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Boston Harbor and Massachusetts Bay: Issues, Resources, Status and Management

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U.S. DEPARTMENT OF COMMERCE
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Boston Harbor and Massachusetts Bay: Issues, Resources, Status and Management

Proceedings of a Seminar
Held June 13, 1985
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U.S. DEPARTMENT OF COMMERCE
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NOAA Estuarine Programs Office
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The NOAA Estuarine Programs Office

and

The U.S. Environmental Protection Agency

present

ESTUARY-OF-THE-MONTH-SEMINAR
BOSTON HARBOR AND MASSACHUSETTS BAY
ISSUES, RESOURCES, STATUS, AND MANAGEMENT

June 13, 1985

U.S. Department of Commerce
14th and Constitution Avenue, N.W.
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WELCOME

by

Dr. James Thomas
Estuarine Programs Office
National Oceanic and Atmospheric Administration
U.S. Department Commerce
Washington, D.C.

Ladies and gentlemen, I would like to welcome you on behalf of the NOAA Estuarine Programs Office and the U.S. Environmental Protection Agency to the fourth Estuary-of-the-Month Seminar, entitled Boston Harbor and Massachusetts Bay: Issues, Resources, Status and Management. The purpose of these seminars is to focus attention on one estuary at a time, elucidating multiple-use impacts, resources at risk, status and trends of an estuary (particularly as a habitat), status and trends of the fisheries, and the resources, economics, and management of a particular estuary.

Estuaries are where humans come in most intimate contact with the marine environment with regard to commerce, recreation, and fisheries. Nearly 50 percent of the Nation lives within 20 miles of the coast or around the Great Lakes. In 1984, total commercial landings of fisheries amounted to $2.5 billion; 70 percent of this amount was derived from estuarine-dependent fisheries.

Thus, it is appropriate that we bring experts here today to inform us of what was, what is, and what we might do in terms of management for our nation's estuaries. I am pleased to welcome Drs. Betsy Brown and Paul Boehm here today from the Battelle New England Marine Research Laboratory located in Duxbury, Massachusetts. I would particularly like to thank them for organizing today's seminar. Dr. Brown is a benthic ecologist specializing in estuarine and marine environmental monitoring. Dr. Boehm is a noted marine organic chemist. Both are knowledgeable experts on Boston Harbor and Massachusetts Bay. They will take charge of today's program, including the panel discussion at the end of the day.

I encourage everyone to stay through the panel discussion in order that we might learn what data and information gaps exist and what we might do to help improve the management of our Nation's estuaries for the mutual benefit of fisheries, commerce and recreation.

INTRODUCTORY REMARKS

by

Dr. Betsy Brown
Battelle New England Marine Research Laboratory
Duxbury, MA

I want to thank you, Jim, for your help and for being the Washington link in organizing today's workshop. We are going to try to stay on schedule today. We have designed the program to leave room for discussion and we purposely limited the number of speakers to have time for questions and comments.

In the past few years, Massachusetts Bay and especially Boston Harbor have been increasingly in the media both in New England and outside New England's boundaries. The public has become aware that Boston Harbor and Massachusetts Bay are not as pristine as we once thought they were. In fact, they are considerably stressed by pollution and heavy use.

Just two days ago, The Boston Globe published an editorial entitled "Fifty Years of Harbor Pollution," and I brought it here today to read to you.

"Fifty years ago--it could have been just yesterday--the Massachusetts Senate passed a bill prohibiting the pollution of Boston Harbor. 'The bill,' said State Senator Edward Carrol during a brief floor debate on the afternoon of June 11th, 1935, 'was necessary to protect swimmers in South Boston and Dorchester.' It must have seemed an easy task back then. The bill was a simple one prohibiting the discharge of oils and their products, refuse, and other materials into the waters of the Harbor.

"As the current generation of legislators and public officials--not to mention swimmers, sailors, and other users of the Harbor--has learned, the task turned out to be not that simple. Over the past half-century, everything that Sen. Carroll's bill sought to keep out of the waters has been dumped into them--as well as toxic chemical substances that were unknown when the bill was filed. Sewer systems were created and treatment plants were constructed, beaches were tended, and a park was created out upon the Harbor Islands, and still the pollution continued. Studies were made, suits were filed in courts, even more pieces of legislation were passed, and still the pollution continued.

"Now the cost of repairing the ravages of the past half century and protecting the waters into the next century is calculated at well over $1 billion. The desirability of a clean harbor and the necessity of taking action was seen clearly that afternoon in the Massachusetts Senate, 50 years ago. That a half-century has passed and the task remains uncompleted should only strengthen the resolve to see it accomplished now."

This article clearly indicates the need (1) for better definition of sources of contamination in the Harbor, the processes driving the Harbor/Bay estuary, and the critical links between the Harbor and Bay, and (2) for corrective action to eliminate sources of contamination of the Harbor/Bay system. There are numerous potential contaminant sources; for example, sewage sludge pumped twice daily into the Harbor, combined sewer overflows, industrial sewage with poor pretreatment, non-point sources. However, the relative importance and effect of these sources is not well understood.

The Boston Harbor/Massachusetts Bay estuary is a very interesting urban estuary. The Harbor and Bay have distinctly unique characteristics and yet, they are tightly coupled in some ways. Our speakers today will tell you what we know about the estuary and will raise many more questions than we have answers for.

HISTORICAL PERSPECTIVES AND OVERVIEW

by

Ms. Kathy Castagna
U.S. Environmental Protection Agency
Region I
Boston, MA

I would like to say "good morning" to everyone and note that EPA Region I is pleased to participate in today's seminar. My name is Kathy Castagna and I work in EPA's Region I as a Project Monitor on the supplemental draft environmental impact statement on the siting of wastewater treatment facilities in Boston Harbor. I have been working on this project for over 2 years, and Boston Harbor/Massachusetts Bay is a topic near and dear to my heart. The purpose of my talk this morning is to give you a general overview and orientation of Massachusetts Bay from several perspectives. I will tell you about the geography of the Bay, some demography, history, general environmental parameters, pollutant loadings to the Bay, and end with my view of some of the critical issues facing Massachusetts Bay.

Boston Harbor and Massachusetts Bay are located on the western edge of the Gulf of Maine north of Cape Cod (Figure 1). The Bay is an inlet of the Atlantic Ocean extending 65 miles along the coast of Massachusetts, southward from Cape Ann to the northern border of Cape Cod (Figure 2). The waterways of eastern Massachusetts that border Massachusetts Bay consist of Boston Harbor and associated rivers.

Boston Harbor is a large, relatively shallow complex of bays and tidal estuaries covering 47 square miles, with 180 miles of tidal shoreline. Draining into Boston Harbor are the Charles River with a length of 80 miles; the Neponset River, with a length of 30 miles; and the Mystic River with a length of 17 miles.

Outlying regions along the coast include the rivers and tidal estuarine systems of the north and south coastal regions of Massachusetts Bay. The north region includes the Ipswich, Pines, and Saugus Rivers as well as Gloucester, Beverly and Salem Harbors. The south coastal region consists of the Jones, North, and South Rivers as well as Gulf, Cohasset and Scituate Harbors on the south shore.

Figure 3 gives a better definition of the major rivers draining into Boston Harbor. The communities that border Massachusetts Bay begin with Rockport and the Cape Ann area and make a semicircular arch southward to Gurnet Point in Duxbury. The greater Boston metropolitan area borders Boston Harbor and Massachusetts Bay. Various portions of the areas described have been continuously occupied by European settlements for more than 350 years. During this time the region has been subjected to ever increasing amounts of municipal wastes and other abuses.

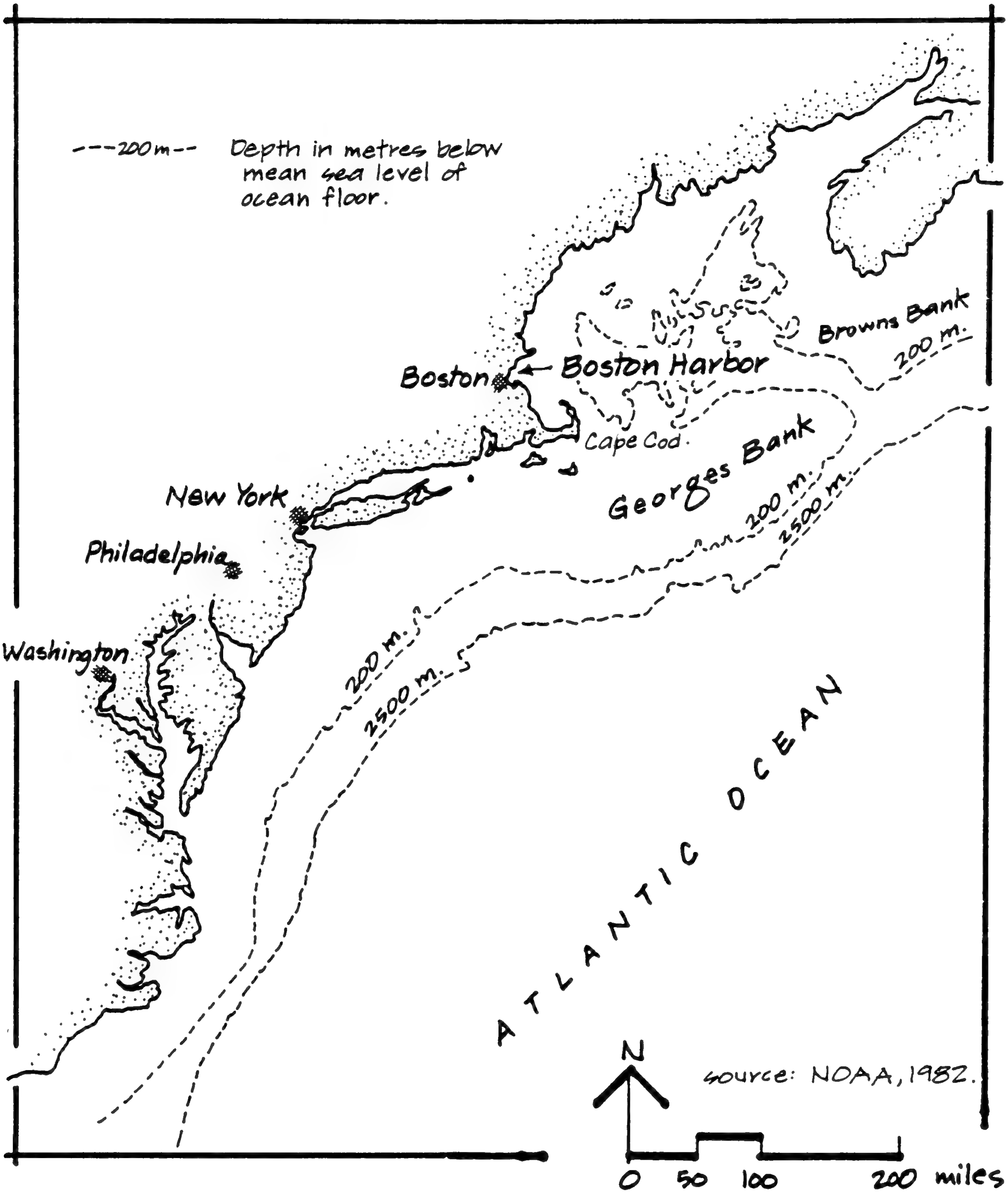

Figure 1. Location of Boston Harbor. From C.E. Maguire Inc.

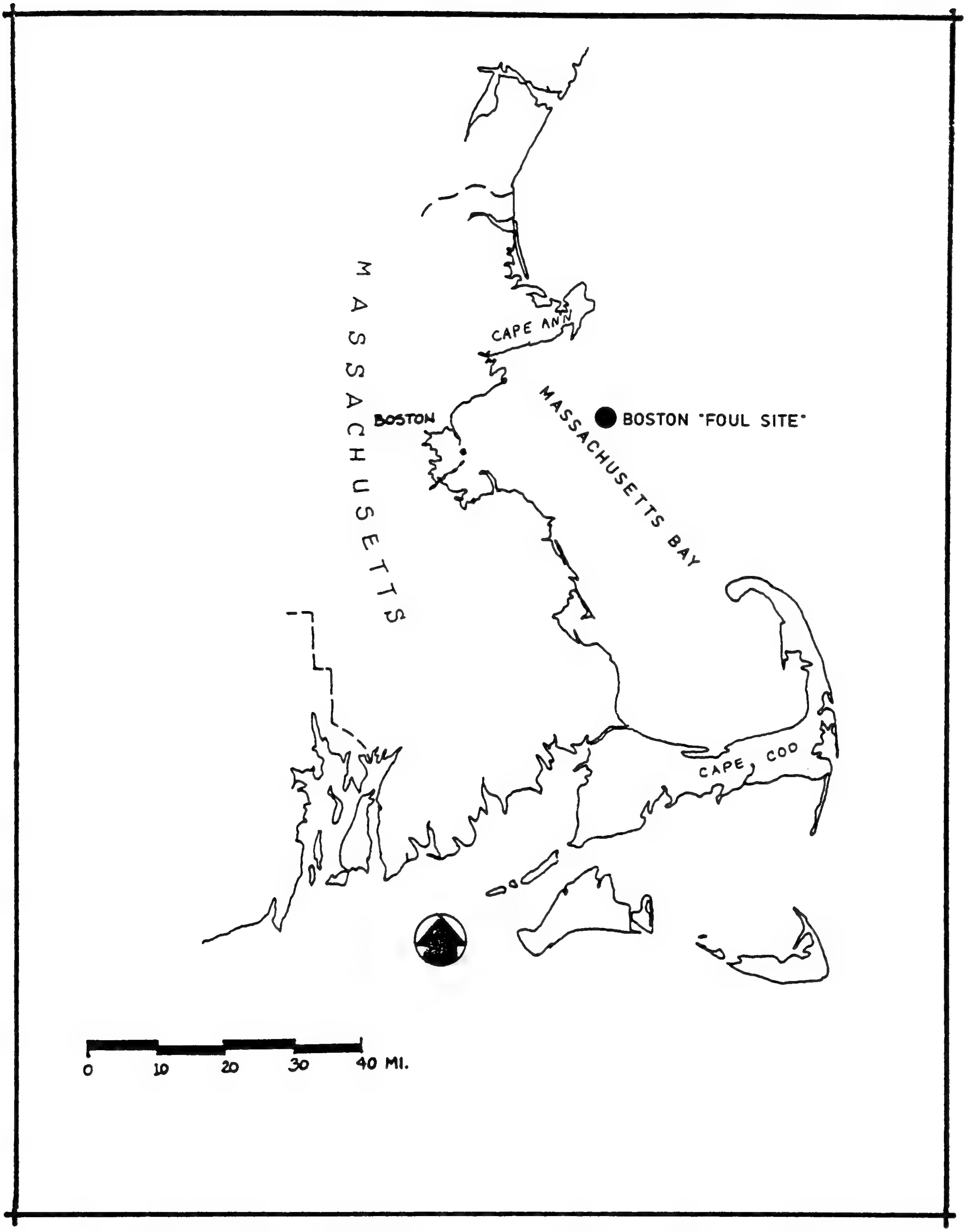

Figure 2. **Map of Massachusetts Bay. From C.E. Maguire, Inc.**

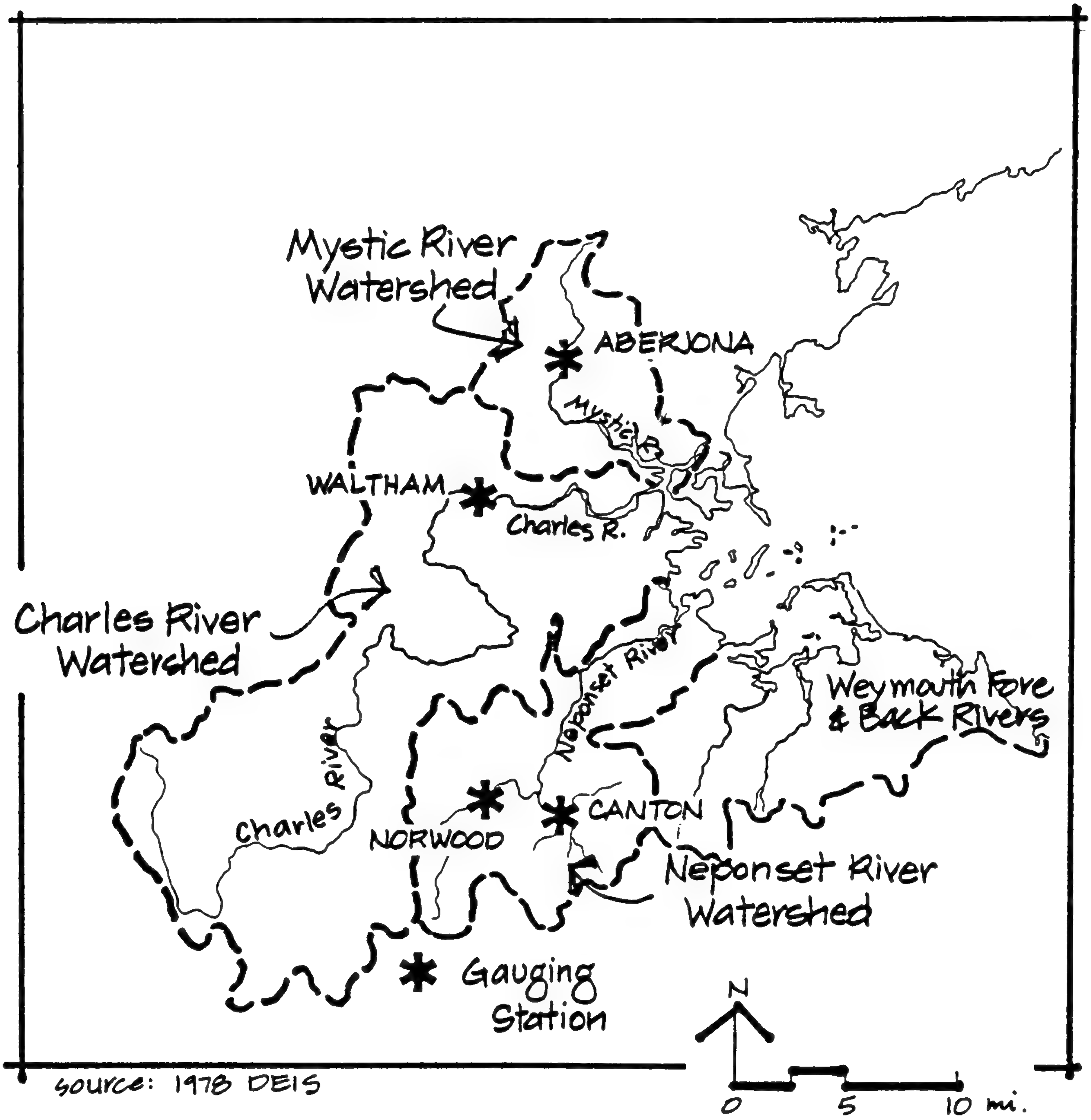

Figure 3. Major Watersheds Draining to Boston Harbor. From C.E. Maguire, Inc.

