outfall came on-line (top) or data from all years (1992-2002) (bottom).

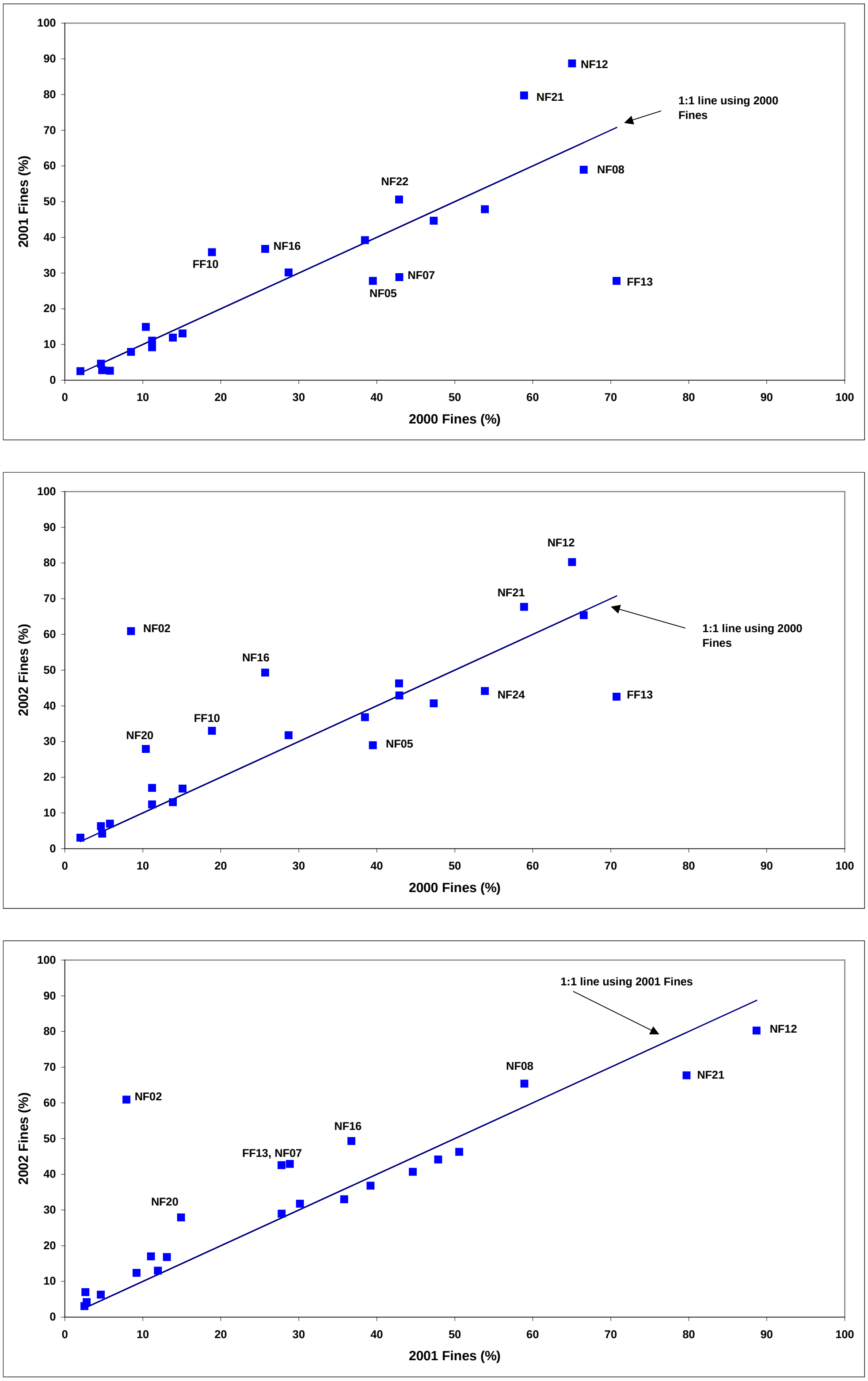


Figure 7. Correspondence between percent fines in 2000 and 2001 (top), in 2000 and 2002 (middle) and 2001 and 2002 (bottom).

