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US ARMY CORPS
OF ENGINEERS
New England District

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Literature Search and Data Gap Assessment

Task 2 Data Gap Analysis Support for Boston Harbor SEIS/EIR

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to

U.S. Army Corps of Engineers
North Atlantic Division
New England District
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1.0 INTRODUCTION

The Boston Harbor Navigation Improvement and Berth Dredging Project (BHNIP) (Figure 1) was authorized by Congress in the Water Resources Development Act of 1990 to deepen Boston's main shipping channel and allow the Port of Boston to remain competitive in national and international marine trade. Pursuant to Federal (NEPA) and Massachusetts (MEPA) Environmental Policy Acts, the Army Corps of Engineers and Massport prepared an Environmental Impact Report/Environmental Impact Statement (EIR/EIS) prior to construction of the project. The Final Environmental Impact Report/Environmental Impact Statement (FEIR/EIS) for BHNIP was submitted in 1995 and Phase 1 of the project began in 1997. Currently, two phases of the project are complete and additional work is pending. Preparation of a supplemental EIS to address changes in the Harbor since 1995 is anticipated. The Army Corps of Engineers, New England District (Corps), contracted Battelle to perform a literature search and data gap analysis to acquire knowledge of all recent (post 1995) scientific studies in areas that may be affected by the project. This report describes the conduct of the literature search, the evaluation completed to date, and preliminary identification of data gaps.

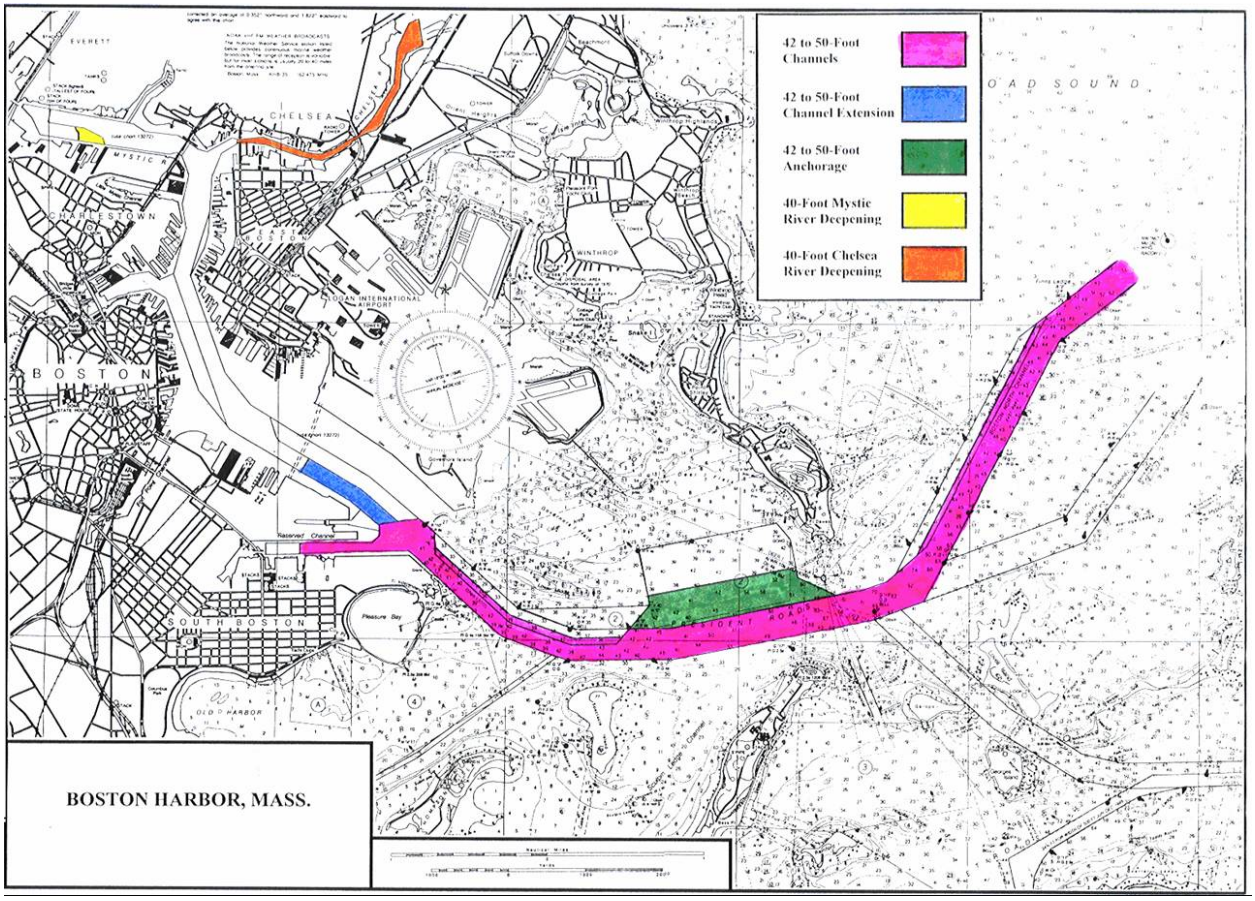

Figure 1. Boston Harbor Navigation Channel

2.0 APPROACH

A dialog search of relevant environmental databases was conducted using a mix of applicable keywords, geographic boundaries, and date restraints. To identify possible sources of relevant, unpublished data, phone calls were made to state agencies and academic research institutions known to have collected data in the study area in the defined period. The original search produced a list of 292 published citations and dozens of leads on unpublished data sets. The results of the original search were presented to the Corps at a technical working group meeting on January 27, 2004. At that meeting, the scope of the project was refined to include Boston Harbor and western Massachusetts Bay only (omitting Stellwagen Bank and Cape Cod Bay). References identified by this process were screened for relevance, categorized by topic area, and entered into a project-specific ProCite© literature database. Abstracts were written for all citations and all documents were obtained. Below is a detailed description of each phase of the literature search.

2.1 Applicable Water Body and Key Word Determination

Before beginning the electronic literature search, key words and search constraints were determined. Many words and phrases found in the Rhode Island Sound Disposal Site Study literature search database (Corps 2002) were incorporated into the list.

The geographic area was initially limited to Boston Harbor, Massachusetts Bay (including Cape Cod Bay), and Stellwagen Bank. Following the technical working group meeting, those locations were limited to Boston Harbor and eastern Massachusetts Bay. Key words were identified based on the topic areas identified in Table 1 and were chosen to reflect critical physical and biological resources potentially affected by the project.

2.2 Initial Electronic and Hardcopy Literature Searches

The initial electronic dialog search used the key words in Table 1 and the geographic area (described above) as criteria for identifying published information available through interlibrary loans. Various references were accessed, including peer-reviewed publications (e.g., books, professional journals), magazine articles, masters theses and doctoral dissertations, among others. Direct computerized searches were conducted at the reference libraries at Woods Hole Oceanographic Institute (WHOI) and Marine Biological Laboratory (MBL) by using the same key words and geographic areas.

Table 1. Key Words Used for the Initial Literature Searches.

Topic Area	Key Words
Fisheries/Shell Fisheries	Aquaculture/Commercial Area, Mussels, Plankton (Fisheries), Oysters, Spawning, Migration, Essential Fisheries Habitats, Economic Value (Catch per Effort), Recreational Uses, Lobster, Nursery All (Fisheries/Shell Fisheries)
Fishing Activities and Human Health Risks	Contaminants, Health Advisories, Nuisance and Toxic Phytoplankton Blooms, Toxicity Testing, All (Fishing Activities and Human Health)
Marine Wildlife and Endangered Species	Habitat, State Status, Federal Status, Marine Mammals, Reptiles, Birds, Endangered Species, All (Marine Wildlife)

Topic Area	Key Words
Physical Oceanographic	Waves and Wind Fetch, Salinity, Tides, Temperature, Hydrography, Circulation, Currents, Sediment Transport, Models, All (Physical Oceanographic)
Public Parklands, Beaches and Sanctuaries	Sanctuaries, Public Beaches, State Parks, Other, All (Public Parklands)
Sediment/Benthos	Sediment Chemistry, Bottom Morphology, Physical Characteristics, Benthic/Benthos, All (Sediment)
Water Quality	Plankton (Water Quality), Nutrients, Thermal Pollution, Metals, Organics, Pesticides, PCBs, Dissolved Oxygen, Bacteria/Pathogens, Suspended Solids, Phytoplankton, Zooplankton, Ichthyoplankton, Other Toxics, Models, All (Water Quality)
Geographic Areas	Boston Harbor, Massachusetts Bay, Stellwagen Bank
Publication Dates	1995 to present

2.3 Direct Contact with Federal and State Agencies and Universities

In addition to the published reports identified by computerized literature searches, an attempt was made to identify recent/current studies that are not yet published. The project team met to discuss the possible sources and came up with a list of contacts. Federal and state agencies, universities, and private sector scientists (listed in Appendix A) were contacted directly for information. The information received was evaluated by the team and the data were requested as appropriate. All initial contacts were made by phone. Most of the follow-up requests for data and reports were made in writing.

2.4 Literature Retrieval and Review

All references identified were entered into a ProCite© database. The database includes entries for both published references and unpublished reports and datasets. All references/reports that were available electronically were downloaded and printed. The list was then scanned for documents known to be held on-site (in Duxbury) or written by Battelle authors. Several MWRA reports that were not available electronically were requested directly from the agency. Requests for data collected in support of the Hubline project were made to the environmental contractor (TRC) and the Corps. All database entries pertaining to Hubline data were obtained from documents supplied by the Corps. Written requests for fish/shellfish data were sent to the Massachusetts Division of Marine Fisheries (MADMF) and National Division of Marine Fisheries (NMFS). The remaining reports were obtained through interlibrary loans, direct requests to the authors, or copied from journals at the MBL library.

Documents were reviewed upon retrieval and abstracts were written for those that didn't have one (approximately 90). To aid in the data gap analysis, "abstracts" were also written for data sets and entered into the ProCite® database. Each document/data set was evaluated for geographic data that would be pertinent to a geographic information system (GIS) representation (to be conducted under Task 3). Those results are listed in the Notes section of the ProCite® database. Citations are listed alphabetically in Appendix B and arranged by topic area, with abstracts in Appendix C.

3.0 DATA GAP ANALYSIS

The following is a summary of recent available data by resource topic based on the study area.

3.1 Sediment or Benthic Resources Data and Investigations

Information on sediment type, grain size, and chemistry useful in characterizing the sedimentary regime in Boston Harbor.

Several studies were identified that provide information on the nature of the sedimentary regime in Boston Harbor. The major study identified is that conducted by the Massachusetts Water Resources Authority (MWRA) during its Harbor and Outfall Monitoring (HOM) Program. The HOM program has sampled sediments from throughout the Boston Harbor since September 1991. Until recently (2003), grab samples were collected twice per year, once in spring and once in late summer, from eight stations in the Harbor. Samples are now collected only in late summer. Grab samples provide data on sediment grain size, total organic carbon (TOC) content, and the incidence of *Clostridium perfringens* spores. Samples obtained under this part of the HOM program are not analyzed for contaminant concentrations. Sediment profile images (SPI) collected once in late summer supplement the grab samples by providing for much broader geographic coverage in the Harbor. The SPI provide information about sediment texture, oxidative state, and the primary processes (physical or biological) affecting the sediments. Other, relatively localized studies provide ancillary information on sediment texture.

Information about sediment contaminant concentrations in Boston Harbor is found among several sources. The U.S. Geological Survey (USGS) has conducted contaminant studies, particularly of metals, from four locations within the Harbor since 1977. These studies have documented a general decline in metals concentration in response to changes in environmental regulation (e.g., lead and silver) and changes in sewage-related discharges into the Harbor. Studies of organic contaminant loads in the Harbor come from a variety of sources, particularly by scientists at the University of Massachusetts (UMASS) Boston and UMASS Amherst. These studies have focused on particular aspects of organic chemistry, such as anaerobic degradation and porewater partitioning, rather than investigated temporal or spatial patterns of contaminant loads. Some studies were conducted as graduate student theses or dissertations. Scientist with the USGS created a comprehensive database housing these contaminant data and other environmental parameters. During the database construction, the USGS determined that general quality of the data was very high as <5% of the data were judged inadequate.

The MWRA's HOM Program has also investigated the role of combined sewer overflow (CSO) discharges on sediment contaminant loads in those parts of Boston Harbor most affected by CSOs. These studies measured concentrations of metals and several organic constituents, including waste-specific markers such as linear alkylbenzenes (LABs) and coprostanol. Data for approximately 10 stations within the Harbor from 1990, 1994, 1997 and 2002 are useful for characterizing contaminant trends in the Harbor over the past ten years.

The U.S. Army Corps of Engineers sponsored several studies of sediment quality during the evaluations conducted prior to dredging projects in Boston Harbor. Five recent reports include evaluation of sediment toxicity, suspended particulate phase toxicity, and bioaccumulation potential for sediments collected from Boston Harbor and the Weymouth/Fore River area.

Information on the presence of benthic resources and processes in Boston Harbor

Studies conducted under the auspices of the MWRA HOM Program comprise the most extensive data set available to characterize the benthic resources of Boston Harbor. Grab samples used to study infaunal communities in the Harbor have been collected at eight stations (three replicates at each) since the summer of 1991. Detailed analyses of the Harbor infaunal communities over the last 12 years of the HOM Program provide a sound baseline with which to characterize the soft-bottom benthos in and near the SEIS study area. Sediment Profile Images (SPI) collected once in late summer supplement the grab samples by providing for much broader geographic coverage in the Harbor. Currently 60 stations are regularly sampled. The SPI provide information about the successional stage of the infaunal communities in the Harbor, and document the presence of various infaunal constituents. Most importantly, the SPI studies have been instrumental in documenting the spread and condition of the *Ampelisca* mats as conditions in the Harbor have changed since 1991. This baseline will be invaluable in evaluating the effects of the dredging project on infaunal communities and will assist in the documentation of their recovery.

Data from one recent infaunal survey sponsored by the U.S. Corps of Engineers and Massport are available. A single survey conducted in late summer 2003 collected 47 infaunal samples from seven berthing areas within the Inner Harbor region. However, preliminary examination of these data indicated that the taxonomy used during the analyses of these samples is inconsistent with the most recent understanding of the infaunal communities in the Harbor. The data are probably usable, albeit some caution must be exercised in evaluating them.

The HOM Program has also conducted benthic nutrient flux studies that began in 1990 to examine the benthic processing of organic matter in Boston Harbor. The overall objectives of the studies have been to quantify sediment-water exchanges of oxygen, total carbon dioxide, and nutrients to define benthic-pelagic coupling in the harbor and bay. In addition, sediment indicators of organic matter loading and processing, such as organic carbon and pigment concentrations and redox conditions, have been studied. Currently four stations, two in the northern harbor and two in the southern harbor, are sampled in May, July, August, and October of each year.

Results for the search of recent characterizations of the hard-bottom areas in the Harbor were limited to the Hubline baseline studies. Data reports for the hardbottom analyses were not received so their geographic relevance is not clear at this time. Battelle is working with the Hubline environmental contactor to obtain these reports for the Task 3 GIS analysis.

Information on the interaction between benthic resources and sediment contaminants in Boston Harbor.

Three studies were identified that have investigated in detail the interrelationships between sediment contaminants and infaunal communities in the Harbor. Each study employed a slightly different approach to the problem. A study funded by the Massachusetts Bays Program studied these interrelationships at 12 stations in the Massachusetts Bay/Cape Cod Bay system in July 1993. Four stations were located within Boston Harbor, one off Deer Island, one in Dorchester Bay and two in the southern harbor. Concentrations of organic and metal contaminants in sediments from these stations were determined. Sediment toxicity was evaluated by conducting acute toxicity tests on the amphipod *Ampelisca abdita*; porewater toxicity was evaluated via a sea urchin fertilization and embryological development assay. Replicate samples were collected and analyzed to determine the constituent infaunal community at each station.

In 1993 the NOAA National Status and Trends Program sponsored a survey of 55 stations in Boston Harbor (Long. *et al* 1995). The data included evaluations of sediment toxicity based on the results of

amphipod survival, microbial bioluminescence, and sea urchin fertilization and embryological development tests. Chemistry analyses determined the concentrations of trace metals, polynuclear aromatic hydrocarbons, chlorinated pesticides, PCBs, and butyltins. However, this study did not evaluate infaunal communities present at the stations that were sampled. As a consequence, the general maps depicting areas where sediments were believed to be toxic overlapped areas shown in the MWRA studies to contain thriving infaunal communities. The results of the study were published in a NOAA Technical Memorandum in 1995.

The third study, done by scientists at UMASS Boston and the MWRA, reanalyzed data collected in the 1980s by employing recently developed multivariate techniques. Prior to the reanalysis, the study provides an historical overview of Boston Harbor's benthic communities and the history of discharges into the harbor. The results of the multivariate analysis of the infaunal communities were evaluated in comparison with sediment contaminant loads and biological features, such as food-caching and the formation of fecal pellets, which may slow the flux of sediment-bound pollutants to the water column. This study provides a useful background against which to evaluate potential impacts of the dredging project on benthic resources in the Harbor.

3.2 Physical Oceanographic Data and Investigations

Information on currents and circulation within Boston Harbor and exchange between Boston Harbor and the adjacent water of Mass Bay.

Basic physical oceanographic information and data including high-resolution seafloor bathymetry, tidal height, tidal current circulation, wind, barometric pressure, and other meteorological parameters relevant to current circulation in Boston Harbor and the exchange between Boston Harbor and the adjacent water of Mass Bay are available from a number of standard sources. Medium resolution bathymetry for Boston Harbor and adjacent reaches of Massachusetts Bay is available in the Coastal Relief Model produced by the National Geophysical Data Center, NOAA. High-resolution bathymetry for many parts of Boston Harbor are available from single beam and multibeam mapping studies conducted by the Corps as part of the BHNIP, the Harbor Tunnel Project and the Hubline Project and from the USGS from side-scan and multibeam studies done between 2000-2002. NOAA has maintained a long-term tide gauge in Boston Harbor from which a multi-year record of sea surface elevation data is available. Data from other privately operated tide stations are also available. Standard mariner guides including United States Coast Pilot and Elbridge Tide and Pilot Book provide an overview of tidal circulation patterns in and around Boston Harbor. Additional information on tidal circulation in Massachusetts Bay and the mouth of Boston Harbor is available in the Atlas of Tidal Elevation and Current Observations on the Northeast American Continental Shelf and Slope by Moody, *et al*.. Both long-term time-series and climatological summaries of winds, barometric pressure and other relevant parameters are available from NOAA buoys maintained in Massachusetts Bay as well as shore-based stations at Logan airport and other locations around Boston Harbor.

Numerical modeling studies of the hydrodynamics of Boston Harbor provide a more detailed picture of the circulation in Boston Harbor both in terms of high-resolution tidal circulation patterns and the incorporation of effects of winds and weather patterns on circulation. The most comprehensive numerical modeling study of Boston Harbor was that conducted by the USGS in 1992. This study included the development of the hydrodynamics model which was later expanded into the Massachusetts and Cape Cod Bays Hydrodynamic Model (completed in 2001) and coupled to a water quality model (ongoing) as part of the MWRA HOM Program. These modeling studies, in particular the 1992 study by Signell, provide detailed information on harbor circulation and exchange, harbor circulation response to wind, and the effect of seasonal stratification on circulation. While the model studies carried out by Hydroqual

under the HOM project for 1992-1994 and 1998–2000 have some relevance to this analysis, their focus is primarily Massachusetts Bay.

Information on water column physical structure in Boston Harbor.

There exists a great wealth information about the physical structure of the water column of Boston Harbor and Massachusetts Bay. The most extensive study of water column physical parameters in the Harbor is the ongoing sampling program being conducted by the MWRA. The program has included water column measurements of temperature, salinity, turbidity and dissolved oxygen, along with other parameters, in two separate field studies since 1992. In one study, sampling has been conducted at three stations inside the Harbor, at regular intervals 6 times per year. In another, 50 stations in Boston Harbor and in the Charles, Mystic and Neponset Rivers are sampled year-round on a rotating schedule, with the most intense sampling in spring and summer. These studies have documented increases in harbor water clarity and little change in dissolved oxygen levels associated with the outfall project. They have also provided important water column density structure information used to build, calibrate, and verify the harbor circulation models described earlier.

A study which involved a series of 12 short-term but high resolution water column mapping events was carried out in 1994 by MWRA. The objective of the study was to characterize the tidally-driven interaction between Boston Harbor and the adjacent waters of Massachusetts Bay. The study results elucidated the physical exchange of water between the Harbor and the Bay and identified a seasonal variation in the physical coupling of the two systems. A number of other area investigators including researchers at Northeastern University, University of Massachusetts and the USGS have also conducted water column surveys of temperature, salinity and other parameters in the harbor.

Information on particulate transport in Boston Harbor.

Considerable effort has been expended to predict the transport of particulates and their long-term fate in Massachusetts Bay including sediment trap, moored instrument, and modeling studies. Studies of the transport of particulates within and through the Boston Harbor system, however, are somewhat limited. A simple model was applied as part of the Boston Harbor Tunnel Project to estimate the extent of the suspended solids plume associated with dredging operations. However, the long-term fate of solids suspended into the water column by dredging operations was not modeled in this study. Nor have MWRA measurements of water column turbidity (described in the previous section) been analyzed with regard to dredging operations or used in dredge plume modeling studies.

3.3 Water Quality: Water Column Characterization

The majority of water column data collected in Boston Harbor since 1995 is associated with the MWRA Harbor and Outfall Monitoring (HOM) Program. The farfield water column surveys, conducted six times annually since 1992, include two stations inside and one just outside the mouth of the Harbor. Parameters measured on farfield surveys include dissolved oxygen, temperature, turbidity, fluorescence, plankton, chlorophyll and nutrient concentration. MWRA conducts a separate harbor sampling program that measures temperature, salinity, bacteria, dissolved oxygen, and turbidity at 50 stations in Boston Harbor and its three largest tributary rivers (Charles, Mystic and Neponset). Monitoring is conducted year-round in each region on a rotating schedule, with the most intense sampling in spring and summer. Summary reports written for MWRA, such as the “State of the Harbor” report and the Outfall Monitoring Overview, provide easy-to-read summaries of annual monitoring results using data collected by both the offshore and Harbor programs.

In addition to MWRA reports, the Massachusetts Department of Environmental Protection (MADEP) prepared a comprehensive water quality assessment for the Harbor in 1999. Several studies conducted by private sector and academic scientists describing zooplankton assemblages, sewage tracers, and nutrient loading were also identified.

3.4 Water Quality: Human Health and Pathogens

The search for water quality studies related to human health and pathogens produced several references describing pathogens (viral and bacterial) in and around Boston Harbor. The majority of those papers describe water conditions at swimming beaches with respect to bacterial indicators such as *Enterococcus*. Two MWRA reports describing bacterial indicators in receiving waters near CSOs were also included. The list also includes two methods papers that were found to have little relevance to this evaluation. Two papers which describe characteristics of fecal indicators in bird populations in and around Boston Harbor describe methods for determining relative amounts of human to bird waste in Boston Harbor.

3.5 Fisheries/Shellfisheries Data and Investigations

Information on the presence of fish populations within Boston Harbor, particularly information based on trawl and similar sampling efforts.

Few quantitative data on fish populations within Boston Harbor were found. A Massachusetts Department of Marine Fisheries (MAMDF) report describes rainbow smelt (*Osmerus mordax*) populations in the Weymouth/Fore River region of the Harbor. Studies completed as part of the HubLine gas pipeline project included information on the distribution and abundance of demersal and pelagic fish in the Harbor.

Anecdotal information was found that indicated that there is an important recreational fishery for striped bass (*Morone saxatilis*) within Boston Harbor, particularly near the many small islands, channels, and ledges found there. However, no quantitative information on the population or landings within the Harbor were found. The MADMF has collected commercial and recreational landings data for striped bass and has published those data in annual landings reports since 1990. However, those data are reported at a relatively coarse geographic level (e.g., county).

Information on the contamination of fish, biomagnification of contaminants, and the pathology of fish populations in Boston Harbor.

Most of the information on contaminant loads born by fish and the pathological conditions of this resource in Boston Harbor is derived from two sources. Studies conducted since the early 1990s by MWRA during the HOM Program have provided most of this information. Annual sampling in the Harbor near Deer Island and in the Inner Harbor by MWRA has focused on the determination of contaminant levels in winter flounder (*Pseudopleuronectes americanus*) fillet and liver. These contaminant levels are compared to applicable federal legal limits. Contaminants measures include organic compounds (PAHs, PCBs, pesticides) and selected metals. The effects of the contaminants on winter flounder are evaluated by examining the fish for general external morphological abnormalities and the incidence of fin erosion. Livers are removed from 50 fish at each site and examined for gross visible abnormalities. Livers are sectioned and examined microscopically for histological abnormalities including vacuolation (centrotubular, tubular, and focal), macrophage aggregation, biliary duct proliferation, and neoplasia. The severity of each lesion is determined and an histological index calculated for each fish.

Additional information on the relationship between contaminants and fish condition has been derived from the National Benthic Surveillance Project (NBSP), a component of the NOAA National Status and

Trends Program. These studies have focused on the occurrence of biomarkers associated with cytochrome P4501A (CYP1A) and other enzyme activities in the livers of winter flounder. The sampling program included four sites within Boston Harbor. CYP1A was measured by two catalytic assays [ethoxyresorufin-*O*-deethylase (EROD) activity and aryl hydrocarbon hydroxylase (AHH) activity] and one immunoassay (ELISA). The results from the Boston Harbor samples were compared to those from other sites along the northeastern and Pacific coasts of the US.

The MWRA has periodically sponsored a one-day study, called Fish Day, to assess the health of winter flounder in Boston Harbor and the surrounding area. Scientists at the University of Connecticut (Storrs) used winter flounder samples collected on Fish Day, 1996 to analyze tissue metals concentrations, protein content, and the biomarkers CYP1A1, cytochrome P450 2E1 (CYP2E1), and metallothionein. The data comprised portions of the dissertations of two graduate students and were published in *Environmental toxicology and chemistry* (Wall *et al.* 1998).

Information on the contamination of shellfish, biomagnification of contaminants, and the pathology of shellfish populations in Boston Harbor.

Most of the information on contaminant loads born by shellfish and the pathological conditions of this resource in Boston Harbor is derived from studies conducted since the early 1990s by MWRA during the HOM Program. Annual sampling in the Harbor near Deer Island by MWRA has focused on the determination of contaminant levels in American lobster (*Homarus americanus*) tail muscle and hepatopancreas and blue mussel (*Mytilus edulis*) tissues. These contaminant loads are compared to applicable federal legal limits. Contaminants measured include organic compounds (PAHs, PCBs, pesticides) and selected metals. A few other studies have examined the effects of organic contaminants on the reproduction and incidence of disease in blue mussels. During another study, the incidence of neoplasia in the soft-shell clam (*Mya arenaria*) collected from five sites in Boston Harbor was evaluated as a potential biomarker of anthropogenic pollution.

Information on the presence of shellfish populations within Boston Harbor, particularly information based on trawl and similar sampling efforts.

Most of the information on shellfish populations and landings has been generated by the MAMDF. The MAMDF gathers landings data for American lobster and published them in a series of annual reports. Boston Harbor is included within one statistical reporting area (Area 4) that also includes waters within Massachusetts Bay out to the territorial limit. The landings data for lobsters caught within Boston Harbor are not separated from those collected outside the Harbor.

The MAMDF has also sampled early benthic phase lobsters within State waters since 1995 to determine which coastal habitats are valuable to these juvenile lobsters. Quantitative data from seven sites within Boston Harbor are available for the years 1997 through 2003.

The MAMDF has also collected landings data on the soft-shell clam from three sites within Boston Harbor since 1997 and from an additional four sites since 2001 or 2002. Data through 2003 are available. Soft-shell clams are collected from restricted sites in Boston Harbor and transported to a depuration facility where the clams are held for at least three days in a system supplied with clean, flowing seawater. Once the contaminants have been purged the clams are returned to commercial harvesters.

3.6 Marine Wildlife and Endangered Species

Information on presence and geographical extent of marine wildlife, Federal and State listed species and critical habitats.

Many of the Marine Wildlife and Endangered Species citations are the summaries of annual marine mammal observations from MWRA surveys. Observations of marine mammals are recorded during all nearfield surveys and other outfall surveys that occur in December through May. Sitings are recorded as the ship transits through Boston Harbor, and therefore some subset of the data is relevant to this analysis.

Other species described in various reports include the loggerhead and leatherback sea turtles (leatherback being the species most likely to occur in the study area), wading birds (snowy egret, cattle egret, glossy Ibus, and Black-crowned Night Heron), and the white-sided dolphin. Several reports identified from the National Marine Fisheries (NMFS) Serbice Stock Assessment program describing whale populations (sei, fin, blue) may not be relevant to Boston Harbor.

The Hubline Environmental Report described marine waterbird and protected species data. Battelle is still trying to obtain those data for further analysis.

3.7 Public Parklands, Beaches and Sanctuaries

Provide information on the location of any public parklands, beaches, and sanctuaries in relation to the study area.

The Division of Urban Parks and Recreation in Boston has been updating GIS layers of public space data since 1995. This information, which is expected to be fairly comprehensive, was requested in writing. Battelle was able to download the relevant datalayers from a publicly-accessible FTP site administered by the state.

The New England Fishery Management Council and the NOAA National Marine Fisheries Service have designated essential fish habitat (EFH) within Boston Harbor for 24 species of fish and shellfish. Habitats included are within the seawater salinity and the mixing water/brackish salinity zones of the Harbor.

3.8 Historic, Cultural and Archaeological Resources

Location of known and potential cultural, historic and archaeological resources in Boston Harbor.

Four references pertaining to archeological resources collected since 1995 were identified. Each study was conducted by the Corps, specifically in support of the BHNIP, and is therefore completely relevant. Various methods to determine archaeologically significant resources were employed including remote sensing (magnetometry), sediment vibracoring (stratigraphic integrity), and ROV operations. Each study concluded that the proposed dredging project would not disturb significant cultural resources in the Harbor.

4.0 CONCLUSIONS

Due to a number of recent and ongoing construction projects in Boston Harbor and the continuation of long term monitoring by the MWRA, the body of data generated since 1995 to support a supplemental EIS for the area is fairly comprehensive. Certain topic areas that were addressed in the 1995 EIS such as Historic, Cultural, and Archaeological Resources, and Public Parks are not expected to change and a large body of supplemental data is not needed. Large-scale construction projects in the Harbor (Hubline, Big

Dig) that were expected to have great potential for impacting earlier assessments, produced site specific characterizations that adequately document the changes in those areas. The one area that appears to be underrepresented relative to its importance, is fishery populations. Few quantitative data on fish populations within Boston Harbor were found. Because of the general concern for disturbance to natural resources by dredging operations, this area should be further investigated. The Massachusetts Division of Marine Fisheries collects landing data for several important species that inhabit the Harbor, but the geographic data associated with those data are limited to the port of departure or a gross geographic level (i.e Massachusetts Bay). Augmentation to the available fisheries data (shellfish and demersal fish populations) will be needed to support natural resource assessments in the supplemental EIS.

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APPENDIX A

Listing of Direct Contacts

APPENDIX B

Alphabetical Listing of Citations

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Zago, C., Giblin, AE., and Bergamasco, A. 2001. Changes in the metal content of surficial sediments of Boston Harbor since the cessation of sludge discharge. *Marine Environmental Research.* 51, 389-415.
Zhuang, G. S., Yi, Z., and Wallace, G. T. 1995. Iron (II) in Rainwater, Snow, and Surface Seawater From a Coastal Environment. *Marine Chemistry.* 50, 1-4: 41-50.
Zorpette, G. 1995. Lobster stew: dredging and reducing sewage may threaten a Boston harvest. *Scientific American.* 273, 32-34.

APPENDIX C

Listing of Citations and Abstracts arranged by Topic Area

Boston Harbor EIS Reference List

ARCHAEOLOGICAL DATA AND INVESTIGATIONS

Lynch, K, M Mulholland, and J Donnelly. 2004. Archaeological Subsurface Testing, Boston Harbor Navigation Improvement Study, Boston Harbor, Boston Massachusetts. University of Massachusetts, Archaeological Services. Amherst, Massachusetts.
Abstract: A remote sensing study and archaeological reconnaissance survey were conducted in 2002-2003 for the proposed improvements of the Boston Harbor Shipping Channel. Using a predictive model for site locational characteristics, sea level curves and reconstructed past land forms, the study predicted that there is a high potential for inundated Native American sites to be located within portions of the project area. Subsurface testing through the use of nine vibratory cores was completed in September 2003. The cores were then analyzed for stratigraphic integrity and evidence of inundated archaeological resources. Both visual means and magnetic susceptibility were used to attempt to detect buried soil horizons. Likely sediments were screened for artifacts. Profiles of visible stratigraphy were recorded and the magnetic susceptibility was plotted and graphically reproduced. The magnetic susceptibility reliably detected changes in stratigraphy. The study proved that potentially preserved cultural resources are well below the maximum depth of the proposed dredging. Preserved sites, if they exist, will not be impacted by the project. No further survey is recommended.
Mulholland M, W Reiss, J Donnelly, C Donta, and I Buynevich. 2003. Remote Sensing Archaeological Survey and Geologic Interpretation: Boston Harbor Navigation Improvement Study, Boston Harbor, Boston, Massachusetts. University of Massachusetts, Archaeological Services. Amherst, Massachusetts.
Abstract: A remote sensing study and archaeological reconnaissance survey was conducted for the proposed improvements of the Boston Harbor Shipping Channel. Using site locational characteristics, sea level curves and reconstructed past landforms, the study found that there is a potential for inundated Native American sites to be located within portions of the project area. Subsurface testing through the use of vibratory cores or split spoon borings is recommended. The historic period background study indicated that at least 93 vessels were lost in the general area of the dredging project, but none are known to be specifically in the route. Analysis of the remote sensing data produced 187 targets that required further consideration; however, only three appear to be potentially historically significant shipwrecks. In addition, one obvious sunken barge rests in two sections near the outer (east) entrance to the North Channel. Dive inspections are recommended for the three targets.
Ocean Surveys, Inc. 2003 . Final Report: Geophysical Explorations: Remote Sensing Archaeological Survey and Geologic Interpretation, Boston Harbor Navigation Improvement Study, Boston Massachusetts. Ocean Surveys, Inc. Old Saybrook, Connecticut. OSI Report No. 02ES066.
Abstract: Marine remote sensing investigations were conducted in Boston Harbor in the fall of 2002 as part of the proposed Navigation Improvement Study for Boston Harbor, with intentions of deepening the main channel. Objectives of this investigation included (1) the identification of acoustic targets and magnetic anomalies in support of a marine archaeological assessment and (2) the delineation of areas possibly containing shallow bedrock and coarse glacial till that might adversely affect dredging operations. A high concentration of man-made objects and debris were identified in the channel. Inspection of those targets deemed potentially significant by archaeologists can be supported via dive operations or remotely operated vehicles.
Robinson DS and B Ford. 2003. Inspection of Magnetic Anomalies: Remote Sensing Archaeological Survey, Boston Harbor Deep Draft Navigation Improvement Study. Public Archaeology Laboratory. Pawtucket, Rhode Island. PAL Report No. 1537.
Abstract: PAL has completed a remotely operated vehicle (ROV) survey of three magnetic anomalies within the Boston Harbor Deep Draft Navigation Improvement Study area. The goal of the survey was to

identify and determine the nature of the three magnetic anomalies situated within the ship channel east of Castle Island. The ROV survey included background research, a systematic visual and magnetic ROV survey, and limited subsurface testing. Background research indicated that the study area was within an area of ancient Native American coastal settlement and that the project area was exposed during the prehistoric period. Historically, the project area was within the heavily traveled main southern ship channel into Boston Harbor. One vessel was documented lost in close proximity to the project area in 1895, and NOAA navigation charts indicate a shipwreck within the project area beginning in 1975. Beginning in the last quarter of the nineteenth century, dredging to improve and maintain the ship channel lowered the channel bottom within the project area 16 feet. The systematic and visual ROV survey consisted of 21 survey lines spaced at 10-foot intervals. Visual and magnetic data were collected along the survey lines. Limited excavation using the ROV thruster-wash deflector was also conducted at the three magnetic anomaly locations. No pre-Contact Period cultural materials or archaeological features were identified during the ROV survey. The only cultural materials noted were lobster pots and modern drift debris. Lobster pots and/or magnetic rock outcrops or boulders caused the magnetic anomalies. The proposed activities within the study area will not affect significant archaeological resources; therefore, no additional archaeological investigations of the Boston Harbor Deep Draft Navigation Improvement Project study area are recommended.