Some of America's oldest towns and cities are located on Massachusetts Bay. They include Gloucester, settled in 1623; Salem, settled in 1626; Marblehead, settled in 1629; and Boston, settled in 1630. As was noted, settlement of Massachusetts Bay Colony began in the early 1620s. Groups of English people founded several small communities around Massachusetts Bay, to the north of the Plymouth Colony and independent of the Pilgrim's Colony, the most important of which was Salem. The next decade of the 1600s brought a large influx of Puritans to the area and with their arrival, settlement of Massachusetts began.

In colonial days, fisheries and trade made Boston a major commercial center. After the Revolutonary War, ships from Salem and Boston opened lucrative trade routes to China. When maritime trade declined in the first years of the 19th century, accumulated commercial wealth helped Massachusetts turn to manufacturing. Textiles dominated the state's economy until well into the 20th century. After World War II, employment in textiles dropped wth a consequent rise in electronics, a science-oriented industry that drew on the academic resources of Cambridge and Boston.

During the period from 1775 through the present, the physical shape of Boston Harbor has been drastically altered by filling. The peninsulas of Boston, South Boston and Charlestown were originally joined to the mainland by tidal marshes, but have been extensively altered by filling. Several islands were leveled and covered over to form what is now Logan Airport. Filling connected with the airport alone has reduced the area of Boston Harbor by more than 2,000 acres (Figure 4).

Boston Harbor and environs are rich in military and cultural history. Since colonial times, the Harbor's commercial significance has made it important from a military defense point of view. Historic forts still exist on many of the Boston Harbor Islands and play a role in some present recreation plans for the Harbor. These fortifications were constructed at various times during the period following the American Revolution through the early 1940s.

The current population of the Greater Boston Metropolitan Area is approximately four million people. The Boston Metropolitan Area has grown 1.4 percent since the 1980 U.S. census. Massachusetts Bay and Boston Harbor are important recreational resources for this population. The Boston Harbor/Massachusetts Bay environment provides plentiful opportunities to residents and tourists for recreational finfishing and lobstering, pleasure boating, and bathing. There are 42 beaches within Boston Harbor totaling approximately 19 miles of shoreline (Figure 5). In addition, there are numerous anchorages, launching ramps and docking facilities for recreational boats. Over three million people in the Greater Boston area live within 25 miles of the Harbor. In Boston alone, over 200,000 people live within walking distance of the Harbor and the rivers entering the Harbor.

The Massachusetts legislature enacted the Boston Harbor Islands State Park Legislation in the early 1970s. In 1972, the Boston Harbor Islands comprehensive plan called for recreational development of the Harbor Islands. The types of activities planned

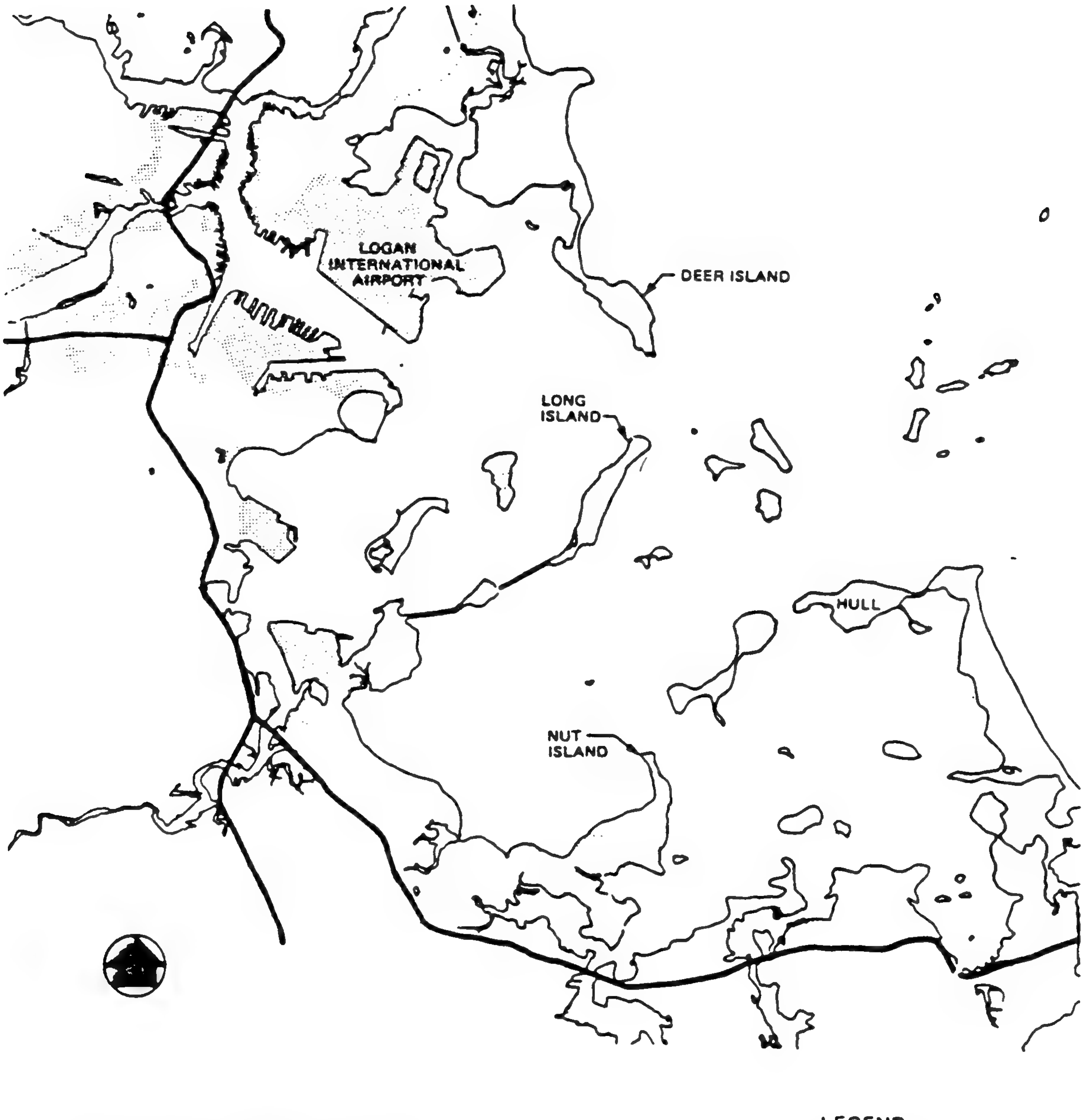

Figure 4. **Alteration of Boston Harbor by Filling - 1775 to Present. From Metcalf and Eddy, Inc.**

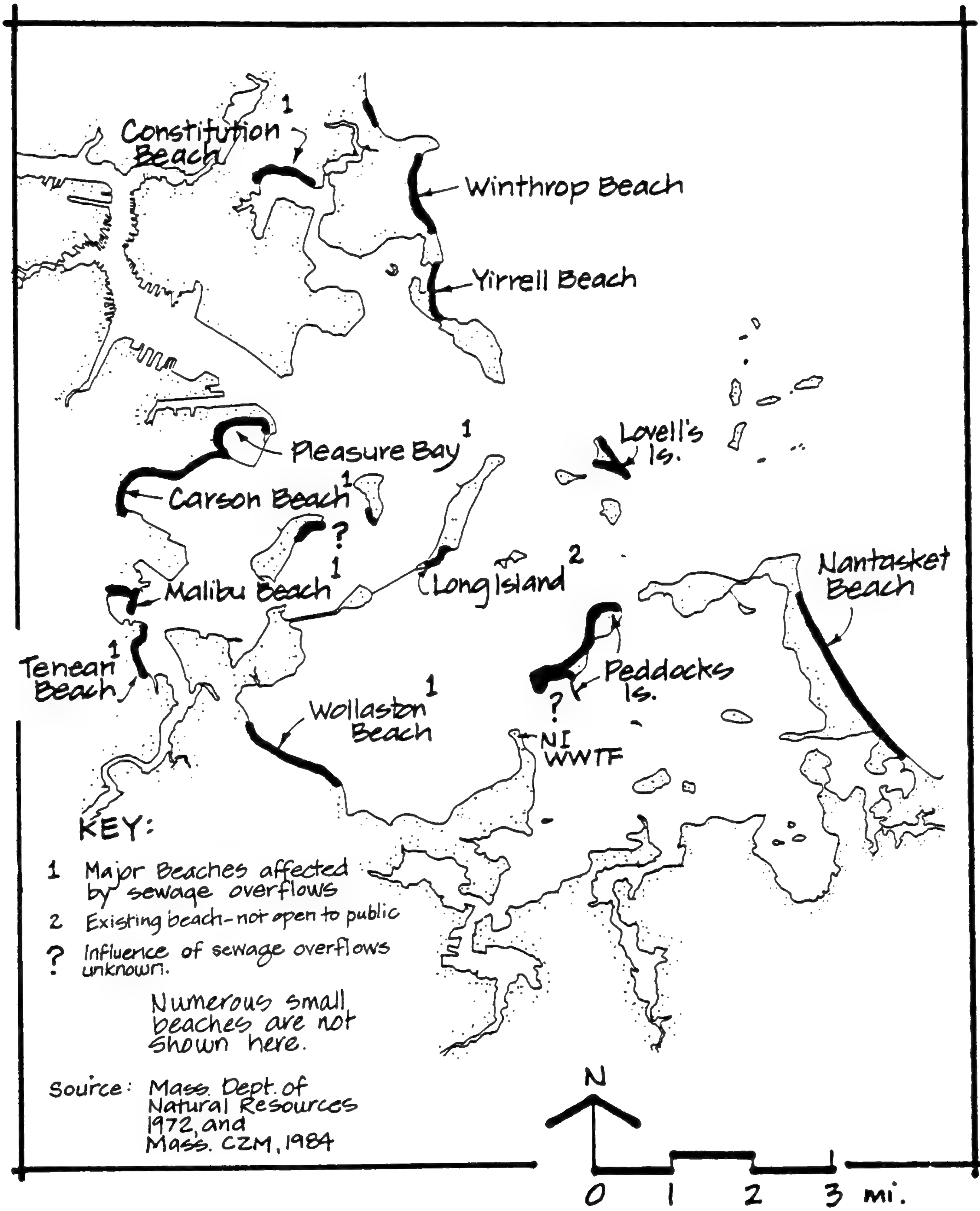

Figure 5. Major Beaches of Boston Harbor. From C.E. Maguire, Inc.

for and currently being implemented on some of the Harbor Islands are swimming, boating, camping, fishing, nature walks, and picnicking (Figure 6).

On the economic front, Boston is a major international seaport, in fact, the busiest in New England. The Harbor has two deep water shipping lanes, President Roads and Nantasket Roads. The port of Boston includes 156 piers, wharfs and docks, and two container facilities.

Other commercial activities in Boston Harbor include finfishing, lobster fishing, restricted clam harvesting, and yacht club and marina operations. Lobster is the predominant commercial fishery in Boston Harbor. Shellfish beds cover about 4,600 acres of Boston Harbor. Half of the area is presently closed to shellfishing because of bacterial contamination of the overlying waters. In remaining beds, shellfish may only be harvested by licensed master diggers, who must transport the shellfish to a depuration plant where shellfish are cleansed prior to sale. A recent estimate of the commercial value of the annual harvest of shellfish in the Harbor has been between five and six million dollars. Another recent estimate on the potential annual value on closed beds has been approximately four million dollars. Overflows and bypasses of raw sewage, poorly treated wastewater from treatment facilities, and storm drainage have all been implicated as sources of bacterial contamination in shellfishing areas around Boston Harbor (Figure 7).

The Massachusetts Bay area is also a leader in high technology industries. Other important employment industries are education, medical centers, financial institutions, government, trade, and service industries. As was noted, shipping and fishing are major activities in the Bay as well as tourism in some of the old towns circling the Bay.

Ocean fisheries have been important to Massachusetts Bay since the earliest settlements. The fresh and frozen seafood industries developed in the 20th century with the introduction of otter trawling and the quick-freezing process. Flounder, cod, haddock, whiting, and ocean perch are the most important fish value. Scallops and shrimp are the chief shellfish. Of the two main fishing ports, Gloucester leads in shrimp, whiting, and ocean perch, and Boston Harbor in haddock and lobster.

Manufacturing is the single most important source of wages and salaries statewide, although the number of jobs in this category and the share of total employment has declined since the end of World War II. Manufacturing still holds an important place in Massachusetts with electrical machinery manufacturing ranking first and nonelectrical manufacturing ranking second.

As was indicated, Boston Harbor/Massachusetts Bay holds a rich cultural history and provides diversity in recreational experience and economic activity. This same diversity holds true for environmental parameters. Boston Harbor is a hydrodynamically complex embayment. Current strength, direction, and patterns are determined primarily by tidal stage, tidal amplitude, and locations of islands, channels, and shelf areas. Sedimentation patterns are correspondingly complex since sediments

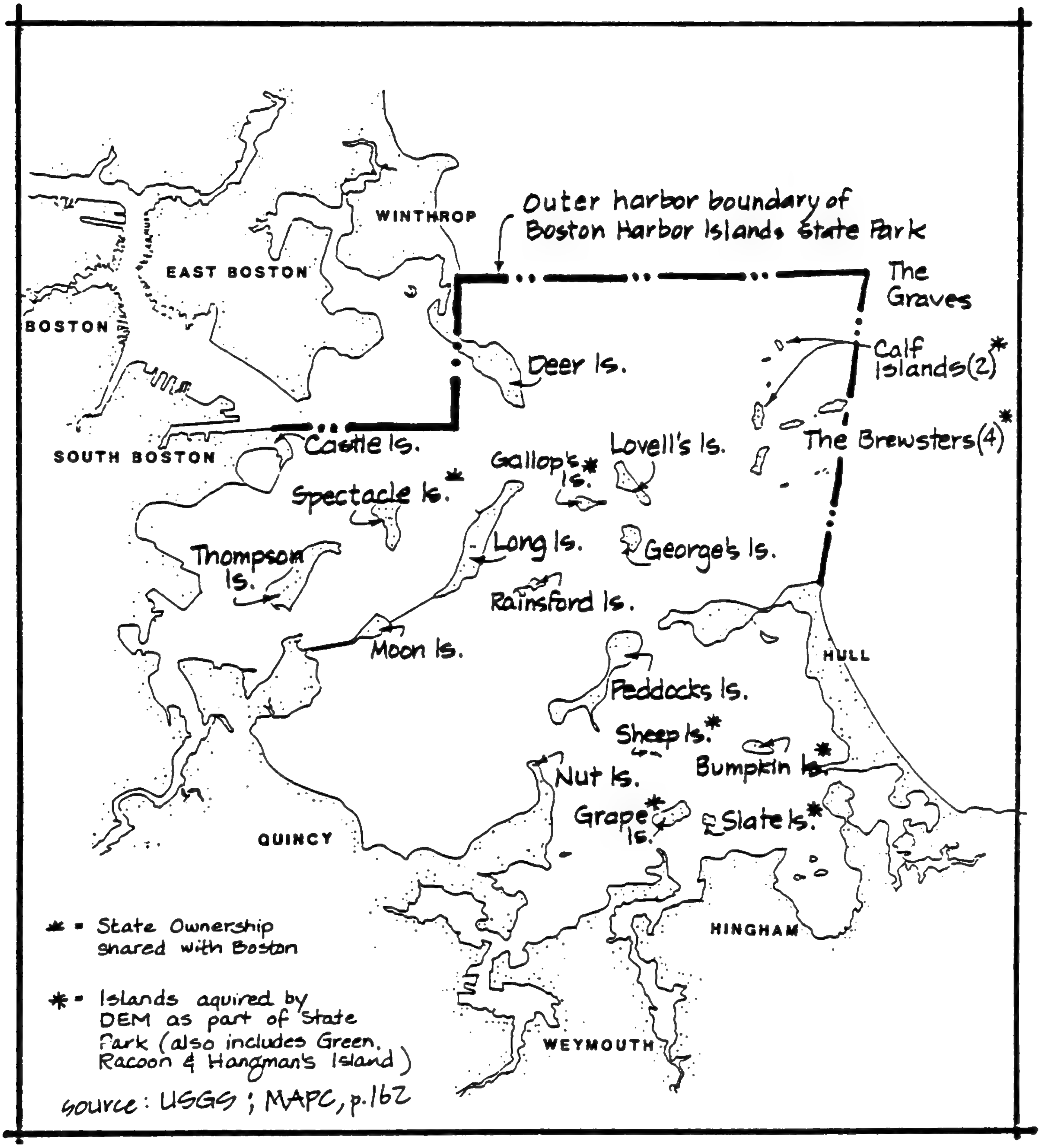

Figure 6. Boston Harbor Islands. From C.E. Maguire, Inc.

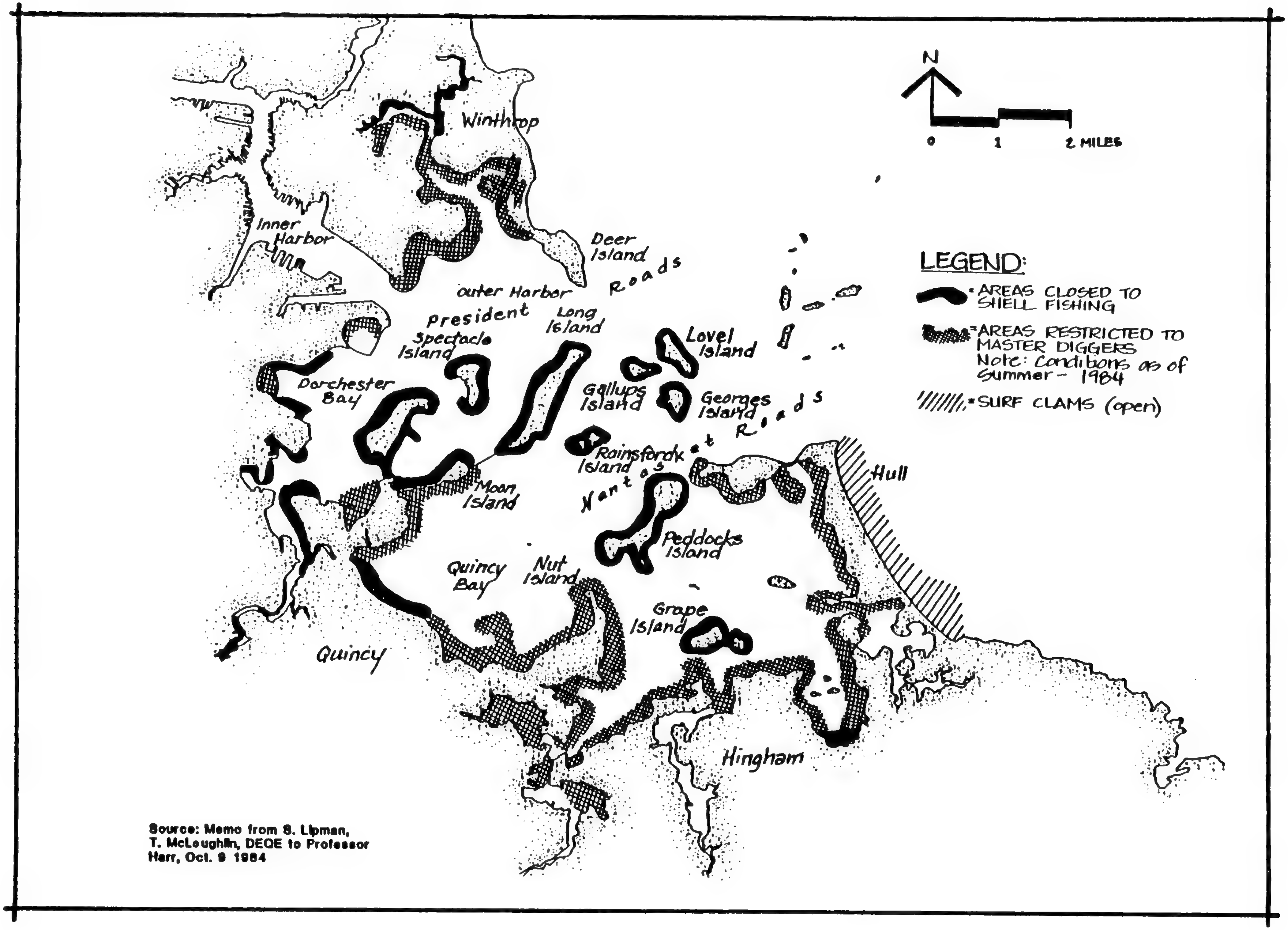

Figure 7. Shellfish Beds in Boston Harbor. From C.E. Maguire, Inc.

observed at a given sampling station observed are mostly the function of the ambient hydrographic regime. Sediments in Massachusetts Bay are very heterogeneous. A 1984 survey (Metropolitan District Commission (MDC) 301(h) application) documents gravel and cobble deposits over much of the surveyed area. The Massachusetts Bay's extensive gravel deposits are glacial in origin.