Table 1. Nearfield stations listed by the change in CPERF abundance in the baseline period relative to the activated diffuser period (data presented to three significant figures).

Figure	Station	Average CPERF Baseline Period (1992-2000)	Average CPERF Activated Diffuser Period (2001-2002)	Percent Difference (%D)
1a. Greatest increase in CPERF	NF17	145	733	407%
	NF23	280	1010	259%
	NF04	356	1110	212%
	NF13	509	1210	138%
	NF14	1090	2490	128%
	NF19	1410	2350	67%
	NF18	1480	2470	67%
1b. Intermediate change in CPERF	NF15	940	1310	39%
	NF02	2020	2470	22%
	NF12	4690	5460	16%
	NF07	2390	2760	15%
	NF05	1680	1870	12%
	NF08	5200	5710	10%
	NF10	2410	2620	9%
	NF24	4890	5230	7%
1c. Greatest decrease in CPERF	NF09	2450	2340	-5%
	FF10	1570	1500	-5%
	NF16	3660	2920	-20%
	NF22	4050	3190	-21%
	NF20	3130	2380	-24%
	FF12	3830	1600	-58%
	NF21	7880	3050	-61%
	FF13	7360	1960	-73%

$$\%D = \frac{(CPERF_{Diffuser} - CPERF_{Baseline})}{CPERF_{Baseline}} \times 100$$

For PCA, a complete set of analyte data is required and the entire sample must be excluded if any one parameter is missing. Samples (1992-2001) excluded from the data analyses are detailed in the 2001 Outfall Benthic Report. Samples from 2002 were omitted for the reasons described below:

- NF08; 1 of 3 replicates had an anomalous Hg value attributed to laboratory error.
- FF10; 1 of 3 replicates had an anomalous TPAH value attributed to particulates containing pitch entrained in the sediment sample.
- NF13; the only sample from this station was dropped due to an anomalous level of Pb attributed to laboratory error.
- NF20; the initial Pb value was omitted due to laboratory error. The substituted value was generated from the re-sampled sample.
- NF24; 1 of 3 replicates had an anomalous Pb value attributed to laboratory error.

V - HARDBOTTOM SPECIAL STUDY

Barbara Hecker and Kenneth Keay

V-1. Introduction and Study Design

Section IV (Sediment Contamination Study) briefly describes the heterogenous distribution of sea-floor environments in the vicinity of the outfall, and the environmental concerns underlying the benthic monitoring studies. MWRA's hardbottom study in the vicinity of the outfall is a special study complementing the more intensive benthic monitoring focused on soft-sediment habitats. The study addresses the monitoring question, "Has the hard-bottom community changed?" (MWRA 1991). The study currently surveys 23 rocky environments within 4 km of the outfall, including the riser caps surrounding area for one active and one closed diffuser (numbers 2 and 44, respectively) (Figure V-1.A). Each June, a small Remotely Operated Vehicle (ROV) is used to obtain video and slide coverage of hardbottom environments at each site, which are analyzed to provide estimates of the abundance and/or percent coverage of sessile and mobile organisms. Details of the study design and recent findings can be found in the project work plan (Williams *et al.* 2002) and the 2001 Outfall Benthic report (Kropp *et al.* 2002), respectively.