BENTHIC RESOURCES OR SEDIMENT DATA AND INVESTIGATIONS

Adams, EE., Stolzenbach, KD., Lee, JJ., Caroli, J., and Funk, D. 1998. Deposition of contaminated sediments in Boston Harbor studied using fluorescent dye and particle tracers. *Estuarine, Coastal, and Shelf Science.* 46, 371-382.

Abstract: The residence time of water and suspended particles in Fort Point Channel, a sub-region of Boston Harbor containing a major combined sewer overflow and highly contaminated sediment, was determined during three field surveys by measuring the disappearance of fluorescent tracers from the water column. Flushing by advective movement was quantified using Rhodamine WT dye, a dissolved tracer which has negligible interaction with suspended sediment. The fate of suspended particles was inferred from measured concentrations of fluorescent pigment particles which were initially well mixed with Rhodamine dye and which have a size range and settling velocity comparable to the sewage particles of interest. Dye and particle concentrations were measured by fluorescent spectroscopy of water samples obtained throughout the channel over a week following tracer introduction. Dye measurements indicate that channel water is replaced on a scale of 1-2.7 days, depending on tidal amplitude and phase during tracer release, and the magnitude of freshwater inflow. Ratios of normalized particle concentration to dye concentration suggest effective deposition velocities of 1.5-3.3 m day^{-1}; this is an order of magnitude faster than observed in laboratory settling columns suggesting that removal of suspended tracer particles from Fort Point Channel during our surveys may have been the result of scavenging by a bottom 'fluff' layer. This finding is consistent with our previous observation of particle deposition in Salem Sound, Massachusetts, U.S.A. and in controlled laboratory studies of particle aggregation at the sediment-water interface.

Berardesco, G., Dyhrman, S., Gallagher, E., and Shiaris, MP. 1998. Spatial and temporal variation of phenanthrene-degrading bacteria in intertidal sediments. *Applied and Environmental Microbiology.* 64, 7: 2560-2565.

Abstract: Phenanthrene-degrading bacteria were isolated from a 1-m^2 intertidal sediment site in Boston Harbor. Samples were taken six times over 2 years. A total of 432 bacteria were isolated and characterized by biochemical testing. When clustered on the basis of phenotypic characteristics, the isolates could be separated into 68 groups at a similarity level of approximately 70%. Several groups (a total of 200 isolates) corresponded to well-characterized species belonging the genera *Vibrio* and *Pseudomonas*. Only 51 of the 437 isolates (< 11.7% of the total) hybridized to a DNA probe that encodes the upper pathway of naphthalene and phenanthrene degradation in *Pseudomonas putida* NCIB 9816. A cluster analysis indicated that the species composition of the phenanthrene-degrading community changed

significantly from sampling date to sampling date. At one sampling time, 12 6-mm-diameter core subsamples were taken-thin the 1-m^2 site to determine the spatial variability of the degrading communities. An analysis of molecular variance, performed with the phenotypic characteristics, indicated that only 6% of the variation occurred among the 12 subsamples, suggesting that the subsamples were almost identical in composition. We concluded that the communities of phenanthrene degrading bacteria in the sediments are very diverse, that the community structure undergoes significant change with time but does not vary significantly on a spatial scale of centimeters, and that the predominant genes that encode phenanthrene degradation in the communities are not well-characterized.

Blake, J. A., Maciolek, N. J., Rhoads, D. C., Gallagher, E. D., and Williams, I. P. 1998. Boston Harbor soft-bottom benthic monitoring program: 1996 and 1997 results. Massachusetts Water Resources Authority. Boston. Report 1998-15. 182 pp.

Abstract: This report constitutes the fifth and sixth years of post-sludge abatement monitoring and includes traditional benthic biology, sediment profile image analysis, and ancillary sediment characteristics. Metals and organic contaminants were also measured and the benthic infaunal database was studied for evidence of long-term trends in community structure and recovery. Boston Harbor and the interconnecting bay systems have shown a marked improvement in benthic conditions from 1991 to 1997. This improvement is best indicated by the spread of amphipod tube mats

Blake, J. A., Williams, I. P., Gallagher, E. D., Hecker, B., Rhoads, D. C., and Arnofsy, P. L. 1998. Massachusetts Bay outfall monitoring program: benthic biology and sedimentology baseline monitoring for 1997 and retrospective analysis of the 1992-1997 database. Massachusetts Water Resources Authority. Boston. Report 1998-16. 221 pp.

Abstract: This report presents benthic biology and sedimentology data collected in 1997 as part of a monitoring program being performed to assess baseline conditions in Massachusetts Bay prior to discharges from the new sewage outfall scheduled to begin operations in 1999. Samples were collected at nearfield, midfield, and farfield stations. Sediment texture at nearfield stations and most midfield stations has exhibited consistency over time. Concentrations of TOC and Clostridium spore counts at nearfield and midfield stations are very similar to each other between stations and years and the patterns detected are often directly correlated with the amount of silt and clay found in the samples. Farfield stations also have low levels of TOC and *Clostridium* spores. Benthic community parameters observed in 1997 were generally similar to those seen in previous baseline monitoring years. Species richness was higher in 1997 than in earlier years, perhaps due to better species identification techniques. Major assemblage patterns are similar across years with the same indicator species present but contributions of these species and the appearance and disappearance of other species changes annually. Diversity at the nearfield stations was found to be slightly higher than average diversity at either midfield or farfield stations. The nearfield hard-bottom benthic communities are temporally stable between 1995 and 1997.

Bothner, MH., Buchholtz Ten Brink, M., and Manheim, FT. 1998. Metal concentrations in surface sediments of Boston Harbor - changes with time. *Marine Environmental Research.* 45, 2: 127-155.

Abstract: The concentrations of metals in surface sediments of Boston Harbor have decreased during the period 1977-1993. This conclusion is supported by analysis of: (1) surface sediments collected at monitoring stations in the outer harbor between 1977 and 1993; (2) metal concentration profiles in sediment cores from depositional areas of the harbor; and (3) historical data from a contaminated-sediment database, which includes information on metal and organic contaminants and sediment texture. The background and matrix-corrected concentrations of lead (Pb) measured in the surficial layer (0-2 cm) of cores decreased by an average of 46% +- 12% among four locations in the outer harbor during the 16 y period. Chromium (Cr), copper (Cu), mercury (Hg), silver (Ag), and zinc (Zn) exhibited similar trends. Results from our sediment sampling are supported by historical data that were compiled from diverse sources into a regional sediment database. This sediment database contains approximately 3000 samples; of these, about 460 samples were collected and analyzed for Cu, Hg, or Zn and many other sediment

parameters in Boston Harbor surface sediments between 1971-1993. The database indicates that the concentrations of these three metals also decreased with time in Boston's Inner Harbor. The decreases in metal concentrations that are observed in more recent years parallel a general decrease in the flux of metals to the harbor, implemented by: (1) ending the sewage sludge discharge to the Harbor in December, 1991; (2) greater source reduction (eg. recovery of silver from photographic processing) and closing or moving of industries; (3) improvements in wastewater handling and sewage treatment; and (4) diminishing use of lead in gasoline beginning about 1973. Despite the general decrease in metal concentrations in Boston Harbor surface sediments, the concentrations of Ag and Hg measured at some outer harbor stations in 1993 were still at, or above, the level associated with frequent adverse effects to marine organisms (guidelines are: Ag 3.7 ug g^{-1}, Hg 1.17 ug g^{-1}, from Long et al., 1995). Concentrations of the other metals listed were in the range considered to occasionally induce adverse biological effects.

Cohen, A. 1997. Boston Harbor - 'Sink for sediments'. *Sea Technology.* 38, 8: 65-68.

Abstract: A five year, multi-disciplinary research program is investigating the transportation and transformation of contaminants in the sediments of Boston Harbor, USA, and the results used to formulate policy. Chemical tracers have been used to investigate the fate of pollutants discharged via combined sewer overflows (CSO). Many backwater areas have been found to trap contaminated sediments. Mathematical models are being used to develop CSO control measures. Sediment cores throughout the harbor have also been analyzed. Sediments were found to be a major contributor to toxic chemical budgets - this will slow water quality recovery. In addition, studies show high contaminant levels in the inner harbor which will require specialist and expensive disposal options.

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. Massachusetts Water Resources Authority. Boston. Report 1995-14. 128pp.

Abstract: The main goals of this study were to assess the effects of specific CSOs on the concentrations of pollutants in the sediments around the CSOs and to determine if concentrations of these contaminants have declined in Dorchester Bay sediment at specific sampling sites between 1990 and 1994. PAH sediment concentrations were comparable between 1994 and 1990 sampling levels at all sites but one--DB14-- which is located near the Commercial Point CSO. Data suggest that DB14 has been (or is) subject to point source PAH pollution, but other studies indicate that Dorchester Bay is an area of significant deposition of pollutants transported from other parts of the Harbor. The elevated levels at DB14 may not be due to the CSO at all, but may originate from a nearby yacht club, from local runoff, or as the result of the aforementioned pollutant transport. The LAB and coprostanol measurements in the 1994 samples were generally similar to what was measured in 1990 and these relative uniform concentrations suggest that the major source(s) of these contaminants may not be local CSO point sources. PCB and pesticide measurements (including DDT) were comparable to those taken in 1990, but the overall data suggest that PCB levels have been declining in the past 5 to 10 years. Concentrations of most metals were consistent with what could be expected for Dorchester Bay and Boston Harbor sediments and do not reflect a nearby point source. However, the concentrations of several metals declined in the sediment in the Old Harbor area between 1990 and 1994 (especially DB01) while the levels detected at other sites were comparable with historical data. The metals concentrations were slightly higher in the Fox Point/Commercial Point area than at other locations. Studies have concluded that local CSOs contributed little to the elevated metal concentrations and attributed the elevated levels to transport from elsewhere in the Harbor. The overall data show relatively small differences in *Clostridium perfringens* densities among the study sites and indicate that the primary source of this contamination is remote to the site locations. *C. perfringens* densities have generally declined between 1990 and 1994 throughout Dorchester Bay, likely the result of improved CSO facilities and the cessation of sludge discharges at the Deer Island and Nut Island treatment plants.

Eganhouse, RP. and Sherblom, PM. 2001. Anthropogenic organic contaminants in the effluent of a combined sewer overflow: impact on Boston Harbor. *Marine Environmental Research.* 51, 51-74.

Abstract: Effluent from a large combined sewer overflow (CSO) in Boston and receiving waters near the CSO outfall were sampled during dry and wet weather conditions. Surficial sediments were also collected from the vicinity of the CSO and at nearby sites. The samples were analyzed for a variety of organic constituents including organic carbon and nitrogen, linear alkylbenzenes (LABs), coprostanol and polychlorinated biphenyls (PCBs). As judged by the presence of waste-specific markers (LABs, coprostanol), the CSO effluent contains sewage under both dry and wet weather conditions. When rainfall occurs, the concentration of suspended solids and all organic constituents in the particulate phase increase, ultimately approaching those characteristic of untreated sewage. The concentrations of LABs and PCBs in the effluent are strongly correlated, indicating that PCBs in the CSO are derived from sewage inputs. During heavy rainfall, the vast majority (> 90%) of the hydrophobic organic substances are associated with suspended particulate matter, whereas during dry weather, a significant fraction resides in the operationally defined 'dissolved' phase. Estimates of the mass emission rates of CSO constituents show that > 70% of the suspended particles and > 90% of the particulate organic carbon, hydrocarbons and trace organics are discharged during wet weather. Particles in the receiving water appear to be strongly influenced by the CSO effluent during wet weather. Concentrations of PCBs in surficial sediments near the CSO are correlated with those of coprostanol and the LABs, indicating that these compounds are derived from similar sources. Based on the observed correlations, approximately 60-80% of the sedimentary PCBs originate from sewage. Comparison of SIGMALAB/coprostanol ratios of effluent particles, surficial sediments and sewage sludges suggest that the vast majority of the marker compounds and the PCBs in sediments are not from the CSO, but are derived from one of two sewage treatment plants that discharged sludge into the harbor until 1991. The sludge-derived contaminants were probably carried by tidal currents into Dorchester Bay and deposited in shallow, quiescent embayments where sedimentation is favored. These results illustrate the potential importance of long-range transport of waste-derived contaminants in urban harbors and their rapid accumulation in localized depocenters.
Environmental Protection Agency. 1995. Proposed Sludge Management Plan, Metropolitan District Commission, Boston, Massachusetts. Volume 2. Appendices. Draft Environmental Impact Statement. United States. 305.

Abstract: The document accompanies Volume I of the Draft Environmental Impact Statement which proposed amendments to Boston's sludge management plan. This volume is a set of appendices dealing with water standards, rock types, floral and faunal species, commercial establishments, infrastructure, and other aspects of the Boston Harbor area.
Environmental Protection Agency. 1995. Proposed Sludge Management Plan, Metropolitan District Commission, Boston, Massachusetts. Volume 1. Draft Environmental Impact Statement. Metropolitan District Commission. 284.

Abstract: The recommended project involves Federal financial assistance for the construction of a primary sludge disposal system owned and operated by the Metropolitan District Commission (MDC), Boston, Massachusetts. As a result of the detailed environmental, cost effectiveness, and energetics analyses which were performed for this impact statement, Region I EPA has suggested a modification to the proposed plan. The sludge management plan proposed by MDC be implemented as described is recommended, except that the ash disposal method not be approved.
Epstein, S. 1997. Microbial food webs in marine sediments. I. Trophic interactions and grazing rates in two tidal flat communities. *Microbial Ecology*. 34, 188-198.
Abstract: The role of grazing by marine sediment flagellates, ciliates, and meiobenthic animals in controlling production of their bacterial and diatom prey was investigated. Several novel or modified techniques were used to enumerate prey (bacteria and diatoms), measure bacterial production, quantify proto- and micrometazoan predators, and evaluate rates of bacterivory and herbivory. The results indicated that, in a temperate, marine intertidal flat composed of fine sand, colorless nanoflagellates, ciliates, and nematodes were the most important bacterivores. Together, these organisms were responsible

for removing up to 53% of bacterial production, by grazing. The observed rates of bacterivory were high enough to hypothesize that periods of grazing control of bacterial production might occur regularly in similar habitats. Colorless microflagellates, ciliates, and nematodes had high rates of diatom consumption. The combined small diatom consumption rate was equivalent to 132% of diatom standing stock per day. Trophic interactions between diatoms and micro- and meiobenthos might be a factor limiting growth of small (around 10 mum) diatoms. In coarse sands of an open beach, all micrograzers except pigmented nanoflagellates were rare, whereas bacterial and diatom assemblages were rather abundant and active. In this type of sediment, the micrograzers were able to consume only a marginal percentage of bacterial production (<1%) and diatom standing stock (3.8%), thus playing a minor role in controlling the dynamics of their prey.

Gallagher ED and KE Keay. 1998. Organism-sediment-contaminant interactions in Boston Harbor. MIT Sea Grant, Publication 98-1. Cambridge MA. 89-132.

Abstract: Sediment contaminant levels directly relate to three features of Boston Harbor's soft-bottom benthic ecology. First, the harbor's steep pollution gradients have created strong gradients in benthic community structure. Second, the analyses of these communities played an important role in the regulatory decisions during the 1980s that forced improvements in Boston's sewage treatment system. Finally--through tube-building, bioirrigation, bioturbation, and pelletization--the soft-bottom benthos substantially alter rates of geochemical processes. This report presents new analyses to document the strong effects of pollution on benthic community structure and discussions on how the activity of the animals that live in the harbor's sediments can affect the long-term fate of pollutants. The report concluded that the distance from the sewage outfalls is a poor predictor of sediment contaminant concentrations and degraded community structure. Contaminants are transported from the outfall sites and focused in depositional areas throughout the Harbor, like the Inner Harbor, the Savin Hill Cove subtidal, and Peddocks Island. These depositional areas have higher organic content and pollutant concentrations than the areas next to the outfalls. These areas are dominated by highly pollution-tolerant benthic species. Also, the shallow depth of Boston Harbor leads to very high summer temperatures. These high temperatures lead to anoxia in harbor sediments that have high concentrations of labile organic matter. Another conclusion reached was that Boston Harbor's benthos is now degraded, with the most organically enriched areas containing a *Capitella--S. benedicti--P. cornuta* community. This community is being replaced by an *Ampelisca--oligochaete--Leptichierus*--Corophiid--*Aricidea catherinae* community throughout the harbor. *Capitella* sp. populations, which occur in the most polluted areas of the harbor, have converted the organic-rich silt-clay particles into sand-sized fecal pellets. This pelletization slows the flux of pollutants to the overlying water column. The pellet breakdown rates are low (~20-year half-life) and pellets are unlikely to be ingested by animals and returned to the sediment-water interface. Food caching may occur in Boston Harbor sediments. Food caching produces the rapid burial of organic-rich particles to considerable depths but may not result in the transport of 'old' organic matter to the surface. Finally, the Boston Harbor benthos is changing rapidly. The authors cannot predict what communities will replace the amphipod community that is now abundant in the harbor. The Pearson-Rosenberg-Rhoads successional model predicts that a community characterized by large sub-surface deposit-feeders will replace the amphipod community. The transition may not occur if organic matter supply to the sediment-water interface from natural processes remains high.

Giblin, A. E., Hopkinson, C. S., Jr., Tucker, J. , Nowicki, B. L., and Kelly, J. R. 1995. Metabolism, nutrient cycling and denitrification in Boston Harbor and Massachusetts Bay sediments in 1994. Massachusetts Water Resources Authority. Boston. Report 1995-13. 56 pp.

Abstract: This study was undertaken to examine seasonal changes in benthic processes in Boston Harbor and Massachusetts Bay and to better characterize their spatial variability. The study's major conclusions are following: (1) Sediment oxygen uptake in the Harbor ranged over the seasonal cycle from approximately 20 mmol m^{-2} d^{-1} in the winter to 105 mmol m^{-2} d^{-1} at an organic rich site in the autumn. (2) Sediment oxygen uptake in the Bay agreed extremely well with data from previous years ranging from 6

to 22 mmol m^{-2} d^{-1}. There was a significant relationship between the oxygen uptake rates of all shallow Massachusetts Bay stations and temperature. (3)Oxygen uptake rates at stations deeper in the Bay in Stellwagen Basin had lower respiration rates than other shallower Massachusetts Bay stations for most of the year. (4) Denitrification rates in Boston Harbor ranged from non-detectable to 6.9.mmol m^{-2} d^{-1}. (5) Denitrification rates in Massachusetts Bay ranged from non-detectable to 2.7 mmol m^{-2} d^{-1}. (6) DIN and phosphate fluxes at the Bay nearfield stations were not as similar to each other as oxygen fluxes but the stations all exhibited similar seasonal trends. The 1994 DIN fluxes were within 20% of the 1993 values, but the phosphate fluxes were nearly twice as high. Silica flux rates at all the nearfield stations were very similar. Silica release from the sediments in 1994 was 48% greater than in 1993, mostly due to higher fluxes in July. (7) A major change in organic delivery to the sediments should be reflected in a measurable change in benthic fluxes. The HydroQual model predicts that benthic fluxes will change by four-fold at the diffuser to non-detectable several km away. If the depositional nearfield areas experience an increase in the range of 50%, it should be detectable. (8) The release of total carbon dioxide over the season gave a higher estimate of carbon mineralized in the benthos than did oxygen uptake for all seasons. (9) At all stations, urea was a very minor component of the nitrogen flux. Over the annual cycle, ammonium was the most important component of the nitrogen flux in the Harbor, followed by N_2, with nitrate making up a smaller, but significant component of the flux. In the nearfield, ammonium and N_2 had nearly identical contributions to the total flux while the most important component in the farfield flux was N_2, which made up 66% of the total. (10) Depositional sediments in Mass Bay could consume between 17% to 28% of the production of the overlying water. Benthic nutrient release could supply 11% of the N and 25% of the P required for primary production. (11) Porewater constituents are important indicators of sediment processes. Porewater sulfide and Eh are very different between the Harbor and the Bay and may provide sensitive indicators of changes in organic matter loading. (12) In general, there is good agreement between measured fluxes and fluxes predicted by HydroQual and silica shows the highest overall consistent difference between measured and predicted.
Giblin, AE., Hopkinson, CS., and Tucker, J. 2002. Benthic metabolism and nutrient cycling in Boston Harbor, Massachusetts: summary of baseline data and observations after one year of harbor-to-bay diversion of sewage effluent. ENQUAD 2002-13. *Estuaries.* 83pp.

Abstract: To gain insight into the importance of the benthos in carbon and nutrient budgets of Boston Harbor and surrounding bays, we measured sediment-water exchanges of oxygen, total carbon dioxide (DIC), nitrogen (ammonium, nitrate + nitrite, urea, N-2O), silicate, and phosphorus at several stations in different sedimentary environments just prior to and subsequent to cessation of sewage sludge disposal in the harbor. The ratio of the average annual DIC release to O-2 uptake at three primary stations ranged from 0.84 to 1.99. Annual average DIC:DIN flux ratios were consistently greater than predicted from the Redfield ratio, suggesting substantial losses of mineralized N. The pattern was less clear for P: some stations showed evidence that the sediments were a sink for P while others appeared to be a net source to the water column over the study period. In general, temporal and spatial patterns of respiration, nutrient fluxes, and flux ratios were not consistently related to measures of sediment oxidation-reduction status such as Eh or dissolved sulfide. Sediments from Boston Harbor metabolize a relatively high percentage (46%) of the organic matter inputs from phytoplankton production and allochthonous inputs when compared to most estuarine systems. Nutrient regeneration from the benthos is equivalent to 40% of the N, 29% of the P, and more than 60% of the Si demand of the phytoplankton. However, the role of the benthos in supporting primary production at the present time may be minor as nutrient inputs from sewage and other sources exceed benthic fluxes of N and P by 10-fold and Si by 4-fold. Our estimates of denitrification from DIC:DIN fluxes suggests that about 45% of the N mineralized in the sediments is denitrified, which accounts for about 17% of the N inputs from land.
Hayes, LA, Nevin, KP, and Lovley, DR. 1999. Role of prior exposure on anaerobic degradation of naphthalene and phenanthrene in marine harbor sediments. United Kingdom. *Organic-Geochemistry* . 30, 937-945.

Abstract: The anaerobic degradation of the polycyclic aromatic hydrocarbons (PAHs) naphthalene and phenanthrene was investigated in several marine harbor sediments. In sediments from Boston Harbor that were heavily contaminated with petroleum, [^{14} C]-naphthalene and [^{14} C]-phenanthrene were oxidized to $^{14}CO_2$ without a lag, suggesting that the microbial community was adapted for anaerobic PAH oxidation in situ. The addition of molybdate, a specific inhibitor of sulfate-reducing microorganisms, inhibited PAH mineralization which suggested that sulfate reducers were involved in the anaerobic oxidation of the PAHs. PAHs were also anaerobically oxidized at another site in Boston Harbor that was less heavily contaminated, but at a slower rate than in the most heavily contaminated sediments. Sediments not contaminated with petroleum did not significantly oxidize the PAHs. A similar correspondence between rates of anaerobic PAH oxidation and the degree of PAH contamination was observed in sediments from Tampa Bay and San Diego Bay. When relatively pristine sediments from San Diego Bay that did not have a significant capacity for anaerobic PAH oxidation were exposed to high concentrations of napthalene, they developed a potential for napthalene degradation that was comparable to that in sediments that had a history of PAH contamination. The increase in potential for napthalene degradation in the sediments exposed to napthalene was associated with an increase in napthalene-degrading microorganisms. These results suggest that many marine harbor sediments contain microorganisms capable of anaerobically oxidizing PAHs under sulfate-reducing conditions and that these microorganisms will respond with an increase in activity when PAHs are introduced into the sediments. Thus, if PAH inputs into harbor sediments from petroleum can be reduced there may be a widespread potential for microorganisms to remove PAH contamination from the sediments, despite anaerobic conditions.

Hilbig, B., Blake, JA., Rhoads, DC., and Williams, IP. 1996. Boston Harbor soft-bottom benthic monitoring program: 1995 results. Massachusetts Water Resources Authority. Boston. Report 1996-08. 94pp.

Abstract: This report describes the fourth year of post-abatement monitoring of benthic biology and sedimentology data. The most significant change in benthic habitat conditions since the 1991 post-sludge abatement has been the explosive growth of the pollution sensitive tube-dwelling amphipod *Ampelisca* spp. Prior to sludge abatement, less than 20% of stations shoed the presence of amphipod tube mats. In 1995, over 60% of the monitoring stations show well developed tube mats. The no-name storm of 1991 may have made the spread of tube mates possible, as it shifted the benthic sediment from mud to mostly fine sand, the preferred substrate for larvae. TOC levels are similar between the pre-sludge abatement and post-abatement periods. Concentrations of *Clostridium perfringens* show significant reductions following sludge abatement. The characteristic benthic infauna in the northern stations have become more similar to that of the southern stations (southern station assemblages typically require higher sediment quality).Species richness has increased harbor-wide since 1991, especially at the northern stations.

Howes, BL. 1998. Sediment metabolism within Massachusetts Bay and Boston Harbor relating to rates and controls of sediment-water column exchanges of nutrients and oxygen in 1997. Massachusetts Water Resources Authority. Boston. Report 1998-20. 80pp.

Abstract: Rates of sediment oxygen uptake were measured along the organic matter gradient from Boston's Inner Harbor to Stellwagen Basin. These data were coupled with seasonal measurements of water column-sediment exchanges of nutrients, sediment oxidation, and porewater chemistry. In addition, parallel measurements of denitrification were conducted at two stations within Boston Harbor. The most notable findings are summarized as follows: (1) Sediment and water column respiration rates in Massachusetts Bay were higher that in previous years. This increase is likely associated with a series of phytoplankton blooms. (2) Colonization of Boston Harbor sediments results in significant increases in carbon and nutrient cycling rates. Rates of SOD, denitrification, and exchanges of dissolved inorganic nutrients all show 2-10 fold increase in spatial comparisons of mat colonized versus uncolonized areas (1995-1997), in intra-annual comparisons during periods when mats are active versus senescent, and in inter-annual comparisons where mats are present one year but absent in subsequent years. (3) Significant

areas of Boston Harbor sediments appear to have been mined of stored oxidizable substrates and nutrients over the past 3 years of amphipod colonization. (4) Infaunal recolonization of Harbor sediments appears to result in shifts in the ratio of key phytoplankton nutrient fluxes from sediments to overlying waters. In contrast to pre-colonization measurement, colonized areas showed an increase in ratio of N and P fluxes, from < 16 to > 16. (5) Bio-irrigation of Harbor sediments resulted in increased oxidation status. The result is a shift in the form of inorganic nitrogen efflux from ammonium to nitrate and decrease in orthophosphate fluxes due to increased retention by sediments. (6) Bay and Harbor sediments have every different patterns of silicate/DIN flux to the water column. Bay sediments show a consistent and high release of silicate relative to DIN (Si/N=10) compared to the more variable and lower ratio of Si/DON in the Harbor, 0.5-2. (7) Phytoplankton appear to be major contributors of oxidizable organic matter to sediments driving sediment oxygen uptake in both Mass Bay and Boston Harbor. At lower levels of sediment chlorophyll a, sediment respiration rates were directly related to the chlorophyll a pool. At higher SOD levels, other factors appear to be more important than chlorophyll at determining rates. (8) Sediment metabolism appears to be a good indicator of perturbation. In Mass Bay sites under current conditions, inter-annual variability is generally < 20% with departures explainable by observed shifts in carbon availability. In contrast, in Boston Harbor sediment, biogeochemical cycling suggests a system undergoing rapid and large changes.

Howes, BL., Schlezinger, DR., Blake, JA., Miller, MC., and Cogan, J. 1997. "Recovery" of Boston Harbor Benthos: Infauna, Carbon-Nitrogen Cycling, and Sediment-Water Column Exchanges. *COASTAL ZONE ' 97, Boston.*

Abstract: Monitoring of sediment carbon and nutrient cycling is currently providing sensitive indicators of the changing ecological health of Boston Harbor. Results from studies of the sediment-infauna complex with the Harbor provide an example of the non-linear responses of marine systems to changes in organic matter loading rates and the need for direct measurements. Rates of sediment oxygen uptake were measured along the organic matter gradient from Boston's Inner Harbor to Stellwagen Basin. Also measured were water column-sediment nutrient exchange, sediment oxidation, porewater chemistry, and denitrification levels. Rates of total sediment community respiration appear to be increasing in portions of Boston Harbor. Seasonal measurements of carbon and nitrogen cycling in surficial sediments indicate that rates of organic carbon and nitrogen remineralization and denitrification were higher in 1995 than in previous years. Concurrently, rapid colonization of Harbor sediments by infauna has been occurring, especially by *Ampelisca* and *Leptocheirus.* This expanded distribution of *Ampelisca* is likely related to improving water quality, particularly in the northern Harbor, due to cessation of sludge discharges and contaminant reduction measures. The greater numbers of *Ampelisca* have increased the degree of sediment oxidation and rates of sediment-water column exchange as well as remineralization and denitrification rates in the Harbor. These results show that a positive feedback loop exists whereby improving habitat quality results in increased persistence and abundance of infaunal populations, which results in accelerated rates of organic matter and nutrient cycling and subsequent removal from Harbor sediments leading to improved habitat.

Hyland JL and H Costa. 1995. Examining Linkages Between Contaminant Inputs and their Impacts on Living Marine Resources of the Massachusetts Bay Ecosystem through Application of the Sediment Quality Triad Method. Massachusetts Bays Program. Boston Massachusetts. MBP-95-03.

Abstract: In this study, the Sediment Quality Triad (SQT) method was used to examine linkages between sediment contaminant concentrations and their potential impacts on living benthic resources of the Massachusetts/Cape Cod Bays ecosystem. The objectives were to (1) determine whether chemical contaminants in sediments at any of the 12 Massachusetts/Cape Cod Bay stations were present at concentrations known to cause adverse effects on marine organisms; (2) to determine whether sediments collected at the stations were significantly toxic to test populations of marine organisms; (3) to examine patterns in macrofaunal community structure among the various sites and identify signs of pollutant-related stress; (4) to examine relationships between the chemical, toxicological, and biological data as a means of identifying sites where sediment contamination could have been responsible for observed

bioeffects; and (5) to compare differences in contaminant trends and degree of biological impacts among the three harbor areas. Six stations showed strong signs of contaminant-induced degradation of the benthic environment (i.e., a combination of sediment contaminant loading above reported bioeffects levels), significant sediment toxicity, and the presence of a stressed benthic community. Every station had at least one contaminant present in potentially toxic concentrations and one station had 23. Unionized ammonia was present in porewater at three sites at concentrations that could have caused toxicity and benthic community degradation. Though the strongest bioeffects were observed in Wellfleet Harbor, the sites in this harbor system had the lowest overall sediment contamination. The most contaminated sites were in Boston and Salem/Beverly Harbors. Contaminants that may be causing the most ecological harm in Boston Harbor are silver, chlordane, and DDT and in Salem/Beverly Harbors, chromium, lead, chlordane and DDD. This study shows the difficulty in finding a nearshore depositional environment in the region that is completely free of chemical contaminant inputs or some level of ecosystem degradation. Factors other than chemical contaminant loading must be considered as possible causes of the biologically adverse condition of sediments in some of these coastal harbor systems. High organic loading and associated increases in the ammonia and hydrogen sulfide content of sediment porewater may be important factors contributing to the high toxicity of Wellfleet Harbor sediments, which appear to have experienced far less chemical contamination that the more urbanized Boston and Salem/Beverly Harbor systems.

Kropp, RK., Diaz, RJ., Dahlen, DT., Boyle, JD., and Hunt, CD. 2001. 1999 harbor benthic monitoring report. Massachusetts Water Resources Authority. Boston. Report 2001-03. 94pp.

Abstract: The principal goal of the Harbor Benthic Monitoring Report is to document the continuing recovery of benthic communities in Boston Harbor and surrounding areas as improvements are made to the quality of wastewater discharges. The monitoring program consists of sediment profile imaging, sediment geochemistry studies, and the sampling of infaunal communities. Overall, general benthic habitat quality within the study area was similar from August 1992 to 1998, although key indicators of benthic quality were slightly lower relative to previous years. Patterns in grain size and TOC content were fairly consistent from 1991 to 1999 at some stations, but variable at others. The unusually high TOC content observed at one station in August 1998 is likely a result of localized inputs from a major storm event in June 1998. *Clostridium perfringens* density patterns were highly variable from 1991 to 1999 at all Traditional stations, although some stations were more variable than others. In general, infaunal abundances in the Harbor were much lower in 1999 than they have been in recent years, but there were no major differences in the number of species collected per station. There was some indication that the infaunal communities are in transition from those that appeared soon after release from the stress caused by sludge to those more likely to be found in a less-polluted Harbor that is still prone to periodic natural disturbance.

Kropp, RK., Diaz, RJ., Dahlen, DT., Boyle, JD., and Hunt, CD. 2002. 2000 harbor benthic monitoring report. Massachusetts Water Resources Authority. Boston. Report 2002-02. 101pp.

Abstract: The principal goal of the Harbor Benthic Monitoring Report is to document the continuing recovery of benthic communities in Boston Harbor and surrounding areas as improvements are made to the quality of wastewater discharges. The monitoring program consists of sediment profile imaging, sediment geochemistry studies, and the sampling of infaunal communities. In 2000, biogenic mixing dominated the surface sediments. The population of *Ampelisca* spp. in the harbor has continued to decline in 2000 with only 33% of stations having a modal classification of tube mat (down from 40% in 1998 and 1999). The infaunal communities were evenly split between pioneering and intermediate successional stages. Overall, general benthic habitat quality was similar from August 1992 to 2000 with minor variation from year to year. None of the stations exhibited monotonic long-term trends, either improving

or declining. Grain size and TOC were strongly correlated across all sampling years. The overall abundance of *Clostridium perfringens* spores appeared to have been decreasing since 1998 and showed correlation with bulk sediment properties, indicating that grain size and TOC are likely controlling factors in the spring. Infaunal abundances in 2000 were similar to those encountered in 1999 and continued to be lower than they have been in recent years. Species diversity between stations was also generally within the same range of values reported in previous years. The observed changes in the Harbor's infaunal communities provide good evidence for improvement in benthic habitat conditions since the cessation of sludge discharge in 1991.
Kropp, RK, Diaz, RJ, Dahlen, DT, Boyle, JD, and Hunt, CD. 2002. 2001 harbor benthic monitoring. Massachusetts Water Resources Authority. Boston. Report 2002-19. 74pp.

Abstract: The principal goal of the Harbor Benthic Monitoring Report is to document the continuing recovery of benthic communities in Boston Harbor and surrounding areas as improvements are made to the quality of wastewater discharges. The monitoring program consists of sediment profile imaging, sediment geochemistry studies, and the sampling of infaunal communities. In 2001, biological processes continued to dominate the structuring of surface sediments (e.g., macrobenthic tubes, feeding pits). The areal distribution of *Ampelisca* spp. tube mats in the harbor appeared to increase for the first year since 1995. In general, not much change has been observed in grain size and TOC content over the sampling years. While concentrations of *Clostridium perfringens* appeared to decrease over time, between 1998 and 2001 the concentrations appeared to be more stable. Infaunal species numbers recorded in 2001 were the highest ever for the monitoring program, continuing the trend in increasing species numbers. The observed changes in the Harbor's infaunal communities provide good evidence for improvement in benthic habitat conditions since the cessation of sludge discharge in 1991.
Kropp, RK., Diaz, RJ., Dahlen, DT., Shull, DH., Boyle, JD., and Gallagher, ED. 2000. 1998 harbor benthic monitoring report. Massachusetts Water Resources Authority. Boston. Report 2000-06. 83 pp.