Circulation in Massachusetts Bay results from tidal forces, wind-induced motion, and other factors such as the Earth's rotational and atmospheric pressure variations. The circulation is generally counterclockwise, and winds are typically offshore from the west.

Water depths in Boston Harbor outside the navigation channels range from 10 to 15 feet at mean low water. Depths of nearly 90 feet occur in the channel at President Roads. The mean tidal rise and fall of Boston Harbor is approximately 9.5 feet. Maximum currents have been noted at Hull Gut at 2.6 knots during ebb tide and in President Roads at 2 knots both during ebb and flood tides (Figure 8).

Boston Harbor sediments have been found to contain high concentrations of heavy metals, particularly in the Inner Harbor and northern area of the Outer Harbor. Under the Massachusetts criteria for the classification of dredge or fill material, most of the Harbor's sediments would be classified under category two or three. These sediments are therefore subject to a more thorough evaluation with respect to biological impacts of dredging or filling than that which is required with class one material.

Data on Boston Harbor sediment characteristics suggest that high concentrations of metals found in the Outer Harbor are associated with fine-grained sediments and organic matter. The limited data on the toxic organic compounds DDT and polychlorinated biphenyl (PCB) suggest that they are also associated with fine-grained sediments and organic deposits.

The reported concentrations of toxic metals and synthetic organics in Harbor sediments are of concern due to the potential for bioaccumulation in organisms dependent on benthic organisms as a food source. Flounder and lobster tissues throughout the Harbor have been found to contain these toxic chemicals in varying concentrations. Sediments in the Harbor, particularly in its northern parts, are finer overall and have a higher organic fraction than those outside the Harbor. There also appears to be evidence of enrichment of metals in the most recent sediment layers in some areas of Massachusetts Bay. In general, coastal stations and the stations to the south and west of the foul area in Massachusetts Bay show elevated levels of metals in the sediments.

In the area of water quality, even though most waters in Boston Harbor meet the water quality standards established by the Massachusetts Division of Water Pollution Control, Harbor waters have higher concentration of pollutants than are found offshore in Massachusetts Bay. Water quality around the Outer Harbor islands and in Hingham Bay is the highest in the Harbor.

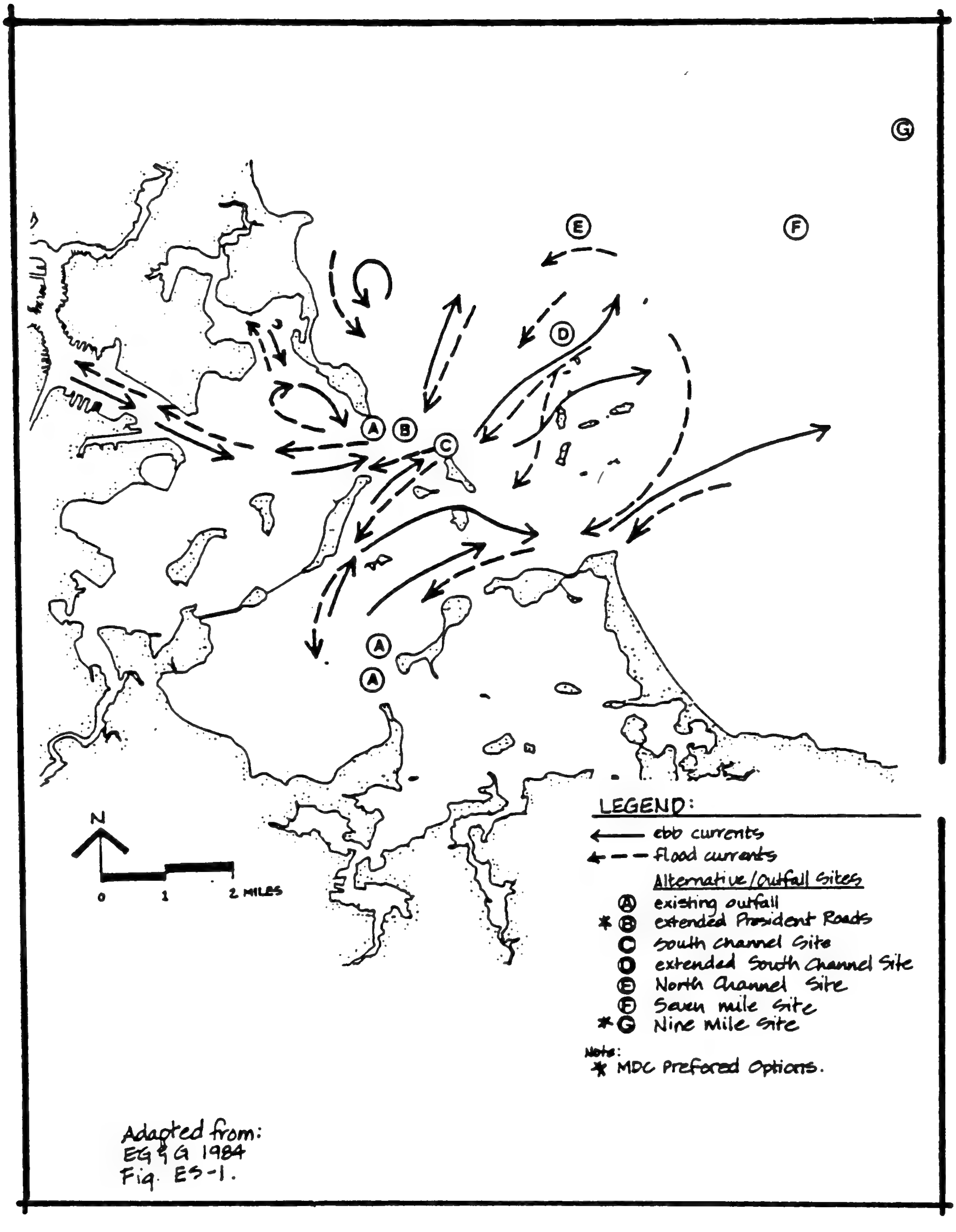

Figure 8. General Tidal Circulation in Vicinity of Existing and Alternative Outfall Sites. From C.E. Maguire, Inc.

In contrast, the waters in the northern area of the Harbor, north and west of Long Island, often have the highest concentrations of pollutants. Inner Harbor waters, northwest of Castle Island, and other nearshore waters frequently fail to meet the minimum water quality standards. Periodic sewer overflows result in nearshore violations of standards in Dorchester and Quincy Bays and in Belle Isle Inlet.

Boston Harbor supports a diverse community of marine organisms. However, the composition of benthic communities in the Inner Harbor, Deer Island/Governor's Island Flats, and Dorchester Bay indicates environmental stress. As noted, fin erosion has been found in winter flounder populations throughout the Harbor.

A wide variety of marine mammals and endangered species frequent Massachusetts Bay: the right whale, humpback whale, fin whale and the pilot whales; leather-back and loggerhead sea turtles; Atlantic white-sided dolphin, harbor porpoise and harbor seal. Stellwagen Bank and Jeffrey's Ledge, both within Massachusetts Bay, are prime feeding grounds for many of the above species, particularly endangered fin, humpback, and right whales. Benthic communities in Massachusetts Bay are spatially variable. Benthic communities appear to be unimpacted by pollutant inputs from recent surveys, but highly variable because of substrate heterogeneity.

The major pollutant discharges to Boston Harbor and Massachusetts Bay fall into the following categories: municipal discharges, sewage sludge, combined sewer overflows (CSOs), individual industrial discharges, and the foul area. Municipal wastewater discharges originate from 13 permitted dischargers with a total design flow of 541 million gallons per day (mgd) bordering Massachusetts Bay. The 13 communities are Rockport, Gloucester, Manchester, Salem, South Essex Sewerage District, Swampscott, Lynn, Massachusetts Water Resources Authority (MWRA), the city of Boston's Long Island Hospital, Hull, Cohasset, Scituate, and Marshfield. Of these, the MWRA is the largest discharger with an average daily flow of approximately 465 mgd, of which 9.4 percent is industrial flow totaling 44 mgd.

The other major municipal discharges in the area are the South Essex Sewerage District, as noted, which produces 41 mgd, with 40 percent industrial flow. Lynn contributes 25.8 mgd to Massachusetts Bay, of which 4 percent is industrial flow and Gloucester contributes 7.4 mgd with a 25 percent flow from fish processing industry and 5 percent from industry. Hull and Swampscott contribute 3 and 0.2 mgd, respectively, in primarily domestic flows.

I would like to briefly mention the status of the waivers for secondary treatment requirements from municipal discharges into Massachusetts Bay pursuant to section 301(h) of the Clean Water Act. There have been five applications filed for discharge into Massachusetts Bay; of these, the status is as follows:

1. MDC (now the MWRA): A final decision for denial of that waiver was issued in April 1985. The reason for denial was impact on biological communities and dissolved oxygen violations projected.

2. South Essex Sewerage District: A tentative approval was reversed to a tentative denial in May 1985. The reason being the inadequate assessment of adverse impacts on recreation. Reapplication is expected on November 1, 1986.

3. City of Lynn: A tentative approval was reached in October 1982, and EPA is currently reviewing public comments on that approval. The waiver application tentatively was denied in 1985. The City of Lynn withdrew its intention to reapply in January 1986.

4. City of Gloucester: A final approval was issued in June 1984.

5. Town of Swampscott: A decision is pending and will be announced by the end of this month. Waiver application denied tentatively in March 1985. Town of Swampscott intends to reapply by November 1, 1986.

Another source of discharges into the Bay is individual industries. A recent reading from our permit files in EPA Region I suggests that approximately 15 individual industries discharge into the Massachusetts Bay. This represents a very insignificant percentage of the industrial flows in the region. Most of the industries discharge into the municipal wastewater treatment facilities of their corresponding cities. As was mentioned, the MWRA is the largest municipal discharger in Massachusetts Bay. The major pollutant loadings into Boston Harbor from the MWRA system are treated effluent, sewage sludge, combined sewer overflows, and dry weather overflows (Figure 9). The other pollutant sources to Boston Harbor unrelated to the MDC system are storm water, urban runoff, and pollution loadings from the major tributary rivers of the Charles, Mystic and Neponset (Figure 3).

One final source of material impacting Massachusetts Bay is the foul area. The foul dumping area site is located 9.3 nautical miles northwest of Boston Light Ship. It has been routinely used for dumping miscellaneous chemicals since 1917. Safety Projects and Engineering, Inc. (SPE) dumped waste chemicals at the site from hospitals, schools, and industry from 1963 through 1976.

From 1973 through 1976, dumping took place pursuant to ocean dumping permits issued by EPA Region I. During this time SPE dumped 933 containers holding over 4,800 gallons of chemicals. From 1946 through 1970, 4,000 containers of low-level radioactive waste licensed by the U.S. Atomic Energy Commission were also deposited in the foul area. A single manifest from February of 1976 indicates that material brought to the foul area included 21 chemicals known to be carcinogenic, mutagenic, or neoplastic; 25 halogenated organic compounds; and numerous toxic heavy metal compounds. SPE's dumping at the site ceased 8 or 9 years ago. Under the Marine Protection, Research, and Sanctuaries Act permits, the U.S. Army Corps of Engineers (COE) continues to dump and approve dumping of dredge spoils at the regional site. The area has EPA interim

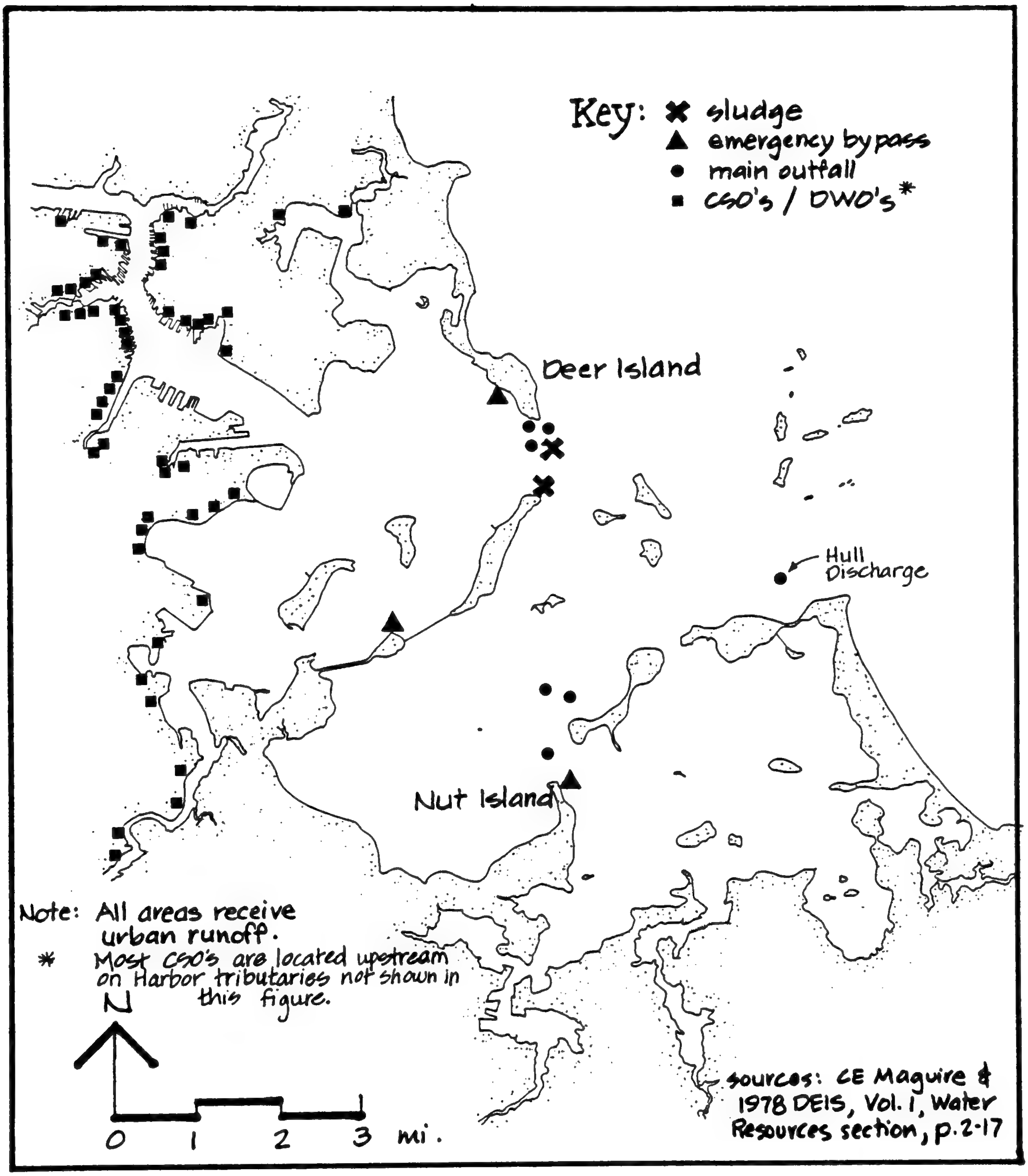

Figure 9. **Point Source Discharges to Boston Harbor. From C.E. Maguire, Inc.**

designation for dredge spoil disposal. The New England Division of the COE recently has been monitoring the area as part of their DAMOS Project.

Recently estimated loadings from all sources for the following pollutants into Massachusetts Bay are listed below:

SOURCE	TONS PER YEAR
PCBs	4,400
Chlorinated hydrocarbons	2,100
Petroleum hydrocarbons	1,760
Cadmium	88
Copper	1,760

The critical issues that face Massachusetts Bay as perceived from EPA's point of view are the following:

1. Cumulative impacts of large municipal wastewater discharges relative to the loadings of metals, toxic contaminant, and organic enrichment.

2. The incidence of fish disease throughout the Bay and possible indications of stressed biological communities within Massachusetts Bay and Boston Harbor.

3. The cleanup of Boston Harbor, of which the following speakers will give much more detail.

EPA Region I feels that a constituency that transcends localized interest needs to be developed for the environmental issues facing Boston Harbor and Massachusetts Bay .

I would like to thank you, and I will be happy to take some time for questions.

Question and Answer Discussion

Dr. Brown: What do you think the best route would be to develop such a constituency in the next two years?

K. Castagna: Well, as you mentioned in introductory remarks, there's been a tremendous amount of media attention on the cleanup of Boston Harbor. I think what would be useful is more public information on the interaction of Boston Harbor and Massachusetts Bay and how the Harbor and the state of pollution in the Harbor affect the Bay on the whole. The Bay, itself, is conceived of as a regional resource, and as we noted, many beaches and recreational facilities are in both the Harbor and the Bay itself.

I think people understand Boston Harbor pollution levels right now. There's been a lot of media attention on that. If there was more understanding of the interaction between Boston Harbor and Massachusetts Bay, we might have a better constituency for a Save-The-Bay type of group.

There is a lot of interest in the Boston Harbor, but localized interest seems to be on where facilities will be sited and the impacts on the community from a land use point of view. There's less of a constituency out there for overall environmental protection of the Bay and the Harbor.

Dr. Cahn: Were those NOAA Ocean Assessment Division's assessments that you gave based on just the last couple of years, five-year spread, or per year?

K. Castagna: I think they are based on information from several years.

Question: What is the status of the EIS you're preparing for Boston Harbor?