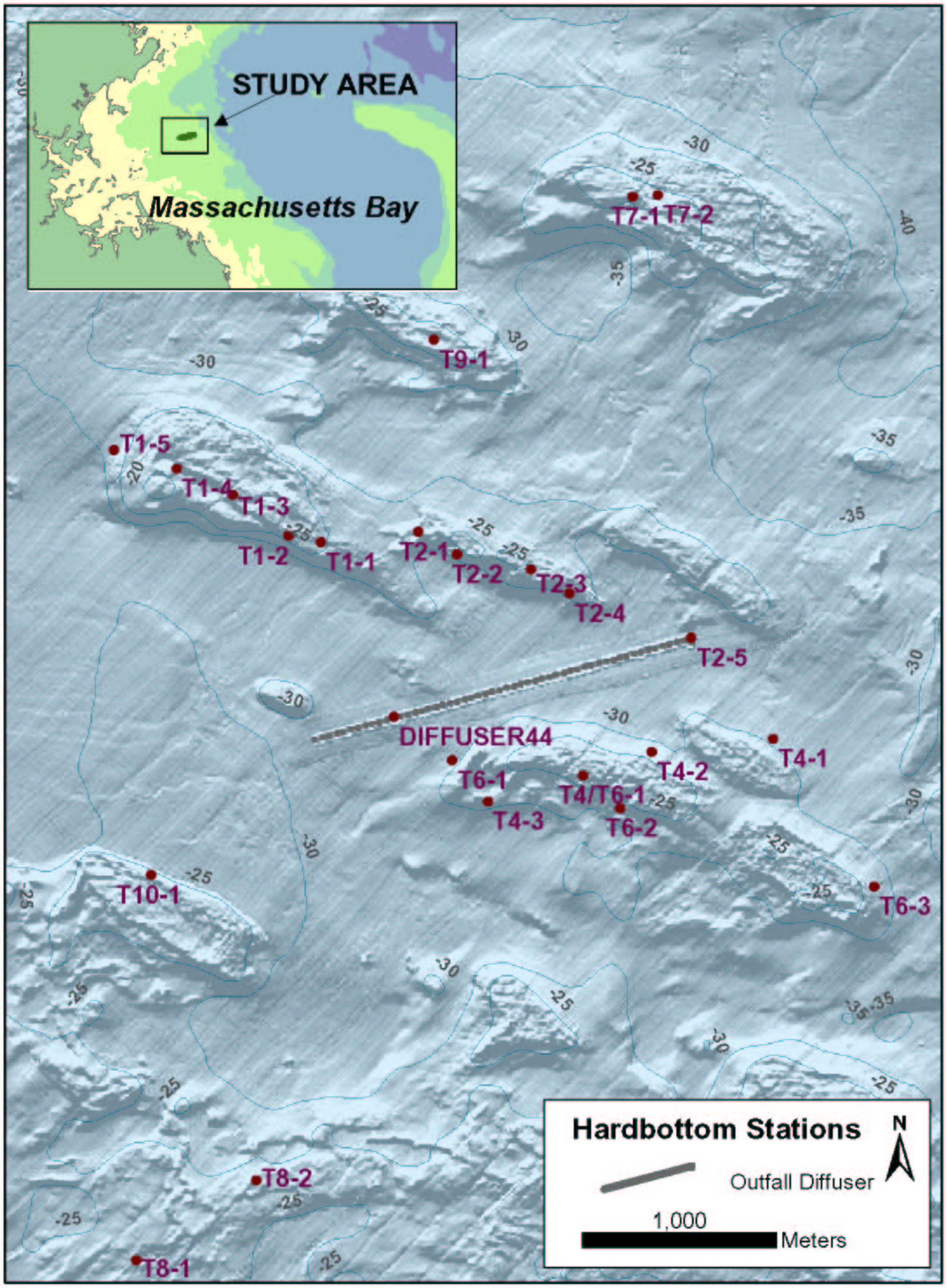
V-2. Monitoring Results

The nearfield hardbottom communities in the vicinity of the outfall, which are characteristic of subtidal epifaunal communities in the southern Gulf of Maine, have been surveyed annually for nine years. The first seven surveys occurred during pre-discharge “baseline” conditions, while the last two have been discharge monitoring. The baseline surveys provided a substantial database that allowed characterization of the habitats and benthic communities found on the drumlins in the vicinity of the outfall. The hardbottom habitats are spatially quite variable, but have shown several consistent trends.

At many of the stations, year-to-year variations in habitat characteristics tended to be relatively small. Depth and habitat relief appeared to be the most important factors determining the distribution of hardbottom communities. Location on the drumlins appeared to be a primary factor in determining habitat relief, with the top of drumlins usually having higher relief (boulders and large cobbles) than the flanks (cobbles and gravel). Sediment drape tended to be light on the shallowest part of the drumlins adjacent to the outfall (T1-2, T1-3, T1-4 and T4/6-1), moderately light at the southernmost reference sites (T8), and moderately heavy or heavy at the other southern reference site (T10), the northern reference stations (T7-2 and T9-1), and some of the flank stations (T4-1 and T6-1). The tops of the drumlins were relatively homogeneous, so that lateral shifts in position did not result in widely different habitat characteristics (*i.e.*, T1-3, T1-4, T4/6-1, T8, T9 and T10). In contrast, the edges of the drumlin tops and the flanks were more heterogeneous, such that small lateral shifts in position frequently resulted in substantially different communities and habitat characteristics (*i.e.*, T1-1, T1-2, T1-5 and T4-2).