Abstract: The principal goal of the Harbor Benthic Monitoring Report is to document the continuing recovery of benthic communities in Boston Harbor and surrounding areas as improvements are made to the quality of wastewater discharges. The monitoring program consists of sediment profile imaging, sediment geochemistry studies, and the sampling of infaunal communities. The observed changes in the structure of the Harbor's infaunal communities, coupled with data from SPI studies, provide good evidence for improvement in the condition of benthic habitats in the Harbor since the cessation of sludge discharge in 1991. Most notable was the dramatic increase in abundance and geographic spread of the amphipod *Ampelisca* sp. Also important was the general increase in infaunal abundance and species numbers that occurred after 1991. The most substantial changes in the Harbor's benthos probably occurred within the first two years after sludge discharge ended. Most recently , there has been some indication that the infaunal communities are in transition from those that appeared soon after release from the stress caused by the sludge to those more likely to be found in a less polluted Harbor that is still prone to periodic natural disturbance.
Kropp, RK., Diaz, RJ, and Keay, K. 1995. Infaunal community changes in Boston Harbor, 1991-1994: A response to sewage sludge discharge abatement. Massachusetts Water Resources Authority. Boston. Report 1995-21. 94pp.

Abstract: To examine potential changes in the Boston Harbor infaunal communities in response to cessation of sewage sludge discharges into the Harbor, the MWRA initiated a series of benthic surveys. After a pre-abatement survey was completed in September 1991, biannual surveys were conducted in April and August 1992-1994. Grab sample analyses revealed substantial changes in the relative importance of several species within the Harbor. In 1991, *Ampelisca abdita* was numerically important, primarily in the southern parts of the Harbor, but by 1994 had expanded its range of importance to include much of the northern Harbor. This change was necessarily accompanied by reduced relative importance

of several annelid worms, notable oligochaetes, *Streblospoi benedicti*, and *Polydora cornuta*. Infaunal abundance increased substantially throughout the Harbor by 1992 and 1993, but then showed a slight decrease by 1994. Strong temporal differences in abundance, some of which were probably seasonal, also were detected. The mean number of species per station increased steadily since the cessation of sludge discharge. Species diversity (H') did not change substantially during the course of the study. Little change in the sedimentary environment, with the exception of *Clostridium perfingens* spore counts, occurred following the abatement of sludge discharge. Habitat quality, as indicated by several sediment profile image parameters, increased through 1993, but may have regressed slightly by 1994. Most of the changes observed in the infaunal communities of Boston Harbor following sludge-discharge abatement appeared consistent with those predicted by the Pearson-Rosenberg model, but occurred without apparent concommitant changes in the organic content of the sediments. Because infaunal community changes were virtually harbor-wide and the possibility that the data collected during this study fall within the range of variability found historically in the Harbor, it is difficult to unequivocally associate them with the cessation of sludge discharges.

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

Abstract: The main goals of this study were to assess the effects of specific combined sewer overflows (CSOs) on the concentration of pollutants in the sediments around the CSOs and to determine if sediment concentrations of these pollutants at specific stations in Dorchester Bay have declines between the sampling years 1998, 1994, and 1990. In all years and in all surveys, sediment was collected near and far from known CSO outfalls, although few parameters show statistically significant differences in contaminant concentrations between individual stations. Sewage tracer (i.e., *Clostridium perfringens*, coprostanol, LABs) values were found to have declined from 1990 values at most stations, although the increase at some stations may have been due to a large storm event in 1998. PAH concentrations at most stations were similar to or lower than those previously measured, except at four South Dorchester Bay stations, which may indicate increased loading at specific CSOs in the area. PCB concentrations were not significantly different at any of the stations between the years. DDT concentrations were found to have decreased significantly at many stations. Concentrations of metals have remained fairly constant at most stations, with some stations showing slight decreases in 1998. The 1998 data, considered in context with the 1994 and 1990 studies, indicate that reductions of sewage tracers and, to some extent, metals and organic constituents throughout Dorchester Bay and Boston Harbor, are partially due to improved sewage treatment at the Deer Island and Nut Island facilities, as well as reductions in discharges at the individual CSOs. Sediment data also points to the potential importance of substantial meteorological events on the contaminant signatures.

Long ER, GM Sloane, RS Carr, KJ Scott, GB Thursby, and T Wade. 1995. Sediment toxicity in Boston Harbor: Magnitude, extent, and relationships with chemical toxicants. Coastal Monitoring and Bioeffects Assessment Division. Silver Spring, Maryland. *NOAA Tech. Memo., NOS ORCA 78.* 85pp.

Abstract: A survey of the toxicity of sediments was conducted by NOAA's National Status and Trends Program throughout Boston Harbor and vicinity . The objectives of the survey were to determine the magnitude and spatial extent of toxicity and the relationship between measures of toxicity and the concentrations of chemical toxicants in the sediments. This survey was conducted as a part of a nationwide program supported by the Coastal Ocean Program and the NS&T Program of NOAA in which the biological effects of toxicants are determined in selected estuaries and bays. The survey was conducted in 1993. Surficial sediments were collected from 55 locations (stations) throughout the Harbor. The survey area covered approximately 57 kilometers2. Station locations were chosen randomly within specified strata. Multiple toxicity tests were performed including: an amphipod survival test performed with whole sediments, a microbial bioluminescence test performed with organic solvent extracts of the sediments, and sea urchin fertilization and embryological development tests performed with the pore

waters extracted from the sediments. These tests were chosen because: they were consistent with the tests used in similar surveys performed elsewhere in the U.S.: they usually provide complementary, but not duplicative, information on toxicity; the results of these tests often are highly correlated with gradients in toxicant concentrations; and they are known to be dose-responsive to the kinds of toxicants commonly found in urban bays, such as Boston Harbor. Chemical analyses were performed on selected samples for trace metals, polynuclear aromatic hydrocarbons, chlorinated pesticides, PCBs and butyltins. In the amphipod and microbial bioluminescence tests, 21.8% and 56.4% of the samples, respectively, were significantly different from controls. In the sea urchin tests performed with 100% pore water, 3.6% and 100% of the samples were significantly toxic in fertilization success and normal embryological development tests, respectively. The results of the different toxicity tests generally showed poor concordance with each other, probably as a result of differences in sensitivity and differential responses to the kinds of chemicals in the sediments. The results of the toxicity tests were weighted to the spatial dimensions of each stratum to estimate the spatial extent of toxicity. Based upon these estimates, 100% of the area was toxic in the sea urchin tests of embryo development in 100% pore water. In contrast, only 6.6% of the area was toxic in the sea urchin fertilization tests performed in 100% pore water. In the microbial bioluminescence and amphipod survival tests, approximately 45% and 10% of the area was estimated to be toxic, respectively. Toxicity was apparent throughout all regions of the study area. Overall, the incidence of toxicity was highest in portions of the inner harbor where chemical concentrations were the highest. Toxicity diminished beyond the entrance to the inner harbor. However, some of the inner harbor samples were not toxic and one sample each from central harbor and northwest harbor were the most toxic of the 55 samples tested. Toxicity was lowest in portions of northwest harbor, central harbor, southeast harbor, and in an area beyond the entrance to Boston Harbor. A determination of the causes of toxicity were not an objective of this survey. Rather, the data were analyzed to determine which substances, if any, may have contributed to toxicity. Correlations between toxicity and chemical concentrations were relatively poor. No single substance or chemical group was highly correlated with toxicity. None of the chemical concentrations were extremely high relative to estimated toxicity thresholds. Furthermore, the bioavailability of many of these substances may have been inhibited by high organic carbon content in the sediments. However, the concentrations of 18 individual substances, including ammonia, were sufficiently high to have contributed to toxicity. The data suggest that complex mixtures of potentially toxic substances, including PAHs, PCBs, pesticides, trace metals, and ammonia probably contributed to the observed toxicity.

Magar, VS., Ickes, J., Cumming, L., Trulli, W., Albro, C., and Lyons, T. 2001. Survey of contaminated sediment resuspension during capping. *1st International Conference on Remediation of Contaminated Sediments, Volume 3: Remediation and Beneficial Reuse of Contaminated Sediments.*
Abstract: Capping was performed at the Wyckoff/Eagle Harbor Superfund Site, WA, and at Boston Harbor, MA, to contain contaminated sediment. The two sites are described briefly, including the capping operations, and results are presented from field sampling conducted to evaluate the release of contaminants into the surrounding water columns. At Eagle Harbor, the capping material was washed off a barge with a high-pressure hose, and at Boston Harbor, a sprinkling method was utilized. For PAHs, total suspended solids, and organics at Eagle Harbor, elevated concentrations were observed during the capping operations, but they decreased with each successive capping day and dissipated after capping had been completed. Similar results were observed at Boston Harbor in terms of PCBs, total suspended solids, and organics.
Manheim, FT., Buchholtz ten Brink, MR., and Mecray, EL. 1999. Recovery and validation of historical sediment quality data from coastal and estuarine areas: an integrated approach. *Journal of Geochemical Exploration.* 64, 377-393.
Abstract: A comprehensive database of sediment chemistry and environmental parameters has been compiled for Boston Harbor and Massachusetts Bay. This work illustrates methodologies for rescuing and validating sediment data from heterogeneous historical sources. It greatly expands spatial and temporal

data coverage of estuarine and coastal sediments. The database contains about 3500 samples containing inorganic chemical, organic, texture and other environmental data dating from 1955 to 1994. Cooperation with local and federal agencies as well as universities was essential in locating and screening documents for the database. More than 80% of references utilized came from sources with limited distribution (gray literature). Task sharing was facilitated by a comprehensive and clearly defined data dictionary for sediments. It also served as a data entry template and flat file format for data processing and as a basis for interpretation and graphical illustration. Standard QA/QC protocols are usually inapplicable to historical sediment data. In this work outliers and data quality problems were identified by batch screening techniques that also provide visualizations of data relationships and geochemical affinities. No data were excluded, but qualifying comments warn users of problem data. For Boston Harbor, the proportion of irreparable or seriously questioned data was remarkably small (<5%), although concentration values for metals and organic contaminants spanned 3 orders of magnitude for many elements or compounds. Data from the historical database provide alternatives to dated cores for measuring changes in surficial sediment contamination level with time. The data indicate that spatial inhomogeneity in harbor environments can be large with respect to sediment-hosted contaminants. Boston Inner Harbor surficial sediments showed decreases in concentrations of Cu, Hg, and Zn of 40 to 60% over a 17-year period.

Massport. 2003. Benthic Infauna Data [Microsoft Word Tables].

Abstract: These data files contained benthic infauna data from 25 samples taken at Chelsea/Sandwich Berths, 3 samples taken at Conoco Phillips Berths, 3 samples taken at Global Petroleum Berths, 3 samples taken at Gulf Oil Berths, 3 samples taken at Irving Oil Berths, 5 samples taken at North Jetty, and 5 samples taken at Condey Terminal on September 4-5, 2003.

McGroddy, SE. and Farrington, JW. 1995. Sediment porewater partitioning of polycyclic aromatic hydrocarbons in three cores from Boston Harbor, Massachusetts. *Environmental Science and Technology.* 29, 1542-1550.

Abstract: Polycyclic aromatic hydrocarbon (PAH) concentrations were measured in sediments and porewaters isolated from three cores from Boston Harbor, MA. Measured porewater PAH concentrations were significantly lower than the concentrations predicted by two- and three-phase equilibrium partitioning models. We hypothesize that only a fraction of the measured sediment PAH concentrations was available to partition rapidly into sediment porewaters.

Myre, P., Walter, P., and Rollings, M. 2000. Geotechnical evaluation of sediment data collected in Boston Harbor CAD Cells. Warwick, RI. *Proceedings, WEDA 2000.*

Abstract: Sediment samples were collected from one of the Boston Harbor in-channel confined aquatic disposal cells prior to and after cap placement in order to evaluate the geotechnical behavior of the dredged material. Core and grab samples were intensively sampled to assess a suite of physical properties that would allow assessment of the change in strength of material resulting both from self-weight consolidation, and the overlying load of the sand cap. The data indicated that the *in situ* cohesion and strength of the sediment was altered by the dredging process, resulting in sediment with high water content and low shear strength. there was no significant difference in sediment properties following five months of self-weight consolidation, whereas the most significant change was an increase in shear strength of the dredged material after capping. In the short-term, results can be used to develop field protocols to assess sediment strength in future CAD projects. In the long-term, the data will be useful in developing quantitative guidelines for assessing geotechnical "cap-readiness" of disposed dredged material in a confined environment.

Nowicki, BL., Requintina, E., Van Keuren, D., and Kelly, JR. 1997. Nitrogen losses through sediment denitrification in Boston Harbor and Massachusetts Bay. *Estuaries.* 20, 3: 626-639.

Abstract: Sediment denitrification is a microbial process that converts dissolved inorganic nitrogen in sediment porewaters to N_2 gas, which is subsequently lost to the atmosphere. In coastal waters, it represents a potentially important loss pathway for fixed nitrogen which might otherwise be available to primary producers. Currently, data are lacking to adequately assess the role of denitrification in reducing or remediating the effects of large anthropogenic nitrogen loads to the coastal zone. This study describes

the results of 88 individual measurements of denitrification (as a direct flux of N_2 gas) in sediment cores taken over a 3-yr period (1991-1994) from six stations in Boston Harbor, nine stations in Massachusetts Bay, and two stations in Cape Cod Bay. The dataset is unique in its extensive spatial and temporal coverage and includes the first direct measurements of denitrification for North Atlantic shelf sediments. Results showed that rates of denitrification were significantly higher in Boston Harbor (mean = 54, range < 5-206 umol N_2 m^{-2} h^{-1}) than in Massachusetts Bay (mean = 23, range < 5-63 umol N_2 m^{-2} h^{-1}). Highest rates occurred in areas with organic-rich sediments in the harbor, with slower rates observed for low-organic sandy sediments in the harbor and at shallow shelf stations in the bay. Lowest rates were found at the deepest shelf stations, located in Stellwagen Basin in Massachusetts Bay. Observed rates were correlated with temperature, sediment carbon content, and benthic macrofaunal activity. Seasonally, highest denitrification rates occurred in the summer in Boston Harbor and in the spring and fall in Massachusetts Bay, coincident with peak phytoplankton blooms in the overlying water column. Despite the fact that sediment denitrification rates were high relative to rates reported for other East Coast estuaries, denitrification losses accounted for only 8% of the annual total nitrogen load to Boston Harbor, a consequence perhaps, of the short water-residence times (2-10 d) of the harbor.

Pain, A. and Cooney, JJ. 1998. Characterization of organotin-resistant bacteria from Boston Harbor sediments. *Archives of Environmental Contamination and Toxicology.* 35, 412-416.

Abstract: Organotins are widely used in agriculture and industry. They are toxic to a variety of organisms including bacteria, although little is known of their physiology and ecology. Bacteria resistant to six organotins - tributyltin (TBT), dibutyltin (DBT), monobutyltin (MBT), triphenyltin (TPT), diphenyltin (DPT), and monophenyltin (MPT) - were isolated from Boston Harbor sediments, Massachusetts, USA. Bacteria resistant to each of the organotins, except DPT, were isolated directly from estuarine sediments. Viability of the organotin-resistant bacteria on serial transfer in the laboratory ranged from 80 to 91%. Each isolate was screened for resistance to the other organotins. All of 250 isolates were resistant to at least two organotins. No DPT-resistant isolates were found on initial isolation on DPT, although there was DPT resistance among the other organotin-resistant bacteria. Eighty percent of TBT-resistant bacteria were TPT-resistant, suggesting that antifouling paints containing TPT will not be a suitable substitute for TBT in paints designed to inhibit microbial biofilms. Debutylation reduced toxicity in some cases while dephenylation did not. Thus, even though trisubstituted organotins are generally believed to be more toxic than di- or monosubstituted organotins, this may not always be the case, and more than one mechanism of resistance may be involved. All the bacteria were resistant to at least six of eight heavy metals tested, suggesting that resistance to heavy metals may be associated with resistance to organotins.

Raven, TM. Sediment resuspension in Boston Harbor . Massachusetts Institute of Technology, Sea Grant. *PhD. Dissertation.*

Abstract: Cohesive sediment resuspension in outer Boston Harbor was investigated with the aim of estimating the resuspension-derived flux of particle-reactive contaminants (e.g., PCBs) into the water, and thereby assessing the hazard posed by resuspension. In general, sediment resuspension is a function of (1) the hydrodynamic phenomena present and the shear stress they apply on the sediment grains, (2) the erodibility of the sediment, and (3) the vertical and horizontal transport processes (e.g., turbulent diffusion and settling). The hydrodynamic (wave and current) environment was characterized on the basis of near-bottom velocity and pressure measurements in Dorchester and Quincy Bay. Analysis of this data indicated that, on an annual basis, local, storm-generated waves on tidal currents constituted the dominant forces relevant to sediment erosion. Cohesive sediment erodibility was estimated using three different approaches. First, correlations of the spatial distribution of hydrodynamic forcing (excess bottom stress) and sediment quality (sand content) were studied. The critical stress that optimized the correlation was proposed as a estimate. Second, an in situ, straight flume was tested and then deployed at three locations in Quincy Bay from August to October. In four of six experiments, the erodibility was fairly consistent. The two other experiments appeared to be influenced by the presence of an algal mat which reduced erodibility by as much as 80%. Third, sediment erodibility was inferred from near-bottom turbidity and

pressure data during two Nor'Easter storms--March 19-20, 1996 (site QB2) and March 7-8, 1996 (site QB3). The erodibility indicated by analysis of the March 19-20 resuspension event was in good agreement with the flume results. Analysis of the March 7-8 resuspension event at QB3 indicated significantly less erodibility at this near-shore, high sand content site. Erosion depths during the observed storms were less than 1 mm. On an annual basis, resuspension-derived fluxes of three PCB congeners were calculated to be an order of magnitude less than the fluxes due to biologically-mediated diffusion from the sediment. Resuspension was probably not responsible for high contaminant levels observed in Quincy Bay flounder and lobster.

Rothermich, MM., Hayes, LA., and Lovley, DR. 2002. Anaerobic, sulfate-dependent degradation of polycyclic aromatic hydrocarbons in petroleum-contaminated harbor sediment. *Environmental Science and Technology.* 36, 22: 4811-4817.

Abstract: It has previously been demonstrated that (^{14}C)-labeled polycyclic aromatic hydrocarbons (PAHs) can be oxidized to $^{14}CO_2$ in anoxic, PAH-contaminated, marine harbor sediments in which sulfate reduction is the terminal electron-accepting process. However, it has not previously been determined whether this degradation of (^{14}C)-PAHs accurately reflects the degradation of the in situ pools of contaminant PAHs. In coal tar-contaminated sediments from Boston Harbor, (^{14}C)-naphthalene was readily oxidized to $^{14}CO_2$, but, after 95 d of incubation under anaerobic conditions, there was no significant decrease in the detectable pool of in situ naphthalene in these sediments. Therefore, to better evaluate the anaerobic biodegradation of the in situ PAH pools, the concentrations of these contaminants were monitored for ca. 1 year during which the sediments were incubated under conditions that mimicked those found in situ. There Was loss of all of the PAHs that were monitored (2-5 ring congeners), including high molecular weight PAHs, such as benzo(a)pyrene, that have not previously been shown to be degraded under anaerobic conditions. There was no significant change in the PAH levels in the sediments amended with molybdate to inhibit sulfate-reducing bacteria or in sediments in which all microorganisms had been killed with glutaraldehyde. In some instances, over half of the detectable pools of in situ 2-3 ring PAHs were degraded. In general, the smaller PAHs were degraded more rapidly than the larger PAHs. A distinct exception in the Boston Harbor sediment was naphthalene which was degraded very slowly at a rate comparable to the larger PAHs. In a similar in situ-like study of fuel-contaminated sediments from Liepaja Harbor, Latvia, there was no decline in PAH levels in samples that were sulfate-depleted. However, when the Latvia sediments were supplemented with sufficient sodium sulfate or gypsum to elevate pore water levels of sulfate to approximately 14-25 mM there was a 90% decline in the naphthalene and a 60% decline in the 2-methylnaphthalene pool within 90 days. These studies demonstrate for the first time that degradation by anaerobic microorganisms can significantly impact the in situ pools of PAHs in petroleum-contaminated, anoxic, sulfate-reducing harbor sediments and suggest that the self-purification capacity of contaminated harbor sediments is greater than previously considered.

Rothermich, MM, Hayes, LA., and Lovley, DR. 2001. Sequential anaerobic degradation of polycyclic aromatic hydrocarbons in contaminated harbor sediment. *Abstracts of the General Meeting of the American Society for Microbiology.* 646-647.

Abstract: Polycyclic aromatic hydrocarbons (PAHs) are common contaminants in the sediments of marine harbors. Previous studies in our laboratory demonstrated that the in situ pools of some lower molecular weight PAHs, such as phenanthrene, were degraded in anaerobic incubations of coal tar-contaminated sediments from Boston Harbor. Here we report that with continued incubation less soluble or higher molecular weight PAHs such as anthracene and chrysene were also degraded. This is the first demonstration that PAHs that are this large and water-insoluble may be degraded in anaerobic sediments. The degradation of the higher molecular weight PAHs was inhibited in sediments in which the activity of sulfate-reducing microorganisms was inhibited with the addition of molybdate, suggesting that sulfate reduction is involved in the degradation of these larger PAHs. Similar results were previously observed with smaller PAHs. The sequential utilization of PAHs of increasing insolubility/molecular weight suggests that PAH-degrading sulfate reducers preferentially degrade more soluble, lower-molecular

weight PAHs and only utilize higher molecular weight PAHs when other, more readily degradable, organic substrates are depleted from the sediments. Additional studies with heavily contaminated sediments from which sulfate-reducing microorganisms had consumed all of the sulfate, indicated that PAHs persisted in the absence of sulfate, but that PAH degradation could be stimulated with the addition of sulfate. These results demonstrate that in order for in situ bioremediation of PAH contamination in contaminated harbor sediments to be successful it will be important to ensure that the sediments are supplied with enough sulfate so that all of the lower molecular weight PAHs will be consumed and the microorganisms will attack the larger molecular weight PAHs which, due to their greater toxicity, are of the greatest concern.

Snelgrove, PV. 1999. Getting to the bottom of marine biodiversity: sedimentary habitats. *BioScience.* 49, 2: 129-138.

Abstract: This paper is part of a special section on the biodiversity of soils and freshwater and marine sediments. Benthic species living on the seafloor comprise one of the richest pools of species in the oceans and, perhaps, on Earth. Benthic organisms living in the sea have to overcome numerous challenges in order to survive, including food limitation and lack of light for photosynthesis. The organisms are involved in such ecologically important activities as global carbon and geochemical cycling, secondary food production, pollution metabolism and burial, filtration, and stabilizing and transporting sediment.

TRC Environmental Corporation. 2002. Application for 401 Water Quality Certification: Supplemental Information Filing. TRC Environmental Corporation. Lowell, Massachusetts.

Abstract: This application contains the HubLine Dredging Analysis and Sediment Handling Plan and a variety of pre- and post-construction monitoring plans. The Dredging Analysis and Sediment Handling Plan presents a summary of the project and a compilation of the construction methods, sediment testing, and management alternatives for dredged sediment generated during construction of the HubLine Pipeline Project. Also discussed in this report are possible pipeline construction method alternatives, dredge site sediment characterization, dredge material management options, and a summary of the sediment handling plan (SHP).

Data Available: Physical and Chemical Characteristics of Sediments along HubLine Route
Human Health Soil Screening and HubLine Sediment Values
Chromium Concentrations along Pipeline Route
Grain Size Distribution of Near-Surface Sediments along HubLine Route
Metals Concentrations, TOC, and Moisture Content of Near Surface Sediments along HubLine Route
PAHs Concentrations in Near Surface Sediments along HubLine Route
Pesticide Concentrations, Total PCBs, and Total TPHs in Near Surface Sediments along HubLine Route
Field Observations of Surface Sediments Collected with Gravity Core or Ponar Grab along HubLine Route
Grain Size Distribution of Sediments to Proposed Project Depth along HubLine Route
Metals Concentrations, TOC, and Moisture Content to Proposed Project Depth along HubLine Route
Vibracore Observations
Results of Bulk Analysis of Sediments along HubLine Route
Description of Sediments Collected by Vibracore along HubLine Route
Percent Survival during 96-hour Acute Toxicity Bioassay for Mysid Shrimp and Inland Silverside
Percent Survival and Percent Normal Development during 69-hour Exposure for Sea Urchin

TRC Environmental Corporation. 2003. Environmental Report, Volume I: Resource Reports 1-13 Accompanying FERC Section 7C Application, Everett Extension Project. TRC Environmental Corporation. Lowell, Massachusetts.

Abstract: This environmental impact report includes a general project description of the Everett Extension Project, project maps, Soil Erosion Control Plan, Project Correspondence, Water Use and Quality Resource Report, Vegetation and Wildlife Resource Report, Socioeconomics Resource Report, Geologic Resources Report, Soils Resource Report, and Land Use, Recreation, and Aesthetics Resource

Report, among a few other irrelevant appendices.

Data Available:
Grain-size Distribution of Near-Surface Sediments along the Everett Extension Route
Concentration of Heavy Metals and TOC in Near-Surface Sediments along the Everett Extension Route
Concentration of PAHs in Near-Surface Sediments along the Everett Extension Route
Concentration of Pesticides, PCBs, and TPH in Near-Surface Sediments along the Everett Extension Route
Temporal Distribution of Demersal Fishes and When Common or Abundant in Boston Harbor
Catch per Unit Effort in Otter Trawl Collections off Deer Island and Shrimp Trawls at Winthrop Harbor and the Airport
Temporal Distribution of Pelagic Fishes and When Common or Abundant in Boston Harbor
Catch per Unit Effort in Gill Net Collections from Massachusetts Bay, 1994 and 1995
Marine Waterbirds of the Massachusetts Bay, Coast and Islands
Federal and State Protected Species within 1/2 Mile of the Everett Extension
Seasonal Occurrences of Northern Right Whales in Cape Cod Bay, 1998-2002
Physical Characteristics of Soil Series/Map Unit Components Crossed by the Everett Extension
TRC Environmental Corporation. 2003. Environmental Report, Volume II: Resource Report Appendices Accompanying FERC Section 7C Application, Everett Extension Project. TRC Environmental Corporation. Lowell, Massachusetts.
Abstract: These appendices to the Environmental Impact Report include various maps and aerial photographs of the project area.
TRC Environmental Corporation. 2002. Final Environmental Impact Report: Maritimes and Northeast Phase III and Algonquin HubLine Pipeline Projects. TRC Environmental Corporation. Lowell, Massachusetts.
Abstract: This Environmental Impact Report includes a Sediment Sampling and Analysis Report as Appendix D.
Data Available:
Field Observations of Surface Sediments along HubLine Route
Grain Size Distribution
Percent Survival During 96-Hour Toxicity Bioassay for Mysid and Silverside
Percent Survival and Percent Normal Development of Sea Urchin after 68-Hour Exposure
Mean Concentration of Dissolved Metals in Site and Elutriate Water
Physical and Chemical Characteristics of Sediments along HubLine Route
Concentrations of Metals, TOC, and % Moisture Content in Near Surface Sediments along the HubLine Route
Concentrations of PAHS in Near Surface Sediments along the HubLine Route
Concentrations of Pesticides, Total PCBS, and TPHs in Near Surface Sediments along the HubLine Route
Vibracore Observations

Also included in the EIR is an Analysis of Remote Operated Vehicle Survey.

Data Available:
Common and Scientific Names of Organisms Observed in Video Review
Vegetation, Shellfish, and Crustaceans Review

Also included in the EIR is an Analysis of Benthic Surveys

Data Available:

Summary of SPI Parameters (i.e., surface relief, RPD, infauna, burrows, oxic voids, anaerobic voids, OSI)
Sediment Grain Size
Estimated Successional Stages
Processes that Dominate Bed Roughness
Dominant Taxa in HubLine Monitoring Stations Classified by Side Scan Sonar

The EIR also includes two volumes of Reponses to Comments
TRC Environmental Corporation. 2002. Implementation Plan: Algonquin Gas Transmission Company HubLine Pipeline Project. TRC Environmental Corporation. Lowell, Massachusetts.
Trueblood, D. D., Gallagher, E. D., and Gould, D. M. 1994. Three stages of seasonal succession on the Savin Hill Cove mudflat, Boston Harbor. *Limnology and Oceanography.* 39, 6: 1440-1454.
Tucker, J. and Giblin, AE. 2002. Stable isotope analyses of sediment and invertebrate samples from Boston Harbor and Massachusetts Bay. Massachusetts Water Resources Authority. Boston. Report ENQUAD 2002-21. 24pp.

Abstract: This study was conducted as an augmentation of previous studies using stable isotopes of nitrogen and sulfur as tracers to demonstrate the incorporation of sewage-derived materials into the food webs of Boston Harbor and Massachusetts Bay. Sediments in the nearfield have experienced notable changed in their $*^{15}N$ values over the past decade. The deposition of harbor sediments onto a nearfield depostional site as well as the complete winnowing of fines from a sandy site after the December 1992 storm were clearly evident in the isotope signal, and correlated well with silver and *Clostridium perfringens* data. Stable isotope results in *M. moliolus* from four hardbottom sites fell within a narrow range (w/in about 1‰ for nitrogen and less than 2‰ for sulfur) that should provide a good reference point for future analyses. The results from harbor and bay amphipod samples raise new questions about changes in their food sources. In general, *L. pinguis* had the lightest $*^{15}N$ values of the three amphipod species, possibly indicating a closer connection to the sediments. *A. abdita* had the heaviest values, with *U. irrorata* in between. These results present interesting questions about changes that were occurring in the phytoplankton, which could be related to dominant species or may be related to the dissolved inorganic nitrogen pool. Although harbor concentrations of nitrogen did not change significantly until outfall diversion, the isotopic signal of the DIN may have changed as treatment processes changed. The results of this study show that the Harbor continues to change towards typical offshore marine conditions.
Tucker, J., Giblin, AE., Hopkinson, C., and Vasiliou, D. 2001. Benthic nutrient cycling in Boston Harbor and Massachusetts Bay. Massachusetts Water Resources Authority. Boston. Report 2001-07. 48pp.

Abstract: This report documents a continuation of the monitoring studies that have examined temporal and spatial patterns of benthic processing of organic matter in Boston Harbor and Massachusetts Bay. This study examined sediment-water exchanges of oxygen, total carbon dioxide, nitrogen, silicate, and phosphorus four times in 2000. In Boston Harbor, lower rates of sediment respiration and nutrient regeneration in the sediments have been observed over the past 3 to 5 years than early in the monitoring program. However, DIN fluxes seemed to be decreasing more slowly than oxygen uptake. Denitrification is an important process in Harbor sediments, since the denitrification rates do not show the decreasing trend noted for sediment respiration and nutrient release. Phosphate fluxes were very small (among the lowest of all baseline years) and often directed into the sediment. Denitrification in Massachusetts Bay is very important, often accounting for the majority of total remineralization.
Tucker, J., Giblin, AE., and Hopkinson, CS., Jr. 1999. Metabolism, nutrient cycling and denitrification in Boston Harbor sediments in 1998. Massachusetts Water Resources Authority. Boston. Report 1999-08. 33pp.

Abstract: This study was a continuation of the monitoring studies that have examined the temporal and spatial patterns of benthic processing of organic matter in Boston Harbor that have been conducted since 1990. The range in dissolved inorganic nitrogen fluxes in Boston Harbor was narrower than in previous years, although these fluxes continue to correlate with benthic infaunal abundances. Although all stations continue to exhibit year to year variability, the very high rates in 1993 and 1995 have not been repeated for three years, even though amphipods continue to be present. This suggests that some "mining" of sediment stores may have taken place. Rates are now typical of productive coastal sediments.
Tucker, J., Giblin, AE., Hopkinson, CS., Jr., and Vasiliou, D. 2000. Benthic nutrient cycling in Boston Harbor and Massachusetts Bay: 1999 annual report. Massachusetts Water Resources Authority. Boston. Report 2000-11. 63pp.

Abstract: This study continues the monitoring research examining the temporal and spatial patterns of benthic processing of organic matter in Boston Harbor and Massachusetts Bay. Results of the benthic nutrient flux studies in 1999 show a continuation of trends observed in previous years. However, there were some changes. At one station (an old sludge disposal site), respiration and nutrient flux have decreased in 1998 and 1999 from the extremely high rates observed in the several years after the cessation of sludge disposal. Sediment carbon and nitrogen content have also decreased. Some *Ampelisca* mats show signs of being in decline, which is consistent with the successional stages inherent in an improving habitat. A large algal bloom in 1999 increased the chlorophyll concentrations at Massachusetts Bay stations and led to the lowest bottom DO measurements ever recorded. These events impacted the benthic sediment as well, leaving indications of recent deposition of organic matter, most likely originating from the blooms. Decreases in organic carbon and nitrogen in Nearfield sediments and the deepening of the RPD are all observations consistent with an increase in the abundances of benthic infauna and the normal successional progression.
Tucker, J., Kelsey, AE., and Hopkinson, C. 2003. 2002 annual benthic nutrient flux monitoring report. Massachusetts Water Resources Authority. Boston. Report ENQUAD 2003-08. 52pp.

Abstract: The Benthic Nutrient Flux studies were initiated in 1990 to examine spatial and temporal trends of benthic processing of organic matter at selected stations in Boston Harbor and Massachusetts Bay. The overall objectives of the studies have been to quantify sediment-water exchanges of oxygen, total carbon dioxide, and nutrients in order to better define benthic-pelagic coupling in the Harbor and the Bay. In addition, sediment indicators of organic matter loading and processing, such as organic carbon, pigment concentrations, and redox conditions, have also been monitored. During 2001 and 2002, the two years since the ocean outfall became operational, small but inconsistent changes have been detected in measures of sediment organic matter, and rates of benthic respiration and nutrient fluxes have been well within or lower than typical baseline observations. Organic matter content of surface nearfield sediments have increased in the past 2 years, but are still within baseline observations. Nearfield C/N ratios of sediment organic matter were high in 2002 compared to baseline, following very low values measured in 2001, which may have been due to the large phytoplankton blooms in 1999-2000. Sediment chlorophyll levels at nearfield stations were typical of baseline conditions, but did not seem to correspond to the high C/N ratios. In 2002, nutrient fluxes were generally in the low end of baseline observations or lower. Temperature and infaunal abundance continued to be an important control on these fluxes. Fluxes of DIN, phosphate, and silica in 2002 were all at the low end of baseline levels. Denitrification rates were typical of baseline measurements and there was no indication of decreased sediment oxidation. Although these observations were from the nearfield of Massachusetts Bay, they may be used to guide the evaluation of Boston Harbor. TOC decreases have been observed at almost all the stations and sediment oxygen demand and all nutrient fluxes were lower at several stations than at any previous time during monitoring. The decrease in the magnitude of benthic fluxes, of oxygen as well as nutrients, in addition to the dramatic decrease in the variability of fluxes across stations suggests that the harbor benthic environment has progressed significantly along the path of "recovery".

Tucker, J., Kelsey, S., Giblin, AE., and Hopkinson, C. 2002. Benthic metabolism and nutrient cycling in Boston Harbor and Massachusetts Bay: summary of baseline data and observations after one year of Harbor-to-Bay diversion of sewage effluent. Massachusetts Water Resources Authority. Boston. Report 2002-13. 83pp.

Abstract: This report documents a continuation of the monitoring studies that have examined temporal and spatial patterns of benthic processing of organic matter in Boston Harbor and Massachusetts Bay. After one year of effluent diversion, no large changes in benthic nutrient cycling were observed in either the harbor or the bay. Although Boston Harbor experienced large water column responses to the diversion, these responses were not as dramatically seen in sediment biogeochemistry. However, reductions in organic matter deposition resulting from water quality improvements will become apparent over time.

Tucker, J., Sheats, N., Giblin, AE., Hopkinson, CS., and Montoya, JP. 1999. Using stable isotopes to trace sewage-derived material through Boston Harbor and Massachusetts Bay. *Marine Environmental Research.* 48, 353-375.