K. Castagna: EPA Region I published a supplemental draft jointly with the Commonwealth of Massachusetts in December of 1984. The final EIS was issued in December 1985 and that will resolve the siting of the new wastewater treatment facilities for the MWRA. The next speaker is going to give a detailed discussion of the challenges of the siting decision for MWRA and EPA. Thank you very much.

SEWAGE MANAGEMENT

by

Ms. Cheryl Breen
Massachusetts Office of Coastal Zone Management*
Boston, MA

I think Kathy Castagna has given us an excellent overview of Boston Harbor and Massachusetts Bay, and I would like to focus on one category of the direct discharges that she mentioned, the municipal sewage treatment plants, which are major contributors of pollutant loading into the marine environment. Specifically, I would like to discuss the wastewater collection and treatment system of the Metropolitan District Commission (MDC) (now the Massachusetts Water Resources Authority) because it is by far the largest of the systems discharging into Massachusetts Bay and its history can offer insight into the complexity of sewage management issues. Basically, I feel that if we can successfully solve the problems in Boston Harbor, we will perhaps be able to solve sewage treatment problems almost anywhere else.

As Kathy mentioned, there are 13 municipal treatment plants which discharge to estuaries and marine waters along the coast of Massachusetts Bay. Many of these, however, are very small systems which discharge between one and three million gallons of sewage a day. The occurrence of occasional disruptions in the operation of these plants, or worse, chronic lack of compliance with discharge permit effluent limitations can create dramatic impacts on nearshore waters. These illegal discharges can lead to localized problems such as closure of shellfish beds and swimming beaches. These types of events should not be ignored; but especially if the plants receive little industrial flow, they cannot be compared to the impacts on Boston Harbor created by the major facilities of the MDC system.

Of all the treatment plants discharging into Massachusetts Bay, MDC is responsible for contributing about 85 percent of the combined total flows. The MDC serves an area of 43 cities and towns in the Boston metropolitan area. It provides its service by operating two primary treatment plants located on Deer Island and Nut Island in Boston Harbor. The total flow from these plants, as Kathy mentioned, is approximately 465 million gallons per day (mgd). In addition to the effluent discharged, the system also contains 108 combined sewer overflow points which discharge primarily during wet weather events, although some discharge even during dry weather. The most dramatic of the discharges from the MDC system is the discharge of sewage sludge. Once the sludge is separated from the effluent during the treatment process, it is put back in with the effluent and discharged on the outgoing tides.

*Current Address: Massachusetts Water Resources Authority, Boston, MA

The MDC has been plagued by a number of management issues that have remained unresolved for the last ten to fifteen years. Basically, it has been a case study of management at its worst. The management issues that are most outstanding involve three areas: (1) determination of a level of treatment that the MDC facilities will provide, (2) the siting of new treatment facilities, and (3) the disposal of sewage sludge.

There have been many reasons for the delay in resolving these issues, but I feel that four of them are most pertinent. The first is simply the magnitude of the system. The service area is so large that to resolve the issues takes more time than it would if you were dealing with smaller systems that discharge 1 to 3 mgd. Secondly, the issues have been the subject of a great deal of public controversy that has impeded reaching decisions. It has been difficult reaching a consensus as to compliance with the environmental regulations and to equitable distribution of responsibility in providing sewage services for the 43 communities. Another important factor in the delay has been that during the last 10 to 15 years, environmental impact assessments have changed as the various regulatory requirements have been revised both for water quality and air quality. Lastly, in the intervening years, new scientific information has prompted better and different management decisions.

Now I would like to discuss three of the main management issues that have been prominant in the Boston Harbor cleanup effort, including a chronology of events and a brief update of more recent developments. First, a long history involving the 301(h) waiver process has determined the level of treatment that the MDC facilities should provide. The MDC applied for its initial waiver from secondary treatment requirements in 1979. Following this application, the U.S. Environmental Protection Agency (EPA) requested that the MDC submit more technical information on the assessment of potential biological impacts. This information was provided in 1982. Following analysis of this supplemental information, EPA issued a tentative denial of the application in 1983 based on questions of whether the primary discharge would be able to meet dissolved oxygen requirements and whether it would also adversely impact benthic organisms in the marine environment near the proposed effluent discharge site.

When faced with this decision, the MDC exercised its right under the 301(h) administrative regulations to reapply for a waiver and submitted a revised application. This revised application, submitted in 1984, included a new deep-ocean outfall site at a different location than proposed in the first application. In April 1985, the EPA again issued a tentative denial for basically the same reasons that it denied the first application. We see that just to resolve the level of treatment the plants are to provide has taken six years. Now that the tentative denial has been issued, EPA will next issue a draft discharge permit. At this stage, there will be opportunity for public comment and for the MDC to contest the denial decision. Ultimately, the drafting of the permit is what will determine the level of treatment required and specifically, what effluent limitations the MDC system will have to meet.

Once the level of treatment has been determined, the second major management issue is the siting of new treatment plants. The adequacy of the MDC system has been studied for quite a few years. Beginning in 1968, the MDC undertook its first comprehensive management study of the metropolitan region to see how and in what manner its two wastewater treatment facilities could be upgraded.

In an unusual sequence of events, EPA determined that it would be useful to draft an environmental impact statement at this point in time, although the environmental review process usually follows actual facilities planning. The draft siting of treatment facilities was completed in 1978, and though information was updated and further refined during a site options study conducted in 1982, no final environmental impact statement was ever issued. In 1983, both EPA and the state agreed that because so many years had elapsed, it was time to determine once and for all where the new facilities should be located, if, in fact, the locations were to change from what they currently are. A joint environmental impact statement and an environmental impact report that would satisfy both Federal and state environmental review regulations was undertaken, completed in December 1984, and put out for public review in February 1985. This report analysed all the past reports, reviewed all the old siting options, and added a few new ones. The initial 22 different siting options were winnowed down to eight remaining viable options, that were presented and fully evaluated in the draft report. At the time, it was felt that because the waiver decision had yet to be resolved, the draft would include siting options for both primary and secondary treatment. The decision for selection of a site could then proceed rapidly after the waiver decision was issued.

The choices involved in the siting of MDC wastewater treatment facilities essentially include evaluating the placement of facilities on three islands in Boston Harbor: the two that are now occupied, Deer Island and Nut Island, and one that lies right in the middle, Long Island. If the MDC proceeds to contest the waiver decision and that decision is ultimately overturned, the sites would include long deep-ocean outfalls. The outfall that was proposed in the 301(h) application extended approximately 9 miles out into Massachusetts Bay. If a secondary treatment option is chosen, the outfalls will be located closer to Boston Harbor, but probably not in their current positions. It was unusual that a preferred alternative was not selected when the draft EIS was issued. The current plan is for EPA, the MDC, and the Commonwealth to make a joint announcement July 10th, 1985 on a preferred siting alternative. Following this announcement, the EPA and the MDC will be able to proceed with completion of a final EIS and a final environmental impact report; this will ultimately lead to a recommended decision that should put to rest the whole question of where the sites for the new treatment plants will be located to rest once and for all.

The third important management issue that I wanted to discuss is sludge disposal, which has a lengthy chronology similar to the siting issue. Sludge management studies began in 1971 when the first major circulation model for the Harbor was developed. Following this, a draft and final EIS were prepared. In 1980, EPA issued a decision on the recommended disposal option. This was something that was not able to be accomplished in the siting process.

An update to all the prior sludge disposal evaluations was performed in 1982. The end result of these reports was that incineration was cited as the recommended alternative for disposal of MDC sludge. I might mention, however, that the Federal environmental impact reports were not deemed as providing an adequate assessment of alternatives under the Massachusetts environmental regulations, so there was no final concurrence on the recommended alternative by the Commonwealth of Massachusetts.

The basic problem was that while all the studies were being conducted from 1971 through 1982, there was a concurrent change in the air quality regulations and permissible air emissions limits. During this time, new regulations were being proposed which dealt with toxic substances in air, especially at the state level. Massachusetts began to undertake a program whereby it would create its own state guidelines for these substances.

At this point in 1982, the sludge management issue had yet to be resolved. Some people felt, in fact, that it could not be resolved until the waiver and siting decisions were made, because each of those decisions placed different restraints on what options are available for sludge management. The most recent event impacting sludge management occurred in July 1984, when EPA issued an administrative order to the MDC. EPA felt, as everyone did, that plans to cease discharge of sludge to Boston Harbor were not moving along quite quickly enough. In response to that order, the MDC has chosen a specific plan to expedite sludge management, involving both interim and long-term initiatives. The long-term facilities plan, which will look at a whole array of disposal options, will begin in July 1985. The interim options have already been the subject of a study and include ways of disposing only the sludge currently produced by the existing treatment facilities, not sludge that will be produced once new facilities are constructed. The options include disposing of the sludge at either existing landfills or existing incinerators, composting it through a pilot facility that is now located on Deer Island, or disposing it in the ocean at the 106-Mile Site off the coast of New York and New Jersey. To summarize, the three issues which created quite a logjam of activity in 1983 were decisions on (1) the level of wastewater treatment, (2) where the plant(s) would be located, and (3) how to dispose of sludge.

One event helping break the logjam was that one of the Harbor communities, the city of Quincy, filed a suit against the MDC and the Commonwealth for pollution of Boston Harbor. Though the actual contents of the suit were very narrow and specific to Quincy's concerns, the suit resulted in a schedule ordered by the state court and a court-appointed master to oversee that schedule. The schedule was developed in cooperation with a number of state environmental agencies and EPA. The work resulted in a comprehensive schedule to deal with upgrading the treatment plants, fixing some problems with combined sewage overflows (CSOs), and decreasing infiltration and inflow into the treatment system.

By far, the greatest result of this court action was that the Massachusetts legislature passed a bill creating a new Massachusetts Water Resources Authority

(MWRA). The MWRA bill was passed in December of 1984 and became effective July 1, 1985, with the MDC's Water and Sewerage Divisions being transferred from the state to an independent Authority. This is an important event because the new Authority will come out from under the constraints of state bureaucracy and be able to raise its own bonds for funding projects and to hiring more staff. Basically, the bill gives the Authority fewer constraints on management of their wastewater treatment system.

The new MWRA Board of Directors has been appointed, and a transition team has been hired. Although the Authority will not officially take over until July 1, 1985, the MWRA Board has already taken a number of initiatives to solve the problems in Boston Harbor. They will be involved in the negotiations of the new National Pollutant Discharge Elimination System (NPDES) permit. They are very actively involved now in determining the siting for the new wastewater and treatment facilities and will be making an announcement with EPA on July 10, 1985, on the preferred location. And as I mentioned, a number of contracts are underway to determine what can be done with sludge in the interim as well as long-term.

In addition, the Authority's other priorities include fixing the CSOs that currently affect many of the swimming beaches and shellfish beds. Most importantly, effort is being put into greater enforcement of the pretreatment program that the MDC had already initiated. The pretreatment program is one that has received Federal approval, but basically has suffered, as have most of the other components of the treatment system, from lack of funding and staff.

I will just mention one recent event. Despite the efforts of the legislature to create the new Authority and of the new Authority to take up its initiatives as soon as possible, a Federal court suit has been filed. The EPA felt that it would be best to move the schedule created under the state court suit into the Federal court, so that it could cover more topics and give all the pertinent agencies a schedule to live by, for the next 10 to 15 years. It will probably take that long to get the new treatment system designed, constructed, and operating.

The point is that the Boston Harbor and MDC experience is a learning experience that comes from making mistakes upon mistakes. We realize when analyzing the MDC problem that we need more effective planning for sewage management for all treatment plants throughout the Harbor and Massachusetts Bay. We have to make sewage management a priority for planning, especially as it relates to future development. Development cannot continue without adequate infrastructure or sewage treatment. Finally, I think we also need to assess all aspects of the sewage system: the effluent, the sludge, the combined sewer overflows, and the industrial inputs. If we can learn anything from the Boston Harbor experience and apply it to other coastal treatment plants, then it will all have been worth it.

I would like to close by saying that, in my opinion, the Boston Harbor situation should improve following the advent of the new MWRA, but it will be important for the

MWRA to also be involved in a broader management perspective for the Harbor and Bay. If we consider that the Harbor and the Bay have a number of specific inputs and that we are looking at the marine resource as a whole, then any decisions that the MWRA makes, either on what level of treatment it will provide or where it will put the treatment plants, will impact the other wastewater treatment facilities.

The MWRA will have an interest in monitoring Boston Harbor to see if any improvement in Boston Harbor's water quality can be charted. Any monitoring that the Authority undertakes should be closely coordinated with monitoring efforts being conducted either by other treatment facilities or other environmental programs.

In making a suggestion for a broad program, I think there are a lot of examples that we can draw from, especially the Chesapeake Bay area and Seattle, Washington, where there was an aggressive program for source control of toxic substances. These are the types of examples that we have to use, so we can determine if all sewage treatment plants are being put to the same level of standards for cleaning up their effluents and so that information is exchanged. In this way, we can get a total picture of whether we are achieving any improvement in the Harbor and Massachusetts Bay.

Question and Answer Discussion

Question: I would suggest that from what I hear that you may be making the same set of mistakes all over again in the following sense--you are proposing, from what I hear, that there be an announcement next month of a site or perhaps two sites for the treatment plant. Yet at the same time you're saying that there is a set of underlying issues, such as overflow, infiltration, inflow, direct discharges into the Harbor. It seems to me that you are very much in danger of moving towards heavy hardware solutions that are simply not going to solve your problems. All you're going to be doing is taking huge amounts of water, up to 90 percent of it for some sort of inflow, and putting it through treatment plants that you have built to handle huge capacities, and yet you are not going to really be solving the Harbor problem. You'll just be meeting EPA requirements of certain standards. So aren't you just repeating the same sets of mistakes that you made before here?

C. Breen: I may not have been clear on that point. First of all, the two treatment plants that are now existing are not functioning well at all. In fact, despite the delay in an ultimate siting decision, EPA has agreed to fund immediate improvements to the plants because we know that it's going to take seven to ten years to design and construct new treatment facilities.

Regardless of the other sources of pollution, something has to be done to create new treatment facilities for the system. Something that I just touched upon is the infiltration and inflow problem that you mentioned. It was a component of the state court suit, and as part of the remedy of that suit, the state department of environmental quality engineering has now designed a very aggressive infiltration and inflow program. This state agency is responsible for granting construction grants to the different communities.

Under this program, grants for construction are contingent upon a certain removal level of infiltration and inflow into the local system. I think it's fair to say that the problem is being attacked on all sides. I was just focusing on what I feel are the three major areas in sewage management. Infiltration and inflow is a major component, and we do currently also have eight priority combined sewer overflow projects that are in various stages of design and construction.

Dr. Brown: Given the large volume of sewage coming into the Harbor, a number of people have suggested that, as an alternative to siting a plant in one place, multiple plants be constructed, with the various townships picking up more responsibility for them--for instance, locating plants at Reading and out towards Needham, rather than one plant having several secondary treatment plants. Why was that option not considered?

C. Breen: What is termed the satellite treatment plant option, whereby smaller plants would be located further west in the Metropolitan District, is one of the options that was analyzed in the supplemental EIS on siting. It was determined, however, that those types of facilities could not meet the water quality criteria for the different rivers into which they would discharge.

Now that it has gone through the siting process once, I think the MWRA knows that in the future if it needs to expand its facilities, will definitely have to look at the construction of new facilities elsewhere than in the Harbor.

When the new facilities are constructed, they will be constructed with a certain design life, usually about a 20-year operation life. When new facilities planning must be undertaken, the Authority will be looking at options that deal not with just whatever sites it picks now, but possibly other sites. We will need to develop treatment plants at other sites that will meet water quality regulations, when at this juncture they could not. It may involve advanced waste treatment options or something of that nature.

Dr. Brown: If constructing satellite treatment plants is going to become necessary in the future, then planning for them needs to be started now, because in 20 years we will again be overtaxing a wastewater treatment system that we create now.

FISHERIES: PAST, PRESENT, AND FUTURE

by

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Massachusetts has a long history in fisheries. In Boston Harbor, it dates back to colonial times, to the 1620s. When Squantum Point was first settled, people began clamming and lobstering. Since that time the fishing community has grown in Massachusetts, particularly in Boston Harbor. During World War II, Boston fishermen landed over 200,000,000 pounds of fish on an annual basis, and Boston was the major processing and distribution center in New England.

More recently, Boston has diminished as an offshore port. The landings have declined to 20,000,000 pounds and fishing vessels have moved to other ports. However, Boston remains a processing and distribution center. Massachusetts fishermen statewide land about 350,000,000 pounds of fish a year, which is worth approximately $1.5 billion on an annual basis to the state's economy.

The three major fisheries within the Harbor are the lobster fishery, the shellfish fishery, and the recreational finfish fishery. In 1983, the lobster fishery, consisting of approximately 120 lobster fishermen, landed about 3,000,000 pounds of lobster and was valued at $7.3 million (Nash, 1984). The recreational finfish fishery consists primarily of a winter flounder sport fishery located throughout the Harbor, but principally in Quincy Bay. The Massachusetts Division of Marine Fisheries (DMF) surveyed this fishery in 1975 and determined that there were about 166,000 angler trips in the sport fishery in Boston Harbor in 1975. Utilizing that number of angler trips and applying the value of an angler day from the National Hunting and Fishing Survey in 1980, DMF estimates that the recreational finfish fishery in Boston Harbor is presently worth about $4 million annually.

Finally, the third largest fishery within the Harbor itself is the shellfish fishery. While about 4,700 productive acres of shellfish flats could support a commercial fishery, about 2,800 acres are open at any one time to restricted harvesting of shellfish. The State allows Master Diggers and Subordinate Diggers under a special permit program to harvest shellfish from moderately contaminated shellfish areas and to transport those shellfish to the Purification Plant in Newburyport. There they are depurated over a 48-hour period to reduce the coliform bacteria so they can be marketed. Last year, DMF processed just under 50,000 bushels of clams from Boston Harbor, valued at $2 million. A conservative estimate on the annual value of all harvested fishery resources in Boston Harbor is $13 million.

DMF has conducted many biological studies throughout the State in the last 20 years. In the early 1960s and 1970s, we collected and published baseline fishery and water quality information in 20 estuaries. In 1978, after the Fishery Conservation and Management Act was passed, DMF changed its emphasis and began to collect fishery resource information or stock assessment information from our coastal waters. Although we started the resource stock assessment program in 1979 to obtain relative abundance information on important commercial fisheries in our coastal waters, we began to look at external diseases on these fish throughout our coastal sampling.

As a result of that work, we have examined about 1,740 fish to date from sampling sites located within one-half mile outside of Boston Harbor. Outside Boston Harbor, the incidence of external diseases, including fin rot, skeletal abnormalities, lymphocystis, and other external lesions, is 1.8 percent. One-third of disease incidence was fin rot (DMF unpublished). In comparison to data collected offshore by the National Marine Fisheries Service (NMFS) in their groundfish surveys throughout the Northeast, we find that the 1.8 percent incidence rate is double the offshore rate. In the 105,000 fish collected and examined offshore by NMFS, the incidence rate was 0.99 percent (Despres-Patanjo et al., 1982).