The benthic communities inhabiting the hardbottom areas showed similar patterns both before and during discharge. Algae dominated on the tops of drumlins, while invertebrates (mostly encrusting or attached forms) were increasingly dominant on the flanks. Encrusting coralline

Figure V-1.A. Locations of nearfield hard-bottom special study stations, projected onto USGS bathymetric relief map of the vicinity of the outfall.(Source: MWRA).

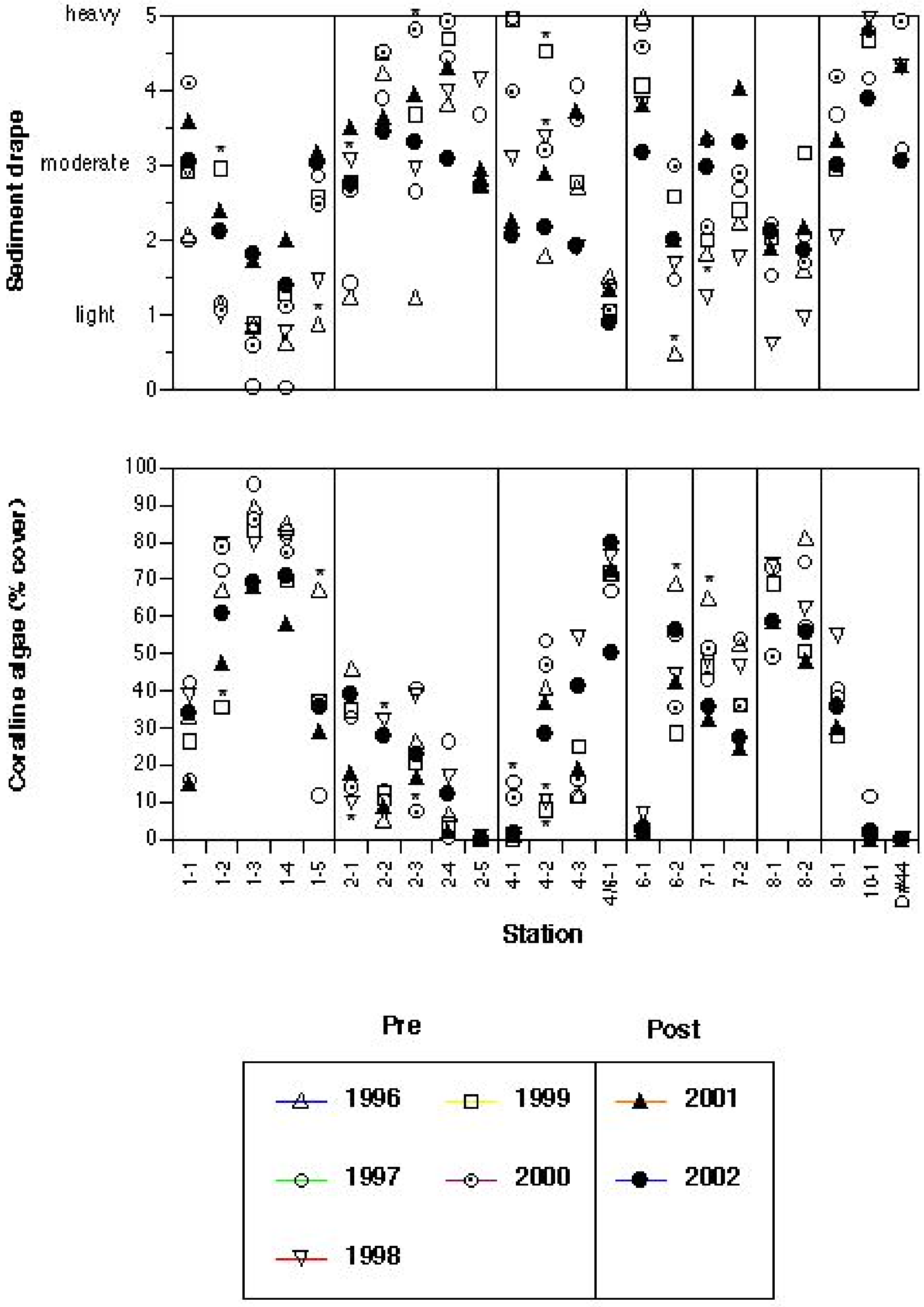


algae was the most abundant and widely distributed taxon encountered during each year of the study. Coralline algae were generally most abundant on the top of drumlins (T1-3, T1-4, and T4/6-1) and least abundant on the flanks (T2-4, T4-1, and T6-1). The percent cover of corallines was most variable near the edges of the tops of drumlins or on the flanks, where small lateral shifts in location frequently resulted in different habitat characteristics. The distribution and areal coverage of coralline algae remained relatively stable during the 1995 to 2000 baseline period, and showed slight decreases in percent cover at several stations in 2001 and 2002 (Table V-2.A, Figure V-2.A).