Abstract: Using stable isotopes, we assessed the effects of long-term sewage inputs within Boston Harbor and extending into adjacent Massachusetts Bay. We used nitrogen and sulfur stable isotopes ($*^{15}N$ and $*^{34}S$) to distinguish between sources of these elements to sediments, particulate organic matter, algae, and animals. The isotope data revealed the widespread presence of sewage-derived particulate and dissolved materials. Incorporation of sewage-derived effluent particulates into sediments of the harbor and into Massachusetts Bay was apparent in the $*^{15}N$ values of surface sediments and in sediment profiles. Changes towards more typical marine values over time indicated a lessening of sewage inputs. The incorporation of sewage particulates into blue mussels as revealed by the combination of $*^{15}N$ and $*^{34}S$ values in their tissues was also evident and suggested the importance of sewage-derived nutrients to the local food web.

Tuit, CB. and Ravizza GE. 2000. Anthropogenic platinum and palladium in the sediments of Boston Harbor. *Environmental Science and Technology.* 34, 6: 927-932.

Abstract: Anthropogenic activity has increased recent sediment concentration of Pt and Pd in Boston Harbor by approximately 5 times background concentrations. Surface sediments and downcore profiles were investigated to evaluate Pt and Pd accumulation and behavior in urban coastal sediments. There is no clear correlation between temporal changes in Pt and Pd consumption and sediment concentration. However, Pt/Pb and Pd/Pb ratios suggest that Pt and Pd flux into the Harbor may not be decreasing with cessation of sludge input as rapidly as other metals. This is supported by the large discrepancy between fluxes associated with sludge and effluent release and those calculated from surface sediment concentrations. This evidence supports catalytic converters as a major source of Pd and Pt to Boston Harbor but cannot preclude other sources. Pd does not exhibit signs of post-burial remobilization below the mixed layer in the sediment cores, although near-surface variability in Pd concentrations may indicate a labile Pd component. Pt displays an inverse correlation with Mn above the oxic/suboxic transition, similar to behavior seen in pristine sediments where Pt is thought to be chemically mobile. This study does not support the use of Pd and Pt as tracers of recent contaminated sedimentation. However, the possibility of a labile Pt and Pd in these sediments highlights the need for further study of the biological uptake of these metals.

U.S. Army Corps of Engineers. 2001. Draft Final Tissue Chemical Data for Boston/Weymouth/President Roads. Battelle. Duxbury, Massachusetts.

Abstract: This collection of data includes PAH, PCB, metals, and lipid weight tissue concentrations for *Nereis* and *Macoma* samples taken from Boston Harbor, Weymouth, and the President Roads area.

U.S. Army Corps of Engineers. 2001. Final Data Report for Boston Harbor, Weymouth Fore River, MA. Battelle. Duxbury, Massachusetts.

Abstract: The work presented in this report was performed to assist the Corps of Engineers North Atlantic Division in gathering physical, chemical, and toxicological data for analyzing the environmental impacts associated with proposed dredging of sediments in Boston Harbor. These data are to support the Corps determination for acceptability of the dredged material for ocean disposal under Section 103 of MPRSA. The first objective was to collect sediment and water samples and the second was to perform evaluations of specific vibracore samples. PCBs and PAHs were detected in all of the sediment composites at levels greater than the Target Detection Limits (1.0 ug/kg and 20 ug/kg, respectively). DDTs and chlordanes were the most commonly detected chlorinated pesticides detected at levels above the Target Detection Limit of 2.0 ug/kg. Fluoranthene and pyrene were the most abundant PAHs in every sample tested. The tested metals were detected in all samples at levels greater than the Target Detection Limits (from 0.02 to 1.0 ug/g). No PCBs or pesticides were detected in the rinsate blanks at levels greater than the detection limits. The rinsate blanks contained measurable levels of some PAHs but concentrations were below the detection limits of sediments. For metals, only Ni and Zn were detected above the target DL in the rinsate blanks. *Macoma* and *Nereis* samples (exposed to site sediments) were analyzed for tissue chemistry parameters. Overall, metals concentrations were higher in *Macoma* samples than in *Nereis.* In all tissue samples, PCBs were detected above the MDL and concentrations in *Nereis* were higher than those detected in *Macoma*. PAHs were also detected in all tissue samples. The suspended phase acute toxicity test survival results were based on a 96-hour exposure period. Mean survival of *Ampelisca abdita* ranged from 1% to 96% in the test sediment composites. Six of the 19 sediment composites were found to be acutely toxic to *A. abdita* while the remaining were not acutely toxic. Mean survival of *Macoma nasuta* in the test sediments ranged from 82% to 99% while mean survival rates for *Nereis virens* ranged from 92% to 99%.

U.S. Army Corps of Engineers. 2002. Final Report: 10 Day Amphipod (*Eohaustorius estuarius*) Bioassay with Sediment from Boston Harbor North Channel. Battelle. Duxbury, Massachusetts.

Abstract: This report describes the bioassay testing of the Boston Harbor North Channel sediments using a free-burrowing amphipod (*Eohaustorius estuarius*). Mean survival in the four test sediment composites ranged from 89% to 98%. According to the Inland Testing Manual guidelines, the Boston Harbor North Channel samples are not acutely toxic to *E. estuarius*.

U.S. Army Corps of Engineers. 1999. Final Survey Report for Vibratory Core Sampling in Boston Harbor, MA. Battelle. Duxbury, Massachusetts.

Abstract: Vibratory core sampling was conducted at 32 stations in Boston Harbor, MA. This survey report describes the activities conducted during sampling and provides a synopsis of the preliminary observations from the survey. A summary of all core survey data is presented in the report. Sediments consisted mainly of black mud. Sediments collected in the Inner Harbor (i.e. near the Coast Guard base and the Charlestown Bridge) had a distinct oily sheen and odor associated with them.

U.S. Army Corps of Engineers. 2001. Laboratory Testing in Support of Environmental Assessment Project: Weymouth Harbor, Fore River: Acute Suspended Particulate Phase Toxicity Tests. Battelle. Duxbury, Massachusetts.

Abstract: The work presented in this report was performed to assist the Corps of Engineers North Atlantic Division in gathering physical, chemical, and toxicological data for analyzing the environmental impacts associated with proposed dredging of sediments in Boston Harbor. These data are to support the Corps determination for acceptability of the dredged material for ocean disposal under Section 103 of MPRSA. This report contains the data gathered in the laboratory during the acute suspended particulate phase toxicity tests on *Americamysis bahia, Menidia beryllina,* and *Arbacia punctulata*.

U.S. Army Corps of Engineers, New England District. 2000. Section 404/10 Application: Executive Summary, Algonquin Gas Transmission Company HubLine Pipeline Project. Earth Tech, Inc. Concord, Massachusetts.

Abstract: This application, submitted in compliance with Section 404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act, includes a concise project description, a description of the

affected environment, a summary of the potential impacts of the project, a description of the actions taken to minimize adverse effects, and a listing of the practicable alternatives.
U.S. Army Corps of Engineers, Waterways Experiment Station. 2000. Acoustic Monitoring of Dredging-Related Suspended-Sediment Plumes. United States. WES/ERDC-TN-DOER-E7. 13pp.

Abstract: This technical note presents the results of acoustic monitoring of suspended-sediment plumes during dredging operations. Monitoring was conducted in Mobile Bay, Alabama, during dredging by a hopper dredge and in Boston Harbor, Massachusetts, during dredging by a clamshell dredge. The results show how acoustic monitoring can be used with other instrumentation to provide valuable data characterizing the extent and dynamics of suspended-sediment plumes. Data presented in this technical note provide input for modeling of suspended- sediment plumes, evaluation of dredging methods, and environmental assessments.
Wang, XC. Zhang YX. and Chen RF. 2001. Distribution and partitioning of polycyclic aromatic hydrocarbons (PAHs) in different size fractions in sediments from Boston Harbor, United States. *Marine Pollution Bulletin* . 42, 11: 1139-1149.
Abstract: The concentrations of 16 US EPA priority pollutant PAHs , e.g., naphthalene, anthracene, fluorene, phenanthrene, and chrysene, were analyzed in four size fractions (<62, 62-115, 125-250, and >250 um) in three contaminated Boston Harbor sediments. Total PAH concentrations ranged from 7.3 to 358 ug/g dry wt. and varied largely among the different size fractions in these sediments. For all three sites, the highest PAH concentrations were associated with the large size (>250 um) fractions while the fine silt and clay fractions (< 62 um) contained relatively low PAHs. Despite the great concentration differences, the composition of PAHs in the four size fractions of these sediments showed similar patterns dominated by PAHs with three or more rings. By examining the distribution patterns of selected alkyl homologs to parent compounds, the results indicate that the major PAHs contributing to the high concentration in the inner harbor sediments were from pyrogenic sources. A positive correlation between PAHs and sedimentary organic carbon exists for all size fractions in the sediments. Calculated organic carbon normalized partition coefficients (log K_{oc}) for selected major PAHs indicate near-equilibrium partitioning of PAHs among the different size fractions despite their large concentration variations. Sedimentary organic matter associated with different size fractions was the controlling factor for the observed distribution differences of PAHs among the size fractions. Our results also suggest that sedimentary organic matter with different origins and maturities may have somewhat different PAH sorption characteristics. Particulate organic matter of charcoal, plant detritus, and *Capitella* fecal pellets in the sediments appear to sorb PAHs more strongly than organic matter associated with clay minerals. The strong association of PAHs with these organic particles in sediments will have a great influence not only on their distribution but also on long-term environmental impact.
Zago, C., Giblin, AE., and Bergamasco, A. 2001. Changes in the metal content of surficial sediments of Boston Harbor since the cessation of sludge discharge. *Marine Environmental Research.* 51, 389-415.
Abstract: Temporal trends of metals in surficial sediments (1991-1998) at two sites in Boston Harbor were analyzed to evaluate the effect of stopping sludge dumping in December 1991. Metal contents of sediments from the old sludge disposal site were higher than those of a station in the central Harbor. Since 1991, carbon, copper, and lead contents have significantly decreased in sediments from the disposal site. Chromium and Zn have shown smaller decreases while Fe, and Mn, have remained relatively constant. Metal content in the central Harbor station, located in an area of sediment reworking, has been quite variable, but, with the exception of Zn which has shown a large decrease relative to iron, the changes seemed to be well correlated with changes in the organic carbon content at this site due to resuspension. Ratios of metals in the sediments are fairly similar at both sites and similar to those of sewage-derived particles, with the exception of Cr, which appears to be enriched in the sediments.
FISHERIES OR SHELLFISHERIES DATA AND INVESTIGATIONS

Carr HA. Fisheries Resources in Massachusetts Bay. Massachusetts Division of Marine Fisheries. Gloucester, Massachusetts.
Abstract: This short paper discusses how more people have access to fishing equipment and advanced marine technology as well as the concentration of people on the coast of the United States has advanced the capability and interest of the recreational and commercial fisherman. As a result, targeted marine species have been declining in abundance. In particular, Atlantic cod dropped threefold between 1983 and 1996. Winter flounder indices have remained low since 1987 and lobster landings in Boston Harbor-Massachusetts Bay have been declining since 1995, after several years of huge increases. Striped bass and Atlantic mackerel are exceptions to these downward trends. The sea urchin and hagfish fisheries are now booming thanks to an international market.
Chang, S., Zdanowicz, V. S., and Murchelano, R. A. 1998. Associations Between Liver Lesions in Winter Flounder (*Pleuronectes americanus*) and Sediment Chemical Contaminants From North-East United States Estuaries. *Ices Journal of Marine Science*. 55, 5: 954-969.
Abstract: Neoplastic diseases, particularly of bottom-dwelling fishes, are more prevalent in coastal areas than in areas that are relatively pristine. Although sediments in many urbanized estuaries contain high concentrations of contaminants, there is little evidence linking a specific organic or inorganic chemical to a particular liver lesion in winter flounder (*Pleuronectes americanus*), despite increasing study in recent years. Between 1984 and 1986, sediments and winter flounder were collected from 10 sites in the north-east United States ranging from grossly polluted to relatively unimpacted. Sediments were analyzed for polycyclic aromatic hydrocarbons (PAHs), chlorinated pesticides, polychlorinated biphenyls (PCBs), and metals. Gross and microscopic pathological examinations were conducted on winter flounder liver sections. Factor and canonical correlation analyses were used to explore associations between biological and chemical measurements. Hepatitis, cholangitis, phlebitis, and macrophage aggregate hyperplasia showed positive associations with low molecular weight, petroleum-derived PAHs (naphthalene, anthracene, l-methylnaphthalene, 2-methylnaphthalene. 2,6-dimethylnaphthalene, acenaphthene, phenanthrene, biphenyl, fluorene, and 1-methylphenanthrene), the pesticides lindane, hexachlorobenzene, heptachlor epoxide, and o,p'-DDD, tri- to hexachlorobiphenyls, and chromium, cadmium, lead, thallium, and selenium, but were negatively associated with the pesticides o,p'-DDT, p,p'-DDT, p,p'-DDE, and mirex. Cytoplasmic hepatocellular vacuolation, cytoplasmic bile duct vacuolation, neoplasms, and pre-neoplasms showed positive associations with most PAHs measured, whether petroleum-derived or combustion-derived (benzo[a]pyrene, benzo[e]pyrene, benzo[a]anthracene, dibenzo[a,h]anthracene, perylene, chrysene, and ftuoranthene), the pesticides dieldrin, trans-nonachlor and alpha-chlordane, and silver, copper, antimony, and tin, but no associations with PCBs were found. Coagulative necrosis, single cell necrosis and haemorrhagic necrosis showed positive associations with hepta- to nonachlorobiphenyls and arsenic, zinc, nickel, and mercury, and negative associations with high molecular weight, combustion-derived PAHs and DDT compounds and metabolites.
Chase BC and AR Childs. 2001. Rainbow Smelt (*Osmerus mordax*) Spawning Habitat in the Weymouth-Fore River. Division of Marine Fisheries, Commonwealth of Massachusetts. Gloucester, MA. TR-5.
Abstract: The spawning habitat of anadromous rainbow smelt in the Weymouth-Fore River, within the cities of Braintree and Weymouth, was monitored during 1988-1990 to document temporal, spatial and biological characteristics of the spawning run. Smelt deposited eggs primarily in the Monatiqot River, upstream of Route 53, over a stretch of river habitat that exceeded 900m and included over 8,000 m^2 of suitable spawning substrate. Minor amounts of egg deposition were found in Smelt Brook, primarily located below the Old Colony railroad embankment where a 6 ft culvert opens to an intertidal channel. The Smelt Brook spawning habitat is degraded by exposure to chronic stormwater inputs, periodic raw sewer discharges and modified stream hydrology. Overall, the entire Weymouth-Fore River system supports one of the larger smelt runs in Massachusetts Bay, with approximately 10,000 m^2 of available spawning habitat. Observations of egg deposition during 1988-1990 indicate that spawning typically begins in early March and egg incubation is complete by late May. Egg deposition observed in the Weymouth-Fore River during 1989 was substantially higher than observed in 1988 and 1990, or any year

since. The movement of yolk-sac larval smelt from the spawning habitat to the upper estuary was recorded for the period of April 14th through May 26th. Measurement of basic water chemistry recorded suitable conditions of temperature, salinity, dissolved oxygen, and pH for adult attraction and egg survival under most conditions. Annual observations since 1990 confirm that smelt continued to spawn in the Weymouth-Fore River and this spawning run supports a modest sportfishery in Hingham Bay and Quincy Bay. Despite this relatively favorable rank among Massachusetts Bay smelt runs, the Weymouth-Fore River appears to be following a region-wide trend of declining smelt populations during the last 15-20 years. The causal factors for this trend are not well identified. Structural impediments of adult smelt migrations to spawning habitat and the chronic degradation of spawning habitat from stormwater inputs are common concerns for many river systems in Massachusetts Bay that support smelt. Symptoms of these two concerns were identified within the Weymouth-Fore River system. Recommendations are provided in regard to these potential sources of impact to the Weymouth-Fore River smelt population.

Collier, TK., Anulacion, BF., and Bill, BD. 1998. Hepatic cyp1a in winter flounder (*Pleuronectes americanus*) along the Northeast coast: results from the National Benthic Surveillance Project. *Marine Pollution Bulletin.* 37, 1-2: 86-91.

Abstract: As part of the National Benthic Surveillance Project, cytochrome P4501A (CYP1A) and associated enzyme activities were measured in more than 700 samples of liver tissue collected from adult non-spawning winter flounder (*Pleuronectes americanus*). Between 1988 and 1994, animals were sampled annually from 20 sites, ranging from Penobscot Bay in Maine to Great Bay, New Jersey. Analyses performed were assays of aryl hydrocarbon hydroxylase (AHH) and ethoxyresorufin-O-deethylase (EROD) activities, and immunoquantitation of CYP1A by enzyme-linked immunosorbent assay (ELISA). From 1988 through 1990, CYP1A was measured by all three methods, to help determine an appropriate method for assessing temporal trends and to allow for eventual comparisons to methods used in other monitoring efforts. From 1991 through 1994, assays were only done for hepatic AHH activity. Fish from virtually all sites showed induction of hepatic AHH activity, consistent with earlier reports, though fish sampled from sites in the coastal waters of Maine generally showed the lowest mean AHH activities. At sites where fish were sampled during three to six separate years (15 of the 20), individual data were analyzed for monotonic temporal trends. There were trends towards increasing AHH activities over time in fish from the Raritan Bay/Long Island Sound area, and generally increasing trends for sites near Massachusetts (especially Boston Harbor) and Rhode Island. A decreasing trend was noted in fish from Great Bay, New Jersey, and there appeared to be decreasing activities in fish from the nearshore waters of Maine, though these trends were not statistically significant at the ∀= 0.05 level. The induction of CYP1A is strongly associated with exposure to chemical contaminants, and while the consequences of widespread and increasing induction of CYP1A are not known, these results suggest that the measurement of this enzyme system in benthic fish can be a useful tool for monitoring our coastal ecosystems.

Downey, PC., Moffat, BD., and Lescarbeau, GR. 1995. Bioaccumulation of selected organic compounds and metals in mussels deployed near Deer Island discharge and in Massachusetts Bay, 1994. Massachusetts Water Resources Authority. Boston. Report 1995-09. 60pp.

Abstract: A mussel bioaccumulation study was conducted in 1994 for the MWRA to determine whether selected PAHs, PCBs, and metals bioaccumulate in mussels deployed near the Deer Island Treatment Facility and to obtain background data on the uptake of specific target compounds by mussels deployed offshore near the projected new outfall. Three stations were used: off the stern of the Discovery (New England Aquarium), near Deer Island Light, and in the vicinity of "B" buoy (LNB). The 60-day harvested mussels showed no lesions or parasites. Average percent solids and percent lipids of mussels were highest in LNB and lowest in Deer Island mussels, although these results were not statistically significant. Average total PAHs tissue concentrations were significantly higher in Discovery mussels than in other deployment groups. Average total PAH body burdens were significantly greater at Deer Island than either pre-deployment (Gloucester) measurements or LNB mussels. Mussels harvested from LNB and

Gloucester had lower average alpha-chlordane body burdens than Discovery or Deer Island mussels. Of the 20 target PCB congeners, 10 were found at or near the detection levels in Deer Island mussels, although Discovery mussels showed the highest observed PCB congener concentrations. Total PCB tissue concentrations were highest in Discovery mussels while LNB mussels were routinely lower when compared to the other stations. All stations showed lower DDT tissue concentrations in 1994 than in 1993. The DDT tissue body burdens were 3 to 5 times higher in Discovery and Deer Island mussels than in Gloucester or LNB mussels. Dieldrin and transnonachlor tissue body burdens were higher in Deer Island and Discovery mussels than in Gloucester or LNB mussels. Deer Island and Gloucester mussels had similar lead body burden levels, but both were significantly higher than LNB levels. Mercury body burden observations were not statistically significant. The 1994 relative spatial trends of mussel body burdens for the three stations were consistent with spatial trends reported in 1991-1993. Total LMW-PAHs were consistently found in the highest tissue concentrations in the Deer Island mussels, suggesting that the Deer Island effluent may be an important source of these contaminants. In contrast, the higher HMW-PAHs body burdens in Discovery mussels suggest that there are other sources within Boston Harbor which are bioaccumulation importance.

Environmental Protection Agency. 1995. Proposed Sludge Management Plan, Metropolitan District Commission, Boston, Massachusetts. Volume 2. Appendices. Draft Environmental Impact Statement. United States. 305.

Abstract: The document accompanies Volume I of the Draft Environmental Impact Statement which proposed amendments to Boston's sludge management plan. This volume is a set of appendices dealing with water standards, rock types, floral and faunal species, commercial establishments, infrastructure, and other aspects of the Boston Harbor area.

Environmental Protection Agency. 1995. Proposed Sludge Management Plan, Metropolitan District Commission, Boston, Massachusetts. Volume 1. Draft Environmental Impact Statement. Metropolitan District Commission. 284.

Abstract: The recommended project involves Federal financial assistance for the construction of a primary sludge disposal system owned and operated by the Metropolitan District Commission (MDC), Boston, Massachusetts. As a result of the detailed environmental, cost effectiveness, and energetics analyses which were performed for this impact statement, Region I EPA has suggested a modification to the proposed plan. The sludge management plan proposed by MDC be implemented as described is recommended, except that the ash disposal method not be approved.

Estrella BT and RP Glenn. 2001. Massachusetts Coastal Commercial Lobster Trap Sampling Program, May-November 2000. Division of Marine Fisheries, Commonwealth of Massachusetts. Technical Report TR-7. 12pp.

Abstract: This is the Massachusetts Division of Marine Fisheries twentieth annual assessment of the status of the American lobster resource in Massachusetts coastal waters. During the period of May through November 2000, eighty-three (83) sampling trips were made aboard commercial lobster vessels. A total of 38,390 lobsters were sampled from 17, 251 trap hauls. the catch rate of marketable lobster, 0.885 lobster per trap, was 2% lower than the 1999 index of 0.902. The proportion of females ovigerous (15.4%) was lower than in the previous year (17.4%). The coastwide fishing mortality estimate (1.38) was higher than the 1999 index of 1.22. Exploitation rate (0.68), increased fractionally, while mean carapace length of marketable lobster (89.4 mm) and mean size of egg-bearing females (88.1 mm) were similar and remained unchanged, respectively. The cull rate (18.2%) decreased about 2% from the 1999 estimate of 20.8%. Less than 1% of the lobster sampled from traps were dead. A time series of data from our bottom water temperature monitoring program is presented for seven locations in Buzzards Bay, Cape Cod Bay, and Massachusetts Bay for the period 1985-2000. The locations of three shallow water sites (<20'), added during summer 2000, are depicted.

Estrella BT and RP Glenn. 2002. Massachusetts Coastal Commercial Lobster Trap Sampling Program, May-November 2001. Division of Marine Fisheries, Commonwealth of Massachusetts. Gloucester, MA. TR-14.
Abstract: This is the Massachusetts Division of Marine Fisheries twenty-first annual assessment of the status of the American lobster resource in Massachusetts coastal waters. During the period of May through November, 2001, seventy- nine (79) sampling trips were made aboard commercial lobster vessels. a total of 33,150 lobsters were sampled from 16,734 trap hauls. The catch rate of marketable lobster (0.761 lobster per trap) was 14% lower than the 2000 index (0.885). Commercial lobster landings from territorial waters were 28% lower than in 2000, the lowest landings in the 21-year time series. The proportion of females ovigerous (18.1%) was higher than in the previous year (15.4%). The coastwide fishing mortality estimate (1.38) was unchanged from 2000. Exploitation rate (0.71) increased fractionally, while mean carapace length of marketable lobster (89.5mm) and mean size of egg-bearing females (88.3mm) were similar to 2000 measurements. The cull rate (19.7%) increased from the 2000 estimate of 18.2%. Less than 1% of the lobster sampled from traps were dead. A time series of data from our bottom water temperature monitoring program is presented for seven locations in Buzzards Bay, Cape Cod Bay, and Massachusetts Bay for the period 1985-2001. Data from an additional three shallow water sites (<20') added during the summer of 2000 are summarized.
Hillman, RE. and Peven, CS. 1995. 1994 annual fish and shellfish report. Massachusetts Water Resources Authority. Boston. Report 1995-05. 82pp.

Lavalli, KL. and Kropp, RK. 1998. Abundance of juvenile lobsters at the new outfall site: comparisons with inshore abundances and discussion of potential impacts on lobster populations. Massachusetts Water Resources Authority. Boston. Report ENQUAD 1998-14. 26pp.

Abstract: The MWRA was mandated by the Outfall Monitoring Task Force to design and execute a study in the cobble-boulder habitats of the new outfall nearfield region to determine the density of early benthic phase lobsters (EBPs), particularly that of new recruits (young-of-the-year) and yearling lobsters. MWRA was also required to determine if the densities of these life history stages were comparable to those of inshore habitats. In September 1998, density sampling was undertaken at both the vicinity of the outfall and two nearby inshore locations. The data collected showed significantly lower densities of the young-of-the-year and yearling lobsters as well as larger EBP lobsters at the outfall compared to the inshore sites. Given the physical characteristics of the outfall site where a strong seasonal thermocline and halocline form a distinct pycnocline that would repel most postlarvae that are competent to settle and where depths may exceed 30 m, it is of little surprise that densities of young-of-the-year and yearlings are lower. Furthermore, for postlarvae that do settle in this area, survival rates most likely would be low and growth rates severely retarded. Other studies have shown that the survival rates of postlarvae are reduced to < 26% at 10 degC compared to those at higher temperatures, where survival was > 75%. This 10 degC cutoff is warmer than the bottom temperatures measured at the outfall in September 1998, which ranged from 3 to 4 degC. In contrast, shallow inshore populations of EBP lobsters benefit from the warmer temperatures there and would presumably grow very rapidly attaining a much larger size. Retardation of growth rates at low temperatures could prolong the vulnerable phase of EBP lobsters and would be predicted to result in a further dwindling of the population of EBP lobsters at the outfall vicinity. These studies and data demonstrate that while the cobble habitat in the vicinity of the outfall is suitable for settlement, it does not represent a major settlement site and thus there is no indication that the outfall will have any appreciable impact on these life stages of the American lobster.

Lefkovitz, LF., Abramson, SL., Hillman, RE., Field, J., and Moore, MJ. 2000. 2000 annual fish and shellfish report. Massachusetts Water Resources Authority. Boston. Report 2000-20. 143pp.

Abstract: The MWRA continued to conduct its biomonitoring program for fish and shellfish in 2000, the goal of which is to obtain the baseline condition of three species (winter flounder, lobster, and blue mussel). Baseline conditions of the species collected were characterized in terms of biological parameters, the presence/absence of disease, and concentrations of organic and inorganic compounds in both edible and liver tissue. The external condition of the winter flounder showed few abnormalities and fin erosion, while low at all stations, was higher at DIF than other stations. CHV prevalence has not changed substantially at any of the stations since 1991. Mean 2000 concentrations of organic contaminants in fillets were generally highest at DIF and lowest at ECCB. Edible tissue contaminant levels were well below federal legal limits. The ratio of male to female lobsters varied greatly between stations and no deleterious external conditions were noted on the lobsters. Lobster tissue contaminant levels and spatial trends are consistent with previous years. although concentrations of PCBs, silver, and copper in lobster hepatopancreas continued to show an upward trend in 2000 at DIF. Lobster tissue was observed to be well below the legal limits for consumption. Mussel contaminant levels were still among the lowest measured since 1991. The 2000 data were similar to previous years with the highest body burden of contaminants observed in mussels deployed at BIH and the lowest at OH. The 1999 contaminant levels measured in mussel tissue were well below legal limits for consumption.

Lefkovitz, LF., Abramson, SL., Hillman, RE., Moore, MJ., and Field, J. 2002. 2001 annual fish and shellfish report. Massachusetts Water Resources Authority. Boston. Report 2002-14. 175pp.

Abstract: The MWRA continued to conduct its biomonitoring program for fish and shellfish in 2000, the goal of which is to obtain the baseline condition of three species (winter flounder, lobster, and blue mussel). Baseline conditions of the species collected were characterized in terms of biological parameters, the presence/absence of disease, and concentrations of organic and inorganic compounds in both edible and liver tissue. The external condition of winter flounder indicated few abnormalities and, while low at all stations, a fin erosion index was higher at DIF than other stations. The prevalence of tubular and CHV was highest at DIF and absent at ECCB. Neoplasia prevalence at DIF has fallen from elevated levels in the 1980s to undetectable levels during 1992-2001. Mean 2001 tissue concentrations of organic compounds were generally highest at DIF and lowest at ECCB. In general, metals were higher in fillet tissue and liver tissue at OS than at other sites. Both tissue and liver concentrations are consistent with or lower than those measured in the baseline period (1992-2000). The 2001 were well below federal legal limits for consumption. The ratio of male to female lobsters varied greatly between stations and no deleterious external conditions were noted. Mean 2001 concentrations of organic compounds in edible tissue and the hepatopancreas were generally highest at DIF and lowest at ECCB. Comparison of 2001 data with baseline years indicates that most spatial distributions were similar. Total DDTs and total chlordanes have noticeably decreased compared to recent years and were similar to pre-1995 levels at all stations. The 2001 levels were below federal legal limits for consumption. The 2001 mussel data were similar to previous years with the highest body burdens of contaminants generally observed at BIH and the lowest at OS or CCB. 2001 levels of Total PAHs and chlordane exceeded the MWRA Caution Thresholds set for these compounds. However, a standard risk analysis indicated that the potential environmental impact from these exceedances are low to non-existent.

Lefkovitz, LF., McLeod, LA., and Moore, MJ. 1999. 1998 annual fish and shellfish report. Massachusetts Water Resources Authority. Boston. Report 1999-06. 200 pp.

Abstract: The MWRA continued to conduct its biomonitoring program for fish and shellfish in 1998, the goal of which is to obtain the baseline condition of three species (winter flounder, lobster, and blue mussel). Baseline conditions of the species collected were characterized in terms of biological parameters, the presence/absence of disease, and concentrations of organic and inorganic compounds in both edible

and liver tissue. The external condition of the winter flounder showed few abnormalities and fin erosion levels are consistent with recent studies. Liver lesion prevalence has not changed substantially at any of the stations since 1991. 1998 body burden measurements appear to be on the low end of contaminant burdens measured since 1992, although a correlation between body burden and prevalence of CHV was still observed. Edible tissue contaminant levels were well below federal legal limits. The ratio of male to female lobsters varied greatly between stations and little or no deleterious external conditions were noted on the lobsters. Most lobster tissue contaminant levels and spatial trends are consistent with previous years. Most edible lobster tissue was observed to be well below the legal limit, although PCB levels have been slightly higher than legal limits since 1996. This, however, is reflected in the current Massachusetts state advisory on lobster tissue. Mussel contaminant levels were the lowest measured overall since 1991. The 1998 contaminant levels measured in mussel tissue were well below legal limits for consumption.
Lefkovitz, LF., Moore, MJ., Abramson, SL., and Field, J. 2000. 1999 annual fish and shellfish report. Massachusetts Water Resources Authority. Boston. Report 2000-10. 155pp.

Abstract: The MWRA continued to conduct its biomonitoring program for fish and shellfish in 1999, the goal of which is to obtain the baseline condition of three species (winter flounder, lobster, and blue mussel). Baseline conditions of the species collected were characterized in terms of biological parameters, the presence/absence of disease, and concentrations of organic and inorganic compounds in both edible and liver tissue. The external condition of the winter flounder showed few abnormalities and fin erosion levels are consistent with recent studies. Liver lesion prevalence has not changed substantially at any of the stations since 1991. 1999 body burden measurements appear to be on the low end of contaminant burdens measured since 1992, although a correlation between body burden and prevalence of CHV was still observed. Edible tissue contaminant levels were well below federal legal limits. However, dieldrin levels detected at station OS exceeded the MWRA Caution Level. The ratio of male to female lobsters varied greatly between stations and no deleterious external conditions were noted on the lobsters. Most lobster tissue contaminant levels and spatial trends are consistent with previous years. although concentrations of PCBs, silver, and copper in lobster hepatopancreas continued to show an upward trend in 1999 at OS and DIF. Most edible lobster tissue was observed to be well below the legal limit, although PCB levels have been slightly higher than legal limits since 1996 at DIF and concentrations of PCBs have been approaching legal limits at OS. This, however, is reflected in the current Massachusetts state advisory on lobster tissue. Mussel contaminant levels were the lowest measured overall since 1991. The 1999 data were similar to previous years with the highest body burden of contaminants observed in mussels deployed at BIH. The 1999 contaminant levels measured in mussel tissue were well below legal limits for consumption.
Lefkovitz, LF., Neff, JM., Lizotte, R., and Hall, MP. 2001. Comparison of two analytical methods for measurement of chlorinated pesticides and PCB congeners in biological tissue - Trends in Boston Harbor lobster tissue. Massachusetts Water Resources Authority. Boston. Report ENQUAD 2001-02. 100pp.

Abstract: Since 1995, the concentrations of PCBs and DDTs in the hepatopancreas of lobster collected at Deer Island Flats (DIF) and the Outfall Site (OS) have steadily increased. A similar increase was not observed in muscle tissue nor was it found for other chemicals of concern in hepatopancreas such as chlorinated pesticides or for PAHs. This report documents the use of alternative analytical methods to determine if analytical artifacts could account for any or all of the observed trends in hepatopancreas burdens of PCBs. The objectives of this study were as follows: (1) assess and discuss changes in analytical methods and the potential implications to the MWRA biomonitoring program; (2) analyze a subset of archived lobster and flounder tissue extracts by GC/MS to evaluate the quality of data and compare results to those obtained using traditional GC/ECD methods; and (3) use findings to determine if the apparent increasing trend of PCBs and DDTs is "real" or caused by artifacts of the analytical method used. It was determined that analytical factors were not causing the trend. Further investigation suggested that lobsters tend to bioaccumulate PCBs and DDTs primarily from their food. Following the cessation of

sludge disposal in the Harbor, lobsters may have switched from a diet rich in animals impacted by the old discharges to other prey items in the nearshore sections of the Harbor, where sediments are contaminated with higher levels of PCBs and DDTs.

Lindholm, JB., Auster, PJ., Ruth, M., and Kaufman, L. 2001. Modeling the effects of fishing and implications for the design of marine protected areas: juvenile fish responses to variations in seafloor habitat. *Conservation Biology.* 15, 2: 424-437.

Abstract: A number of recent studies have linked post-settlement survivorship of Atlantic cod (*Gadus morhua*) with the complexity of the seafloor to which fish settle. Survivorship is greater in habitats of higher complexity (e.g., pebble-cobble substratum with emergent epifauna > pebble-cobble > sand), where cover provides shelter from predators. Fishing with mobile gear such as bottom trawls and dredges reduces the complexity of seafloor habitats. We used a dynamic model to (1) link patterns in habitat-mediated survivorship of post-settlement juvenile cod with spatial variations in habitat complexity, (2) simulate habitat change based on fishing activities, and (3) determine the role of marine protected areas in enhancing recruitment success. Density-dependent natural mortality was specified as three alternative functional response curves to assess the influence of different predator foraging strategies on juvenile survivorship during the first 12 months of demersal existence. We applied the model to a theoretical patch of hard-bottom substrata and to a case study based on seafloor habitat distributions at Stellwagen Bank National Marine Sanctuary (Gulf of Maine, Northwest Atlantic). Our results demonstrate that patterns in the shape of response surfaces that show the relationship between juvenile cod survivorship and density as well as movement rate were similar regardless of functional response type, that juvenile cod movement rates and post-settlement density were critical for predicting the effects of marine protected-area size on survivorship, and that habitat change caused by fishing has significant negative effects on juvenile cod survivorship and use of marine protected areas can ameliorate such effects.

Mackenzie, CL, VG Burrell, A Rosenfield, and WL Hobart. 1997. History, Present Condition, and Future of the Molluscan Fisheries of North and Central America and Europe. Volume 1. Atlantic and Gulf Coasts. - Technical rept. NOAA-TR-NMFS-127, 141-169.