During our routine 1983 sampling operation to collect information on lobsters, we examined 272 lobsters for external diseases, principally black gill and shell disease at 12 sites along the Massachusetts coast. The two areas with the highest incidence were Boston and New Bedford Harbor. Both are heavily polluted with organic substances and metals. Black gill disease in New Bedford occurred in 54 percent of those animals examined, and shell disease in 50 percent. Lobsters outside of Boston Harbor showed a 33 percent incidence of black gill disease and a 12.5 percent incidence of shell disease (Estrella, 1984).

In February 1984, DMF was contacted by the Massachusetts Office of Coastal Zone Management with a proposal to collect winter flounder in Boston Harbor in conjunction with the NMFS. The Office of Coastal Zone Management was interested in examining internal diseases, principally neoplasias on the liver of winter flounder, because Dr. Murchelano had been studying the same phenomenon offshore and found little or no incidence of neoplasia in flounder or other fish offshore. We agreed to obtain samples of winter flounder for NMFS and work with them on a brief study just to see if, in fact, neoplasia was occurring in Boston Harbor. I believe the information was also used as part of the State's review of the 301(h) waiver document that was prepared by Metcalf and Eddy for the Metropolitan District Commission.

The first sampling of fish occurred in April 1984. We sampled 100 fish: 50 from off of Long Island in Boston Harbor, and another 50 fish from Deer Island Flat, which is just southeast of the Logan Airport area. Twenty percent of all of those fish showed gross liver lesions; eight percent, after histological examination by Dr. Murchelano, proved to be cancerous and showed extreme neoplasia. Subsequent sampling on June 26 of another 100 fish in one sample from the Deer Island area showed exactly the same incidence of gross lesions and neoplasia (Murchelano and Wolke, 1985).

This was surprising because Dr. Murchelano had found a 3.4 percent incidence of neoplasia but no gross lesions in a sample of fish in upper Narragansett Bay and New Haven Harbor, I believe. He also subsequently found one fish out of 77 taken off Salem Harbor to have the same neoplasia. I do not believe that any other estuary along the U.S. East Coast has a higher incidence of carcinoma in fish than has been shown by these two samples from Boston Harbor.

We conducted further sampling in January 1985 and obtained only 13 fish, principally because the winter flounder were in deep water outside the Harbor at the time and were not available to sampling gear within the Harbor. One of these 13 fish had neoplasia. We sampled an additional 36 fish on March 14, 1985. Sixty-four percent of the March 14 sampling displayed gross lesions and 42 percent had hepatic neoplasia.

Because tomcod have displayed hepatic carcinoma in the Hudson River, we examined tomcod from the Weir River which drains into Boston Harbor. We sent 54 livers to Dr. Murchelano from samples taken in January 1985, and we found no gross liver lesions nor neoplasia in tomcod. The tomcod is basically a year-round, brackish water resident in the estuary, usually confined to depths of less than 20 feet. Remaining in the mouths of the small tributaries that drain into Boston Harbor, the tomcod possibly would be subject to some of the same environmental conditions that the winter flounder are, except that it has different feeding habits and much shorter life span.

We were also able to look at 16 of the winter flounder at random from the second sampling in Boston Harbor collected on June 26, 1984. We analyzed both the flesh and the livers separately for presence of polychlorinated biphenyls (PCBs) to get a comparison of what the levels might be in both the flesh and the livers. The analyses of the flesh showed a range from nondetectable PCB concentrations to a level of 1.6 parts per million (ppm), with an average of 0.4 ppm. However, livers from the same fish ranged from 5.1 ppm of PCBs to a high of 19.9 ppm of PCBs, with a mean of 10.4 ppm.

Another area where in concert with Dr. Murchelano, we have looked for neoplasia, is New Bedford Harbor. On May 15, 1984, we collected 25 winter flounder and 24 windowpane flounder from New Bedford Harbor. We felt that because New Bedford Harbor is highly contaminated with PCBs, the flounder might display the same symptoms. However, according to Dr. Murchelano, there were no gross liver lesions in any of the windowpane or winter flounder, and no neoplasia in any of those fish. It should be noted, however, that a sample collected in May 1985 revealed some winter flounder with hepatic necrosis, which was non-neoplastic.

Briefly, the cause of neoplasia in winter flounder is unknown, but the possibility exists that polynuclear aromatic hydrocarbons (PAHs), PCBs or synergistic action between several chemicals, including heavy metals, may prove to be involved. The only similar instance is in Puget Sound on the West Coast, where neoplasia in English sole and crabs occurred for about five years. Dr. Malins from the Seattle NMFS Laboratory has statistically related that situation to the high incidence of PAHs in the sediments of Puget Sound. The PAH contamination is caused by a military fuel depot and a creoste manufacturing plant.

Dr. Malins has also induced neoplasia in salmon by injecting pyro-a-benzene. He found that when PAHs in the Puget Sound sediments reach a level of 500 parts per billion, he almost always sees carcinoma in the English sole (Malins et al., 1984). High levels of PAHs have also been found in polychaete worms living in these sediments. Polychaete worms are the principal food of the English sole.

Clearly, the Boston Harbor situation needs further study--it needs a comprehensive study. Unless we know or have an idea of the source of the PAHs or the compounds that may be causing this phenomenon, remedial actions will not be possible. The long-term future of Boston Harbor environment and fisheries may depend on how we respond to the problem now. A cooperative effort by state and federal agencies, as well as the private sector, will be needed to adequately address the problem.

Question and Answer Discussion

Question: At one point you mentioned that PCBs in fish flesh were something like 1.4 ppm. At what point does that become a health hazard to recreational fishing or to a person eating that fish?

L. Bridges: The federal standards for all fish products for PCBs up until August 1984 was 5 ppm. Since then, it has been reduced to 2 ppm. Up to this point, the state has not adopted the federal standard and considers 5 ppm a problem. However, the Massachusetts Department of Public Health has informed me that they will be holding public hearings within a month, to adopt the 2-ppm standard.

We've examined other fish in Boston Harbor, but I merely pointed out the flounder because they were from the same fish in which neoplasia were discovered. Most of the fish flesh from flounder in Boston Harbor has been below the 2-ppm level.

There has been no examination of lobster, and lobster concentrate PCBs as much as or possibly even more than winter flounder, based on our experience in New Bedford Harbor. We had lobster in New Bedford Harbor with up to 78 ppm in the flesh. We have no information on PCBs in Boston Harbor lobster. Gordon Wallace and Dr. Eganhouse will be doing studies of PCBs in Boston Harbor. We have recently collected 30 animals to analyze because public hearings are coming up and because we want to know something about the PCB levels in lobster in Boston Harbor. I would point out, though, that from our experience in New Bedford, we find that if you separate the tamale in the lobster from the flesh, the tamale is usually higher by a factor of ten than the normal flesh.

A. Rosenfeld: I was wondering if there was any information on what the impact of these neoplasias of fish populations might be in terms of population dynamics and population fluctuations or the presence of high levels of chemicals, for example, in the lobster. Has there been any evidence of a decline in the overall fishery in Boston Harbor for winter flounder as well as lobster?

L. Bridges: I should have given a little more background on the lobster fishery in Boston Harbor because in the past ten years the landings have shown a steady trend upward from about 2 million pounds up to 3 million pounds. Now, that doesn't mean that just because the landings have increased, that the population has increased. What it might mean is that the effort to harvest those animals has increased. Because of the value of the product, increasing numbers of traps are being set for lobsters all the time. The coastal waters of Massachusetts are just full of lobster traps because they're so valuable. So the effort just keeps increasing dramatically.

To answer your other question about the impact of the fish health on the population itself, we have absolutely no information on this particular situation or on most situations on what disease might be doing in a wild situation. I would say that all of the flounder we looked at were over 25 cm, which indicates to me that while we didn't age them, they would probably all be around between 6 and 7 years old, at least.

There was a study done on Torch Lake Michigan in the 1940's I believe, and perhaps more recently, where they had the same phenomenon of neoplasia in yellow perch. They found that by comparing the longevity of those animals to the longevity of yellow perch in other Michigan lakes that the carcinoma reduced the longevity on the average by about 2 years. That is the only study I am aware of where they had some mortality information to compare to.

Question: Concerning this very significant recreational fishery for winter flounder in Boston Harbor, are any of those fish making their way into commercial markets? And if so, where?

L. Bridges: I should point out that although the winter flounder migrate outside of the harbor in the summer, they remain out in the deeper water of about 40 to 50 feet throughout the winter. They are harvested commercially. They do enter the commercial catch.

Question: I'm talking about recreationally caught fish in the Harbor.

L. Bridges: No commercial fishing for winter flounder is allowed within the Harbor because it might interfere with navigation. Some of those fish are entering the commercial fishery outside the Harbor, and, of course, there is always some illegal commercial fishing, principally at night inside the Harbor. But the incidence of illegal commercial fishing at night within Boston Harbor has declined over recent years because of better enforcement.

Dr. Brown: I think that's all the time we have for questions. To follow up on Leigh's talk we are fortunate to have Bob Murchelano to come speak to us today on histopatholgy of the winter flounder from the Oxford Laboratories.

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STATUS OF THE HABITAT: CHEMICAL CONSIDERATIONS

Metals and Nutrients

by

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Metal contamination of coastal marine environments has been linked to human health problems in areas where massive contamination has occurred (Kurland et al., 1960). However, the effects of chronic metal contamination on a lesser scale have been ill-defined, either from a human health or coastal ecosystem perspective. Human health concerns associated with the consumption of mercury-contaminated seafood have generally raised the level of public concern regarding ingestion of seafood potentially contaminated by toxic materials introduced into marine and fresh waters. However, sublethal threats to the ecosystem have received less attention, perhaps because of the uncertainty surrounding attempts to quantify such effects. We cannot, for example, definitively answer questions concerning the relative magnitudes of the effect of pollution and overfishing on valuable fisheries resources. Our ignorance of potential low-level effects of pollutants in coastal marine environments is coupled with increasing pressure to use these same coastal environments to receive large quantities of wastes. The Boston Harbor and adjacent Massachusetts Bay coastal environment is perhaps one of the most significant examples of this situation where ignorance coupled with inappropriate disposal practices has left us with a legacy of long-term contamination and uncertainty about the resultant effects on the ecosystem.

One aspect of this contamination includes the introduction of metals, some of which are known to be toxic, to the Boston Harbor/Massachusetts Bay ecosystem. The predominant sources of metals to Boston Harbor are shown in Figure 1. Effluent from primary wastewater treatment enters the Harbor at the Deer Island, Nut Island, and Hull outfalls. Metals and other contaminants are also introduced into the Harbor from the combined sewer overflows principally located in the Inner Harbor and Dorchester Bay.

Boston Harbor can be classified, using the definition of Fairbridge (1980), as a marine estuary. Freshwater input is minimal. The relative magnitude of sewage and riverine inputs into the Harbor is given in Table 1. The rivers account for approximately one-third of the freshwater input. The bulk of the remaining freshwater input is primary effluent from the two sewage treatment plants with smaller amounts coming from the combined sewer overflows (CSOs). Dry weather inputs are the primary source of pollutants to the Harbor from CSOs rather than those from wet weather flows.

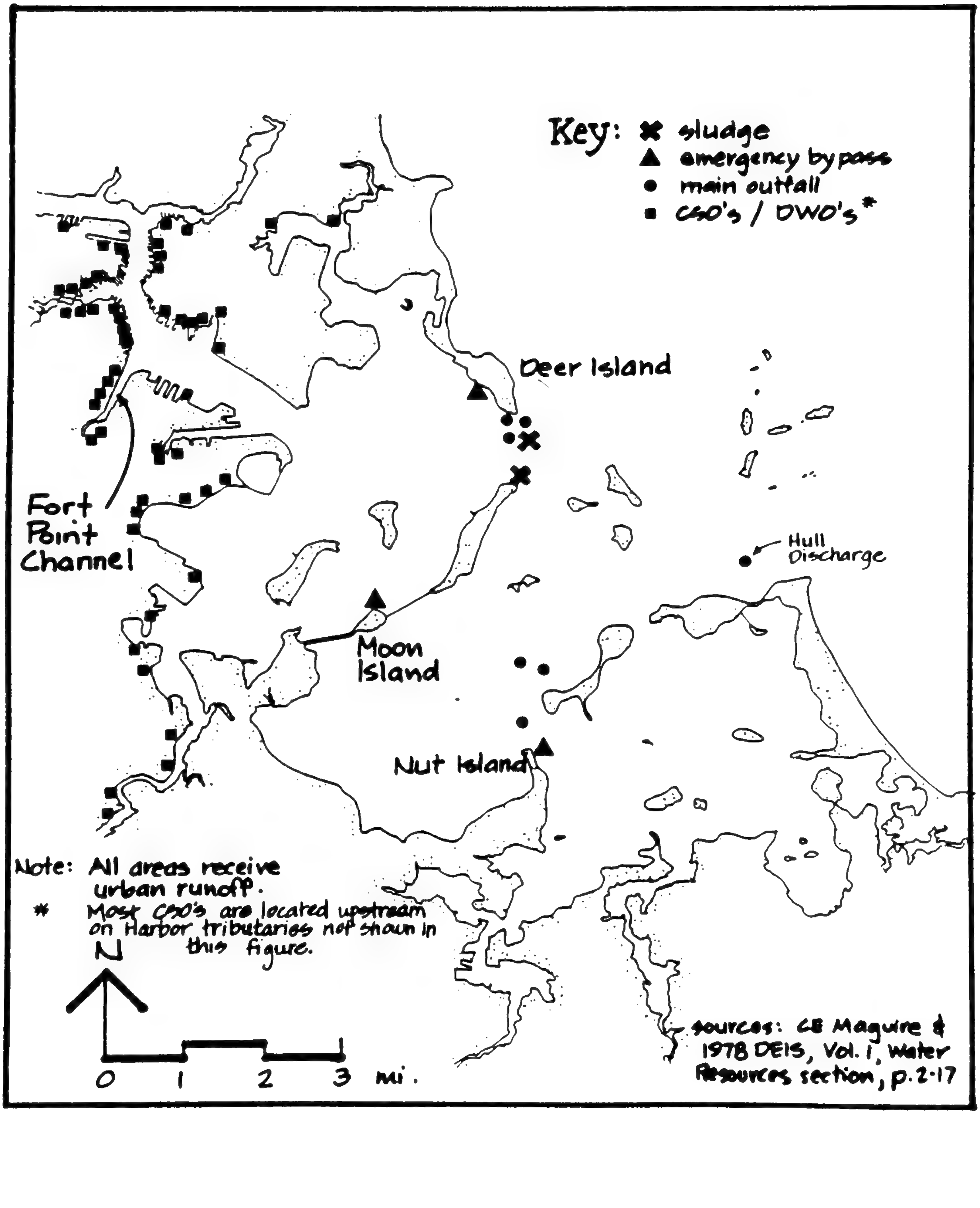

Figure 1. Point Source Discharges to Boston Harbor.

TABLE 1. ANNUAL INPUTS TO BOSTON HARBOR.

Source	Inputs (m^3)	Percent Contribution
Rivers	3.3×10^8	35%
Effluent	5.8×10^8	60%
Combined Sewer Overflows	0.2×10^8	2%
Dry Weather Overflows	0.3×10^8	3%
Total	9.6×10^8	100%

Annual mass fluxes of selected metals entering the Harbor in Deer Island effluent are shown in Figure 2. While there is a hint of a trend downward in some of the later data, the 1982 and 1983 values are discouraging and indicate that the mass flux for some metals remains quite high and is likely to remain so until an effective pretreatment plan is instituted.

Annual inputs of copper and lead to a number of estuaries and coastal waters have been compiled by Nixon et al. (1986). When the effluent inputs of these same two metals are calculated for Boston Harbor, their annual mass loadings are second only to that for the Hudson Raritan Bay system (Figure 3). The estimate for Boston Harbor excludes contributions from the CSOs or non-point sources. Also an unknown fraction of the input is most likely rapidly transported into Massachusetts Bay. However, until additional data become available, these estimates are probably of the right order of magnitude and valid for comparative purposes.

Sediments are a known sink for contaminants in aquatic environments. Fine-grained, organic-rich sediments are most efficient in retaining pollutants. The distribution of sediment types in Boston Harbor, shown in Figure 4, includes large extensive regions of these fine-grained, organic rich muds, some having an organic content greater than 10 percent, and, therefore, representing potentially efficient traps of both inorganic and organic pollutants introduced into Harbor waters.

Lead distribution in the sediments of Boston Harbor illustrates this fact (Figure 5). Sediment lead concentrations in the Inner Harbor and in the vicinity of Moon Island (Figure 5) are much higher than lead concentrations found in sediments sampled in Massachusetts Bay (Table 2). The particularly high sediment concentrations of lead in the vicinity of Moon Island are probably associated with the Moon Island discharge, which is used as an emergency by-pass upon system failure and results in the discharge of raw sewage to that area. However, because of the absence of data, transport and deposition of metal-laden particulate matter from other regions of the Harbor to the sediments in the vicinity of Moon Island cannot be ruled out. High sediment concentrations of lead similar to those found in the vicinity of Moon Island are also observed in sediments in the Inner Harbor. Again, the sources of lead in Inner Harbor sediments have not been accurately defined, but may reflect the large number of CSOs discharging into this part of the Harbor.

The concentrations of a selected number of metals in Boston Harbor sediments are compared with those sampled in other contaminated areas such as the New York Bight, Massachusetts Bay, and Commencement Bay (a Superfund site) in Table 2. Metal concentrations in Massachusetts Bay sediments are comparable with those observed in sediments at the sludge dump site in the New York Bight (Carmody et al., 1973). Metal concentrations in Boston Harbor are comparable to, and in some cases substantially exceed, those in Commencement Bay and at some sites reach the mg/g (parts per thousand) dry weight range. Most of the highest metal concentrations have been observed in an area of the Harbor known as the Fort Point Channel, which receives approximately 40 percent of the total CSO discharges to Boston's Inner Harbor (see Figure 1).