Table V-2.A Estimated percent cover of coralline algae from 1996 to 2002. Large differences between pre- and post-discharge are bolded. Asterisks mark differences that appear to be related to shifts in position of the areas surveyed.

Transect	Waypoint	Pre-discharge					Discharge Monitoring	
		1996	1997	1998	1999	2000	2001	2002
1	1	35	42	37	26	16	15	34
	2	71	72	79	36*	79	**47**	**61**
	3	90	96	80	83	86	**68**	**69**
	4	87	83	82	70	77	**58**	71
	5	68*	12	39	37	37	29	35
2	1	45	33	9*	35	14	18	39
	2	5	13	33*	13	10	9	28
	3	27	41	39	21	8*	17	23
	4	7	27	18	4	1	2	12
	5	<1	<1	<1			0	0
4	1		16*	<1	0	11	1	2
	2	41	53	9*	8*	47	37	28
	3	12	12	56*	25	16	19	41
4/6	1	72	67	77	72	71	73	80 (50)
6	1	2	4	5	2	2	3	3
	2	69*	55	45	29	36	42	56
7	1	65*	43	49	47	52	**32**	**36**
	2	53	54	45	36	36	**24**	**28**
8	1		73	74	69	49	58	59
	2	82	75	65	51	58	48	56
9	1		40	54	28	38	30	36
10	1		12	<1	2	3	0	1
Diffuser	44		<1	<1		<1	0	0

Figure V-2.A Sediment drape and percent cover of coralline algae at nearfield hardbottom sites determined from the 1996 to 2002 surveys.