Abstract: The region from Massachusetts Bay through Raritan Bay has long been an important producer of mollusks. The oyster, Crassostrea virginica; northern quahog, Mercenaria mercenaria; and softshell clam, *Mya arenaria*, have been harvested since pre-colonial times. The bay scallop, *Pecten irradians*, has been harvested since the 1800's, the smooth conch, Busycotypus canaliculatus, since the 1930's, and since the 1980's and 1990's, the surfclam, *Spisula solidissima*, and blue mussel, *Mytilus edulis*. The oyster industry expanded during and after the 1820's when immense quantities of oysters were imported from Chesapeake Bay to Long Island Sound and Raritan Bay for planting. Owing to the imports and shelling of the seed beds, the industry grew to a production peak of 4,250,000 bushels a Year in the 1890's and early 1900's. After 1900, the oyster industry declined because of poor demand and small supplies. The oyster industry in Connecticut has recently grown substantially. From the 1700's to the early 1900's, fishermen developed tongs and various types of rakes to harvest northern quahogs, mostly from boats, and, since about 1940, dredges also have been used. Softshells have been harvested in several areas of the region with multitined diggers and churning hoes used with scoop nets. From the 1800's into the 1940's, the clams were commonly shucked in fishermen's homes and peddled locally. Surfclams have traditionally been harvested on the north shore of Massachusetts, and recently with hydraulic dredges in Long Island Sound, where production ranged between 41,000 to 516,000 bushels/year from 1985-91. Bay scallops have traditionally been harvested mostly in bays and ponds from Massachusetts through Long Island, N.Y., in the fall and winter. The blue mussel fishery developed, especially in Massachusetts, in the last 10 years or so, when a market demand for them developed. They were harvested in coastal bays and from an ocean bed. Conchs have been harvested with pots. In 1990, the number of active fishermen on the molluscan beds was about 3,350 in the summer and 2,336 in the fall. A comparison of landings in the past with those in 1990 shows that several species have declined in abundance. Total production has declined from 3,712,000 bushels in 1901-02 to 2,380,000 bushels in 1990, when about 6% of landings were from hatchery-produced seed.

Massachusetts Division of Marine Fisheries. 2003. Densities of Early Benthic Phase Lobsters [Microsoft Excel Spreadsheet].
Abstract: A Excel spreadsheet showing the density (m^2) of early benthic phase lobsters in seven different sites in Boston Harbor between 1995 and 2003.
McBride HM, MJ Dean, and TB Hoopes. 2000. 2000 Massachusetts Lobster Fishery Statistics. Massachusetts Division of Marine Fisheries. Gloucester, Massachusetts. TR-9.
Abstract: This report is the thirty-forth annual publication of data compiled from the catch reports of licensed lobster fishermen. The number of licenses issued in 2000 totaled 2,167 commercial and 11,805 non-commercial. The commercial licenses are further broken down into coastal (1,541 licenses), offshore (534), and seasonal (92). In 2000, 15,022,011 pounds of lobster were reported landed by commercial lobstermen in Massachusetts, a 5.56% increase from 1999. This total was valued at $54,830340, a 7.83% decrease from 1999. Of that 15,022,011 lobsters reported, 9,855,003 were taken from the territorial waters of the Commonwealth (these include statistical areas #s 1-14, of which Boston Harbor is # 4). Essex County had the most lobsters landed of the territorial waters catch, followed respectively by Plymouth County, Barnstable County, Suffolk County, Norfolk County, and Bristol County. The report includes a table that lists the number of fishermen and pounds of lobster landed per home port. The home port of Boston had 55 licensed lobstermen and landed 481,157 pounds of lobster (inshore and offshore) in 2000. These landings rank the port of Boston as 12th in the state for pounds landed and reported. The first port on this table is Gloucester, with 2,892,254 pounds landed and reported. Recreational licenses issued in 2000 totaled 11,805, with 6,564 of these licensees reporting that they actually fished for lobster. Recreational landings totaled 327,541 pounds, only 2.18% of the commercial landings. The greatest harvest of lobster from territorial waters (Areas 1-14) was from the Boston Harbor vicinity, where approximately 21% of the state's territorial harvest was caught. Territorial landings were up 2.62% from 1999 landings. The average catch per trap haul for coastal lobstermen was 0.7256 pounds, an decrease from 1998.
McBride HM and TB Hoopes. 1999. 1999 Massachusetts Lobster Fishery Statistics. Massachusetts Division of Marine Fisheries. Gloucester, Massachusetts. TR-2.
Abstract: This report is the thirty-third annual publication of data compiled from the catch reports of licensed lobster fishermen. The number of licenses issued in 1999 totaled 2,164 commercial and 11,633 non-commercial. The commercial licenses are further broken down into coastal (1,549 licenses), offshore (526), and seasonal (89). In 1999, 15,905,731 pounds of lobster were reported landed by commercial lobstermen in Massachusetts, a 20.9% increase from 1998. This total was values at $59,487,434, a 24.91% increase from 1998. Of that 15,905,731 lobsters reported, 9,603,589 were taken from the territorial waters of the Commonwealth (these include statistical areas #s 1-14, of which Boston Harbor is # 4). Essex County had the most lobsters landed of the territorial waters catch, followed respectively by Plymouth County, Barnstable County, Suffolk County, Bristol County, and Norfolk County. The report includes a table that lists the number of fishermen and pounds of lobster landed per home port. The home port of Boston had 58 licensed lobstermen and landed 520,218 pounds of lobster (inshore and offshore) in 1999. These landings rank the port of Boston as 12th in the state for pounds landed and reported. The first port on this table is Gloucester, with 2,848,518 pounds landed and reported. Recreational licenses issued in 1999 totaled 11,633, with 8,948 of these licensees reporting that they actually fished for lobster. Recreational landings totaled 335,275 pounds, only 2.11% of the commercial landings. The greatest harvest of lobster from territorial waters (Areas 1-14) was from the Boston Harbor vicinity, where approximately 24.04% of the state's territorial harvest was caught. Territorial landings were up 25.52% from 1998 landings. The average catch per trap haul for coastal lobstermen was .8160 pounds, an increase from 1998.
McDowell, JE., Lancaster, BA., Leavitt, DF., Rantamaki, P., and Ripley, B. 1999. The effects of lipophilic organic contaminants on reproductive physiology and disease processes in marine bivalve molluscs. *Limnology and Oceanography.* 44, 3, part 2: 903-909.

Abstract: Marine bivalve molluscs such as the blue mussel (*Mytilus edulis*) and the soft shell clam (*Mya arenaria*) have been used as sentinel organisms of contaminant bioavailability and the biological consequences of contaminant exposure. Biological responses that may contribute to the impairment of reproductive and developmental processes include responses that can be categorized as interfering with bioenergetic processes such as feeding and nutrient allocation; biosynthetic processes, such as the synthesis of energy stores; and morphogenic processes, such as those involved in structural development. Case studies within New Bedford and Boston Harbors (Massachusetts) are used to examine the relationship between contaminant uptake and effects on the reproductive cycle and bioenergetics of mussels and soft shell clams. The results observed illustrate that disruption in bioenergetics in bivalve molluscs exposed to chemical contaminants can result in loss of reproductive output and increased susceptibility to disease. Differences in the extent of reproductive impairment may be linked specifically to energetic strategies of individual species.
Mitchell, DF., Maciolek, NJ., Hopkins, KM., and Wandland, KD. 1998. Biology of the lobster in Massachusetts Bay. Massachusetts Water Resources Authority. Boston. Report ENQUAD 1998-13. 83pp.

Abstract: The American lobster is a commercially important species that represents a major fishery in Boston Harbor and Massachusetts Bay. Public concern over the potential impact on the lobster of the secondary-treated effluent to be discharged to Massachusetts Bay prompted the present review of the biology of the lobster in this area. A risk assessment of the potential impacts to lobster populations in Massachusetts Bay was conducted with the following conclusions: (1) the ambient water quality criteria (AWQC) are protective of larval lobsters; (2) exposure of larval lobsters to effluent is likely to be limited due to the trapping of the plume below the pycnocline during summer months when lobster larvae are present in the surface water; (3) the habitat area for juvenile lobsters potentially affected by the outfall will be significantly reduced and shifted away from nearshore habitats; and (4) exposure of juvenile lobsters to the plume is unlikely based on the life history of the lobster, the diffuser design, and the plume's buoyancy. It is concluded that no significant potential risk is posed to the larval and juvenile life stages of the lobster from the MWRA outfall.
Mitchell, DF., Moore, MJ., and Downey, PC. 1996. 1995 annual fish and shellfish report. Massachusetts Water Resources Authority. Boston. Report 1996-03. 112pp.

Abstract: The MWRA continued to conduct its biomonitoring program for fish and shellfish in 1995, the goal of which is to obtain the baseline condition of three species (winter flounder, lobster, and blue mussel). Baseline conditions of the species collected were characterized in terms of biological parameters, the presence/absence of disease, and concentrations of organic and inorganic compounds in both edible and liver tissue. The external condition of the winter flounder showed few abnormalities and fin erosion levels were considered to be at the low end of the range and well below that observed in the late 1980s. Liver lesion prevalence has shown a significant decrease over the period 1987-1995. Neoplasia was absent in flounder except for one specimen. Elevated concentrations of DDTs and PCBs and reduced concentrations of chlordane were some of the trends that continued in 1995 from previous years. Edible tissue contaminant levels were well below federal legal limits. For the lobster specimens, little or no deleterious external conditions were noted on the lobsters. Most lobster tissue contaminant levels and spatial trends are consistent with previous years. All tested lobster tissue was observed to be well below the legal limits. Spatial and temporal trends in mussel contaminant levels were consistent with those observed in 1992-1994. The 1995 contaminant levels measured in mussel tissue were well below legal limits for consumption.
Mitchell, DF, Moore, MJ, and Downey, PC. 1997. 1996 annual fish and shellfish report . Massachusetts Water Resources Authority. Boston. Report 1997-10. 114pp.

Abstract: The purpose of the 1996 report was to further define the baseline conditions of three indicator species: winter flounder, lobster, and the blue mussel. The external condition of winter flounder samples showed few abnormalities and the amount of fin erosion observed was at the low end of the range and well below that observed in the late 1980s. Neoplasia was absent from fish collected in 1996 except in one specimen. In 1996, DDT and PCB concentrations were higher than in previous years but metals were generally similar to or lower than in previous years. Contaminant levels were well below the legal limits for consumption. In lobsters, no deleterious external conditions were noted (with one exception). Most lobster tissue contaminant levels were comparable to the range observed in previous years. Contaminant levels were well below the legal limits for consumption. The spatial and temporal trends observed in mussel contaminants were consistent with those observed in 1992-1995.

Moore, M. J., Smolowitz, R. M., and Stegeman, J. J. 1997. Stages of Hydropic Vacuolation in the Liver of Winter Flounder (*Pleuronectes americanus*) From a Chemically Contaminated Site. *Diseases of Aquatic Organisms.* 31, 1: 19-28.

Abstract: Hydropically vacuolated hepatic epithelia are abnormal cells prevalent in winter flounder from chemically contaminated habitats. These cells often have been associated with certain hepatic neoplasms. Here we define the 3 stages of the lesion and show an age and length-specific progression of each stage. The first cells to undergo vacuolation are centrotubular preductular cells. Intermediate stages involve entire hepatic tubules, and advanced stages consist of grossly visible foci of vacuolation that often encapsulate neoplastic foci. Vacuolation was found in fish from Boston Harbor, Massachusetts, USA, that were maintained on clean food and in clean water for 5 mo. These data are consistent with vacuolation being a persistent condition. The early involvement of preductular cells, possibly oval cell equivalents, the likely persistence of hydropic vacuolation after chemical exposure, and the close association of vacuolation to neoplastic foci, are consistent with suggestions that vacuolated cells may be Linked to hepatocarcinogenesis in these fish. Definition of 3 distinct stages of hydropic vacuolation suggests that the prevalence of each lesion stage may reveal temporal and spatial trends in environmental health in winter flounder and possibly other fishes.

Moore, MJ. 2003. Winter flounder ulcer final report for fish and shellfish monitoring. Massachusetts Water Resources Authority. Boston. Report ms-088. 16pp.

Abstract: This report is on the continuation of flounder monitoring as part of MWRA's HOM program. During the 2003 survey, a marked prevalence of ulcers was observed on the blind surface of a number of flounder. This was regarded as a novel finding. These lesions had not been noted in marked numbers prior to 2001 and the highest prevalence was observed in the Boston Harbor--western Massachusetts Bay region. Due to the general uncertainty about the specific etiology of skin lesions, it is not possible to determine the cause of the observed ulcerations of winter flounder.

Moore, MJ., Shea, D., Hillman, RE., and Stegeman, JJ. 1996. Trends in hepatic tumours and hydropic vacuolation, fin erosion, organic chemicals, and stable isotope ratios in winter flounder from Massachusetts, USA. *Marine Pollution Bulletin.* 32, 6: 458-470.

Abstract: Liver lesions including neoplasia and hydropic vacuolation have been described in winter flounder (*Pleuronectes americanus*) from sites in Boston Harbor, and were highly prevalent near the Deer Island sewage outfall. A marked decline in prevalence of neoplasia has been seen over the period 1987 to 1993 in fish from near the Deer Island outfall. This decline in disease in Deer Island fish correlated with and probably resulted from reported reduced chemical input over that time. Stable isotope ratios suggest that Deer Island winter flounder, in contrast to fish from elsewhere, fed significantly on sewage sludge-derived organic matter prior to 1992 and that their along-shore movement is slight. Between 1991 and 1993 hydropic vacuolation remained much more prevalent in flounder taken near Deer Island and another sewage outfall, than at sites distant (less than or equal to 45 miles) from the outfalls. Hydropic vacuolation prevalence correlated closely with content of chlorinated hydrocarbon residues in the liver, and in particular with DDT/DDD/DDE. This suggests that between 1991 and 1993 there was a persistent chemical-associated difference in fish from the planned and current outfall sites, and that monitoring of

winter flounder will provide necessary assessment of altered chemical carcinogenesis risk during and after the switch to the offshore outfall planned for 1998.

Myers, M. S., LL. Johnson, OP. Olson, CM. Stehr, BH. Horness, TK. Collier, and BB. McCain. 1998. Toxicopathic hepatic lesions as biomarkers of chemical contaminant exposure and effects in marine bottomfish species from the Northeast and Pacific coasts, USA. *Marine Pollution Bulletin.* 37, 1-2: 92-113.

Abstract: Relationships between toxicopathic hepatic lesions and chemical contaminants in sediments, stomach contents, liver and bile were evaluated in English sole, starry flounder and white croaker from 27 sites on the Pacific Coast, and winter flounder from 22 sites on the Northeast Coast of the USA, as part of the NOAA's National Benthic Surveillance Program (NBSP). Prevalences of and relative risks for most toxicopathic lesions were significantly higher in fish from contaminated sites in Puget Sound, the Los Angeles area, and San Francisco and San Diego Bays on the Pacific Coast, and in Boston Harbor, Raritan Bay and certain urban sites in Long Island Sound on the Northeast Coast. Exposure to polycyclic aromatic hydrocarbons (PAHs), PCBs, DDTs, chlordanes and dieldrin were significant risk factors for all lesion types in Pacific Coast species. In winter flounder from the Northeast Coast, exposure to PAHs, DDTs or chlordanes were significant risk factors only for hydropic vacuolation, nonneoplastic proliferative and nonspecific necrotic lesions, and less commonly for neoplasms and foci of cellular alteration. Risk of hepatic disease generally increased with fish age, but sex was rarely a risk factor. Temporal trends analyses of hepatic lesion prevalences in starry flounder, white croaker and English sole from NBSP sites on the Pacific Coast failed to detect any significant monotonic increases or decreases in lesion prevalence. Recent studies utilized a two-segment 'hockey-stick' regression technique applied to NBSP data to determine threshold levels of sediment PAHs, which are clearly associated with toxicopathic hepatic lesions in English sole. Significant chemical threshold levels for these lesions are in the vicinity of 500-1000 ppb ΓPAHs in sediment, values considerably lower than those reported for other techniques. Application of this dose-response model to these subacute and chronic lesions involved in hepatocarcinogenesis, provides nonlethal sediment quality assessment endpoints for contaminant concentrations that may have long term health implications for chronically exposed native fish populations. Overall, these relationships provide strong evidence for environmental contaminants as etiologic agents for hepatic lesions in several marine bottomfish species, and clearly indicate their utility as biomarkers of contaminant-induced effects in wild fish, whether in national and regional biomonitoring programs or within the injury assessment phase of the legal process of assessing damage to fishery resources.

National Oceanographic and Atmospheric Administration. Summary of Essential Fish Habitat Designation. *Webpage. Last accessed April 9, 2004.*

Abstract: The 1996 amendments to the Magnuson-Stevens Fishery Conservation and Management Act strengthened the ability of NMFS and the Councils to protect and conserve the habitat of marine, estuarine, and anadromous finfish, mollusks, and crustaceans. This habitat is termed "essential fish habitat" and is broadly defined to include "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity." The Act requires the Councils to describe and identify the essential habitat for the managed species, minimize to the extent practicable adverse effects on EFH caused by fishing, and identify other actions to encourage the conservation and enhancement of EFH. This site describes the specific life stages/species for which Boston Harbor is designated and EFH.

Nelson GA. 2003. 2002 Massachusetts Striped Bass Monitoring Report. Massachusetts Division of Marine Fisheries. Gloucester, Massachusetts. TR-19.

Abstract: During 2002, the commercial fishery for striped bass in Massachusetts harvested about 44,897 fish weighing 924,870 pounds. Total losses due to commercial harvesting (including release mortality) were 54,128 fish, weighing 1,011,283 pounds. The recreational fishery harvested about 309,582 striped bass weighing over 4.3 million pounds. Total losses due to recreational fishing (including release mortality) were 767,114 fish, weighing 8.2 million pounds. Combined losses (includes losses due to scientific sampling) were 821,242 fish weighing 9.2 million pounds, which reflects a 6% increase in

numbers lost and a 17.9% increase in weight lost compared to 2001 (773,038 fish; 7,800,929 pounds). The majority of losses, 93% by number and 89% by weight, was attributed to the recreational fishery.
Nelson GA, M Armstrong, and T Hoopes. 2000. Massachusetts 2000 Striped Bass Fisheries Monitoring Report. Massachusetts Division of Marine Fisheries. Gloucester, Massachusetts. **Abstract:** During 2000, the commercial fishery for striped bass in Massachusetts harvested about 40,256 fish weighing 779,736 pounds. Total losses due to commercial harvesting (including release mortality) were 52,798 fish, weighing 891,308 pounds. The recreational fishery harvested about 175,533 striped bass weighing over 2.5 million pounds. Total losses due to recreational fishing (including release mortality) were 747,019 fish, weighing 5,638,423 pounds. Combined losses (includes losses due to scientific sampling) were 800,846 fish weighing 6,537,732 pounds, which reflects an increase (43% by number) in losses compared to 1999 (557,943 fish; 4,778142 pounds). The majority of losses, 93% by number and 86% by weight, was attributed to the recreational fishery.
Nelson GA and T Hoopes. 2002. Massachusetts 2001 Striped Bass Fisheries Monitoring Report. Massachusetts Division of Marine Fisheries. Gloucester, Massachusetts. TR-11.
Abstract: During 2001, the commercial fishery for striped bass in Massachusetts harvested about 40,248 fish weighing 815,054 pounds. Total losses due to commercial harvesting (including release mortality) were 52,131 fish, weighing 933,410 pounds. The recreational fishery harvested about 288,032 striped bass weighing over 3.6 million pounds. Total losses due to recreational fishing (including release mortality) were 720,904 fish, weighing 6.8 million pounds. Combined losses (includes losses due to scientific sampling) were 773,038 fish weighing 7,800,929 pounds, which reflects a 3% decrease in numbers lost but is a 19.6% increase in weight lost compared to 2000 (800,847 fish; 6,534,931 pounds). The majority of losses, 93% by number and 88% by weight, was attributed to the recreational fishery.
Nobbe, G. 1998. Growing fish in Boston Harbor. *Wildlife Conservation.*
Abstract: Scientists at the Massachusetts Institute of Technology (MIT) have begun an urban aquaculture project in Boston Harbor. Five or ten years ago, aquaculture could not even have been contemplated because of pollution in the Harbor. Stiff pollution controls and a tunnel to carry effluent out into the bay make aquaculture a viable proposition. MIT scientists have already raised red drum, a species suitable for farming, and plan to experiment with fingerling native haddock.
Pala, S., Lefkovitz, LF., Moore, MJ., and Schaub, E. 2003. 2002 annual fish and shellfish report. Massachusetts Water Resources Authority. Boston. Report 2003-05. 176pp.

Abstract: The MWRA continued to conduct its biomonitoring program for fish and shellfish in 1998, the goal of which is to obtain the baseline condition of three species (winter flounder, lobster, and blue mussel). Baseline conditions of the species collected were characterized in terms of biological parameters, the presence/absence of disease, and concentrations of organic and inorganic compounds in both edible and liver tissue. The external condition of winter flounder showed few abnormalities. Age-corrected hydropic vacuolation prevalence suggests that there has been a steady system-wide reduction in contaminant-associated pathology in winter flounder in the past decade. In general, flounder contaminant levels were not significantly different during the post-discharge period than during the pre-discharge period. Contaminant levels detected in 2002 were well below the legal limits for consumption. The ratio of male to female lobsters varied drastically between stations and no deleterious external conditions were observed. The concentrations of most organic contaminants in lobster were similar to or lower than historical values, with many contaminants decreasing steadily since the late 1990s. Lobster contaminant levels were not significantly different during the post-discharge period than during the pre-discharge period. Mussel contaminant levels were determined to be lower than the legal limit for consumption.
Ryan, RL., Lachmayr, KL., Jay, JA., and Ford, TE. 2001. Developmental effects of PCBs on the hard clam (*Mercenaria mercenaria*). *Journal of Environmental Science and Health* . 36, 9: 1571-1578.
Abstract: Development of hard clam (*Mercenaria mercenaria*) larvae was examined as a potential biomarker of exposure to polychlorinated biphenyls (PCBs). Clams from clean sites in Massachusetts Bay were thermally induced to spawn in the laboratory using seawater, and the gametes were collected and

pooled by sex prior to fertilization. The larvae were cultured in seawater amended with Aroclor 1254, at concentration ranges bracketing environmentally relevant levels. A dose-response relationship was observed for larval development in the presence of Aroclor 1254; at higher doses, fewer larvae developed to the normal straight-hinge, or D-shaped stage, relative to the controls, while the number of abnormally shaped larvae increased.

Sheppard JJ, MP Armstrong, DJ McKiernan, and DE Pierce. 2003. Characterization of the Massachusetts Scup (*Stenotomus chrysops*) Fisheries. Massachusetts Division of Marine Fisheries. Gloucester, Massachusetts. TR-10.

Abstract: Throughout the 2001 fishing season (April-November), DMF personnel collected biological data (length and age) on scup through se sampling and port sampling from both the recreational and commercial fisheries in the Commonwealth. Biological data were collected from five different fisheries that target scup and from one fishery that targets *Loligo sp*., in which scup is a bycatch. In addition, DMF personnel collected length, weight, and age data from seafood dealers that process scup caught from local fishermen. Data collected were used to characterize landings and discards by length, age, and ratios of discards-to-landings for each fishery. Length frequency distributions and age keys were constructed for both landed and discarded catches of scup. Age data analyses indicated landings in each fishery were comprised mainly of age-3 and age-4 scup, whereas the majority of discards were comprised of age-2 fish. These results agree with those of the NEFSC 31st Stock Assessment Review Committee that predicted strong 1997, 1998, and 1999 year classes. Sea sampling results also suggested that discarding of scup was not a significant problem in the spring small-mesh otter trawl fishery. Discards-to-landings ratios generated from the commercial pot, hook, and line, and recreational fisheries were used to determine future sampling intensities using bootstrapping and other statistical techniques. State and federal seafood dealer transaction forms were collected and reviewed to determine level for fishing effort. Weirs constituted the majority of landings during spring, whereas the commercial hook and line fishery was the dominant fishery during summer and autumn seasons contributing over fifty percent of total landings of scup for the year. In addition, landings generated from seafood dealer transaction forms were compared to landings reported to DMF and to NMFS. Differences in landings estimates and reporting requirements were analyzed and discussed. Recommendations for improving reporting requirements are provided.

Smolowitz, R. and Leavitt, D. 1996. Neoplasia and other pollution associated lesions in *Mya arenaria* from Boston Harbor. *Journal of Shellfish Research (Abstract of Annual Meeting).* 520.

Abstract: Northeast coastal populations of *Mya arenaria*, the soft shell clam, are affected by Hematopoietic Neoplasia. High prevalences of this disease have been related to highly polluted waters by some researchers. Therefore, *Mya* was chosen to investigate as a possible biological monitor of pollution in Boston Harbor. Twenty animals were collected from 5 sites in Boston Harbor and 2 control sites in Cape Cod Bay. The occurrence of Hematopoietic Neoplasia in these samples was determined using a neoplasia cell specific antibody in a modified immunocytochemical staining method. In addition, paraffin embedded tissues were examined from each animal for other possible pathologies. Multivariant statistical methods were used to determine what pathologies were highly correlated with animals collected from polluted sites. Out of 33 possible pathologies, the occurrence of the following in *Mya* was highly correlated with population: gonadal inflammation, inflammation of the mantle, gill inflammation, gill hyperplasia, papilloma, kidney hyperplasia, brown cell accumulation in the renal epithelium, protozoal infection in the kidney, and pericardial gland changes. Hematopoietic Neoplasia was not positively correlated with site pollution. Surprisingly, 5/20 animals from only one polluted site showed a neoplasia not identified previously in *Mya*. This neoplasia appeared to be branchial in origin and had numerous metastatic nodules in other tissues. Whether this neoplasia was caused by pollution, an infectious agent, or a combination of causes, is not known.

Staffier, MM. 1997. Bioconcentration of eight metals by the mussel (*Mytilus edulis*) in Boston Harbor .

Abstract: The purpose of this study was to develop a mathematical model which relates the rate of bioconcentration of metals by the mussel Mytilus edulis with the concentration of labile metal in the surrounding seawater. It has been shown by Robinson and Ryan (1988) that not only is the mussel (*Mytilus edulis*) a qualitative indicator of marine pollution but, can also be used as a quantitative tool to estimate a particular contaminants seawater concentration. This can be done by examining the relationship between rate of accumulation and seawater concentration for a particular species. Studies such as the one done by Ritz *et al.* (1982) in which groups of *Mytilus edulis* were exposed to various concentrations of metals for a certain length of time, showed that the relationship between the rate of metal bioconcentration and metal seawater concentration was linear. Therefore by using the equation of the line it is possible to determine a particular metal's average seawater concentration by simply determining its rate of bioconcentration. A metal's rate of bioconcentration at a particular site can be determined by conducting a mussel transplant study. These studies involve transplanting groups of mussels taken from a clean site to a polluted site. By using literature derived bioaccumulation equations, a particular metal's average seawater concentration can then be determined. In this study the mathematical relationships described above will be tested by conducting field studies involving transplanted mussels.

Sung, W. 1999. Applying continuous-flow stirred tank reactor methodology to mussel biomonitoring & effluent discharge data. *Civil Engineering Practice.* 63-74.

Abstract: Bioconcentration factor measurements (BCFs) were used in the study of Boston Harbor wastewater treatment, placing various biomonitoring and discharge studies into context. A continuous-flow stirred tank reactor methodology was applied in the harbor to provide an easy evaluation of the total maximum daily loads using published water quality criteria. The use of BCFs permits the linking of mussel body concentrations of metals in receiving water concentrations, which in turn permits the calculation of mass loading rates or water exchange rates.

Terceiro M. 2003. Stock Assessment of Summer Flounder for 2003. NOAA Northeast Fisheries Science Center. Woods Hole, Massachusetts. NSFC Ref. Doc. 03-09.

Abstract: This assessment of the summer flounder (Paralichthys dentatus) stock along the Atlantic coast (Maine to North Carolina) is an update through 2002/2003 of commercial and recreational fishery catch data, research survey indices of abundance, and the analyses of the data. For 2002, commercial and recreational fishery quotas were 6,612,000 tons and 4,408,000 tons respectively, for a total of 11,020,000 tons. The reported commercial landings used in this assessment for 2002 were 6,407,000 tons, while estimated recreational landings were 3,610,000 tons, for a 2002 landings total of 10,017,000 tons. An analytical assessment of commercial and recreational total catch at age was conducted. Indices of recruitment and stock abundance were developed from NFSC winter, spring, and autumn, Massachusetts spring and autumn, Rhode Island annual, Connecticut spring and autumn, New Jersey annual, and Delaware annual trawl survey. Recruitment indices were also developed from young-of-the-year surveys conducted by the states of North Carolina, Virginia, and Maryland. The stock assessment indicates that the summer flounder stock is not overfished and overfishing is not occurring relative to the current biological reference points. The fishing mortality rate has declined from 1.32 in 1994 to 0.23 in 2002, below the overfishing definition reference point (F=0.26). There is an 80% chance that the 2002 F value was between 0.21 and 0.28. The estimate of F for 2002 may understate that actual fishing mortality; retrospective analysis shows that the current assessment method tends to underestimate recent fishing mortality rates (e.g., by about 40% over the past three years). Total stock biomass has increased substantially since 1989, and on January 1, 2003, was estimated to be 56,100,000 tons, 5% above the biomass threshold of 53,200,000 tons. There is an 80% chance that total stock biomass in 2003 was between 51,000,000 and 63,000,000 tons. Spawning stock biomass (SSB; Age 0+) declined 72% from 1983 to 1989, but has since increased eightfold, with improved recruitment and decreased fishing mortality. Retrospective analysis shows a tendency to slightly overestimate the SSB in the most recent years. The arithmetic average recruitment from 1982 to 2002 is 40 million fish at age 0, with a median of 35 million fish. The 2002 year class is currently estimated to be about average at 38 million fish. There is no consistent retrospective pattern in the estimation of the abundance of age 0 fish over the last three

years. If the landings for 2003 do not exceed the Total Allowable Landings (TAL) and the proportion of catch does not increase, the TAL in 2003 would need to be 12,790,000 tons to meet the target F rate of F_{max}=0.26 with 50% probability.

TRC Environmental Corporation. 2003. Environmental Report, Volume I: Resource Reports 1-13 Accompanying FERC Section 7C Application, Everett Extension Project. TRC Environmental Corporation. Lowell, Massachusetts.

Abstract: This environmental impact report includes a general project description of the Everett Extension Project, project maps, Soil Erosion Control Plan, Project Correspondence, Water Use and Quality Resource Report, Vegetation and Wildlife Resource Report, Socioeconomics Resource Report, Geologic Resources Report, Soils Resource Report, and Land Use, Recreation, and Aesthetics Resource Report, among a few other irrelevant appendices.

Data Available:

Grain-size Distribution of Near-Surface Sediments along the Everett Extension Route
Concentration of Heavy Metals and TOC in Near-Surface Sediments along the Everett Extension Route
Concentration of PAHs in Near-Surface Sediments along the Everett Extension Route
Concentration of Pesticides, PCBs, and TPH in Near-Surface Sediments along the Everett Extension Route
Temporal Distribution of Demersal Fishes and When Common or Abundant in Boston Harbor
Catch per Unit Effort in Otter Trawl Collections off Deer Island and Shrimp Trawls at Winthrop Harbor and the Airport
Temporal Distribution of Pelagic Fishes and When Common or Abundant in Boston Harbor
Catch per Unit Effort in Gill Net Collections from Massachusetts Bay, 1994 and 1995
Marine Waterbirds of the Massachusetts Bay, Coast and Islands
Federal and State Protected Species within 1/2 Mile of the Everett Extension
Seasonal Occurrences of Northern Right Whales in Cape Cod Bay, 1998-2002
Physical Characteristics of Soil Series/Map Unit Components Crossed by the Everett Extension

TRC Environmental Corporation. 2003. Environmental Report, Volume II: Resource Report Appendices Accompanying FERC Section 7C Application, Everett Extension Project. TRC Environmental Corporation. Lowell, Massachusetts.

Abstract: These appendices to the Environmental Impact Report include various maps and aerial photographs of the project area.

TRC Environmental Corporation. 2002. Implementation Plan: Algonquin Gas Transmission Company HubLine Pipeline Project. TRC Environmental Corporation. Lowell, Massachusetts.

U.S. Army Corps of Engineers, New England District. 2000. Section 404/10 Application: Executive Summary, Algonquin Gas Transmission Company HubLine Pipeline Project. Earth Tech, Inc. Concord, Massachusetts.

Abstract: This application, submitted in compliance with Section 404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act, includes a concise project description, a description of the affected environment, a summary of the potential impacts of the project, a description of the actions taken to minimize adverse effects, and a listing of the practicable alternatives.

Wahle R, R Glenn, P Lawton, D Robichaud, R Steneck, and C Wilson. 2002. New England Lobster Settlement Index: Update 2002.

Abstract: This sampling program aims to evaluate the strength of lobster year classes when they first arrive as post-larvae in shallow near-shore nurseries where they spend the first few years of life. The data are being generated to gain a better understanding of the role environmental factors play in determining regional population trends. The surveys are done by suction-sampling cobble-boulder nurseries (late-August in southern New England, mid-October in the north). Sixty-five sites are sampled from Beaver Harbor, New Brunswick to Point Judith, Rhode Island. One pattern discerned from the time series of data is that eastern Maine consistently has lower settlement than regions to the west or further east. The time

series is also beginning to suggest a coherence in annual fluctuations among some areas, particularly between geographically isolated areas. This suggests that there may be times when larger-scale oceanic/atmospheric processes dominate annual settlement trends, whereas at other times, more local processes dominate.

Wall, KL, Jessen-Eller, K., and Crivello, JF. 1998. Assessment of various biomarkers in winter flounder from coastal Massachusetts, USA. United States. *Environmental toxicology and chemistry.* 17, 12: 2504-2511.

Abstract: Since 1992, the Massachusetts Water Resource Association has organized a Fish Day to assess the health of winter flounder in Boston Harbor and nearby areas. This report describes the levels of metal contaminants and selected biomarkers in flounder from Fish Day. 1996. Mean age for males and females was 3.5 years, which is lower than the age reported for fish collected during previous efforts. Body weight/body length ratios were significantly higher in females versus males. Liver Cd. As, Zn, and Cu, and muscle As were all elevated relative to U.S. Environmental Protection Agency designations for marine fish liver and muscle tissue in all animals from all sites. Male flounder from Boston Harbor had significantly higher liver Cd levels than female flounder from Cape Cod and Boston Harbor. Female flounder from Boston Harbor showed significantly less metallothionein (MT) protein and lower liver metal levels than those from Cape Cod. Metallothionein mRNA did not significantly differ between sites nor did MT protein or mRNA between males and females from Boston Harbor. Cytochrome P450 2E1 (CYP2E1)-like and CYPIAI activities were significantly higher at optimal temperatures than activity measured at field temperatures. No differences between groups were observed for either parameter at ambient temperatures, but at optimal temperature(s). Boston Harbor females had significantly higher CYP2E1-like and CYP1A1 activities than Boston Harbor males. A negative correlation was found between maximal CYP1A1 activity and age for the Boston Harbor fish and a positive correlation for all fish between CYP2E1-like activity at ambient temperature and percent liver lipid. No differences were observed for liver lipid and microsomal protein between any of the groups. Liver glycogen showed a sex-dependent difference for the Boston Harbor group with levels in females significantly higher than males. These differences in contaminant levels and biomarkers are discussed within the context of data from previous Fish Days and the implications for flounder health within Boston Harbor.

Wintermyer, M., Leavitt, D., and McDowell, J. 1995. A settlement bioassay assessing the response of soft shell clam larvae to sediments from various sites in Massachusetts Bay. *The Biological Bulletin.* 189, 240-241.

Abstract: This report is part of a special section on papers presented at the general scientific meetings of the Marine Biological Laboratory on August 14-16. A settlement bioassay was used to evaluate the impacts of various levels of contaminated sediments from Massachusetts Bay on the survival and settlement of larvae of the soft shell clam (*Mya arenaria*). Hatchery-reared larvae of the soft shell clam were exposed to sediment collected from 5 sites in the bay, representing a range of polycyclic aromatic hydrocarbon levels. Filtered seawater and an artificial sediment made up of microbeads were used as controls. Regardless of the contaminant loading, each of the sediments could induce settlement of the larvae, and, with the exception of one sediment, larval mortality was not affected.

Zorpette, G. 1995. Lobster stew: dredging and reducing sewage may threaten a Boston harvest. *Scientific American.* 273, 32-34.

Abstract: Two large planned projects may have an adverse effect on the ecology of Boston Harbor, which supports a thriving lobster fishery. The projects, which are both scheduled for the next few years, are the dredging of shipping channels and berths and the rerouting of sewage outflows. The projects could add to pollution in the harbor while removing a food source for shrimp and lobsters.