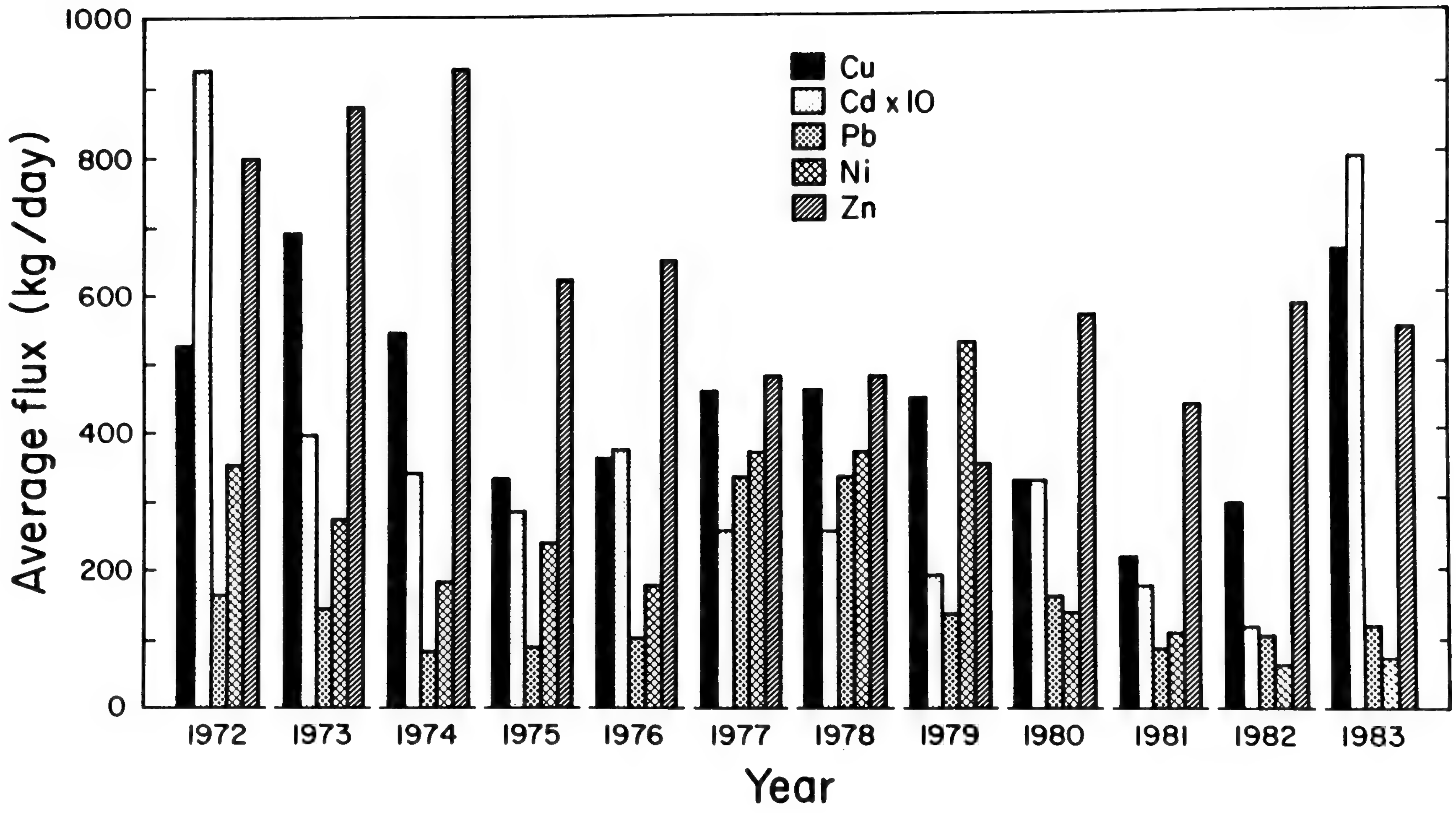

Figure 2. Deer Island Effluent Mass Discharges of Cu, Cd, Pb, Ni and Zn, kg/day, for the Years 1972 Through 1983. Discharge Rates are Arithmetic Mean of Monthly Concentrations in Effluent Times Effluent Flow.

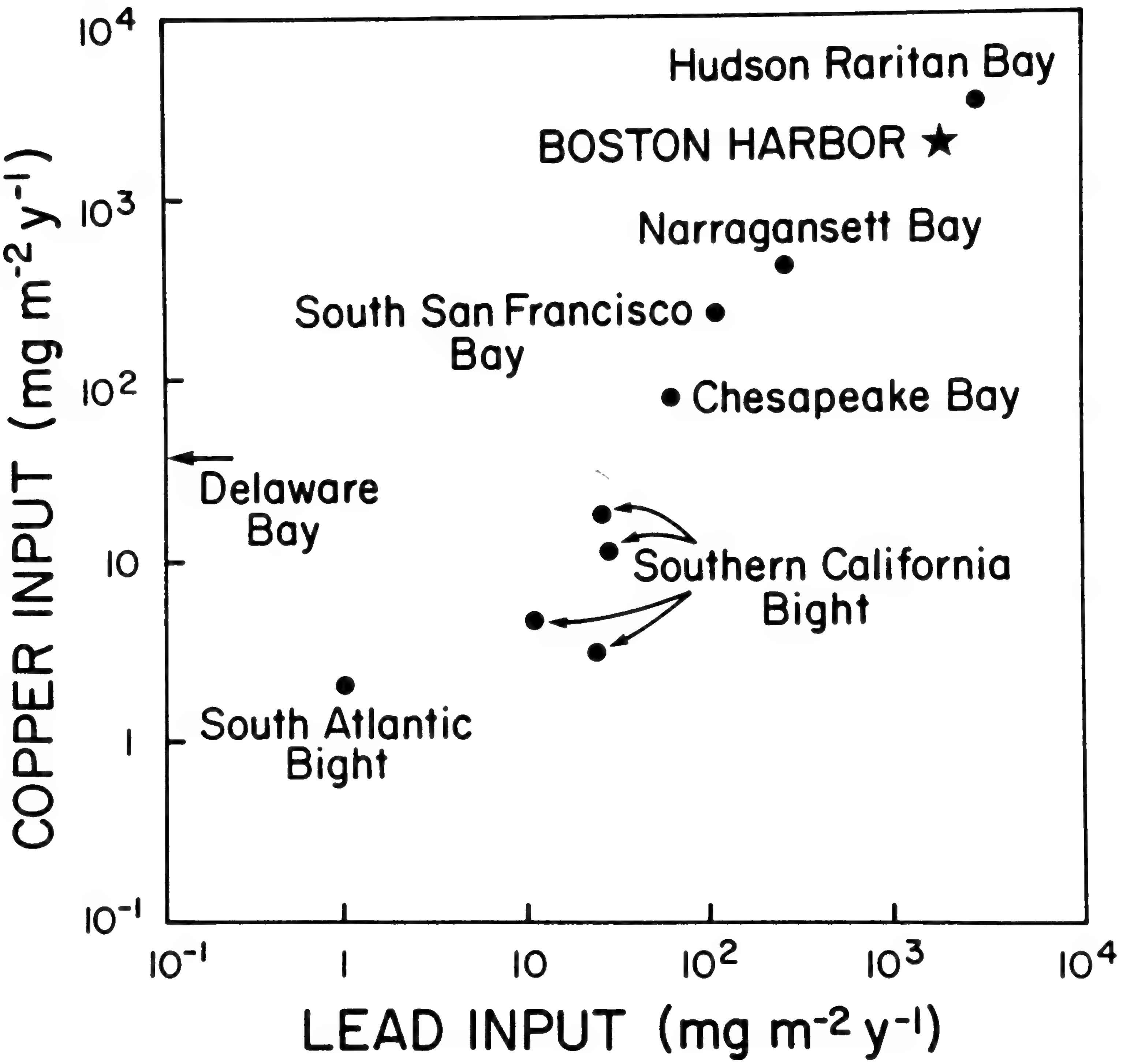

Figure 3. Comparison of Annual Mass Loading of Copper and Lead to Boston Harbor with that of Other Estuaries for which Data are Available. Modified from Nixon et al., 1986.

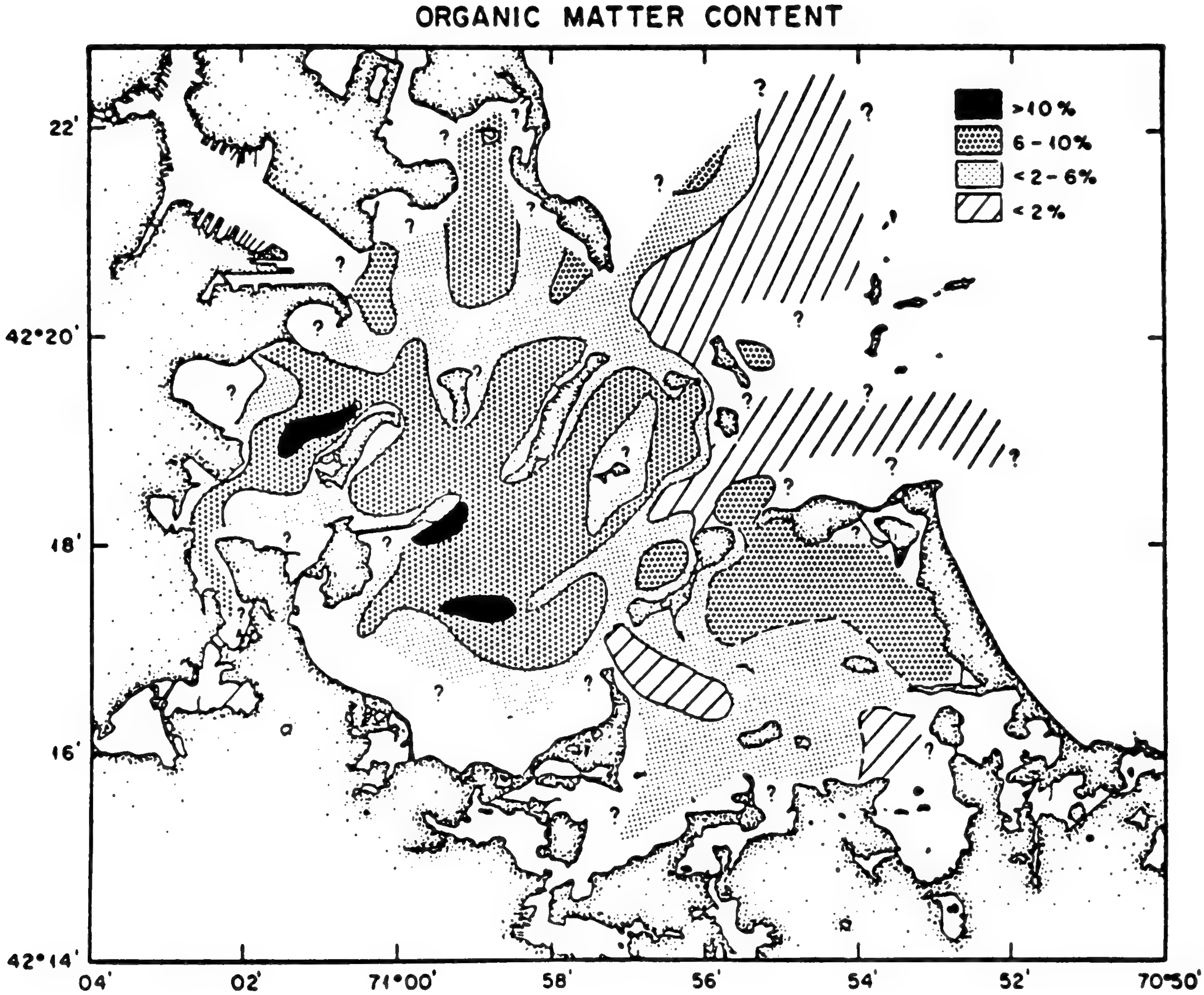

Figure 4. Organic Matter Content of Boston Harbor Sediments. From Fitzgerald, 1980.

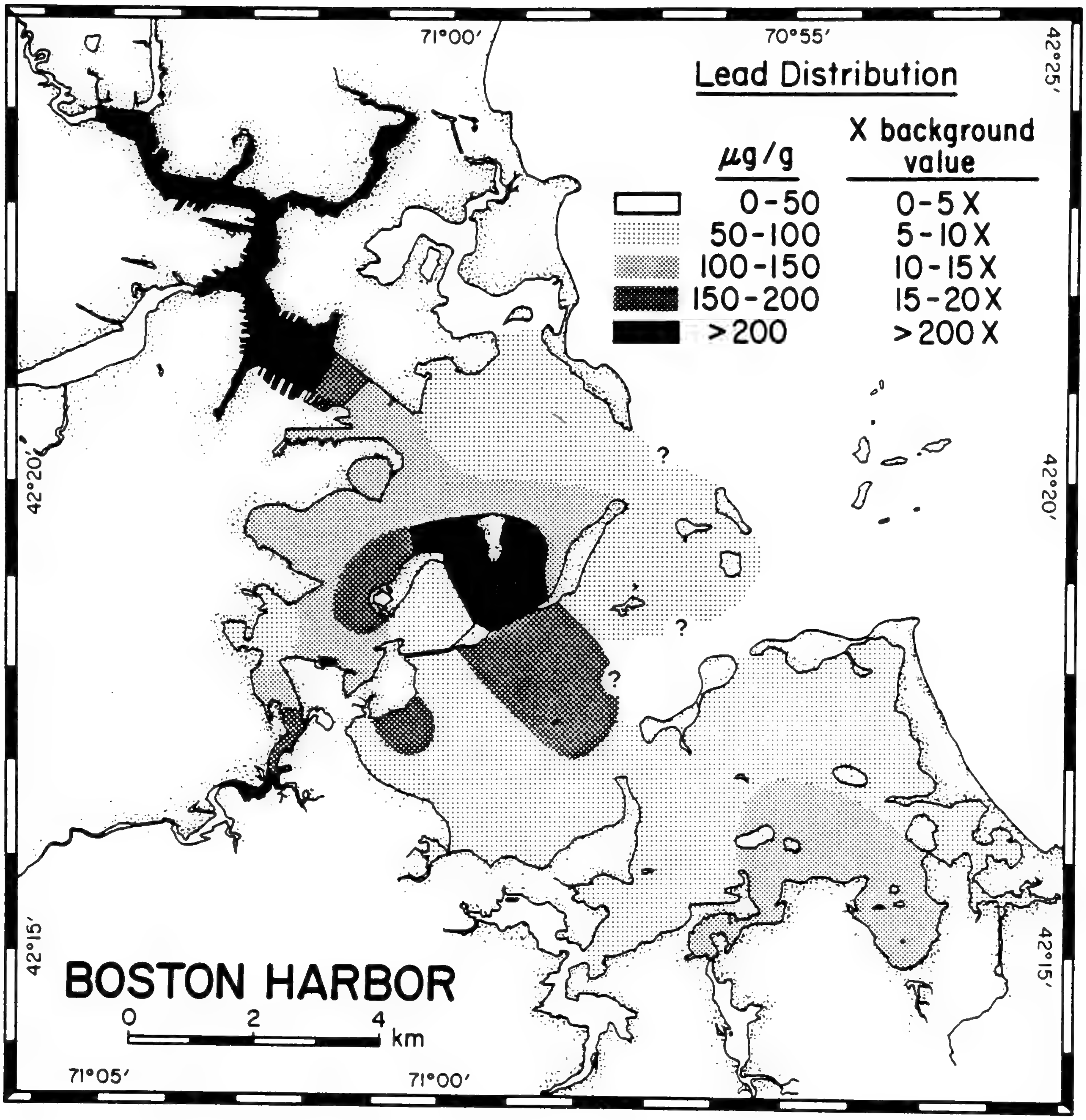

Figure 5. Lead Distribution in Boston Harbor Sediments. Data Contoured by Hand Using Data Compiled of Fitzgerald (1980) and White (1972). Background Sediment Concentrations are Based on Average Value of Four Massachusetts Sediment Samples. See White (1972) for Details.

TABLE 2. METALS IN SURFICIAL SEDIMENTS (mg/kg dry weight).

Location	Cu	Zn	Ni	Cd	Pb	Hg*	Cr
New York Bight (sludge dumpsite)	140	250	24	-	170	-	110
Massachusetts Bay	2-35	9-270	4-56	0.1-3.6	6-149	33-568	3-126
Boston Harbor	8-1000	32-2200	8-750	0.3-30	12-1200	200-9400	20-437
Commencement Bay	23-1600	-	19-64	4-16	14-790	60-1000	26-59

*ug/kg dry weight

Metal concentrations in the sediments of Massachusetts Bay, reported in a study undertaken by the New England Aquarium in 1976, are similar to recent data generated by NOAA although concentrations reported in the NOAA data tend to be somewhat lower (V. Zdanowicz, NOAA, Sandy Hook, NJ; pers. comm.). Of interest in the New England Aquarium's sediment data for chromium (Figure 6) is the apparent shoreward increase in concentration in the vicinity of Salem Sound. This distribution is consistent with what little we know about discharges in this area. The South Essex Sewage District discharges primary, or until recently, raw sewage effluent into Salem Harbor. Analyses of this effluent in the past have found rather remarkable concentrations of chromium (in the mg/l range) in the effluent (South Essex Sewage District 301h Waiver Application).

The existing data for metals in Massachusetts Bay sediments do not clearly indicate a spatial pattern that would implicate Boston Harbor as a source of the observed metals. This lack of a pattern is not surprising considering the variable nature of the sediments in Massachusetts Bay, especially the occurrence of coarse-grained sediments inshore (Fitzgerald, 1980). However, potential long-range transport of metals to Massachusetts Bay from Boston Harbor and their subsequent deposition at offshore locations is a distinct possibility in this environment.

Copper concentrations (Figure 7) tend to increase towards Boston Harbor although there is a gap in the data in the area immediately adjacent to the Harbor, perhaps because of the difficulty in sampling coarse-grain sediments in that area. Indeed, knowledge of the fate of the contaminant-laden sludge discharged at the mouth of the Harbor over the past two decades is non-existent. The short- and long-term fate of this material is essentially unknown. Local deposition in the Harbor, if Fitzgerald's (1980) estimates are correct is, a minor sink for metals discharged from the treatment plants.

Assessing the degree of contamination in a region simply on the basis of bulk sediment metal concentrations, however, is difficult because grain size and organic content of the sediments are important variables influencing sediment metal concentrations; and, these variables may or may not be associated with pollutant sources. Unfortunately, much of the sediment sampling and analyses performed on Boston Harbor and Massachusetts Bay samples have not included appropriate analyses of the different size fractions present.

Sediment geochronology in conjunction with contaminant analysis has been shown to be useful in documenting the pollution history of regional sediments (Goldberg et al., 1977). Data from a core taken in Dorchester Bay by Fitzgerald (1980) represents a similar effort to assess the pollution history of Boston Harbor sediments (Figure 8). Well-known problems are associated with the use of lead-210 in sediment geochronology, particularly associated with the biological mixing of surficial sediments. However, for the purposes of this discussion, we will accept Fitzgerald's assignment of 1900 as the age of sediment found at 39 cm in the Dorchester Bay core.