* denotes changes related to shifts in position

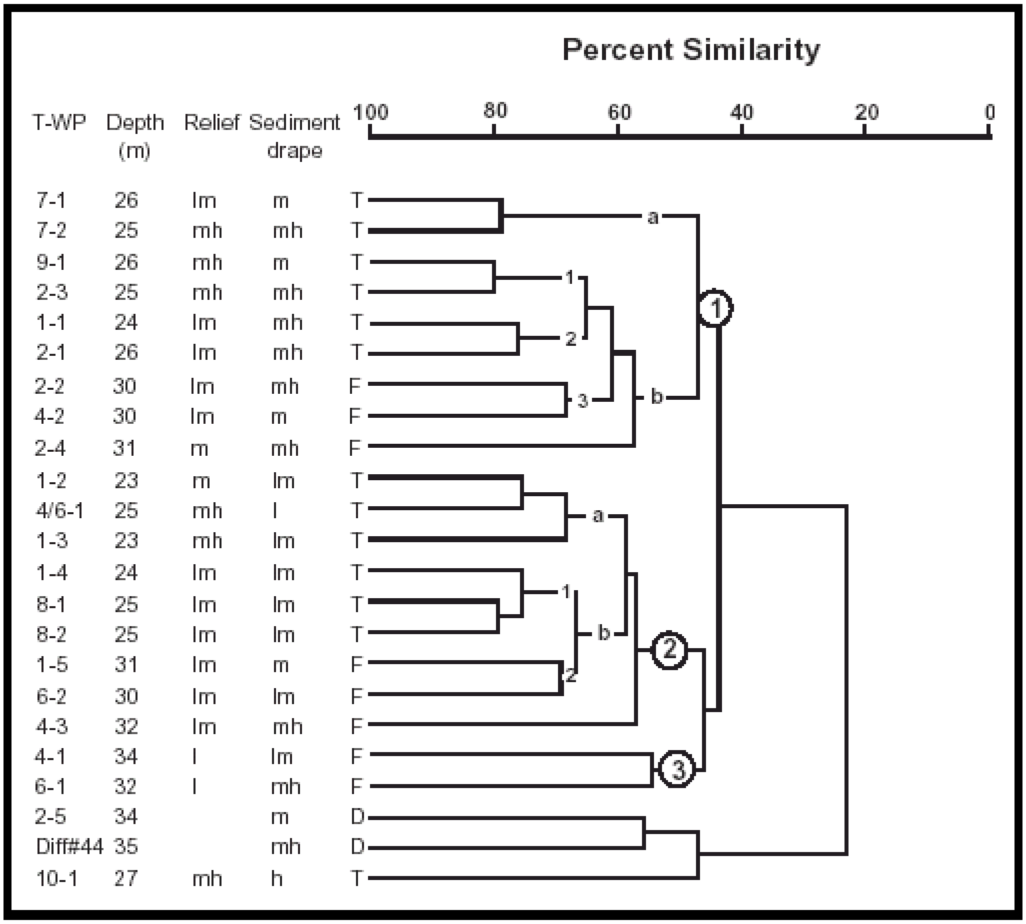
The abundance of corallines appears to be strongly related to sediment drape; percent cover was highest in areas that had little drape and lowest in areas with moderate to heavy drape. This is not surprising, because the encrusting growth form of coralline algae would make them susceptible to smothering by fine particles. Five stations north of the outfall showed a decrease in percent cover of coralline algae in 2001, and this decrease was again observed at four of these stations in 2002 (Figure V-2.A).

Corresponding to the decrease in coralline algae, in 2001 these 5 stations had slightly more sediment drape than at any time during the baseline period. This trend of slightly elevated sediment drape at Stations T1-2, T1-3, T7-1 and T7-2 was also observed in the 2002 data (Figure V-2.A). On transect 1 (waypoints 2, 3, and 4) sediment drape increased from clean to light between 1995 and 2000 to moderately light in 2001 and 2002, while on transect 7 it increased from moderately light to moderate at T7-1 and moderately light to moderately heavy at T7-2. In contrast, coralline algae cover was not reduced, and sediment drape was not elevated, at any of the other stations. Reasons for the increase in sediment drape and decrease in coralline cover at transects 1 and 7 but not at the other locations are not readily apparent, but may be related to the discharge.

The pattern of hardbottom community structure has been remarkably consistent throughout the study period. Classification analysis of the first post discharge data set (Kropp *et al.* 2002) yielded results similar to those from the last five years of baseline monitoring (Figure V-2.B).

At many of the sites the benthic communities remained stable during the baseline period and the first year of discharge. Three instances of departure from baseline conditions in cluster designation were noted in the 2001 data. All three of these instances (T2-2, T4-1, T4-2) appear to reflect spatial variability in the benthic communities rather than changes in community structure due to the discharge (Kropp *et al.* 2002). The data from 2002 have not yet been completely analyzed, but they do not appear to be substantially different from the 2001 data.

Figure V-2.B Cluster analysis of data collected from still photographs taken during the 2001 nearfield hardbottom survey.