HUMAN HEALTH, PATHOGENS, AND HARMFUL ALGAL BLOOMS

Ballester, NA, Fontaine, JH, Moore, AE, and Margolin, AB. 2001. Occurrence of phage and anthropogenic viruses in Boston Harbor using an enrichment and integrated cell culture PCR/nested PCR. *Abstracts of the General Meeting of the American Society for Microbiology.* 644.

Abstract: Over the past 5 years, MWRA has been monitoring their receiving waters for indicator bacteria, phage, and anthropogenic viruses to evaluate the impact of Boston's Deer Island Sewage Treatment Plant discharge. Originally, phage and enteric viruses were assayed using traditional double agar overlay and cell culture techniques. Recent advances in viral detection, using a two step enrichment procedure proposed for the Groundwater Rule for phage detection, and the use of an integrated cell culture-nested polymerase chain reaction (ICC-nPCR) for detection of enteric viruses (poliovirus, coxsackie virus, echovirus, rotavirus, adenovirus 40/41 and astrovirus), have permitted increased sensitivity and specificity for detection of both types of organisms. In the last 12-18 months, data has been collected on the presence of phage and enteric viruses using these new techniques. In the original analysis, 13 percent of the samples were positive for male-specific phage and 11 percent were positive for somatic phage. When samples taken from these same areas were evaluated by the enrichment procedure, approximately 80 percent were positive for male phage and 83 percent were positive for somatic phage. Two percent of the samples were positive for virus by the MPN method and 4% were positive by direct PCR. Reanalysis of these samples by ICC-nPCR demonstrated that more than 15% of the samples were positive for virus and several samples that were originally negative using the cell culture or direct PCR now demonstrated the presence of one or more viruses. Preliminary comparative results demonstrate that effective and efficient monitoring of anthropogenic contamination can be achieved using these more sensitive techniques.

Coughlin, K. and Stanley, A. M. 2001. Water quality at four Boston Harbor beaches: results of intensive monitoring 1996-2001. Massachusetts Water Resources Authority. Boston. Report 2001-18. 46pp.

Abstract: This report summarizes the results of five years of water quality monitoring at four Boston Harbor beaches: Constitution Beach in East Boston, Carson Beach in South Boston, Tenean Beach in Dorchester, and Wollaston Beach in Quincy. There were two goals for the study: (1) to characterize bacterial water quality at each beach and (2) to learn how rainfall affected water quality. Water samples were collected daily during the swimming season (late June through early September of each year) and analyzed for counts of fecal coliform and *Enterococcus.* All beaches met EPA criterion of a geometric mean of less than 35 colonies/100mL and met the MA state criterion for fecal coliform of a geometric mean of less than 200 colonies/100mL. Two beaches (Tenean and Wollaston) failed to meet the MA state *Enterococcus* criterion 10% of the time and frequently exceeded limits (during wet weather) set by MDC for swimming. None of the beaches was suitable for swimming at all times. Carson was the cleanest, followed by Constitution, Tenean, and Wollaston. Water quality at all four beaches was significantly worse during wet weather, but the relationship between water quality and rainfall was somewhat weak. However, an analysis of the relationship between antecedent 24-hour rainfall and bacteria levels did find a threshold of rainfall at which bacteria counts at each beach exceeded swimming standards. These thresholds were the same for fecal coliform and *Enterococcus* and the report reports those thresholds as a guidance for beach managers.

Gong, G, Lieberman, J, and McLaughlin, D. 1996. Statistical analysis of combined sewer overflow receiving water data, 1989-1995. Massachusetts Water Resources Authority. Boston. Report 1996-09. 52pp.

Abstract: The objective of this study was to test the hypothesis that sewage indicator bacteria counts in the CSO receiving water system have experienced statistically significant decrease over the period from 1989 to 1995, in response to systemwide improvements to the CSO drainage and treatment network during this period. A factorial analysis of variance (ANOVA) technique was developed to perform the statistical analysis, adding a randomized blocks procedure to account for competing environmental variability. This methodology utilizes advanced statistical techniques yet still falls under the realm of classical statistics. The analysis follows an approach which fully utilizes all available data by considering the entire receiving water system as a whole, and systematically accounts for naturally-occurring bacteria count variability by addressing five key variables which affect bacteria counts: sampling year, rainfall,

geographic location, tidal condition, and season. By following this approach, the statistical analysis is allowed to focus on isolating the temporal effect of CSO system improvements that have taken place between 1989 and 1995. This temporal effect is evaluated by comparing two time periods: 1989-1991 which represents conditions prior to implementation of the CSO system improvements and 1992-1995, which represents conditions after improvements have taken effect. The factorial ANOVA was successfully able to detect statistically significant temporal reductions in both fecal coliform and *Enterococcus*. The reduction is greatest under heavy rain conditions and smallest under dry conditions, which is consistent with the nature of improvements to the CSO system. Fecal coliform counts in the receiving water system are generally higher than *Enterococcus* counts; they exhibit a greater amount of temporal reduction and have a higher degree of statistical significance. Thus, the quantity of bacteria present appears to have an impact on the magnitude and statistical significance of temporal reductions attributed to CSO system improvements.

Gong, G, Lieberman, J, and McLaughlin, D. 1998. Statistical analysis of combined sewer overflow receiving water data, 1989-1996. Massachusetts Water Resources Authority. Boston. Report 1998-09. 120pp.

Abstract: CSO receiving water data were collected between 1989 and 1996 and were analyzed for counts of fecal coliform and *Enterococcus*. The objectives of this report are to select, apply, and evaluate statistical methods suitable for answering the question: has CSO receiving water quality improved despite natural variations in rainfall and other environmental factors, and, if so, at what level of statistical significance? A statistical methodology was developed which isolated the effect of CSO system improvements that have taken place, primarily during 1992. This methodology helped draw the following conclusions: (1) improvements to the CSO system resulted in a statistically significant reduction (36%) in fecal coliform counts across the receiving waters; (2) CSO improvements do not result in a statistically significant reduction in *Enterococcus* counts within the receiving waters; (3) a statistically significant temporal reduction in fecal coliform counts only occurs during wet weather, indicating that wet weather improvement to the CSO system have been primarily effective; and (4) *Enterococcus* count reductions did not occur under any rainfall condition.

Massachusetts Department of Public Health, Environmental Toxicology Program. 2003. Marine and Freshwater Beach Testing in Massachusetts, 2002 Season. Massachusetts Department of Public Health.

Abstract: This report summarizes beach monitoring and testing data from Massachusetts public and semi-public marine and freshwater beaches in the 2002 season. In total, 189 communities, 1,150 beaches, and 13,216 water samples were available for analysis. In general, the bathing beach water quality had a marked improvement between the 2001 and 2002 seasons. The report highlights the need for a consistent sanitary survey protocol, electronic submission of data, use of appropriate bacterial indicators, and tighter links between exceedences and beach postings. An electronic data reporting system and posting system on the world wide web, as well as a GIS inventory of beaches in Massachusetts, are being developed for marine beaches first. Such a system may follow for freshwater beaches in future seasons.

Massachusetts Department of Public Health, Environmental Toxicology Program. 2002. Marine and Freshwater Beach Testing in Massachusetts, 2001 Season. Massachusetts Department of Public Health.

Abstract: This report summarizes beach monitoring and testing data from Massachusetts public and semi-public marine and freshwater beaches in the 2001 season. In total, 179 communities, 879 beaches, and 12,851 water samples were available for analysis. The report highlights the need for a consistent sanitary survey protocol, electronic submission of data, use of appropriate bacterial indicators, and tighter links between exceedences and beach postings. A beach monitoring inventory and GIS database were created to organize and analyze the data, as well as to provide a template for future monitoring efforts.

Morrison, A. M., Coughlin, K., Shine, J. P., Coull, B. A., and Rex, A. C. 2003. Receiver Operating Characteristic Curve Analysis of Beach Water Quality Indicator Variables. *Applied and Environmental Microbiology.* 69, 11: 6405-6411.
Abstract: Receiver operating characteristic (ROC) curve analysis is a simple and effective means to compare the accuracies of indicator variables of bacterial beach water quality. The indicator variables examined in this study were previous day's *Enterococcus* density and antecedent rainfall at 24, 48, and 96 h. Daily *Enterococcus* densities and 15-min rainfall values were collected during a 5-year (1996 to 2000) study of four Boston Harbor beaches. The indicator variables were assessed for their ability to correctly classify water as suitable or unsuitable for swimming at a maximum threshold *Enterococcus* density of 104 CFU/100 ml. Sensitivity and specificity values were determined for each unique previous day's *Enterococcus* density and antecedent rainfall volume and used to construct ROC curves. The area under the ROC curve was used to compare the accuracies of the indicator variables. Twenty-four-hour antecedent rainfall classified elevated *Enterococcus* densities more accurately than previous day's *Enterococcus* density (P = 0.079). An empirically derived threshold for 48-h antecedent rainfall, corresponding to a sensitivity of 0.75, was determined from the 1996 to 2000 data and evaluated to ascertain if the threshold would produce a 0.75 sensitivity with independent water quality data collected in 2001 from the same beaches.
Rex, A. and Coughlin, K. 1995. Correlation between fecal coliform counts and *enterococcus* counts in Boston Harbor and its tributary rivers: variation with rainfall. *Abstracts of the General Meeting of the American Society for Microbiology.* 455.
Rex, AC., Coughlin, K., and DiPietro, P. 1997. Water quality at three Boston beaches: results of intensive monitoring, 1996. Massachusetts Water Resources Authority. Boston. Report 1997-01. 28pp.

Abstract: This study was an effort to develop a predictive measure, using rainfall, of bathing beach quality at three Boston Harbor beaches: Constitution Beach, Carson Beach, and Wollaston Beach. Water samples were collected daily during the swimming season and analyzed for counts of fecal coliform and *Enterococcus*. Daily rainfall measurements were made. The severity and frequency of bacterial pollution differed dramatically between the three beaches and among different locations at each beach. Dry weather pollution was a significant problem at some locations and high bacteria counts were associated with light to moderate rain at other locations. Elevated bacteria counts due to rain storms usually returned to acceptable levels after one day. The high variability in conditions associated with bacterial contamination makes it difficulty to establish a "rule of thumb" for weather conditions which should trigger beach postings. Continued monitoring and guidelines are recommended for precautionary postings after rain events.
Ricca, DM. 2000. Fecal indicators in Boston Harbor and in resident bird populations . University of Massachusetts, Boston. *PhD Dissertation.* 106.

Abstract: Sewage pollution problems in Boston Harbor are hard to rectify due to uncertainty over whether fecal indicators come from sewage or animal wastes, such as bird feces. Of 108 Boston Harbor water samples tested, somatic coliphages, fecal coliforms, enterococci and F-specific phages were present in 107, 105, 73 and 58 water samples respectively. The means of all samples, per 100 ml, were 196 pfu (range: 0-1833) for somatic coliphages, 101 cfu (0-2670) for fecal coliforms, 20 pfu (0-261) for F-specific phages and 3 cfu (0-32) for *Enterococci*. There was no apparent influence of season, salinity or proximity of marinas on coliphage counts. High numbers of F-specific phages from sewage but low counts of these phages in bird feces suggests sewage as a primary source of these phages to Boston Harbor. Feces from feral populations of pigeons, geese and herring gulls living around Boston Harbor contained up to 10^6 somatic coliphages, 10^8 enterococci and 10^9 fecal coliforms per gram of feces. F-specific phages were not detected in pigeons or geese. Three of 32 gulls expressed F-specific phages in their feces at no greater than 10^2 pfu/g. The presence of F-specific phages in the droppings of gulls but not in goose or pigeon feces suggests that a contaminated food supply may influence the presence of coliphages in animal feces.

Canada geese and pigeons expressed, and then eliminated, fecal phages in several days when given a meal of feed spiked with phage MS2. Large numbers of somatic coliphages in the feces of wild geese but small numbers of these phages in the feces of captive geese suggest environmental factors influence phage expression. Somatic coliphages in pigeon feces can fluctuate over several orders of magnitude in a day. Thus phage expression was more ephemeral than chronic. Several isolates of bacteria from sewage functioned as host to phages from sewage, yet no bacteria from dog feces were sensitive to phages from dog feces. This may indicate insufficient phage-host systems in animal gastrointestinal tracts to maintain large phage populations. The conjecture that F-specific phage concentrations track sewage pollution better than fecal coliforms, *Enterococci* or somatic coliphages is supported by the discovery of low numbers of F-specific phages in birds. The low numbers of F-specific phages detected in Boston Harbor shows that better means of concentrating phages from seawater samples will be needed. Coliphages in bird feces represent a source of fecal pollution that is not currently assessed using standard monitoring techniques. Since phage expression in bird feces was responsive to food contamination, potential contaminated food sources should be considered when assessing birds as a source of coliphages.

Ricca, DM. and Cooney, J. 1998. Coliphages and indicator bacteria in birds around Boston Harbor. *Journal of Industrial Microbiology and Biotechnology.* 21, 28-30.
Abstract: Droppings from feral populations of pigeons, geese and herring gulls from the urban/suburban environment around Boston Harbor, MA, USA contained up to 10^6 somatic coliphages, 10^8 enterococci, 10^9 thermotolerant coliforms and 10^2 F-specific coliphages per gram of feces. Somatic coliphages, *enterococci* and thermotolerant coliforms were common in the feces of all three kinds of birds but F-specific coliphages were found in droppings from only three of 32 gulls. Thus these sources of bacterial and viral Indicators should be considered when dealing with the ecology of fecal pollution Indicators. Moreover, microbial indicators of fecal or sewage pollution originating from bird droppings may be mistaken for indicators that come from humans. This may cause an overestimate of the hazard from human pathogens in water and confound attempts to locate sources of fecal or sewage pollution.
MARINE WILDLIFE AND ENDANGERED SPECIES

Brown, MW., OC. Nichols, MK. Marx, and JN. Ciano. 2002. Surveillance of North Atlantic Right Whales in Cape Cod Bay and adjacent waters - 2002. Center for Coastal Studies. Provincetown, Massachusetts. 75.

Abstract: In 2002, from aerial and shipboard efforts in all areas combined, there were 139 sightings of right whales, of which 135 right whales were photographed and analyzed for this report. Of those 135 photographed sightings, 54 were from Cape Cod Bay and state waters along the outer coast of Cape Cod between Chatham and Provincetown (39 from aerial surveys and 15 from vessel cruises), 30 were from aerial surveys of Stellwagen Bank/Wildcat Knoll, and 51 were from the Great South Channel. To date, of the 135 photographed sightings, 48 of 54 (88%) in Cape Cod Bay and adjacent state waters and 21 of 30 (70%) in Stellwagen Bank/Wildcat Knoll have been matched to an individual right whale. The 54 sightings from Cape Cod Bay consisted of at least 24 different right whales. There were 18 right whales identified from aerial and vessel surveys and five additional whales that have yet to be matched, but that do not match any of the 18 animals plus one right whale photographed in the Cape Cod Canal on 15 April that was not seen during surveys. The 30 photographed sightings on Stellwagen Bank/Wildcat Knoll represent 29 different whales of which 21 have been matched to an individual in the catalogue. Of note is one of the identified whales (#1145), an adult female, which was seen with a calf. This mother calf pair was not recorded during any other surveys or on the calving ground in the southeast US. Our sighting of the calf brings the annual reproduction total for 2002 to 22 calves. Only one whale was seen on more than one occasion (#1424, an entangled right whale) and there remain eight individuals to be matched. There were 51 photographed sightings obtained in the great South Channel aerial surveys. Of those, only four

whales, two mother calf pairs also seen on the calving grounds, have been matched. The presence of right whales in nearby areas outside of the critical habitats of either Cape Cod Bay or the Great South Channel in 2002 and in past years suggests that a re-evaluation of the area protected by the ESA Critical Habitat designation is needed and timely enough to adequately reflect the distribution and movements of right whales. Consideration should be given to changing the boundaries of the neighboring Cape Cod Bay and Great South Channel Critical Habitats to include those areas of seasonal importance to right whales. The report recommends that the data collected in the Stellwagen Bank/Wildcat Knoll area over the past five years be assessed using sightings-per-unit-effort analysis to determine the density and seasonality of right whale use and that the area be considered a target for habitat sampling to assess the conditions of the food resources and for passive acoustic monitoring equipment to augment visual sightings.

McLeod, LA. 1999. Summary of marine mammal observations during 1998 surveys. Massachusetts Water Resources Authority. Boston. Report 1999-01. 9pp.

Abstract: Since 1995, MWRA has included marine mammal observers on monitoring surveys to verify the presence and absence of right whales in the vicinity of the outfall. These observations are required as part of the discharge permit and to assess the potential environmental impacts of effluent discharge. Observers also conducted observations for other marine mammals. During the 1998 monitoring year, 23 individual whales (5 humpback, 3 right, 5 minke, and 9 unidentifiable whales) were observed. Eight of these sightings were within the Stellwagen Bank Marine Sanctuary and six whales were spotted in the vicinity of the Nearfield. These data are consistent with the previous years' sightings. Marine mammal observers sighted 19 harbor seals and one Grey seal during the winter and spring seasons. Between 23 and 32 dolphins were observed in 1998.

McLeod, LA. 2001. Summary of marine mammal observations during 2000 surveys . Massachusetts Water Resources Authority. Boston. Report 2001-01. 11pp.

Abstract: Since 1995, MWRA has included marine mammal observers on monitoring surveys to verify the presence and absence of right whales in the vicinity of the outfall. These observations are required as part of the discharge permit and to assess the potential environmental impacts of effluent discharge. Observers also conducted observations for other marine mammals. During the 2000 monitoring year, 55 individual whales (29 humpback, 4 finback, 3 minke, and 19 unidentifiable whales) were observed. 47 of these sightings were within the Stellwagen Bank Marine Sanctuary. These data are consistent with the previous years' sightings. No right whales were sighted during these surveys, however, which is different than the previous two years. Marine mammal observers sighted 65 harbor seals during the winter and spring seasons. Only 10 dolphins were observed in 2000, which is a marked difference from previous years.

McLeod, LA. 2002. Summary of marine mammal observations during 2001 surveys . Massachusetts Water Resources Authority. Boston. Report 2002-01. 13pp.

Abstract: Since 1995, MWRA has included marine mammal observers on monitoring surveys to verify the presence and absence of right whales in the vicinity of the outfall. These observations are required as part of the discharge permit and to assess the potential environmental impacts of effluent discharge. Observers also conducted observations for other marine mammals. Marine mammal observers were present on 29 water quality surveys in 2001. During the 2001 monitoring year, the following were observed: 7 right whales, 4 humpback whales, 4 minke whales, and 5 unidentifiable whales. The total number of whales sighted (n=20) is considerably less than the number reported during the previous two years. This may be due to changes in sampling routes, resulting in less time spent in the Stellwagen Bank area, where most whales had been observed in previous years. Marine mammal observers also sighted 138 harbor seals throughout the 2001 sampling season. The report speculates on the reasons behind the differences in the number of whales sighted between the past few years. One reason could be the

opportunistic nature of the observations (no line transect methodology is employed). Another reason could be that whale numbers are known to naturally fluctuate in response to prey density and distribution.
McLeod, LA., Hunt, TE., and Asmutis-Silvia, RA. 2000. Summary of marine mammal observations during 1999 surveys. Massachusetts Water Resources Authority. Boston. Report ENQUAD 2000-01. 11pp.

Abstract: Since 1995, MWRA has included marine mammal observers on monitoring surveys to verify the presence and absence of right whales in the vicinity of the outfall. These observations are required as part of the discharge permit and to assess the potential environmental impacts of effluent discharge. Observers also conducted observations for other marine mammals. During the 1999 monitoring year, 59 individual whales, 10 harbor porpoises, and over 56 Atlantic white-sided dolphins were directly observed. Included in these sightings were 2 right whales, 12 humpback whales, 27 finback whales, 4 minke whales, and 14 unidentifiable whales. Forty-nine of the whale sightings were within the boundaries of the Stellwagen Bank Marine Sanctuary and two were sighted in the vicinity of the nearfield. At least one large baleen whale was sighted in the vicinity of the outfall diffuser in 1998 and 1999. Twenty-five harbor seals were also observed during the winter and spring seasons. Sightings of large baleen whales, pinnipeds, and dolphins were comparable with the previous year. However, harbor porpoises were sighted only in 1999. It is also notable that for the third time since 1984, no mother-calf pairs were observed in Cape Cod Bay during the 1999 monitoring season.

McLeod, LA., Short, L., and Smith, J. 2003. Summary of marine mammal observations during 2002 surveys. Massachusetts Water Resources Authority. Boston. Report 2003-01. 21pp.

Abstract: Since 1995, MWRA has included marine mammal observers on monitoring surveys to verify the presence and absence of right whales in the vicinity of the outfall. These observations are required as part of the discharge permit and to assess the potential environmental impacts of effluent discharge. Observers also conducted observations for other marine mammals. Marine mammal observers were present on 29 water quality surveys in 2002 and one benthic survey. During the 2002 monitoring year, the following were observed: 2 right whales, 7-10 humpback whales, 1 minke whale, 3 finback whales, and 3 unidentifiable whales. The total number of whales sighted (n=16-19) is similar to the number reported in 2001. Observations of large baleen whales were considerably less (n=6) than in previous years (1998-2001). Dolphin sightings in 2002 totaled only 10-13, the lowest number since 1998. Marine mammal observers also sighted 138 pinnipeds throughout the 2002 sampling season. The low number of baleen whales sighted is corroborated by other independent reports of low humpback and minke whale use for much of the season. A comparison of pre-discharge and post-discharge marine mammal sightings is made in the report, and this showed that the number of whales sighted were similar in the Nearfield, Farfield, and Cape Cod Bays for the two years prior and two years after the start of the outfall. However, sightings in Stellwagen Bank have been noticeably lower since the divergence of the outfall.
National Heritage Endangered Species Program. 2003. Atlantic Sturgeon (*Acipenser oxyrinchus*). Massachusetts Division of Fish and Wildlife. Westborough, Massachusetts. 1p.

Abstract: A brief description of the endangered species, including its habitat, food, life history, and threats. However, it is unlikely that Atlantic Sturgeon would be impacted by the Boston Harbor projects, as they are only found in the Merrimack and Taunton rivers.
National Marine Fisheries Service, Southeast Fisheries Science Center. 2001. Stock assessments of loggerhead and leatherback sea turtles and an assessment of the impact of the pelagic longline fishery on the loggerhead and leatherback sea turtles of the Western North Atlantic. U.S. Department of Commerce. NOAA Tech. Memo NMFS-SEFSC-455. 343 pp.

Abstract: This report concerns the status and condition of the loggerhead and leatherback sea turtle stocks in the Western North Atlantic. Since neither of these species breeds in the Boston Harbor--Massachusetts Bay area, the foraging and migratory sections of the report are the most relevant. In addition, leatherback turtles are the species most likely to occur in the study area. The report discusses the geographic range of the leatherback, seasonal distributions, population size and status, age and growth, sex ratios, strandings, and anthropogenic impacts. A second section of the report includes a study on the impact that longline fisheries have on these species, including an analysis of the marine turtle bycatch by the U.S. Atlantic pelagic longline fleet, the sizes of sea turtles incidentally captured in pelagic longline fisheries, a review of post-capture mortality and selected mortality rates, and a summary of take incidents in the selected regions.

National Marine Fisheries Service Stock Assessment Program. 2002. Blue Whale *(Balaenoptera musculu*s): Western North Atlantic Stock. 3pp.

Abstract: This report describes information available about the Western North Atlantic stock of the Blue whale, as of January 2002. Topics covered include geographic range, population size, productivity rates, annual mortality, and stock status.

National Marine Fisheries Service Stock Assessment Program. 2002. Fin Whale *(Balaenoptera physalu*s): Western North Atlantic Stock. 6pp.

Abstract: This report describes information available about the Western North Atlantic stock of the fin whale (*Balaenoptera physalu*s), as of January 2002. Topics covered include geographic range, population size, productivity rates, annual mortality, and stock status. New England waters represent a major feeding ground for the fin whale and studies have shown that fin whales feeding in these waters exhibit patterns of seasonal occurrence and annual return (site fidelity). The abundance estimate for the Western North Atlantic stock of fin whales is approximately 2,814; however, this is thought to be a conservative estimate given the known range of the fin whale and population structure uncertainties. Based on theoretical modeling, the maximum net productivity rate is assumed to be 4%. A review of anecdotal records from 1996 to 2000 yielded an average of 1.6 human-caused mortalities per year, 0.4 per year resulting from fishery interactions/entanglements (USA and Canada) and 1.2 due to vessel collisions (USA waters). This species is listed as endangered under the Endangered Species Act.

National Marine Fisheries Service Stock Assessment Program. 1998. Sei Whale (*Balaenoptera borealis*): Western North Atlantic Stock. National Marine Fisheries Service. 3pp.

Abstract: This report describes information available about the Western North Atlantic stock of the sei whale (*Balaenoptera borealis*), as of December 1998. Topics covered include geographic range, population size, productivity rates, annual mortality, and stock status. Nova Scotian waters represent a major feeding ground for the fin whale, although their range does stretch south to the Gulf of Maine and Georges Bank. The abundance estimate for the Western North Atlantic stock of fin whales is unknown but can be based on previous estimates from the 1970s at between 1,393 and 2,248 sei whale individuals. However, there is a high degree of uncertainty on these numbers. Based on theoretical modeling, the maximum net productivity rate is assumed to be 4%. There were no reported fishery-related mortality or serious injury to sei whales observed by NMFS during 1991-1997. One mortality was reported by the New England Aquarium in 1994. The sei whale is listed as an endangered species under the Endangered Species Act.

Parsons, K. C., Schmidt, S. R., and Matz, A. C. 2001. Regional patterns of wading bird productivity in northeastern U.S. estuaries. *Waterbirds, vol. 24.* 323-330.

Abstract: We investigated wading bird productivity in four estuaries from Delaware Bay to Boston Harbor in northeastern U.S.A. over the period 1986-1998. To document and characterize reproductive performance of numerically dominant species for use in wildlife and habitat management planning, we recorded 1) number of eggs laid, 2) percent of eggs hatched, 3) percent of hatchlings surviving 10-15 days post-hatch, 4) number of nestlings produced, and 5) factors of offspring mortality in nests of Black-crowned Night Heron (*Nycticorax nycticorax*), Snowy Egret (*Egretta thula*), Cattle Egret (*Bubulcus ibis*), and Glossy Ibis (*Plegadis falcinellus*). We randomly selected 30-50 nests of each species (as available) for study at colonies in Delaware Bay (1993-1998), New York Harbor (1986-1994), Cape Cod (1990-94), and Boston Harbor (1993-94). In addition, we recorded abundance of nesting wading birds and avian predators in most years of study. Colony size ranged from 120-8,300 nests. Clutch size of all species was greater at northern-most sites. Loss of eggs varied between estuaries for all species except Glossy Ibis. Hatching success ranged from 75-88% and differed between estuaries for Black-crowned Night Heron and Glossy Ibis. Hatchling survival ranged from 16-87% and was lowest in Delaware Bay for all species. Nestling production was lowest in Delaware Bay for all species. In general, predation was high in Delaware Bay and egg inviability was high in Boston Harbor. Predation of nestlings was greatest in Delaware Bay for Cattle Egret, but there were no differences between estuaries for other species. Proportions of avian predators to nesting herons did not explain high predation rates in Delaware Bay.

Parsons, KC., Matz, AC., Hooper, MJ., and Pokras, MA. 2000. Monitoring wading bird exposure to agricultural chemicals using serum cholinesterase activity. *Environmental Toxicology and Chemistry.* 19, 5: 1317-1323.

Abstract: Organophosphorus (OP) and carbamate (CB) insecticides are widely used and have a variety of lethal and sublethal effects on nontarget wildlife, primarily through cholinesterase (ChE) inhibition. To assess possible exposure to anti-ChE compounds in wading birds, we monitored breeding colonies in northeast U.S. estuaries (Boston Harbor, MA; New York Harbor, NY; Nantucket Sound, MA; Delaware Bay, DE; and Rehoboth Bay, DE) from 1991 to 1996. We documented serum ChE activities in black-crowned night-heron (*Nycticorax nyticorax*), cattle egret (*Bubulcus ibis*), snowy egret (*Egretta thula*), little blue heron (*E. caerulea*), and glossy ibis (*Plegadis falcinellus*), and we investigated factors known to affect ChE, including age, nutritional and immune status, location of the colony (estuary), and exposure to ChE-inhibiting compounds. Exposure to anti-ChE compounds in all species was supported by at least one of the following: positive pyridine-2-aldoxime methochloride (2-PAM; OP) and/or spontaneous (CB) ChE reactivations, negative or nonsignificant age correlations in most species, or regional land-use patterns. We observed negative or nonsignificant relationships between ChE and age in most species. Only glossy ibis showed the age-related patterns of ChE activity observed in other altricial species. Of the remaining potential explanatory factors, location (estuary) but not nutritional or immune status was the only one having a significant relationship with ChE activity ($p < 0.024$). Significant differences among colonies were consistent with surrounding land uses, specifically active agriculture. We conclude that extensive monitoring of serum ChE in wildlife can identify locations of exposure and provide reference data for wildlife pesticide-risk assessment.

TRC Environmental Corporation. 2003. Environmental Report, Volume I: Resource Reports 1-13 Accompanying FERC Section 7C Application, Everett Extension Project. TRC Environmental Corporation. Lowell, Massachusetts.

Abstract: This environmental impact report includes a general project description of the Everett Extension Project, project maps, Soil Erosion Control Plan, Project Correspondence, Water Use and Quality Resource Report, Vegetation and Wildlife Resource Report, Socioeconomics Resource Report, Geologic Resources Report, Soils Resource Report, and Land Use, Recreation, and Aesthetics Resource Report, among a few other irrelevant appendices.

Data Available:

Grain-size Distribution of Near-Surface Sediments along the Everett Extension Route

Concentration of Heavy Metals and TOC in Near-Surface Sediments along the Everett Extension Route

Concentration of PAHs in Near-Surface Sediments along the Everett Extension Route
Concentration of Pesticides, PCBs, and TPH in Near-Surface Sediments along the Everett Extension Route
Temporal Distribution of Demersal Fishes and When Common or Abundant in Boston Harbor
Catch per Unit Effort in Otter Trawl Collections off Deer Island and Shrimp Trawls at Winthrop Harbor and the Airport
Temporal Distribution of Pelagic Fishes and When Common or Abundant in Boston Harbor
Catch per Unit Effort in Gill Net Collections from Massachusetts Bay, 1994 and 1995
Marine Waterbirds of the Massachusetts Bay, Coast and Islands
Federal and State Protected Species within 1/2 Mile of the Everett Extension
Seasonal Occurrences of Northern Right Whales in Cape Cod Bay, 1998-2002
Physical Characteristics of Soil Series/Map Unit Components Crossed by the Everett Extension

TRC Environmental Corporation. 2003. Environmental Report, Volume II: Resource Report Appendices Accompanying FERC Section 7C Application, Everett Extension Project. TRC Environmental Corporation. Lowell, Massachusetts.
Abstract: These appendices to the Environmental Impact Report include various maps and aerial photographs of the project area.
Weinrich, MT., Belt, CR., and Morin, D. 2001. Behavior and ecology of the Atlantic white-sided dolphin (*Lagenorhynchus acutus*) in coastal New England waters. *Marine Mammal Science.* 17, 231-248.
Abstract: Atlantic white-sided dolphins (*Lagenorhynchus acutus*) are among the most abundant, and least studied, cetaceans in coastal New England. Between April and October 1984 through 1997 we sighted 1,231 groups of Atlantic white-sided dolphins, primarily on Stellwagen Bank and Jeffreys Ledge (two shallow glacial deposits along the coasts of Massachusetts, New Hampshire, and Maine). Mean group size was 52 (+/-90.9), and was significantly larger from August through October (71.9 +/- 111.4) than April through June (35.0 +/- 45.4). Calf sightings were uncommon until June and July, after which they were present in over 50% of groups. Combined with observations of apparent newborn calves, this confirms that early summer is an important calving period. The presence of calves did not, however, solely account for the increase in group size. Boat interaction (bow- and stern-wake riding) was the most commonly recorded behavior (47.4% of sightings), followed by traveling (31.4%), interactions with other cetacean species (27.6%), social interaction (15.5%), and feeding (9.5%). While feeding was uncommon, one observation of apparently coordinated "ball" feeding was seen with sand lance (*Ammodytes* spp.) as the visible prey. Aerial behavior showed a positive correlation with group size, although it was often impossible to tell whether the same dolphins were leaping repeatedly. Eighty-eight dolphins were photo-identified using either unusual body pigment or a distinctive dorsal fin. While several individuals were reidentified between years and between areas, no reidentifications were made within a year in the same area. Unusually pigmented individuals were much more likely to be reidentified than those with distinctive dorsal fins, most likely due to higher visibility. We suggest that Atlantic white-sided dolphins are generally using the study area as transients in what appears to be a large home range.
Wennemer, J., Gagnon, C., Boye, D., and Gong, G. 1998. Summary of marine mammal and turtle observations during the 1997 nearfield water quality surveys. Massachusetts Water Resources Authority. Boston. Report 1998-03. 17pp.

Abstract: Since 1995, MWRA has included marine mammal observers on monitoring surveys to verify the presence and absence of right whales in the vicinity of the outfall. These observations are required as part of the discharge permit and to assess the potential environmental impacts of effluent discharge. Observers also conducted observations for other marine mammals. During the 1997 nearfield water quality surveys, three unidentified whales and one minke whale were sighted, along with two harbor porpoises, four unidentified dolphins, and three unidentified seals. During the farfield survey, one

unidentified whale, two minke whales, 3-5 fin whales, and 2-3 humpback whales were sighted, along with one harbor seal.

PARKLAND, SANCUTARIES, AND BEACHES DATA AND INVESTIGATIONS

Executive Office of Environmental Affairs, Commonwealth of Massachusetts. 2004. Protected and Recreational Open Space in Boston Harbor and Surrounding Area. GIS Datalayers.
Abstract: These are GIS ArcView datalayers of the MDC- and DEM-owned land in Boston Harbor and the immediate surrounding area. Attribute tables are included.

PHYSICAL OCEANOGRAPHIC DATA AND INVESTIGATIONS

Butman, B., Signell, RP., Bothner, MH., and List, JH. 1996. Predicting Sediment Transport and the Fate of Contaminants in Massachusetts Bay. Boston, Massachusetts. U.S. Geological Survey Fact Sheet FS 172-97. *COASTAL ZONE '97: The Next 25 Years (Conference Proceedings).* 6.

Abstract: The transport and accumulation of sediments in the Massachusetts Bays is determined principally by the residual circulation, major storms, the bathymetry, and the geometry of the semi-enclosed basin. The mean current, driven principally by the along-shore coastal current in the western Gulf of Maine, proceeds in a counterclockwise direction around Massachusetts Bay. Superimposed on this residual flow pattern are tidal, density, and wind-drive currents that can alter the direction and speed of residual flow on a daily basis. Northeast storms generate large swells that propagate into Massachusetts Bay from the Gulf of Maine. The oscillatory currents associated with these waves cause resuspension of bottom sediments in water depths less than about 50 m over areas exposed to the northeast, principally along the western shore of Massachusetts Bay. The near-bottom currents associated with the northeast winds are to the south and offshore and carry the resuspended material southward toward Cape Cod Bay and offshore into Stellwagen Basin. The area to the west of Cape Cod is sheltered from the large swell associated with northeasters, and the waves are rarely large enough to resuspend the sediments in the deep Stellwagen Basin. Sediments that are transports to these two areas from the western side of Massachusetts Bay, by the residual circulation or the storm-driven currents, are less likely to be resuspended again, and thus these areas are long-term sinks for fine sediments and associated contaminants. This conceptual model is supported by direct observations of currents and sediment resuspension during storms, wave and 3D current modeling, by the observed accumulation of fine-grained sediments in Cape Cod Bay and Stellwagen Basin, and by the lack of fine sediment along the western shore of Massachusetts Bay. The model is also consistent with the distribution of silver and Clostridium perfringens spores, most likely input to the Massachusetts Bays from Boston's sewage system. The role of internal waves, a potential mechanism for resuspending sediments in Stellwagen Basin in the summer, remains to be determined.