Most of the metal concentrations increase dramatically with core height above the 1900 horizon. The more recently deposited sediments in the core have much higher

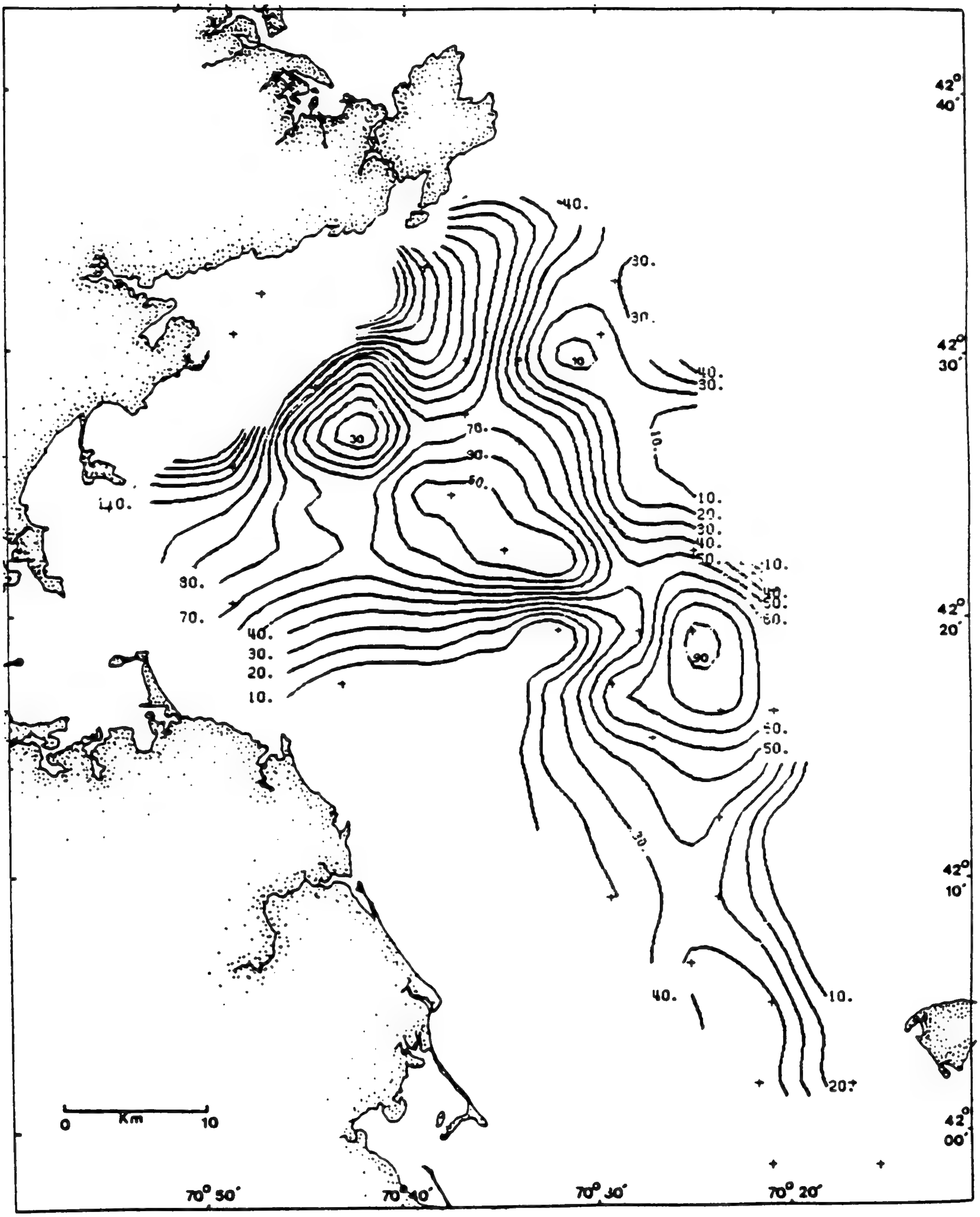

Figure 6. Chromium Distribution in Massachusetts Bay Sediments. Units in μg/g Dry Weight. From Gilbert et al., 1976.

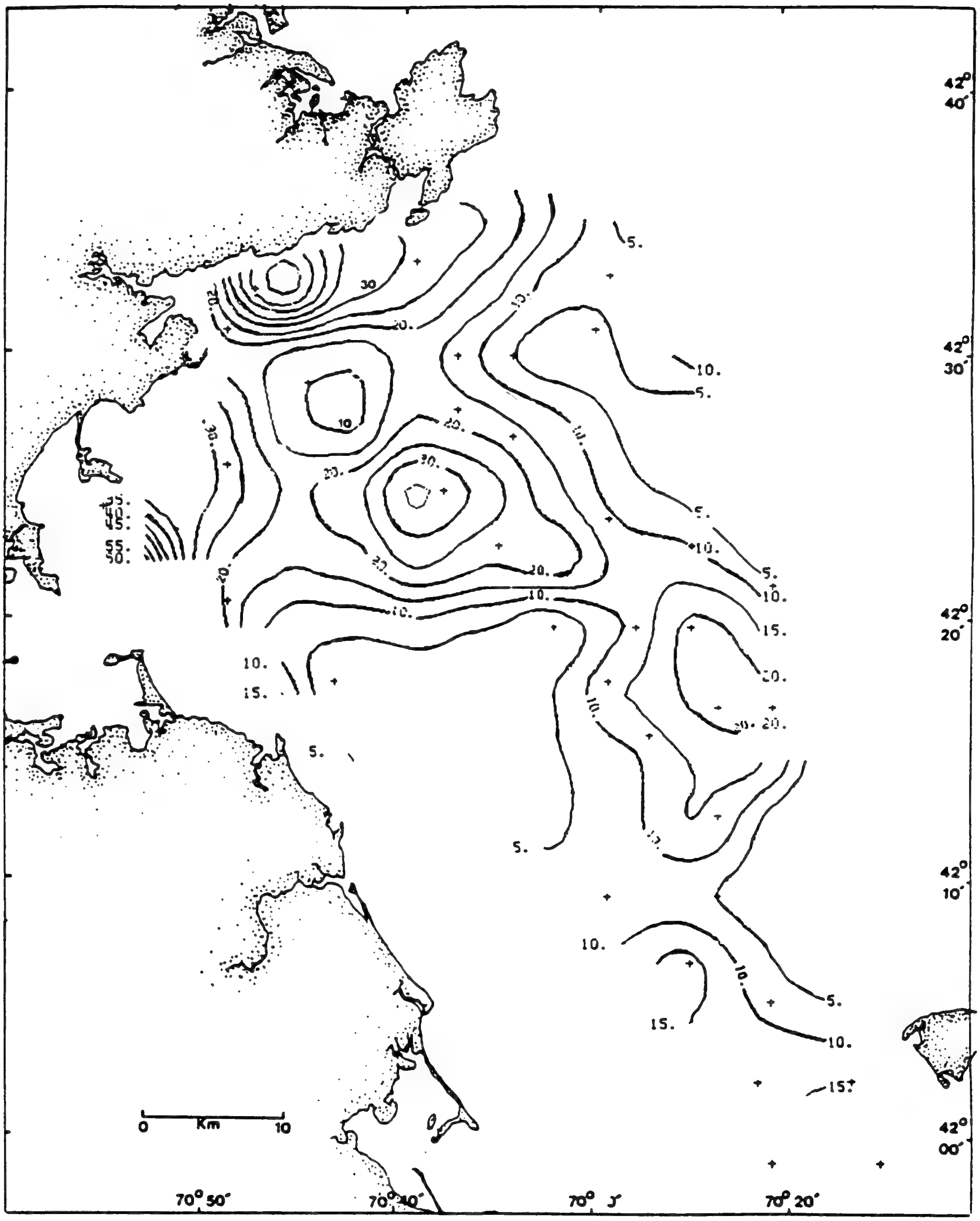

Figure 7. Copper Distributions in Massachusetts Bay Sediments. Units in µg/g Dry Weight. From Gilbert et al., 1976.

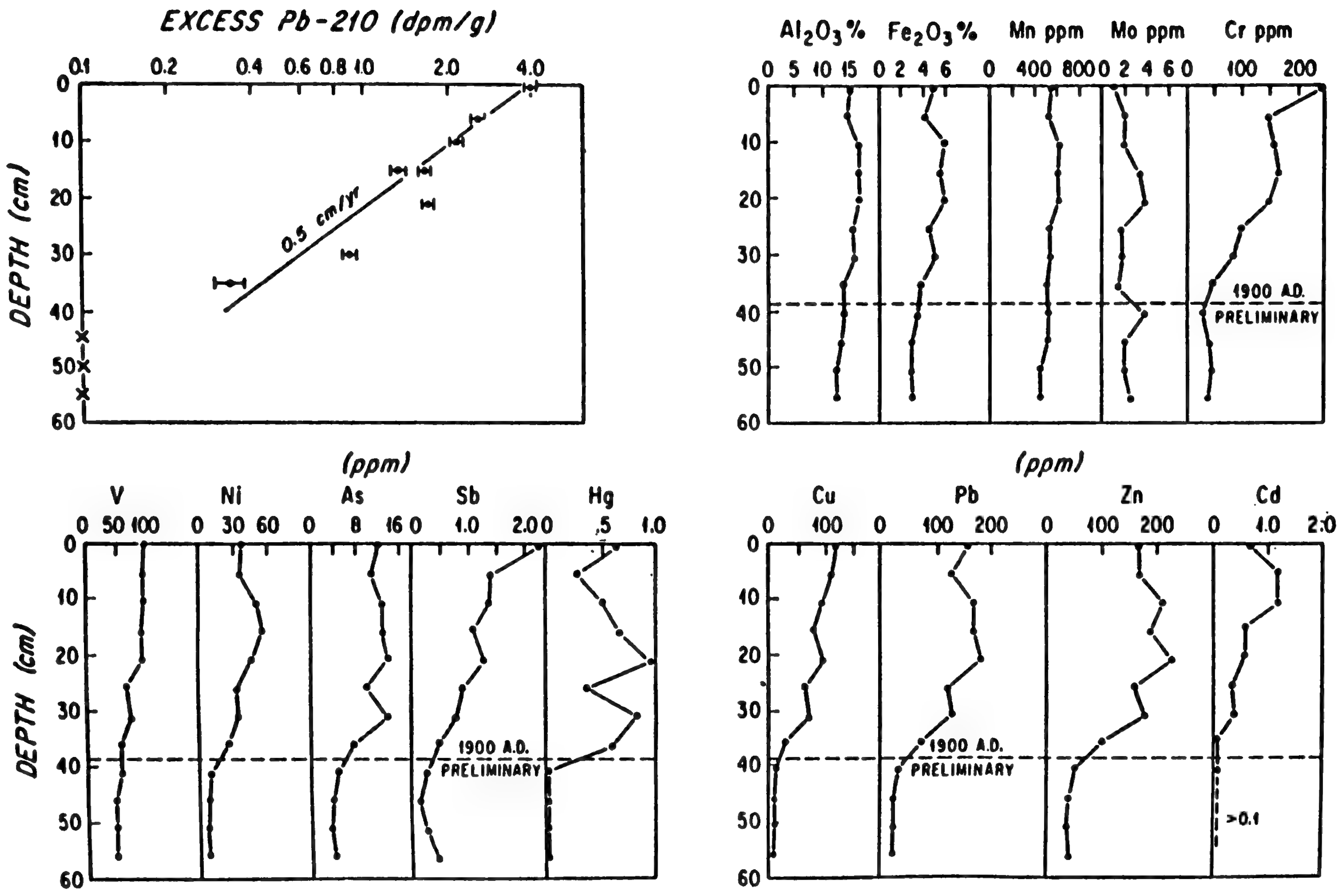

Figure 8. Vertical Profile of Trace Metals and Pb-210 in a Core Taken in Dorchester Bay, Boston Harbor. From Fitzgerald (1980).

concentrations of metals than those below the 1900 horizon. Similar observations have been made in cores taken in other areas of the world. To my knowledge, there are no similar data for Massachusetts Bay sediments. Such data would be of value in assessing the relative increase in metal concentrations of Boston Harbor and Massachusetts Bay sediments as well as the potential influence of the Boston Harbor discharges on Massachusetts Bay sediment quality.

While sediments of estuarine and coastal marine environments are a known sink for contaminants, the efficiency with which these sediments trap metals and other contaminants is not well understood (Turekian, 1977; Nixon et al., 1984). The efficiency with which the sediments of Boston Harbor retain metals introduced into the Harbor was erroneously stated in the original version of Fitzgerald's thesis to be about 33 percent for metals emanating from the effluent of the two treatment plants. In fact, when later corrected for an order of magnitude error used in his calculation, Fitzgerald's estimate of this trapping efficiency becomes only 3 percent. The implication that metals in the Harbor sediments represent only a very small portion of the total loading to the Harbor suggests that most of the metals introduced into the Harbor are transported offshore into Massachusetts Bay and either dispersed or accumulated in the fine-grained deposits that were referred to by Dr. Boehm. At this point it is probably most accurate to say that the mass balance of metals has not been established and that the fate of metals introduced into the Boston Harbor/Massachusetts Bay system is not well understood.

While sediment concentrations serve to qualitatively integrate the history of metal pollution in coastal environments, water column concentrations reflect the shorter time frame of pollution. However, it is difficult to accurately measure water column concentrations of metals in the nanomolar and picomolar range. Because of the frequent poor quality of such data, meaningful interpretation of the distribution of metals and, consequently, the identification of processes critical to understanding their fate and transport in nearshore environments have remained obscure.

Previously reported water column concentrations of metals in Boston Harbor have been shown to be erroneously high, in some cases by as much as three orders of magnitude (Wallace et al., in press). Data in Figure 9 compare the recently obtained range in concentrations of selected metals in the Harbor by Wallace et al. with those reported by the Massachusetts Division of Water Pollution Control (DWPC). Concentrations observed by the DWPC for these metals in Deer Island sewage treatment plant effluent are also given for comparison. Metal concentrations in the Harbor as determined by the DWPC are frequently in the same range as concentrations they reported to be present in the sewage effluent. Because Harbor waters have a salinity in the range of 30 o/oo and, therefore, contain only a small fraction of sewage effluent, the metal concentrations reported by the DWPC for the Harbor are probably incorrect.

The data of Wallace et al. (in press) were acquired using techniques suitable for use in open-ocean waters that have analytical resolutions orders of magnitude lower than those used by most non-academic institutions. Although concentrations for all the metals analyzed (copper, zinc, nickel, cadmium, and lead) ranged from 10 to 1,000 times lower

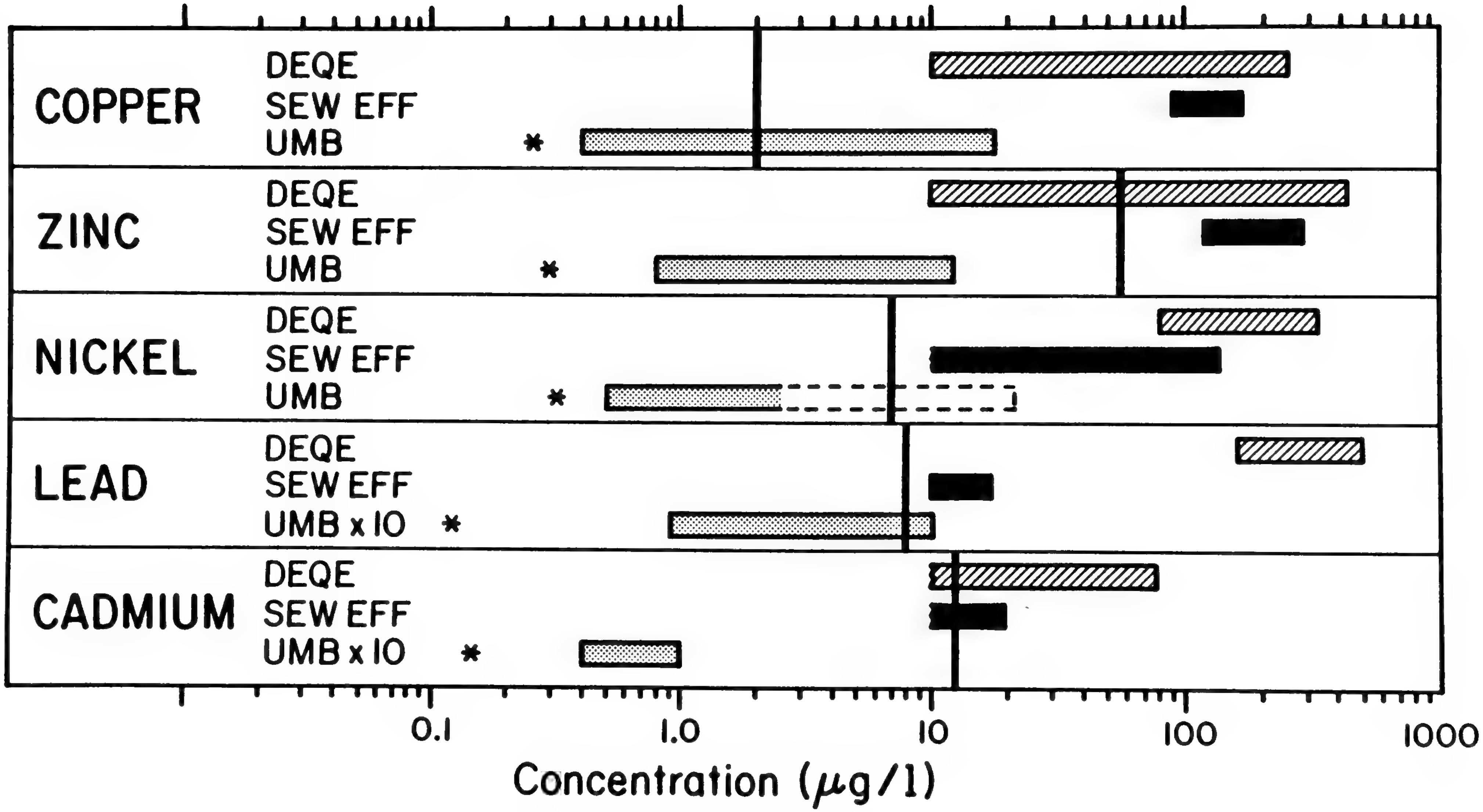

Figure 9. Comparison of Metal Concentrations in Boston Inner Harbor Water Column Samples (DEQE) and Sewage Effluent (SEW EFF) from Deer Island Determined by the Massachusetts Department of Environmental Quality Engineering, Division of Water Pollution Control, with Water Column Data Determined by Wallace et al., in Press (UMB). Preliminary Data Determined by Wallace (Unpublished Results) for Massachusetts Bay Surface Water are Indicated by Asterisks. EPA 30 Day Average Water Quality Criteria Concentrations for Protection of Marine Aquatic Life are Shown As Vertical Lines for Each Metal.

than reported previously, their concentrations are rather high when compared with recent reliable data for these metals in open-ocean waters. For example, typical open-ocean surface concentrations of copper are 1 to 2 nmol/l per liter. Typical clean coastal water, on the other hand, contains 2 to 3 nmol/l per liter of copper.

The distribution of copper in Boston Harbor reported by Wallace et al. (in press) is of particular interest. The distribution of copper at low tide, shown in Figure 10, provides three important pieces of information. First, at all stations sampled, the concentration of copper exceeded the current EPA standards for marine waters of 2 μg/l (31.5 nmols/l). Second, concentrations in the southern parts of the Harbor were in excess of 200 nmol/l, among the highest reported in the reliable literature for estuarine and coastal waters. Finally a sample taken directly from the Deer Island plume contained, as expected, a higher copper concentration than observed at adjacent stations.

High concentrations of copper were also observed in the Inner Harbor and may reflect a combination of local sources and/or longer residence times of water in the Inner Harbor. Unfortunately, our ignorance of the dynamics of metals in Boston Harbor is coupled with our ignorance of the physical oceanography of Boston Harbor. Except for some initial studies in the vicinity of the Deer Island and Nut Island discharges, virtually nothing is known about the physical circulation in the Harbor.