T-WP	Depth (m)	Relief	Sediment drape	
7-1	26	lm	m	T
7-2	25	mh	mh	T
9-1	26	mh	m	T
2-3	25	mh	mh	T
1-1	24	lm	mh	T
2-1	26	lm	mh	T
2-2	30	lm	mh	F
4-2	30	lm	m	F
2-4	31	m	mh	F
1-2	23	m	lm	T
4/6-1	25	mh	l	T
1-3	23	mh	lm	T
1-4	24	lm	lm	T
8-1	25	lm	lm	T
8-2	25	lm	lm	T
1-5	31	lm	m	F
6-2	30	lm	lm	F
4-3	32	lm	mh	F
4-1	34	l	lm	F
6-1	32	l	mh	F
2-5	34		m	D
Diff#44	35		mh	D
10-1	27	mh	h	T

Observations at the 2 risers occupied by the study document that very little change in the fouling community has been observed since startup, even on these maximally exposed surfaces (Figure V-2.C).

Figure V-2.C Representative photographs from diffuser #44 from surveys in (a) 1998 and (b) 2000 (baseline), and in 2002 (discharge).

a)

b)

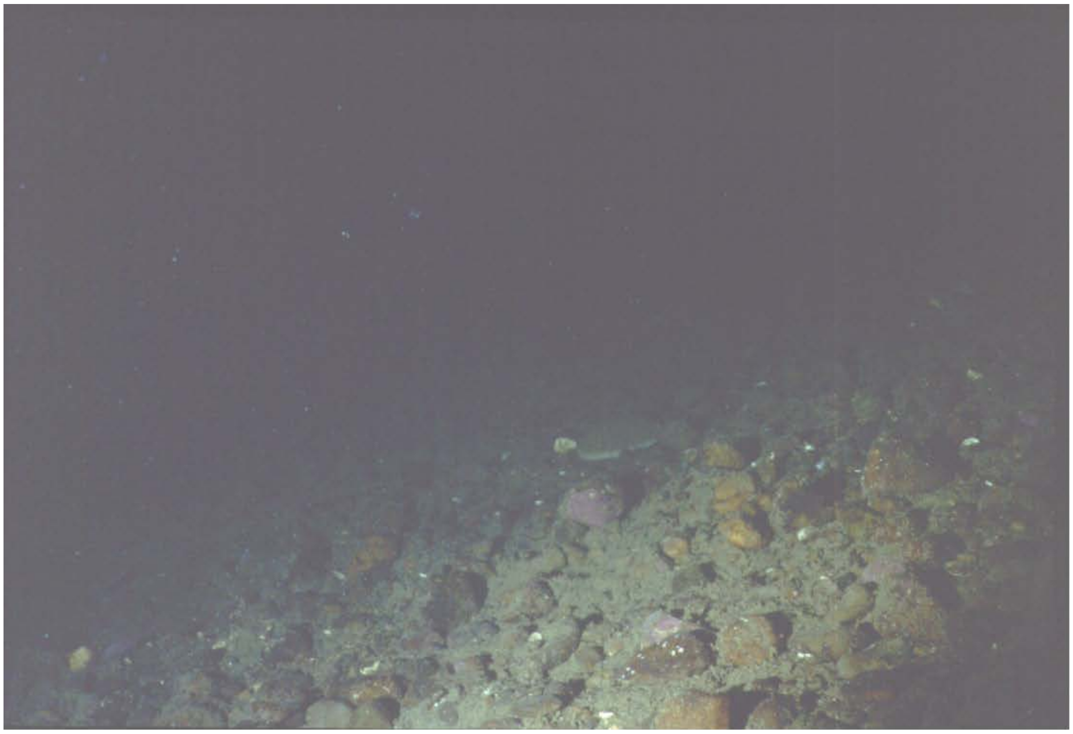
Finally, several striking trends have been observed in the abundance of large mobile taxa during the study. These may reflect regional temporal changes in their population structures, and do not appear to be related to the outfall discharge. The green sea urchin *Strongylocentrotus droebachiensis* showed a steady decline in abundance during the baseline period from 478 individuals in 1996 to 159 individuals in 2000, and a subsequent increase to 181 individuals in 2001, and 229 individuals in 2002 (Table 3). In contrast, three other species, the crab *Cancer* sp., the lobster *Homarus americanus*, and the cod *Gadus morhua*, are observed more frequently recent years than they were early in the study. In the still photographs, one to six *Cancer* crabs were seen annually between 1996 and 1999, 20 were seen in 2000, 54 were seen in 2001, and 76 were seen in 2002. This pattern was also reflected in the video data, with 3 to 17 *Cancer* crabs observed annually between 1996 and 1999, 105 in 2000, 147 in 2001, and 205 in 2002. A similar trend was seen in the video data for codfish, with none seen in 1996, 41 seen in 2001, and 53 seen in 2002. Interestingly, no cod had been seen at the diffuser stations during the baseline years, yet they have been seen at both diffusers during both post discharge surveys. Six and eight cod were seen at T2-5 and Diffuser #44, respectively, in 2001 and 12 and 3 cod were respectively seen in 2002. Codfish generally tend to shy away from the ROV, frequently ducking behind rocks, but at the diffuser sites they were much less hesitant and occasionally came right up to the vehicle. In contrast, the codfish seen at the other stations tended to avoid the ROV.