Buynevich, I. V., Fitzgerald, D. M., Smith, L. B., and Dougherty, A. J. 2001. Stratigraphic Evidence for Historical Position of the East Cambridge Shoreline, Boston Harbor, Massachusetts. *Journal of Coastal Research.* 17, 3: 620-624.
Abstract: Sediment cores were used to examine the stratigraphy at a site in East Cambridge, Massachusetts to ascertain its environment and the original shoreline position prior to artificial filling. Through the analysis of historical charts, sediment characteristics, and salt marsh plant species, it was determined that over 70%, of the study area were above mean-high water prior to urban development. The fibrous nature of peat immediately underlying the fill material and the in-situ remains of *Spartina patens* and *Distichlis spicata* indicated a high marsh environment. The fact that the supratidal peat is below the present mean-high water is clue to a combination of: (1) sea-level rise since the artificial infilling of the marsh in 1880-90s; (2) possible removal of marsh peat prior to filling; (3) compaction of peat by overlying anthropogenic fill, and (4) compaction and subsidence of underlying sediments. This study provided convincing physical evidence, of the historic shoreline position that was necessary to establish former tideland boundaries.

HydroQual. 2003. Bays Eutrophication Model (BEM): Model Verification for the Period 1998-1999. Massachusetts Water Resources Authority. Boston. Report 2003-03. 318pp.

Abstract: The Bays Eutrophication Model (BEM) was used to assess the potential impact of the relocation of the effluent discharges from Boston's Nut and Deer Island WWTPs to the outfall. This report provides a summary of the modeling analysis conducted for the years 1998 and 1999 and determined how well the previously calibrated BEM could reproduce the conditions that occurred in 1998 and 1999. The unique events that occurred in those years were the lack of a spring bloom in 1998 and low DO levels in 1999. It was discovered that, although the model overpredicts the productivity in Boston Harbor, the model did a fair job of reproducing water quality conditions in Massachusetts and Cape Cod Bays. The report recommends that the BEM continue to be applied and refined using the water quality data provided by the ongoing HOM program. Work should be done on improving the calibration of the fall diatom group, reducing the number of field sampling stations, and correcting the phytoplankton estimates in the harbor.

HydroQual and Signell, RP. 2001. Calibration of the Massachusetts and Cape Cod Bays Hydrodynamic Model: 1998-1999. Massachusetts Water Resources Authority. Boston. Report 2001-12. 170pp.

Abstract: The MWRA, as part of its discharge permit for the Deer Island Wastewater Treatment Plant, is required to use the coupled hydrodynamic/water quality model developed for Massachusetts and Cape Cod Bay to analyze impacts of the treatment effluent on the bays following the September 6, 2000 startup of the offshore outfall. This report contains the final calibration of the hydrodynamic model for the years 1998 and 1999. The report also includes the model inputs and the calibration process. Some modifications were made to the model to enhance its performance. Observations were made that the model computed very high temperatures in the surface layer during the warmer months of the year. This prompted a modification to the heat flux code and allowed more short wave radiation to penetrate deeper into the water column. The calibrated model itself performs well overall. The model produces the seasonal trends observed in the data, as well as some of the short-term events. Based on the analysis of the hydrodynamic model calibration, the following conclusions can be made. 1998 and 1999 are very different years in terms of temperature and salinity and provide a good test of the model's flexibility and applicability to year-to-year variations. The average meteorological and river gage data were adequate to specify these inputs to the model. Modifications to the way solar insulation is distributed vertically in the water column improved the hydrodynamic model's ability to reproduce temperature data. The current hydrodynamic model calibration should be adequate for use as input to the water quality model.

Jones, JR., Cameron, B., and Willey, KL. 1995. Shape shifting: an analysis of clast sphericity from sediment source to sink on a drumlinoid island, Boston Harbor, Massachusetts. *Northeastern Geology and Environmental Sciences.* 17, 2: 162-169.

Abstract: Indices of sphericity were determined from principle axes lengths (a-, b-, c-) of granodiorite clasts sampled from a drumlin island cliff source and compared with clasts of the same lithology on an adjacent northeast exposed beach at Thompson Island, Boston Harbor, Massachusetts. The purpose of this study was (1) to test for significant differences between clasts of the two deposits in regards to sphericity and axes lengths before erosion from the drumlin cliff source and after deposition on the beach; (2) to test if clast sorting by shape and axes length occurred within the beach zone at the berm, the mid-tide line and the low-tide line. The dominant Zingg shape classes for the drumlin clasts and the beach clasts were bladed and prolate (rods) with an average maximum projection sphericity of 0.54 and 0.55, respectively. Significant differences ($p<0.05$) did not emerge for the four Zingg class shapes, the maximum projection sphericity, the b-axis lengths and the c-axis lengths among the beach zone sampling stations. Although differences in clast shape and axes lengths were not found between the drumlin cliff source and the beach samples, there is apparently clast shape and axes length sorting occurring within the beach zone samples by wave action. The more spherical shaped and longer b- and c-axis length clasts are associated with

lower wave energy beach conditions while the less spherical and shorter b-axis and c-axis lengths clasts are associated with higher wave energy beach conditions.

Kelly, J. R. and Doering, P. H. 1999. Seasonal deepening of the pycnocline in a shallow shelf ecosystem and its influence on near-bottom dissolved oxygen. *Marine Ecology Progress Series.* 178, 151-168.

Abstract: A 3 yr record (1992 to 1994) of dissolved oxygen (DO) concentrations from an intensive grid of 21 sampling stations in a ~100 km^2 study area of western Massachusetts Bay (~25 to 50 m water depth) showed a regular seasonal decline in bottom waters during stratification, but considerable spatial and temporal variability within and across years. Mean near-bottom, subpycnocline DO concentrations for the area reached 7.57, 7.85, and 6.2 mg l^{-1} in mid October 1992, late September 1993, and late September 1994, respectively; individual station readings were as low as 4.8 mg l^{-1} in 1994. Overall stratified-season rates of subpycnocline DO decline were ~0.025 to 0.031 mg l^{-1} d^{-1}, but rates increased late in the season as the bottom layer sharply warmed to its annual temperature maximum. Concurrent with relatively lower DO concentrations in 1994, field measurements indicated high bottom-water temperatures >12°C (>=4°C above 1992 to 1993) and a deepened pycnocline just prior to overturn. To address how factors like temperature and vertical structure of the water column interact with metabolic processes to shape observed trends in DO decline and spatio-temporal variability, we used a simple model with physical and biological measurements from field monitoring as inputs. From field and model sensitivity results, we conclude that temperature and stratification strongly influence DO minima and rates of decline, and these factors interact with the bathymetric slope, as well as the topographic and depositional heterogeneity of the study area, to create subpycnocline variability in DO. With respect to lower DO in 1994, temperature contributed by accelerating both water and sediment metabolism, but a major effect was the late-season deepening of the pycnocline that enhanced the contribution of sediment respiration to DO decline by isolating a thin near-bottom water layer. In addition, dynamics of seasonal pycnocline deepening are a principal influence on interannual variability in bottom-water DO because, in contrast to the late-season effect, early in the stratified season a shallow pycnocline depth may moderate DO decline by allowing mid-water primary production to add DO to subpycnocline water.

Kelly, JR., Albro, CS., and Geyer, WR. 1996. High-resolution mapping studies of water quality in Boston Harbor and Massachusetts Bay during 1994 . Massachusetts Water Resources Authority. Boston. Report 1996-01. 169pp.

Abstract: During water quality monitoring surveys for the MWRA in 1994, a variety of intensive, high-resolution mapping studies were carried out. Twelve high-resolution surveys were conducted in February, March, April, June July, August, September, and October 1994. High-resolution maps were developed from data collected by a suite of in situ sensors housed in a towfish that sampled continuously as it oscillated from near-surface to near-bottom at vessel speeds from 4 to 7 knots. A primary objective was to characterize the tidally-mediated interaction between Boston Harbor and adjacent western Massachusetts Bay. A secondary objective was to characterize variability in water quality conditions more broadly across Massachusetts Bay. The April data strongly indicated that a portion of early spring coastal runoff advecting from the north of Massachusetts Bay did not enter the Bay, but skirted it east of Stellwagen Bank. South of Cape Ann within the Bay, the data showed some sporadic surface-water inflow to the Bay, but the fresher pools of surface water were depleted in chlorophyll relative to surrounding resident Bay water, This suggests a strong degree of coupling in space and time between physical processes and plankton distributions. October data demonstrated that variability in physical structure was a function of water depth. Inshore waters and the water column over Stellwagen Bank were vertically well-mixed. In waters deeper than 25 m, there was a horizontal continuity of density stratification and the majority of the Bay was similarly layered--a lingering result of seasonal warming. A general depression of DO was also observed in bottom waters. The DO minimum measured in October 1994 was well below the state

standard of 6.0 mg/L^{-1}. This report provides generalized conceptual models to illustrate the seasonal variability in the Harbor's coupling with the Bay. This coupling is influenced by variability in physical structure as well as differences in seasonal cycles of phytoplankton in inshore vs. offshore waters. During some periods the Harbor appears to import chlorophyll from the Bay and during other periods it exports chlorophyll to the Bay. One fundamental conclusion of the report is the identification of a seasonally variation in the physically-mediated coupling of the Harbor and Bay ecology and biogeochemical cycles. Another conclusion is that different vertical layers of the Bay freely communicate with the Harbor at different seasons. A number of summer surveys demonstrated a tidally- and bathymetrically-induced upwelling of water from within the pycnocline to the surface in the shallow western Bay region fringing the Harbor. There was also evidence for a weak estuarine circulation, with net outflow at the surface and net inflow near the bottom bathymetry. Further calculations documented an internal tide that was likely induced by the abrupt bathymetric variation in western Mass Bay near the Harbor entrance. This internal tide may be an important source of energy for vertical shears and it provides a physical mechanism for the observed upwelling near the channel leading into Boston Harbor from the Bay.

Kelly, JR. and Doering, PH. 1997. Monitoring and modeling primary production in coastal waters: studies in Massachusetts Bay 1992-1994. *Marine Ecology Progress Series.* 148, 155-168.

Abstract: During 1992-1994, we made shipboard incubations suitable for determining rates of primary production in water from Boston Harbor, Massachusetts Bay, and Cape Cod Bay (Massachusetts, USA). These measurements were part of an extensive baseline monitoring program to characterize water quality prior to diversion of effluent from Boston Harbor directly into Massachusetts Bay via a submarine outfall diffuser. Production (P) was measured using whole-water samples exposed to irradiance (I) levels from -5 to 2000 uE m^{-2} s^{-1}. P-I incubations were performed on 6 surveys a year, spaced to capture principal features of the annual production cycle. The number of stations and depths examined varied between years. There were 10 stations and 2 depths sampled in 1992-1993. In 1994, we performed in-depth studies at 2 stations (Boston Harbor's edge and western Massachusetts Bay) by sampling 4 depths. Using depth-intensive 1994 data a simple empirical regression model, using information on chlorophyll biomass, incident daily light, and the depth of the photic zone, predicted integrated primary production rates derived from P-I incubations. The regression model was virtually the same as described for other coastal waters, giving confidence in general use of the model as an extrapolation tool. Using the 1994-based empirical model, we obtained favorable comparisons with production rates modeled from 1992-1993 P-I incubations. Combining the regression model with data on chlorophyll, light, and the photic zone collected on frequent hydrographic surveys (up to 16 yr^{-1}), annual primary production was estimated for 1992-1994. Primary production in an intensively studied region of western Massachusetts Bay (21 hydrographic profile stations in an area apprx 100 km-2) ranged from 386 to 468 g C m^{-2} yr^{-1}. For a station at the edge of Boston Harbor near Deer Island extrapolations suggested production rates of 263 to 546 g C m^{-2} yr^{-1}. Based on 2 stations in central Cape Cod Bay (1992-1993 only), model extrapolations suggested an annual production of 527 to 613 g C m^{-2} yr^{-1}. Analyses using incubation and modeling results suggested that production variability was strongly related to fluctuations in incident irradiance, especially at daily to seasonal time scales. Chlorophyll variability secondarily influenced production, especially at seasonal to annual time scales. Finally, we provide a case where equivalent production was achieved in environments with contrasting water quality (nutrient and chlorophyll concentrations) because of variations in the depth of the photic zone (controlled by both chlorophyll and non-chlorophyll turbidity). Comparative analyses showed that our study estimates of primary production were consistent with the literature on nutrient-rich shelf environments. In conclusion, our study validated an empirical modeling approach to determining primary production in coastal marine waters.

Knebel, HJ. 1993. Sedimentary environments within a glaciated estuarine-inner shelf system: Boston harbor and Massachusetts Bay. *Marine Geology.* 110, 7-30.

Abstract: Three modern sedimentary environments have been identified and mapped across the glaciated Boston Harbor estuary and adjacent inner shelf of Massachusetts Bay by means of an extensive set of sidescan sonar records and supplemental bathymetric, sedimentary, subbottom and bottom-current data.

(1) Environments of erosion and nondeposition appear on the sonographs either as patterns with isolated reflections (caused by outcrops of bedrock, glacial drift, and coastal plain rocks) or as patterns of strong backscatter (caused by coarse-grained lag deposits). Sediments in these environments range from boulder fields to gravelly sands with megaripples. Inside the harbor, areas of erosion or nondeposition are found primarily near mainland and insular shores and within constricted tidal channels, whereas, on the shelf, they are present over extensive areas of hummocky topography near the coast and atop local bathymetric highs offshore. **(2)** Environments of sediment reworking are characterized on the sonographs by patterns with patches of strong to weak backscatter caused by a combination of erosional and depositional processes. These environments have diverse grain sizes that range from sandy gravels to muds. Within the harbor, the locations of reworked sediments are uncorrelated with the bottom topography, but, on the shelf, they are found on the lower flanks of bathymetric highs, within broad lows and in relatively deep water (30-50 m). **(3)** Environments of deposition are depicted on the sonographs as uniform patterns of weak backscatter. These areas contain relatively fine-grained muddy sands and muds. Inside the harbor, depositional environments are found over extensive subtidal flats and within sheltered depressions, whereas, on the shelf, they are restricted to broad lows mainly in deep water. The extreme patchiness of modern sedimentary environments within the Boston Harbor-Massachusetts Bay system reflects the interaction between the irregular bottom topography and both geologic and oceanographic processes. The estuarine part of the system is an effective trap for fine-grained detritus because of its protected nature, low wave climate, and large supply of sediments. The open shelf, however, is largely mantled by winnowed and sorted sediments as a result of erosion during past sea-level fluctuations, sediment resuspension and transport by modern waves and currents, and a spatially variable supply of fine-grained sediments.

Knebel, HJ. and Circe, RC. 1995. Seafloor environments within the Boston Harbor-Massachusetts Bay sedimentary system: a regional synthesis. *Journal of Coastal Research.* 11, 1: 230-251.

Abstract: Modern seafloor sedimentary environments within the glaciated, topographically complex Boston Harbor and Massachusetts Bay area have been interpreted and mapped from an extensive collection of sidescan sonar records and supplemental marine geologic data. Three categories of environments are present that reflect the dominant long-term processes of erosion or nondeposition, deposition, and sediment reworking. (1) Environments of erosion or nondeposition comprise exposures of bedrock, glacial drift, coarse lag deposits, and possibly coastal plain rocks that contained sediments (where present) ranging from boulder fields to gravelly sands and occur in areas of relatively strong currents. (2) Environments of deposition contain fine-grained sediments ranging from muddy sands to muds that have accumulated in areas of predominantly weak bottom currents. (3) Environments of sediment reworking contain patches with textures ranging from sandy gravels to muds that have been produced by a combination of erosion and deposition in areas with variable bottom currents. The distribution of sedimentary environments across the Boston Harbor-Massachusetts Bay area is extremely patchy. Locally, this patchiness is due either to modifications of bottom-current strength (caused by the irregular topography and differences in water depth) or to small-scale changes in the supply of fine-grained sediments. Regional patchiness, however, reflects differences in geologic and oceanographic conditions among the estuarine, inner shelf, and basinal parts of the sedimentary system. The estuarine part of the system (Boston Harbor) is a depositional trap for fine-grained sediments because it is protected from large waves, has generally weak and variable tidal currents, and receives a large supply of fine-grained detritus from natural and anthropogenic sources. The inner shelf, on the other hand, is largely an area of erosion or nondeposition due to sediment removal and redistribution during past sea-level changes, to sediment resuspension and winnowing by modern waves and currents, and to an inadequate supply of fine-grained. The basinal part of the system (Stellwagen Basin) is mainly a tranquil depositional environment in which fine-grained sediments from several potential sources settle through the water column and accumulate under weak bottom currents. This study indicates areas within the Boston Harbor-Massachusetts Bay sedimentary system where fine-grained sediments and associated contaminants are

likely to be either moved or deposited. It also provides a guide to the locations and variability of benthic habitats.

Lermusiaux, PFJ. 2001. Evolving the subspace of the three-dimensional multiscale ocean variability: Massachusetts Bay. *Journal of Marine Systems.* 29, 385-422.

Abstract: A data and dynamics driven approach to estimate, decompose, organize and analyze the evolving three-dimensional variability of ocean fields is outlined. Variability refers here to the statistics of the differences between ocean states and a reference state. In general, these statistics evolve in time and space. For a first endeavor, the variability subspace defined by the dominant eigendecomposition of a normalized form of the variability covariance is evolved. A multiscale methodology for its initialization and forecast is outlined. It combines data and primitive equation dynamics within a Monte-Carlo approach. The methodology is applied to part of a multidisciplinary experiment that occurred in Massachusetts Bay in late summer and early fall of 1998. For a 4-day time period, the three-dimensional and multivariate properties of the variability standard deviations and dominant eigenvectors are studied. Two variability patterns are discussed in detail. One relates to a displacement of the Gulf of Maine coastal current offshore from Cape Ann, with the creation of adjacent mesoscale recirculation cells. The other relates to a Bay-wide coastal upwelling mode from Barnstable Harbor to Gloucester in response to strong southerly winds. Snapshots and tendencies of physical fields and trajectories of simulated Lagrangian drifters are employed to diagnose and illustrate the use of the dominant variability covariance. The variability subspace is shown to guide the dynamical analysis of the physical fields. For the stratified conditions, it is found that strong wind events can alter the structures of the buoyancy flow and that circulation features are more variable than previously described, on multiple scales. In several locations, the factors estimated to be important include some or all of the atmospheric and surface pressure forcings, and associated Ekman transports and downwelling/upwelling processes, the Coriolis force, the pressure force, inertia and mixing. (c) 2001 Elsevier Science B.V.

Ravens, Thomas M. and Gschwend, Philip M. 1999. Flume measurements of sediment erodibility in Boston Harbor. *Journal of Hydraulic Engineering.* 125, 998-1005.

Abstract: To obtain in situ measurements of sediment erodibility in defined bottom shear stress environments, a portable, straight flume was built, tested, and deployed in the field for six experiments at three locations in Quincy Bay of Boston Harbor, Mass. The flume had a 1.0-m-long inlet section, which included a boundary-layer trip and a roughened, plexiglass bottom; this design prevented erosion of the sediment bed in the boundary-layer-development region. Downstream of the inlet section was a 1.2-m-long sediment test section, which had a laboratory-verified, uniform bottom stress. In the absence of algal mats, our flume experiments on sites exhibited a range of bed properties indicated quite uniform erodibility, with a critical shear stress. The measured rates were consistent with those of many other in situ studies. We observed markedly reduced erodibility in early October 1995 when the sediment was covered by a benthic diatom mat, and measured erosion rates were lessened by 50-80%. The possibility of depth-dependent sediment erodibility in near surface (top 3 mm) was investigated by calculating a set of depth-dependent erosion parameters. The parameters obtained suggested that both the critical shear stress and the erosion rate constant were depth-sensitive (both doubling by 1 mm into the sediment).

Signell, R. P. and List, J. H. 1997. Effect of wave-enhanced bottom friction on storm-driven circulation in Massachusetts Bay. *ASCE Journal of Waterway, Port, Coastal and Ocean Engineering.* 123, 5: 233-239.

Abstract: Massachusetts Bay is a shallow (35 m average depth) semienclosed embayment, roughly 100 x 50 km, which opens into the Gulf of Maine at its eastern boundary. Surface waves associated with winter storm winds from the northeast cause large sediment resuspension events, and wave and circulation fields during these events have a quasi-steady response to the wind stress. Coupled wave, circulation, and boundary layer models indicate that wave-enhanced bottom friction has a significant damping effect on storm-driven circulation in Massachusetts Bay. The simulated response exhibits significant three-dimensional structure, but still can be fundamentally understood using idealized models.

TRC Environmental Corporation. 2003. Environmental Report, Volume III: Appendix to Resource Report 6, Detailed Geophysical Investigation. TRC Environmental. Lowell, Massachusetts.

Abstract: This appendix includes a final report on the marine geophysical survey conducted for the Everett Extension Project in Boston, Massachusetts. The survey was conducted to assess bottom conditions, investigate subbottom stratigraphy, and verify the presence/absence of any cultural resources that may impact the proposed route design and installation.

Data Available:
Summary of Seabed Conditions Along Route Centerline
Vibratory Core Analysis Results
Grain Size Analysis, Atterberg Limits, and Water Contents
Direct Shear Test Results
TRC Environmental Corporation. 2002. Implementation Plan: Algonquin Gas Transmission Company HubLine Pipeline Project. TRC Environmental Corporation. Lowell, Massachusetts.
Walter PJ, RM Valente, and TJ Fredette. 2002. Evaluating Sub-Channel Confined Aquatic Disposal Cells: Experience from the Boston Harbor Navigation Improvement Project. Orlando Florida, May 5-8. Conference Proceedings. *Dredging '02: Key Technologies for Global Prosperity* .
Abstract: The Boston Harbor Navigation Improvement Project (BHNIP) provided an opportunity to evaluate the efficacy of capping contaminated dredged material (DM) within a confined in-channel environment. One of the main challenges of the project was to maximize coverage of coarse-grained sand cap over lower strength fine-grained DM excavated by an environmental bucket. Sequential monitoring surveys were conducted and used to modify operational methods of cap placement resulting in improved cap coverage during each successive phase of the project.
WATER QUALITY DATA AND INVESTIGATIONS

American Society of Civil Engineers. 2003. Boston Harbor Cleanup: 2000. Perspectives in Civil Engineering: Commemorating the 150th Anniversary of the American Society of Civil Engineers.
Abstract: Part of a special issue commemorating the 150th anniversary of the American Society of Civil Engineers. The $3.8 billion cleanup of Boston Harbor in Massachusetts is described. To build a new plant at Deer Island in 1990, workers moved a hill that contained 2.4 million cu yd of soil and removed a prison and a former artillery range. In 1991 the Massachusetts Water Resource Authority constructed a facility in Quincy, Massachusetts, to convert sludge into dried pellets for use as fertilizer, which ended the practice of dumping the sludge into the harbor. One of the more significant features of the project was the 9.5-mile-long Effluent Outfall Tunnel, which conveys treated wastewater from Deer Island to an underwater discharge point. The Boston Harbor project has achieved decreased levels of bacteria and harmful nutrients and improved dissolved oxygen levels and water clarity.

Cibik SJ, BL Howes, CD Taylor, DM Anderson, CS Davis, TC Loder, RD Boudrow, and JD Bowen. 1996. 1995 Annual Water Column Monitoring Report. Massachusetts Water Resources Authority. Boston, Massachusetts. ENQUAD 96-07. 254pp.

Abstract: This report presents the results of the 1995 water column monitoring program. The Massachusetts Bay system undergoes a seasonal progression from a vertically mixed water column in winter to a stratified column in summer. Stratification in 1995 lasted from early June until mid-October. Seasonal events that are closely related to this stratification pattern are the spring and fall phytoplankton blooms, which are triggered by increasing sunlight and water temperatures (spring) and the release of bottom water nutrients (fall turnover). The bloom events in 1995 were consistent with an annual nutrient cycle. Average measured chlorophyll concentrations on a regional basis were the lowest for the four-year baseline period. The annual DO maximum in the vertically mixed water column occurred in late February, with saturated conditions remaining until May. DO minima in stratified bottom waters occurred in all regions around the beginning of October. DO minima, however, did not reach the baseline period record lows, which occurred in 1994. The peak period of primary productivity in the nearfield was in late

April, comprising 20% of total annual production. Water column respiration was uniformly distributed during the pre-stratified period. During the stratified period, bottom water rates were an order of magnitude lower than the surface mixed layer rates, due to lower temperature and lower quantity and quality of carbon substrate. The seasonal distribution of carbon mineralization suggested that the spring bloom and summer production periods were the key intervals related to sub-pycnocline oxygen uptake. The plankton communities showed a general trend of increasing abundance until mid-summer. Oxygen and carbon balances suggested that bottom water oxygen depletion is driven primarily by in situ respiration, which is driven in turn by temperature, stratification duration, and substrate quantity and quality. Carbon fixation is sufficient to supply remineralization during the mixed period.
Cibik SJ, KB Lemieux, BL Howes, CD Taylor, CS Davis , TC Loder, and RD Boudrow. 1998. 1996 Annual Water Column Monitoring Report. Massachusetts Water Resources Authority. Boston, Massachusetts. Report ENQUAD 98-11. 416pp.

Abstract: This report presents the results of the fifth continuous year of water column monitoring. In 1996, nutrients in the well-mixed water column were plentiful in early February, leading to a system-wide diatom bloom in late February, and eventually causing the depletion of surface nutrients by March. Chlorophyll and carbon were found in the lower water column, resulting in high bottom water respiration. Vertical stratification was occurring in the nearfield in April and May and a spring freshet resupplied nutrients to the surface water in May. But chlorophyll concentrations remained low, potentially as a result of grazing as total zooplankton abundances peaked. Through August, the water column remained vertically stratified due to strong temperature differential and nutrient concentrations in the surface layer were low, except for in Boston Harbor, which remained well-mixed. DO concentrations in bottom water declined throughout the stratified period, with minimum measurements detected in October. Storm activity in September mitigated the severity of the DO decline by ventilating the bottom layer. Two blooms occurred in the latter part of the year: a centric diatom bloom in August in the Harbor and adjacent coastal waters and a cryptophyte and diatom bloom in the fall in Massachusetts Bay. The interannual monitoring results were assessed for chlorophyll and dissolved oxygen, because these two parameters are useful for determining eutrophic impacts. The spring bloom during 1996 was the largest documented during the baseline monitoring period (1992-1996). However, 1996 ranked fifth in the baseline monitoring period for summer and fall average chlorophyll concentrations. 1996 ranked fourth in the baseline period for severity of low seasonal DO concentrations in the nearfield and it ranked third in the rate of seasonal oxygen decline during the stratified period. These results further emphasize the inherent variability in the Massachusetts Bay system. DO concentration in bottom waters is subject to influence by water temperature, carbon inputs, respiration rates, stratification characteristics, resuspension activity, and reaeration characteristics.

Cibik SJ, KB Lemieux, JK Tracey, SJ Kelly, BL Howes, CD Taylor, and TC Loder. 1998. 1997 Annual Water Column Monitoring Report. Massachusetts Water Resources Authority. Boston, Massachusetts. ENQUAD 98-19. 258pp.

Abstract: This report presents the results of the sixth continuous year of water column monitoring. The interannual summary focuses on chlorophyll and dissolved oxygen in order to assess eutrophic impacts to the water column. 1997 ranked lowest of the six-year baseline in terms of average annual chlorophyll concentrations in the nearfield, and fifth for the annual average of all Massachusetts Bay samples combined. The spring bloom in 1997 appeared to be "interrupted" by an extended period of cloudy days, which may have imparted light-limiting conditions during a period when the bloom is typically undergoing strong development. Grazing pressure in April may have also controlled the bloom's development and reduced the magnitude of the overall seasonal average. The fall bloom yielded high

densities of diatoms, but elevated chlorophyll results were largely restricted to a single survey. Productivity rates, however, were documented to initially increase in September in the nearfield. 1997 ranked third in the baseline record with respect to bottom water dissolved oxygen minima. The two blooms and the carbon associated with them produced high water column respiration rates, leading to the low bottom water DO concentrations. Carbon cycling in western Massachusetts Bay appears to be driven by internal recycling of nutrients based on parallel measurements of production and respiration.
Cibik, SJ, Lemieux, KB, Davis, CS, and Anderson, DM. 1998. Massachusetts Bay plankton communities: characterization and discussion of issues relative to MWRA's outfall relocation. Massachusetts Water Resources Authority. Boston. Report 1998-08. 140pp.

Abstract: The goal of this report was to characterize the baseline of the phytoplankton and zooplankton communities in the Mass Bay system prior to relocation of the MWRA effluent discharge 15km offshore. Available plankton data were examined to identify seasonal and interannual differences in plankton assemblages. Water column nutrient concentrations reach annual maxima in the winter. A strong phytoplankton bloom typically develops during late winter which can deplete nutrients throughout the water column. This bloom may be followed by a spring bloom, particularly if the first bloom was not strong and a lot of nutrients remain. Nitrogen is typically the limiting macronutrient in the system. Microflagellates are typically the numerically dominant class of phytoplankton in the nearfield through most of the year. The major spring blooms are dominated by centric diatoms while the fall bloom is dominated by pennate diatoms. Interannual variability in the abundance of seasonally dominant taxa is often two to three orders of magnitude, while variability in major classes is around one order of magnitude. Zooplankton abundance and species composition also exhibit strong seasonal and interannual variation. Regionally, the coastal species assemblage was dominated by *Acartia* while offshore species compositions were characterized by *Calanus* and *Pseudocalanus* in winter/spring and *Centropages typicus* and *Paracalanus parvus*. The seasonal patterns for most dominant taxa are similar to those found in shelf regions along the eastern U.S.
Connor, MS. and Sommaripa, L. 1997. Tightening the relationship between monitoring and pollution abatement: the Massachusetts Water Resources Authority Contingency Plan. *Marine Pollution Bulletin.* 34, 1: 9-14.
Abstract: The Massachusetts Water Resources Authority has developed a contingency plan that describes potential modifications to the new 9.5-mi offshore wastewater outfall in Massachusetts Bay and evaluates the environmental impact of nutrients, organic material, toxic contaminants, pathogens, solids, and floatables. The plan identifies approximately 30 water-quality characteristics to be monitored, and collective actions are developed should threshold levels be exceeded. An overview of the contingency plan is presented, including the setting of the thresholds, the design of the monitoring program, enforceability, and public relations.

Davis, CS. and Gallagher, SM. 2000. Data report for video plankton recorder cruise R/V Peter W Anderson, February 23-28, 1999. Massachusetts Water Resources Authority. Boston. Report 2000-03. 132pp.

Abstract: This data report presents results from a Video Plankton Recorder survey of Massachusetts and Cape Cod Bays during February 23-28, 1999. The purpose of this survey was to obtain high-resolution data on the 3-dimensional distribution of dominant planktonic taxa together with environmental variables during late winter. Three characteristic water types were found in the Bays: warm salty, colder fresher, and very cold and fresh. The different planktonic taxa observed had different water-type affinities, thus providing some insight into their origins. There was a large bloom of the diatom *Chaetoceros socialis*, which the data suggested came from northeastern Mass Bay offshore and were transported and mixed into

the middle of Cape Cod Bay. Copepods did not, however, penetrate as deep into Cape Cod Bay as did the diatoms. Comparison of VPR data with HOM data showed they were generally in agreement.
Davis, CS and Gallagher, SM. 1998. Data report for video plankton recorder cruise R/V Peter W Anderson, March 12-14, 1998. Massachusetts Water Resources Authority. Boston. Report 1998-22. 118pp.

Abstract: A Video Plankton Recorder survey was conducted during March 12-14, 1998 in Massachusetts and Cape Cod Bays. The data collected during the survey will help provide insights into how and why the plankton is distributed in the Bays over a broad range of scales. Two main water types were found in the Bays: Massachusetts Bay Bottom Water (MBBW) and Cape Ann Plume Water (CAPW). The CAPW is colder and fresher and was present in the upper part of the water column throughout the northern and western parts of the Bays. The MBBW is warmer and saltier and was present throughout the lower part of the water column in Massachusetts Bay and northern central Cape Cod Bay. Characteristic spatial distributions were found for both phytoplankton and zooplankton taxa and the different taxa were found to have different affinities for the water types. Dominant phytoplankton features include a bloom of diatoms in eastern Cape Cod Bay, corresponding to high fluorescence values and the presence of a warm surface plume in this area. The region of CAPW had lower fluorescence and plankton abundance values. A less intense but broader distribution of *Chaetoceros* diatoms was found throughout southern Mass. Bay and was associated with the MBBW, suggesting an offshore origin. The dominant zooplankton copepod (*Oithona*) was distributed throughout southern Mass. Bay, but extended further into northern Mass. Bay. Egg-bearing *Oithona* were found to be more abundant and more patchy at depth. Ostracods/cyprids were substantially abundant at depth. These groups were associated with the MBBW. Zooplankton abundance was much lower in the CAPW. The plankton taxa, except for rod-shaped diatoms and unidentified copepods, exhibited a sharp loss in correlation over very short distances (~2-4 km). Such a decline was not observed in the physical variables or in fluorescence or attenuation, implying taxa-specific small-scale patchiness. For the environmental variables, as well as for most plankton taxa, a negative correlation was found at large length scales (40-60 km). This trend was due to large-scale gradient in values across the entire region due to the intrusions of the CAPW and the MBBW. All these data suggest that the CAPW serves to dilute the plankton in the northern and western parts of the Bays but also contributes to the formation of the Cape Cod Bay water. This CAPW water flows from Cape Ann along the western side of the Bays and into Cape Cod Bay. Cape Cod Bay acts as a cul-de-sac in which local surface heating may be important in initiating phytoplankton blooms during spring.
Environmental Protection Agency. 1995. Proposed Sludge Management Plan, Metropolitan District Commission, Boston, Massachusetts. Volume 2. Appendices. Draft Environmental Impact Statement. United States. 305.

Abstract: The document accompanies Volume I of the Draft Environmental Impact Statement which proposed amendments to Boston's sludge management plan. This volume is a set of appendices dealing with water standards, rock types, floral and faunal species, commercial establishments, infrastructure, and other aspects of the Boston Harbor area.

Environmental Protection Agency. 1995. Proposed Sludge Management Plan, Metropolitan District Commission, Boston, Massachusetts. Volume 1. Draft Environmental Impact Statement. Metropolitan District Commission. 284.

Abstract: The recommended project involves Federal financial assistance for the construction of a primary sludge disposal system owned and operated by the Metropolitan District Commission (MDC), Boston, Massachusetts. As a result of the detailed environmental, cost effectiveness, and energetics analyses which were performed for this impact statement, Region I EPA has suggested a modification to

the proposed plan. The sludge management plan proposed by MDC be implemented as described is recommended, except that the ash disposal method not be approved.

Golomb, D., Barry, E., Ryan, DK., and Wade, TL. 2002. Wet and dry deposition of toxic metals and PAHs near New England coastal waters. *Abstracts of Papers American Chemical Society.* ENVR 22.

Abstract: Measurement of atmospheric deposition in the wet and dry form of toxic metals (Al, Cd, Co, Cr, Cu, Mn, Ni, Pb, Sb, Se and Zn) was rendered at two sites near Massachusetts Bay, Nahant and Truro, and several PAH species at three sites, Nahant, Truro and Wolf Neck near Casco Bay, Maine. Nahant experienced much higher dry deposition of metals and PAHs than Truro and Wolf Neck, which we attribute to local emission sources from the Boston metropolitan area, including Logan Airport. On the other hand, wet deposition at Truro and Wolf Neck was either equal or greater than at Nahant, which we attribute to the supposition that pollutants are incorporated into precipitating clouds that sweep up emissions from regional sources as far as hundreds of kilometers away, and the clouds follow trajectories that favor Truro and Wolf Neck over Nahant. For metals no clear cut seasonal pattern was discerned; wet and dry deposition of PAHs is definitely higher in the heating than in the non-heating season because of the higher rate of fossil fuel and wood combustion in winter.

Kelly, JR. 1997. Nitrogen flow and the interaction of Boston Harbor with Massachusetts Bay. *Estuaries.* 20, 2: 365-380.

Abstract: This paper summarizes evidence that most of the considerable nitrogen loading (~8, 470 mmol total N m^{-2} yr^{-1}) to Boston Harbor (Massachusetts, USA) is expelled to shallow shelf waters of Massachusetts Bay, where it strongly influences ecological dynamics. Examination of nitrogen concentrations in the harbor, compared with loading, indicated that removal processes are active in the harbor. Comparison to other estuarine systems showed that the harbor's nitrogen concentrations are consistent with its loading, if they are corrected for tidal flushing effects on the water residence time. Furthermore, extensive measurements of sediment denitrification confirmed that rates of N_2 gas loss are high in an absolute sense (~600-800 mmol N m^{-2} yr^{-1}) but nonetheless remove only a small portion (< 10%) of the annual land-derived nitrogen loading. Burial in sediments apparently removes only about 2% of the N input, implying export to offshore environments as the major removal process (~88-90% of N input). Western Massachusetts Bay receiving waters were examined for a signature of export from the harbor. Data consistently show a gradient of decreasing nitrogen concentrations from the harbor to about 10-20 km into the bay. In many cases, plots of nitrogen concentrations versus salinity show nearly conservative mixing character, which implies virtual export. Seasonally, the data suggest most of the export from the harbor in winter is as dissolved inorganic forms (NH_4^+, NO_3^-, NO_2^-). In summer, export is dominated by the outflow of organic

Kelly, JR. 1998. Quantification and potential role of ocean nutrient loading to Boston Harbor, Massachusetts, USA. *Marine Ecology Progress Series.* 173, 53-65.

Abstract: While tidal flushing helps export most of the nitrogen added to Boston Harbor (MA, USA) from land sources (>8000 mmol N
m-$^{-2}$ yr^{-1}; 90% in sewage effluent) to the offshore waters of Massachusetts Bay, the tidal inflow also brings material into the Harbor. For Boston Harbor and many other coastal embayments, tidal inputs must be quantified if we are to develop complete nutrient budgets. This study quantifies tidal input of nutrients and suspended solids (i.e. 'ocean loading') and predicts the future role of ocean loading after sewage effluent discharge is diverted away from the Harbor to a location about 15 km into the Bay. Ocean loading is determined by simple box modeling using data sets available for the 1994 annual cycle. Critical data for modeling include a series of surveys on which high-resolution data for salinity and turbidity were collected using in situ sensors housed in a towed instrument package (i.e. a 'towfish'); surveys covered 2 transects in and out of the 2 Harbor inlets which regulate tidal exchange. Study results show that ocean loading dominates the input-output budgets of nutrients and suspended solids, generally providing more than twice the loading from present land sources. Results further suggest that, although the absolute values of ocean loading will decrease after effluent diversion, the relative contribution of the ocean to the Harbor budget will increase. Predictive modeling suggests that total nitrogen concentrations will decrease

about 20% and dissolved inorganic concentrations will decrease about 50% from present levels; these predicted decreases are smaller than one would calculate if the ocean loading term of budgets were neglected. Ocean loading thus will have a role in the nature of Harbor recovery from the planned sewage diversion.

Kelly, JR and Doering, PH. 1995. Nutrient issues update 1995: metabolism in Boston Harbor, Massachusetts and Cape Cod Bays, MA (USA) during 1992-1994. Massachusetts Water Resources Authority. Boston. Report 1995-19. 38pp.

Abstract: This report is part of an extensive baseline monitoring program developed by the MWRA in an effort to characterize water quality prior to the diversion of effluent from Boston Harbor directly into Massachusetts Bay. Whole water samples were exposed to irradiance levels from ~5 to 2000 uE m^{-2} sec^{-1}. In each year, P-I incubations were preformed on six surveys, spread over the year to capture seasonal features of production dynamics. Results are presented in terms of P-I curves and these are compared to previous studies. A simple empirical model was developed to predict integrated primary production rates using information on chlorophyll biomass, incident daily light, and the depth of the photic zone. Results suggested primary production at the edge of Boston Harbor near Deer Island was ~ 266 gC m^{-2} y^{-1}, whereas western Massachusetts Bay was much higher: ~435-468 gC $m^{-2}y^{-1}$. Using the empirical model, favorable comparisons were obtained with production rates calculated from 1992-1993 P-I incubations. Therefore, data from 1992 and 1993 were extrapolated to estimate annual production rates of 386 and 620 gC m^{-2} y^{-1} for western Massachusetts Bay in 1992 and 1993, respectively, an 416-555 and 486 gC m^{-2} y^{-1} for the edge of Boston Harbor in 1992 and 1993.The high estimates of primary production are consistent with the literature on nutrient rich coastal shelf environments and much of the variability in production on daily, seasonal, and annual timescales may be ascribed to variations in light availability. In addition, production variability was related to integrated photic zone chlorophyll. Using primary production estimates for an ~100 km^2 region in western Massachusetts Bay, tentative metabolic budgets were constructed for carbon. Results suggested that bottom sediments (32 m average water depth) consume ~ 5% of overlying production and that most of the production (~70%) is consumed in the photic layer of the water column (~20 m deep). In addition, seasonal and annual variations in bottom water DO concentrations appear to be semi-independent of metabolism and cannot reliably be predicted by trends in production or respiration. It is concluded that primary production is a poor early warning indicator of bottom water DO problems. Primary production measurements should be considered to provide a metabolic framework for understanding the fate of organic matter in this environment.

Kennish, MJ. 2002. Environmental Threats and Environmental Future of Estuaries. *Environmental Conservation.* 29, 1: 78-107.

Abstract: Estuaries exhibit a wide array of human impacts that can compromise their ecological integrity, because of rapid population growth and uncontrolled development in many coastal regions worldwide. Long-term environmental problems plaguing estuaries require remedial actions to improve the viability and health of these valuable coastal systems. Detailed examination of the effects of pollution inputs, the loss and alteration of estuarine habitat, and the role of other anthropogenic stress indicates that water quality in estuaries, particularly urbanized systems, is often compromised by the overloading of nutrients and organic matter, the influx of pathogens, and the accumulation of chemical contaminants. In addition, the destruction of fringing wetlands and the loss and alteration of estuarine habitats usually degrade biotic communities. Estuaries are characterized by high population densities of microbes, plankton, benthic flora and fauna, and nekton; however, these organisms tend to be highly vulnerable to human activities in coastal watersheds and adjoining embayments. Trends suggest that by 2025 estuaries will be most significantly impacted by habitat loss and alteration associated with a burgeoning coastal population, which is expected to approach six billion people. Habitat destruction has far reaching ecological consequences, modifying the structure, function, and controls of estuarine ecosystems and contributing to the decline of biodiversity. Other anticipated high priority problems are excessive nutrient and sewage inputs to estuaries, principally from land-based sources. These inputs will lead to the greater incidence of

eutrophication as well as hypoxia and anoxia. During the next 25 years, overfishing is expected to become a more pervasive and significant anthropogenic factor, also capable of mediating global-scale change to estuaries. Chemical contaminants, notably synthetic organic compounds, will remain a serious problem, especially in heavily industrialized areas. Freshwater diversions appear to be an emerging global problem as the expanding coastal population places greater demands on limited freshwater supplies for agricultural, domestic, and industrial needs. Altered freshwater flows could significantly affect nutrient loads, biotic community structure, and the trophodynamics of estuarine systems. Ecological impacts that will be less threatening, but still damaging, are those caused by introduced species, sea level rise, coastal subsidence, and debris/litter. Although all of these disturbances can alter habitats and contribute to shifts in the composition of estuarine biotic communities, the overall effect will be partial changes to these ecosystem components. Several strategies may mitigate future impacts.

Kratch, K. Boston Harbor realizing pipe dreams in effluent outfall tunnel construction. *Water Environment & Technology.*

Abstract: The world's biggest and longest ocean effluent outfall tunnel is being completed as part of the $3.5 billion Boston Harbor Project. Fifty-five diffuser pipes are currently being connected to the effluent tunnel using the latest survey equipment. On completion, the diffusers will spray the effluent into 33.5 m deep waters so that it can be dispersed rapidly by tidal flow and currents. Project completion is planned for 1998.

Leo, WS., Rex, AC., Carroll, SR., and Connor, MS. 1995. The state of Boston Harbor 1994: connecting the Harbor to its watersheds. Massachusetts Water Resources Authority. Boston. Report 1995-12. 37pp.

Abstract: The annual State of the Harbor reports have documented that the Harbor has entered the early stages of ecosystem recovery. Public use of the Harbor's recreational offerings has been bolstered. A watershed-based approach in the coming years will prove essential in developing both the Harbor and its adjoining watersheds for the benefit of the surrounding communities.

Letson, D., Suman, D., and Shivlani, M. 1998. Pollution prevention in the coastal zone: An exploratory essay with case studies. *Coastal Management* . 26, 3: 157-175.

Abstract: In the past decade, national and international pollution policies have increasingly opted for prevention over remediation. As an anticipatory, comprehensive approach that might save money and avoid end-of-pipe regulations, pollution prevention (P2) warrants careful consideration. We focus on the coastal zone because of its unique geographical characteristics, its ecological and economic importance, and the increasing pressures on its integrity. Over the past 25 years, U.S. legislation has increasingly embraced P2 principles in the management of coastal environments. Four case studies illustrate P2's prospects for the variety of pollution problems within the coastal zone: Boston Harbor (wastewater); Chesapeake Bay (nutrients); Broward County, Florida's P2 program for marinas (toxic substances); and the cruise line industry (solid waste). These case studies represent a range of circumstances in the coastal zone: a number of pollutants; point and nonpoint sources; land-based and ocean-based sources; mandatory versus voluntary P2 approaches; localized and regional approaches; small-scale versus large-scale responses; and pollutant-generating activities that range from agriculture and wastewater treatment to maritime transportation. These examples illustrate that P2 potentially enjoys wide applicability in coastal pollution management. If environmental policy continues its long-term trend toward an anticipatory, voluntary, and cross-media emphasis, P2 will increasingly influence coastal management. However, anticipatory and comprehensive are not always better, and sources do not always volunteer to reduce. Significant obstacles to adoption of P2 may be economic, political, or social. Economic challenges include weak incentives to adopt clean technologies and the absence of a systematic accounting that considers the positive values of enhanced environmental amenities. Political obstacles arise through lack of grassroots acceptance of P2, weak political will, and enforcement difficulties. Nor are all P2 solutions socially acceptable. Despite these obstacles, P2 offers a comprehensive, integrated, holistic approach to pollution management that fits well with models of effective integrated coastal management.

Libby S, C Albro, C Hunt, R Geyer, A. Keller, C Oviatt, and J Turner. 2000. 1998 Annual Water Column Monitoring Report. Battelle. Duxbury, Massachusetts. Report No. 99-16. 173pp.

Abstract: The MWRA has collected water quality data in Massachusetts and Cape Cod Bays since 1992 in order to assess the potential environmental effects of the relocation of effluent discharge from Boston Harbor to Massachusetts Bay. The data are being collected to establish baseline water quality conditions and ultimately to provide the means to detect significant departure from that baseline. In 1998, the region was influenced by weather patterns associated with El Nino. As a result, the winter was warm and the winter and spring had many storm events and large amounts of rainfall. This led to warmer water temperatures and high flow conditions in the early spring, which effectively lowered the surface salinity levels in Western Massachusetts Bay and created strong stratification in the water column. No spring bloom was recorded in 1998 and data indicate that spring blooms may not be as typical for Massachusetts Bay as once thought. Since there was no bloom, phytoplankton abundance steadily increased from February to maximium levels in the summer and fall, followed by a drop-off in November-December. The phytoplankton assemblages were numerically dominated by microflagellates and cryptomonads, with some chain-forming diatoms. There was a year-long bloom of *Ceriatum longipes/C. tripos*, but this was 1 to 2 orders of magnitude less abundant than previous years. In 1998, zooplankton assemblages were dominated by copepod nauplii, adults, and copepodites of *Oithona similis* and *Pseudocalanus* spp. Zooplankton abundance increased from February through April, reaching the highest numbers in mid-May. Levels remained high from June through December. In 1998, the fall bloom dominated the seasonal productivity pattern and was not a single species bloom. Rather, it was a general increase in the numbers of a variety of chain-forming diatoms. The water column was stratified until November throughout much of the nearfield and a deep halocline was still present in December at some of the deeper eastern stations. Due to this persistent stratification, bottom water DO concentrations decreased over the June-December time period. In November and December, abnormally high concentrations of ammonia and phosphate were observed in the western nearfield but the source has not been determined. However, the high concentrations may have been due to the transfer of south system sewage flow from Nut Island to the Deer Island facility, increased secondary treatment at Deer Island, or other unknown factors.
Libby S, C Hunt, L McLeod, R Geyer, A Keller, C Oviatt, D Borkman, and J Turner. 2001. 2000 Annual Water Column Monitoring Report. Battelle. Duxbury, Massachusetts. Report 2001-17. 196pp.

Abstract: The MWRA has collected water quality data in Massachusetts and Cape Cod Bays since 1992 in order to assess the potential environmental effects of the relocation of effluent discharge from Boston Harbor to Massachusetts Bay. The data are being collected to establish baseline water quality conditions and ultimately to provide the means to detect significant departure from that baseline. In 2000, substantial blooms occurred in both the spring and the fall. In the fall, evidence of vigorous mixing was not evident, although there was a fairly rapid reduction in stratification and strong downwelling. Therefore, mixing did not appear to influence the major chlorophyll bloom observed in this period. The 2000 seasonal trends in nutrient, chlorophyll, and dissolved oxygen concentrations were typical for the nearfield area when compared to baseline years. In general, nutrient concentrations across Massachusetts Bay have been increasing since 1998. Ammonium in particular has increased in Boston Harbor, apparently due to the increased discharge of ammonium from the Deer Island Facility. Chlorophyll concentrations have also increased and 2000 measurements were unprecedented, continuing a steady increase in chlorophyll concentrations that began in 1997. A system-wide bloom of *Phaeocystis pouchetii* was substantial. This bloom and the high chlorophyll concentrations suggest that there was a substantial amount of organic material produced in the nearfield. However, the Stellwagen Basin and nearfield bottom DO concentrations were in the middle of the range of baseline values. There was also a fall 2000 ctenophore "bloom" when a anomalously high abundance of *Mnemiopsis leidyi*. September 2000 marked the end of the baseline measuring period, allowing MWRA to calculate the final threshold values by which unacceptable changes to the ecosystem will be evaluated.

Libby, S, C Hunt, R Geyer, A Keller, C Oviatt, and J Turner. 2000. 1999 Annual Water Column Monitoring Report. Battelle. Duxbury, Massachusetts. Report No. 2000-09. 180pp.

Abstract: The MWRA has collected water quality data in Massachusetts and Cape Cod Bays since 1992 in order to assess the potential environmental effects of the relocation of effluent discharge from Boston Harbor to Massachusetts Bay. The data are being collected to establish baseline water quality conditions and ultimately to provide the means to detect significant departure from that baseline. In 1999, the region was affected by very dry conditions during the summer and a fall drought. This led to high salinity measurements in nearfield bottom waters since the lack of significant storm events weakens vertical mixing and decreases freshwater inflow. In general, 1999 temporal trends in nutrient, chlorophyll, and dissolved oxygen concentrations were typical for the nearfield area in comparison to previous years. A review of annual mean nutrient concentrations shows a significant trend of increasing nutrients across the region from 1992 to 1999. In Boston Harbor, an increase in ammonium concentration increased substantially over the baseline period, and chlorophyll concentrations also increased and exceeded some warning thresholds. One effect of the chlorophyll increase may have been an increase in organic material to bottom waters and the resultant low DO concentrations noted in 1998 and 1999. The 1999 nearfield mean bottom water DO concentration was the lowest observed since the monitoring program began and was lower than the warning threshold. In 1999, a winter/spring phytoplankton bloom was observed in the nearfield and much of the farfield, although total phytoplankton counts were not substantially elevated when compared with other years. Assemblages consisted mainly of microflagellates and diatoms. Because the abundant taxa during this bloom were large, chain-forming diatoms (*Chaetoceros*) with a large cell size and a high chlorophyll per cell ratio, there was an observed disconnect between the high chlorophyll concentrations and total phytoplankton abundance. Bottom water respiration rates were substantially higher in the spring of 1999, in response to the availability of organic matter from the bloom. These also contributed to the unprecedented low DO concentrations. A late summer phytoplankton bloom was observed throughout much of Massachusetts Bay in August and September, composed mainly of microflagellates and the diatom *Leptocylindrus danicus* . Zooplankton showed typical patterns of increases through the year. The typical dominants, *Oithona similis* and *Pseudocalanus* spp., comprised most assemblages. A low abundance of *Acartia* copepods was also noted, which appears to be a continuing trend.

Libby S, R Geyer, A Keller, J Turner, D Borkman , M Mickelson, C Hunt, and C Oviatt. 2002. 2001 Annual Water Column Monitoring Report. Battelle. Duxbury, Massachusetts. Report 2002-22.

Abstract: The MWRA has collected water quality data in Massachusetts and Cape Cod Bays since 1992 in order to assess the potential environmental effects of the relocation of effluent discharge from Boston Harbor to Massachusetts Bay. The data are being collected to establish baseline water quality conditions and ultimately to provide the means to detect significant departure from that baseline. The various water quality parameters observed in 2001 followed the general sequence of events observed over the baseline period. Nutrient, biomass, and production data suggested that the winter/spring bloom had peaked before February 2001 in Massachusetts Bay. The decline of the bloom and the influx of nutrients from precipitation and runoff led to elevated spring nutrient concentrations in spite of the minor bloom of *Phaeocystis pouchetii* in April. The calm weather and warm temperatures led to a delay in water column destratification and a late fall bloom from October to December. In 2001, a decrease in annual mean nutrient concentrations was observed throughout the bays, except that NO_3 and NH_4 increased from 2000 to 2001 in the nearfield. The largest change was a drop in annual mean NH_4 concentrations in Boston Harbor, which was directly due to the transfer of MWRA discharge from the harbor to the bay. The lack of major winter/spring and fall blooms in 2001 resulted in decreases in annual chlorophyll concentrations in Boston Harbor, coastal, nearfield, and Cape Cod Bay waters. The presence of elevated chlorophyll at the offshore and boundary stations suggests that chlorophyll concentrations in Massachusetts Bay continue to be influenced by regional Gulf of Maine factors. The annual minimum DO concentrations and percent saturations were relatively high in 2001, which was expected given the relatively low biomass

concentrations. It appears that regional processes and advection are the primary controlling factors governing bottom water DO concentrations in Massachusetts Bay. The natural variability that has been observed on seasonal and interannual time scales and across the spatial expanse of Massachusetts and Cape Cod Bays is so large, it is a challenge to detect outfall effects.

O'Brien K, M Weinstein, and R McVoy. 2002. Boston Harbor 1999 Water Quality Assessment Report. Massachusetts Department of Environmental Protection. Worcester, Massachusetts. Report 70-AC-1.

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

Abstract: This report is an annual summary of the condition of Boston Harbor. The first section of the report illustrates in detail the six steps involved in the primary treatment process at Deer Island: pumping, grit removal, solids removal, solids digestion, disinfection, and odor control. The remainder of the report looks at how Boston Harbor has responded to past efforts in improving water quality and how it may respond to recent and future plant improvements. Among the pollutant groups discussed here are pathogens, toxic contaminants, organic material (BOD), total suspended solids (TSS), nutrients, and floatables.

Rex, AC. 2000. The state of Boston Harbor 1997-1998: beyond the Boston Harbor project. Massachusetts Water Resources Authority. Boston. Report 2000-05. 24pp.

Abstract: This report is an update on three pollutants in wastewater discharges into Boston Harbor: bacteria, metals, and solids. The environmental effects of these pollutants are also tracked.

Rex, AC. and Connor, MS. 1997. The state of Boston Harbor 1996: questions and answers about the new outfall. Massachusetts Water Resources Authority. Boston. Report 1997-05. 32pp.

Abstract: This report answers questions about the new outfall in Boston Harbor, including the overarching concern: Could the bay become degraded by sewage effluent as Boston Harbor once was? The answer is no for these three reasons: (1) the effluent is much cleaner now, with source reduction and secondary treatment; (2) the outfall provides for better dilution of effluent; and (3) the MWRA and other organizations will be constantly monitoring the health of the surrounding ecosystem and will have contingency plans in place for emergencies.

Rex, AC., Coughlin, K., and McKenna, K. 1995. Dye study of MWRA Squantum force main and Wollaston Beach storm drains in Quincy, Massachusetts. Massachusetts Water Resources Authority. Boston. Report 1995-11. 11pp.

Abstract: The Squantum Force Main carries wastewater under pressure from the Squantum Pump Station to the High Level Sewer in Quincy, running parallel to Wollaston Beach in Quincy. The force main is in proximity to storm drains that discharge into Quincy Bay at Wollaston Beach. The City of Quincy asked MWRA to perform a dye test to evaluate the possibility that sewage might be leaking from the Force Main and infiltrating into the Wollaston Beach storm drains. Rhodamine dye was introduced into the Force Main via the Squantum Pump Station. Samples were collected at seven storm drain outfalls and in storm drain manholes before the dye was introduced, and then three times after the dye was introduced, throughout a complete tidal cycle. No dye was found in any of the storm drains, and samples collected at the High Level Sewer and at the Nut Island Treatment Plant were positive, confirming that the dye did travel through the Force Main. The results confirmed the previous observations that the storm drains contain fecal coliform bacteria. The dye study did not indicate any leakage of sewage from the Force Main into the storm drains.

Rex, AC., Wu, D., Coughlin, K., Hall, MP., Keay, KE., and Taylor, DI. 2002. The state of Boston Harbor: mapping the Harbor's recovery. Massachusetts Water Resources Authority. Boston. Report 2002-09. 42pp.

Abstract: This report summarizes the changes in the environmental quality of Boston Harbor since the transferring of effluent from the Harbor to the outfall in 2000. Emphasis is put on the tributaries leading into the Harbor, since a significant fraction of the pollution entering the Harbor now (after the outfall opening) comes from the three main rivers.

Shine, JP. and Wallace, GT. 1995. The formation of surface-active organic complexes of copper in coastal marine waters. *Marine Chemistry.* 51, 145-157.

Abstract: The importance of surface-active organic matter on the speciation of copper in coastal seawater was examined over a 22 month period in Massachusetts Bay. Concentrations of copper associated with dissolved surface-active organic matter ranged from 15 pmol/kg during winter (0.67% of total dissolved copper) to 850 pmol/kg (18% of total dissolved copper) at the peak of primary production during a spring bloom and, following a spring bloom, accounted for 36% of the total dissolved copper concentration. Association of copper with surface-active organic matter may have occurred by direct complexation with surface-active organic ligands or indirectly via organic-organic interactions with non-surface-active organic complexes of copper. Although total dissolved copper at the site was inversely related to salinity, indicative of freshwater/continental sources, the amount of copper bound to surface-active organic matter was significantly correlated with estimated rates of phytoplankton primary production ($r^2 = 0.78$). The primary source of surface-active organically bound copper in Massachusetts Bay is apparently in-situ biological production and not export of anthropogenic/freshwater ligands from continental sources. Although they represent a small but significant fraction of the total copper species present in coastal seawater, surface-active forms of copper assume added importance due to their active role in the transport and biogeochemical cycling of this element.

Siegener, R. and Chen, R. F. 2002. Caffeine in Boston Harbor Seawater. *Marine Pollution Bulletin.* 44, 5: 383-387.

Abstract: Caffeine has been detected in Boston Harbor seawater with concentrations ranging from 140 to 1600 ng l^{-1}, and in Massachusetts Bay seawater at concentrations from 5.2 to 71 ng l^{-1}. Sources of caffeine appear to be anthropogenic with higher concentrations in the seawater of Boston's inner harbor and in freshwater sources to the harbor. Charles River water and Deer Island sewage treatment plant effluent, the two major sources of freshwater to the harbor, contained 370 and 6700 ng l^{-1} of caffeine, respectively, in 1998. Sewage influent and effluent concentrations appear to be consistent with consumption estimates of caffeinated beverages for the Boston area and total organic carbon removal targets for treated sewage. Caffeine was inversely correlated to salinity in a transect from the mouth of Boston Harbor to Stellwagen Basin, indicating it may be a useful chemical tracer of anthropogenic inputs to marine systems.

Siegener, R and Chen, RF. 2000. Detection of pharmaceuticals entering Boston harbor. *Analysis of Environmental Endocrine Disruptors.* 125-132.

Taylor, DI. 2003. 24 months after 'offshore transfer': an update of water quality improvements in Boston Harbor . Massachusetts Water Resources Authority. Boston. Report 2003-04. 94pp.

Abstract: This report documents the changes in Harbor water quality for the first full 24 months after the transfer of Deer Island WWTF effluent to the offshore outfall. The water quality after the first 24 months is compared with the water quality measured during a 3-7 year baseline period before transfer. Therefore, this report only identifies the large changes that fell outside the range seen in the Harbor during baseline. A reduction in nitrogen and phosphorus was detected and these decreases were highly significant and observed all over the Harbor. The dissolved inorganic fractions of nitrogen and phosphorus contributed most of the decreases. The Harbor showed a significant decrease in Harbor-wide concentrations of chlorophyll a. An improvement in water clarity was also detected at individual stations as was an improvement in bottom water dissolved oxygen. Highly significant decreases in *Enterococcus* and fecal

coliform concentrations also were detected. This report supports the conclusion of the earlier report that water quality in Boston Harbor has improved significantly since wastewater discharges to the Harbor ended.
Taylor, DI. 2001. Comparison of water quality in Boston Harbor before and after inter-island transfer . Massachusetts Water Resources Authority. Boston. Report 2001-09. 104pp.

Abstract: In 1998, the MWRA transferred wastewater previously treated at the Nut Island WWTF through the upgraded Deer Island WWTF, an event known as the inter-island transfer. The entire transfer took 4 months, from April 1998 to July 1998. The inter-island transfer ended the discharge of primary treated wastewater into the South Harbor region of Boston Harbor and increased the discharge of secondary treated wastewater to the North Harbor region. This report compares the water quality in the two Harbor regions in the first 24 months following the inter-island transfer with water quality from 2 to 5 years before transfer. Three water quality issues were focused on: eutrophication symptoms, water clarity, and sewage indicator bacteria counts. Analysis of the data indicated that water quality in the Harbor during the 24 months after transfer was significantly different than before transfer. This difference was especially pronounced for N and P nutrient concentrations, which were generally lower after transfer than before. DO percent saturation values in the bottom waters were significantly lower after transfer than before transfer. The harbor as a whole showed a significant decrease in *Enterococcus* and two stations showed decreased counts of fecal coliform bacteria.
Taylor, DI. 2000. Inter-island transfer, and water-quality changes in the North Harbor and South Harbor regions of Boston Harbor . Massachusetts Water Resources Authority. Boston. Report 2000-13. 60pp.

Abstract: In 1998, the MWRA transferred wastewater previously treated at the Nut Island WWTF through the upgraded Deer Island WWTF, an event known as the inter-island transfer. The entire transfer took 4 months, from April 1998 to July 1998. The inter-island transfer ended the discharge of primary treated wastewater into the South Harbor region of Boston Harbor and increased the discharge of secondary treated wastewater to the North Harbor region. This report examines the water quality changes in the two Harbor regions over the first year following the inter-island transfer. Specifically, this report looks at water clarity, eutrophication symptoms, and levels of pathogens. Two sets of stations were monitored in each region: the "outfall" stations and the "receiving water" stations. The results indicated that, after the first year, the inter-island transfer led to large improvements in water quality in the South Harbor without causing a large region-wide reduction in water quality in the North Harbor.
Taylor, DI. 2001. Trends in water quality in Boston Harbor during the 8 years before offshore transfer of Deer Island flows. Massachusetts Water Resources Authority. Boston. Report 2001-05. 54pp.

Abstract: The purpose of this report was to document the baseline water quality and trends in water quality during the 8 years before the transfer of wastewater from Deer Island WWTF to the outfall. This report will serve as a baseline with which to assess the future changes. The data indicate that significant changes in water quality were already occurring in the Harbor during the 8 years prior to transfer. Significant negative trends were observed for total nitrogen, TN:TP, percent saturation of DO, and fecal coliform and Enterococcus bacteria. Significant positive trends were observed for total phosphorus and total suspended solids concentrations. The South Harbor showed significant negative trends for DIN and DIP. The North Harbor showed significant positive trends for DIN, DIN as %TN, and DIP, and a significant negative trend for Secchi depth. It was determined that many of these trends were the result of natural, background environmental fluxes and trends.
Taylor, DI. 2002. Water quality improvements in Boston Harbor during the first year after offshore transfer of Deer Island flows . Massachusetts Water Resources Authority. Boston. Report 2002-04. 61.

Abstract: This report assesses water quality in Boston Harbor during the first 12 months after the Deer Island WWTF discharges were transferred to the outfall. Three water quality issues are addressed in the

report: water column eutrophication, water clarity, and counts of sewage indicator bacteria. During the 12 months after the transfer, Harbor concentrations of total nitrogen and total phosphorus and molar ratios of TN:TP were all significantly lower than before transfer. These decreases in nitrogen were likely responsible for the decrease in phytoplankton biomass and chlorophyll a as well. A highly significant increase in water clarity was also detected in the Harbor, which may increase the public use of Harbor beaches and facilitate recolonization of the seafloor by macrophyte habitats. Bottom water dissolved oxygen also showed improvements at individual stations as did sewage indicator bacteria counts (*Enterococcus* and fecal coliform). Salinity was found to be higher at 60% of the stations during the 12 months after transfer.

Taylor, DI., Rex, AC., Coughlin, K., and Toolan, T. 1999. Nut Island flow transfer, and water-quality changes in the Central Harbor. Massachusetts Water Resources Authority. Boston. Report 1999-10. 54pp.

Abstract: This report compares water quality in the Central Boston Harbor before and after flows from Nut Island WWTF were transferred through the Deer Island WWTF in the Northwest Harbor. One set of stations included three 'outfall' stations located in the immediate vicinity of the previous Nut Island outfalls. The other set included three 'receiving water' stations located along a transect extending from west to east across the Central Harbor. After the discharges from Nut Island were ended, the wastewater signal at the outfalls disappeared, and improvements in water quality were observed region-wide in the Central Harbor. At the east outfall (the only outfall where nutrients were measured), average DIN concentrations decreased 80% (from 58.8 to 12 umol l^{-1}). At the receiving water stations, the decrease was 40% (10.5 to 6.4 umol l^{-1}). Average DIP concentrations decreased 68% at the outfall (3.4 to 1.1 umol l^{-1}) and 47% at the receiving water stations (1.5 to 0.8 umol l^{-1}). Average counts of fecal coliform at the outfalls went from 9 to 3 cfu 100 ml^{-1} and from 3 to 1 cfu 100 ml^{-1} at the receiving water stations. Average counts of *Enterococcus* at the outfalls decreased from 28 to 6 cfu 100 ml^{-1} and from 2 to <1 cfu 100 ml^{-1} at the receiving water stations. The number of exceedances at the outfalls of State swimming standards (200 cfu 100 ml^{-1})decreased for fecal coliform from 1-6 times/year to zero times/year. At the receiving water stations, the decrease was from 1-9 times/year to zero times/year. For Enterococcus, the number of exceedances of the State guideline (33 cfu 100 ml^{-1}) decreased from between 9-14 times/year to <1 time/year at the outfalls and from between 4-12 times/year to 1 time/year at the receiving water stations. Average Secchi depths at the outfalls increased from 1.7 to 2.7 m (59%), but the receiving water stations showed no significant change. At the east outfall, average TSS concentrations decreased from 4.5 to 3.8 mg l^{-1}. No decreases in biomass of phytoplankton (measured as chl a concentrations) were detected after transfer. Preliminary evidence suggests that any decreases in chl a that might have resulted from the ending of N inputs from Nut Island were compensated for by an increase in phytoplankton growth caused by increased water clarity that followed the end of TSS inputs. Neither set of stations showed significant changes in DO concentrations. This may indicate that the decrease in BOD loadings from Nut Island were too small to cause changes in DO in the region. It should be noted that 12 months is a short period of time over which to detect changes in water quality; therefore, the changes should be considered tentative pending further data collection.

Turner, J. T. 1994. Planktonic Copepods of Boston Harbor, Massachusetts Bay and Cape-Cod Bay, 1992. *Hydrobiologia.* 292/293, 405-413.

Abstract: Zooplankton were collected by vertical tows with 102 mum mesh at ten stations in Boston Harbor, Massachusetts Bay and Cape Cod Bay in February, March, April, June, August, and October, 1992. This study was part of a larger monitoring program to assess the effects of a major sewage abatement project, and sampling periods were designed around periods of major phytoplankton events such as the winter-spring diatom bloom, the stratified summer flagellate period, and the autumn transition from stratified to mixed waters. There was considerable seasonal variation in total zooplankton abundance, with minimal values in April (1929-11631 animals m^3) during a massive bloom of *Phaeocystis pouchetii*, and maximum values (67316-261075 animals m^3) in August. There were no

consistent trends of total abundance where any particular station had greater or lesser abundance than others over the entire year. Zooplankton abundance was dominated by copepods (adults + copepodites) and copepod nauplii (30.4-100.0% of total zooplankton, mean = 83.2%). Despite the large seasonal variation in zooplankton and copepod abundance, the copepod assemblage was dominated throughout the entire year by the small copepod *Oithona similis*, followed by *Paracalanus parvus*. Other less-abundant copepods present year-round were *Pseudocalanus newmani*, *Temora longicornis*, *Centropages hamatus*, *C. typicus, and Calanus finmarchicus*. Two species of *Acartia* were present, primarily in low-salinity waters of Boston Harbor: *A. hudsonica* during cold periods, and *A. tonsa* in warm ones. *Eurytemora herdmani* was also a subdominant in Boston Harbor in October. The potential role of zooplankton grazing in phytoplankton dynamics and bloom cycles in these waters must be considered in view of the overwhelming numerical dominance of the zooplankton by Oithona similis which may feed primarily as a carnivore. Furthermore, it seems unlikely that eutrophication-induced alteration of phytoplankton assemblages could cause significant 'trophic domino effects', reducing abundances of *Calanus finmarchicus* that are forage of endangered right whales seasonally utilizing Cape Cod Bay because *C. finmarchicus* has long been known to be a relatively unselective grazer, and most importantly, it is a trivial component of total zooplankton or total copepod abundance in these waters.

Twombly, R. 2001. Boston pee party: caffeine as a marker of human sewage spills. *Environmental Health Perspectives.* 109, 5: 204.

Abstract: Robert Chen, an oceanographer in the Environmental, Coastal, and Ocean Science Department, University of Massachusetts, Boston, has developed a new marker for sewage pollution. Chen and graduate student Ray Siegener established the baseline caffeine component of Boston Harbor by repeatedly employing GC-MS. The baseline caffeine concentration reflects the small percentage of caffeine not eliminated by sewage treatment, and anything above this baseline level may indicate the occurrence of sewage spill. Analysis at points within a body of water and establishment of the area in which the readings are highest may enable the sources of sewage spills to be traced.

U.S. Army Corps of Engineers, New England District. 2000. Section 404/10 Application: Executive Summary, Algonquin Gas Transmission Company HubLine Pipeline Project. Earth Tech, Inc. Concord, Massachusetts.

Abstract: This application, submitted in compliance with Section 404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act, includes a concise project description, a description of the affected environment, a summary of the potential impacts of the project, a description of the actions taken to minimize adverse effects, and a listing of the practicable alternatives.

Zhuang, G. S., Yi, Z., and Wallace, G. T. 1995. Iron (II) in Rainwater, Snow, and Surface Seawater From a Coastal Environment. *Marine Chemistry.* 50, 1-4: 41-50.

Abstract: Using a newly developed HPLC method for the determination of Fe(II) concentration in a variety of aqueous environmental samples we found that Fe(II) accounts for 50-74% of the total filterable Fe in coastal surface seawater, 25-53% in rain samples, and 25-74% in snow collected from the vicinity of Massachusetts Bay, and Boston Harbor. We also found the residence time of Fe(II) in natural seawater to follow pseudo-first-order kinetics with an apparent half-life on the order of 30-70 min, much longer than previously thought. The observation of high Fe(II) concentrations and long apparent half-life reflect the product of as yet undefined chemical processes occurring in either atmosphere and/or seawater environments. These significant concentrations of Fe(II) may represent an important source of Fe influencing phytoplankton growth in coastal seawater.