Conclusions. The hardbottom benthic communities near the outfall were relatively stable over the 1995 to 2000 baseline time period, and this did not substantially change with the activation of the outfall. The remarkable similarities among all the surveys indicate that major departures from baseline conditions have not occurred during the two years of discharge. The only observable change, an increase in sediment drape, and a concurrent decrease in percent cover of coralline algae, was noted in 2001 at a subset of stations on the top of the drumlin north of the outfall and at the two northernmost reference sites. This trend has continued during the second year of discharge monitoring. Whether these modest changes are related to the outfall discharge is presently not known.

V-3 Proposed changes to the monitoring plan

The hard-bottom study is intended to answer the monitoring question “Has the hard-bottom community changed?” In the first 2 years of discharge monitoring, only modest changes suggestive of outfall impact have been identified, and those only at a subset of stations. Lush epifaunal growth continues to be found both on risers occupied by the study, and throughout many of the other stations occupied. Even though outfall impacts appear to be minimal, any changes to the hardbottom communities could be chronic and/or cumulative. We therefore propose only modest changes to the study at this time. For sampling in 2003, we propose discontinuing station T4-1 and shifting the field and analytical/interpretive effort to a new reference station to be established at 34 meters depth off Scituate on hard substrate similar to that found on drumlins in the nearfield. This site was visited in June 1999 (as part of an unrelated study) and was found to support a dense benthic hardbottom community. Discontinuation of Station T4-1 is being proposed because the fauna at this low relief cobble/gravel pavement (Figure V-3.A) has consistently been relatively depauperate during the baseline and immediate post discharge periods. The community at that site consistently forms an outlier in the classification analyses (Figure V-2.B), and we believe replacing it with a distant site for which baseline data are available would enhance the study.

Figure V-3.A Representative slides from station T4-1 from the 2001 survey.



Another proposed substitution is the replacement of Station T4-3 with a new reference station to be established on a nearfield drumlin further removed from the outfall. Station T4-3 is relatively heterogeneous in substrate type and therefore in the epibenthos, and may be less useful to the study than a further removed reference station, even though there would be no baseline data available from such a site.

Future changes under consideration: If the results of this study in 2003 and 2004 are similar to those obtained so far, MWRA believes that more substantive reductions in station coverage may be appropriate for 2005 monitoring. These reductions might consist mostly of drumlin flank stations, which tend to be spatially heterogeneous and less useful to the study than the less variable drumlin top stations. Beyond 2005, our benthic monitoring team has suggested that after a review of the first 5 years of discharge monitoring data, the frequency of benthic monitoring studies, including the hardbottom study, could be decreased to every other year.

References

Kropp RK, Diaz RJ, Hecker B, Dahlen DT, Boyle JD, Abramson SL and Emsbo-Mattingly S. 2002. 2001 Outfall Benthic Monitoring Report. Boston: Massachusetts Water Resources Authority. Report 2002-15. 137 p.

Williams IP, Maciolek NJ, Boyle JD, Dahlen DT and Baptiste-Carpenter EM. 2002. Combined work/quality assurance plan for benthic monitoring: 2002-2005. Boston: Massachusetts Water Resources Authority. Report ms-076. 109 p.

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