Perhaps the most remarkable feature of the copper distribution in the Harbor was the high concentrations observed in the southernmost areas of the Harbor. These high concentrations may reflect a combination of geomorphological, chemical, and biological parameters. For instance, the shallow nature of the southern Harbor, coupled with biogeochemical remobilization of copper from particles accumulating in the underlying sediment may account for this observation. We should also note that the remobilization of copper from sediments may involve temporal scales of days and perhaps even hours. Recent data on the kinetics of nutrient fluxes from sediments (Garber, 1984) support this hypothesis. The possibility that such rapid remobilization might happen is not generally considered when assessing impacts of waste disposal in the nearshore zone.

Finally, with the high ambient concentration of copper in the Harbor, it becomes obvious that any discharge of copper to Boston Harbor waters from any source would probably violate EPA Water Quality Criteria. The discharge from Boston's new secondary plant, when constructed, may therefore have to be located further offshore to meet these standards. Unfortunately, the chemical speciation, toxicity, and transport and fate of copper and other metals in the Boston Harbor/Massachusetts Bay area are not understood. Until such knowledge is obtained, decisions regarding matters such as the extension of the outfall, a decision involving hundreds of millions of dollars, must be made in ignorance.

Knowledge of the sources, distribution, and processes influencing the fate of metals in Massachusetts Bay is also non-existent. Evidence that metal concentrations in Massachusetts Bay sediments are higher than those observed in clean areas has already been presented. However, because of our limited knowledge in the above mentioned areas, we cannot make reasonable judgements concerning the potential influence of

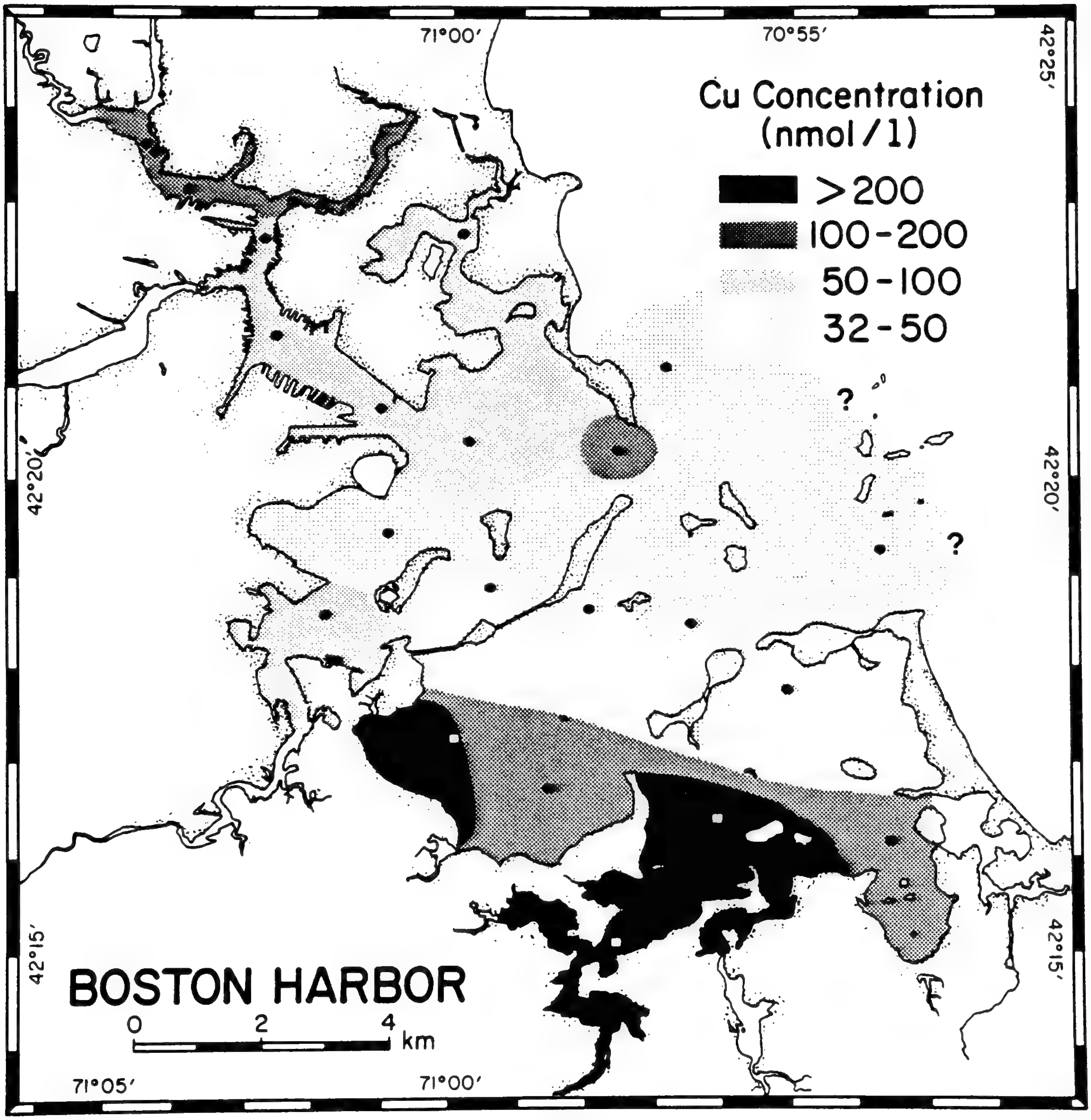

Figure 10. Contour Plot of Copper Concentrations Observed at Low Tide on August 17 and 18, 1983. Contours Arbitrarily Drawn by Hand. Sampling Locations Indicated by Black Dots. Data from Wallace et al. (In Press).

enhanced toxic loadings, as would occur, for example, from the possible extension of the Boston Harbor outfall, on the Massachusetts Bay environment.

Elevated concentrations of toxic contaminants in aquatic environments sometimes manifest themselves in elevated tissue concentrations in organisms, some of which we eat. For that reason, it is of interest from a public health perspective to determine the extent to which such edible tissues are contaminated. Data for lobsters, winter flounder, and clams taken from Boston Harbor are now beginning to be collected. Initial findings, with respect to metals, report that no recognizable human health problem is apparent.

Human health should not be the only concern, however, when assessing the effects of contaminants in our nearshore coastal waters. For example, the concentration of copper in Boston Harbor reaches levels previously shown to exert noticeable effects on the biota in nearshore waters. These effects include inhibited bacterial and phytoplankton growth, change in succession of phytoplankton species, and reduced zooplankton fecundity (Hodson et al., 1979). Also, physiological mechanisms used by organisms to mediate effects of metal pollution have some metabolic cost. An example is synthesis of metallothionein, a metal-binding low-molecular-weight protein used by a variety of organisms to prevent metals from reaching critical cellular components such as enzymes. The synthesis of this protein requires energy that might otherwise be used for growth or other activities of the organism. Such effects are difficult to assess and even more difficult to understand in their influence on ecosystem dynamics as a whole.

Frequently, the egg and juvenile stages of developing organisms in the near-shore coastal environment are the most susceptible to impact by metals. This fact may be of particular significance in Boston Harbor because of its importance as a spawning ground for winter flounder and the importance of the winter flounder fishery itself in the Harbor (Jerome et al., 1966).

Eutrophication has been and continues to be a major concern in the disposal of sewage in coastal waters. Nutrient distributions and dynamics in Boston Harbor and Massachusetts Bay are essentially unknown. The existing data were generally obtained in the summer and are restricted to observations of either short temporal variations at specific sites (Fitzgerald, 1980) or semi-synoptic sampling. Seasonal variations, uptake by primary producers, and regeneration and storage in Harbor sediments have not been examined. Because the flux of nutrients to the Harbor will not decrease but may, in fact, be increased by applying secondary treatment, information on nutrient dynamics in the Boston Harbor/Massachusetts Bay system is needed. Nutrient dynamics not only affect the biota, but are also critical in influencing pollutant transport and retention in both the sediments and water column.

Officer and Ryther (1977) have presented data suggesting that secondary treatment of wastes followed by disposal in coastal waters with restricted circulation is less desirable than offshore disposal of untreated wastes, at least with respect to the impact on oxygen concentrations in the respective receiving waters. Data gathered in the preparation of Boston's 301(h) Waiver Application indicate occasional depressed oxygen concentrations in Massachusetts Bay, the cause of which has not been determined. The occurrence of these low oxygen concentrations in Massachusetts Bay contributed to the decision of the U.S. Environmental Protection Agency to deny the 301(h) application. As Officer and Ryther point out, the nitrogen flux available for plant growth from secondary treated effluent may exceed that from untreated sewage. Thus, potential enhanced nutrient fluxes from Boston's future secondary sewage treatment plant raise important questions concerning the fate of nutrients and their effect on oxygen concentrations in the Boston Harbor/Massachusetts Bay system. Ironically, the application of secondary treatment, while serving to reduce the flux of contaminants to this system, may well result in accelerated eutrophication of the Boston Harbor/Massachusetts Bay system. Clearly, we need to understand the nutrient dynamics of Boston Harbor and Massachusetts Bay.

In summary, I would like to identify critical areas where the lack of data either directly or indirectly influence our understanding of the inorganic chemistry of Boston Harbor and Massachusetts Bay.

1. The physical circulation and the parameters that govern such circulation have not been adequately defined for either the Harbor or the Bay. These data are required to determine transport, distribution, and fate of contaminants in this system and, ultimately, the potential influence of these contaminants on the biota.

2. The efficiencies with which contaminants are retained in both Boston Harbor and Massachusetts Bay sediments are critical in any attempt to assess the existing and future fate of contaminants introduced into this system.

3. Accurate assessment of the nature and quantities of metals and nutrients entering the system must be obtained.

4. Knowledge of the chemical speciation of metals is of critical importance in any attempt to understand the geochemical behavior and toxicity of these contaminants to the biota.

The above areas are not exhaustive, but rather serve as areas where immediate information is required, especially in view of the massive funds (about two billion dollars) being expended on the design and construction of facilities to reduce the pollution of Boston Harbor. Even with such improvements, the quantities of metals and nutrients entering this system will still be substantial. Ignorance in the above areas will enhance the possibility of costly engineering mistakes in the next decade that may adversely effect the health and welfare of this ecosystem for many decades to come.

Question and Answer Discussion

Question: Has there been any monitoring for metals in shellfish?

Dr. Wallace: Not in any systematic way. I know of one study where metals were analyzed in clams taken from the Harbor. In addition, we are currently analyzing a limited number of clams from Boston Harbor. Incidently, one of the critical parameters in any of this work, and I'm sure Paul will support me in this, is proper validation of the methods we use. Historically, the methodology has not been properly validated. For example, there frequently is no reference standard analyzed. Unfortunately, we cannot accept concentrations in tissues with any degree of confidence unless we have that information. If we accept current analyses as valid, no public health problem appears to be associated with metal concentrations in the edible tissues of clams from the Harbor.

Question: Do you have any insight into the amount of reduction that has resulted in the metals loading to sewage treatment plants?

Dr. Wallace: Yes. For example, the reduction in copper and other metals has been shown in a number of reports. The best example I know where ocean disposal is involved is the effect of pretreatment on the municipal discharges along the southern California coast. Pretreatment resulted in about a 40 percent decrease in influent copper concentrations. Secondary treatment, in the absence of pretreatment, can increase removal from 25 percent for primary to 70 percent removal for secondary, or in other words by a factor of 2 to 3 with respect to primary.

Question. Without pretreatment?

Dr. Wallace: Without pretreatment. Exactly. So to accomplish dramatic decreases in effluent metal concentrations there has to be a rather effective pretreatment program.

Question: Is there any data indicating a mass balance distribution between industry and other sources of metals?

Dr. Wallace: Not to my knowledge. That's a difficult problem. I would defer to Cheryl Breen or the EPA for the answer to that question. Have you been able to identify individual industrial sources of the various metals in the system?

C. Breen: No industrial sources.

Question: I mean, that's the obvious question.

Dr. Wallace: Exactly. I agree.

Dr. Thomas: Do you have any gut feeling concerning, say, boat ship traffic and anti-fouling paint as sources, minor source, heavy?

Dr. Wallace: In my opinion, the point discharges are probably the most important. However, we don't know anything about non-point discharges to Boston Harbor. But I suspect, by analogy to Narragansett Bay and other areas, that non-point sources are a significant, but not primary source.

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STATUS OF THE HABITAT: CHEMICAL CONSIDERATIONS

Organic Chemistry

by

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I would like to thank the previous speakers who have really set the stage for a general overview of the chemical status of the Boston Harbor/Massachusetts Bay habitat. I will be presenting our findings on toxic organic chemical compounds in the region and Gordon Wallace will be talking next, primarily about the metals results.

In recent years, it has become increasingly apparent that the concentrations of toxic compounds in coastal marine systems not only represent indicators of the health of a system, but also affect the use and value of marine resources. These toxic compounds affect the value of marine resources directly through increases in body burdens, increases which may result in body burden levels approaching maximum levels set by the U.S. Food and Drug Administration (FDA) for harvesting marine resources. Toxic compounds also affect marine resources indirectly through their presence in the habitat (e.g., in the sediments) which in turn affect the ecosystem, and individual animal's health. The polychlorinated biphenyl (PCB) contamination in New Bedford Harbor, Massachusetts, a marine Superfund site, and the effects of the contamination on the resources in Buzzards Bay is a well-known case study for a direct effect where the lobster resources have been closed due to high levels in tissue. The case of polynuclear aromatic hydrocarbon (PAH) contamination in Puget Sound embayments and its probable impact on the health of marine animals exemplifies an indirect effect. Similar linkages between toxic compound abundances and environmental health are strongly suggested by recent chemical and histopathological studies in Boston Harbor. This afternoon, Dr. Murchelano will expand much more on this latter topic.

This morning I would like to summarize the results of recent studies on toxic organic compounds in the sediments of Boston Harbor and Massachusetts Bay. Sediments are mid- to long-term integrators of pollutant inputs, and, therefore, may be used as indicators of general environmental health. I am going to place these findings in perspective vis-a-vis other areas and relate these findings to possible impacts on the overall health of the system. After I summarize what is known, I would like to equally highlight how little we really do know about the system on which to base sound management decisions.

PCBs and PAHs are two classes of toxic organic compounds which have received a great deal of attention. They are by no means the whole toxic contaminant "story" in any system, but I will be focusing primarily on those compounds as leading indicators of toxic contaminant problems.

I am going to begin by stating the overall conclusions of the study, so that when I do present some of the information, you will be able to see how I arrived at these conclusions. A major conclusion of recent studies is that PCB levels in Boston Harbor are fairly typical for moderately polluted estuaries, such as New York Harbor and Buzzards Bay. PCB levels in Massachusetts Bay are elevated over a wide area, similar in overall distribution to the New York Bight Apex, which has been well studied. The PCB distributions are more widespread in Massachusetts Bay than they are in New York Bight Apex. The depositional basins in Massachusetts Bay are potential traps for PCBs, PAHs and other sewage-associated and harbor-associated material that may be transported from the coastal area to adjacent receiving waters. The PAH levels in Boston Harbor range from values fairly typical for polluted estuaries to some of the highest values reported anywhere. This fact is one of the major findings that I have discovered so far in Boston Harbor. In the Harbor, we find pockets of very high PAH levels that coincide with high coprostanol values. Coprostanol is a fecal steroid, an indicator of (mammalian) sewage input, and is often analyzed in sediments along with toxic organic compounds as a tracer. The PAH loading in Massachusetts is similar to that of the New York Bight Apex. Offshore Massachusetts Bay and the New York Bight Apex are fairly similar in overall loadings of PAHs as determined from sediment concentration distributions.

Other researchers have determined that the overall health of the region appears to be mixed, with degraded bottom habitats observed in the Harbor and sporadically offshore. The health of finfish is relatively poor and directly related to pollutant concentrations in the animals' habitats, the sediments from which they ultimately derive food.

The residence time of contaminants in Boston Harbor is a key management parameter and is really not very well known. From data on other metropolitan harbors, such as New York Harbor, I estimate that the contaminant residence time in sediments is probably on the order of a decade or more. This raises the question: if we changed pollutant inputs, what type of recovery or response time will we observe for chemical loadings? It is probably on the order of a decade or more, rather than months or years.

One of the mistakes we can make in considering toxic contaminant problems of Boston Harbor is to consider that sewage sludge inputs and sewage treatment plant inputs are the only potential source of toxic contamination in the area. This point does not minimize the importance of the sewage issue, but rather indicates that sources other than sewage outfalls are very important. All along the Boston Harbor shoreline and in the Charles River, there are also combined sewage overflows and other discharges. The impacts of riverine inputs, and the Charles River in particular, are not trivial. The Charles River is a major source of coliform bacteria and its sediments contain high levels of PAHs.

Despite many studies in the Harbor, I think that our inability to understand the system has really been caused by a set of fairly myopic study plans. We have studied 301(h) (secondary treatment water) problems and sewage outfall problems on a pipe-by-pipe basis, but there has not been any overall management or environmental assessment on the area.

As previously stated, the major point sources include sewage treatment plants and sewage sludge discharges. These discharges contain high levels of PCBs, up to about 30 parts per million (ppm) on a dry-weight basis, which is a very high level.

Other toxic organic concentrations in sewage discharges have been studied and are available in a variety of unpublished reports. Generally, the amount of toxics in these discharges exceed water quality criteria even after initial dilution, but there are sources of PCBs in the area other than sewage. Some data on sediments indicate that high levels of PCBs are found in the Inner Harbor areas approaching the Charles River, a finding which may or may not be directly related to the sewage inputs. Combined sewage overflows and other industrial inputs probably are very important in defining organic pollutant distributions in the harbor.

In recent studies, scientists at Battelle have sampled several stations in the Outer Harbor and Massachusetts Bay, focusing on sewage treatment plants inputs and the general distributions of PCBs and PAHs in the area (Figures 1 and 2).

The Harbor contains the highest levels of PCBs (0.06 to 0.33 ppm), levels that are not exceptional according to all the information from other areas we have evaluated so far. What is really exceptional in the Harbor are the various pockets of very high levels of PAHs. A hot spot was discovered at Station BH-2, an area called Deer Island Flats and a site of potential deposition of sewage sludge discharged to the east. This area is a mud flat with high organic content (Figure 1). Station BH-2's sediments contain extremely high levels of PAHs (880 ppm), very much higher than areas such as New York Harbor and other highly polluted estuaries. PAH concentrations are highly variable in the Harbor. Our study is based on only seven stations with PAH concentrations ranging from 2.7 to 880 ppm and a mean of 180 ppm (Table 1). Other PAH hotspots might exist in the Harbor. The ratio of these toxic organics to coprostanol, the sewage indicator, indicates that sewage or sewage overflows are prevalent inputs of chemicals to the sediments in the area.

Looking at Massachusetts Bay, we see the topography is a basin-bank-type of system. Stellwagen Bank approaches a depth of 20 meters from the sea surface. The Bank is an area with a great deal of whale activity. There are other basin areas in the region such as Stellwagen Basin, westward of Stellwagen Bank. Other basins in the region represent potential "traps" for coastal sediments and for pollutants that are discharged from along the coast and from Boston Harbor. The relatively high percent of silt in the Bay characterizes the basin areas and suggests that these are potential deposition areas of pollutants. There are cobble or gravel areas closer to shore, but with increasing distance offshore, there are potential traps for pollutants that are discharged from along the coast and from Boston Harbor.

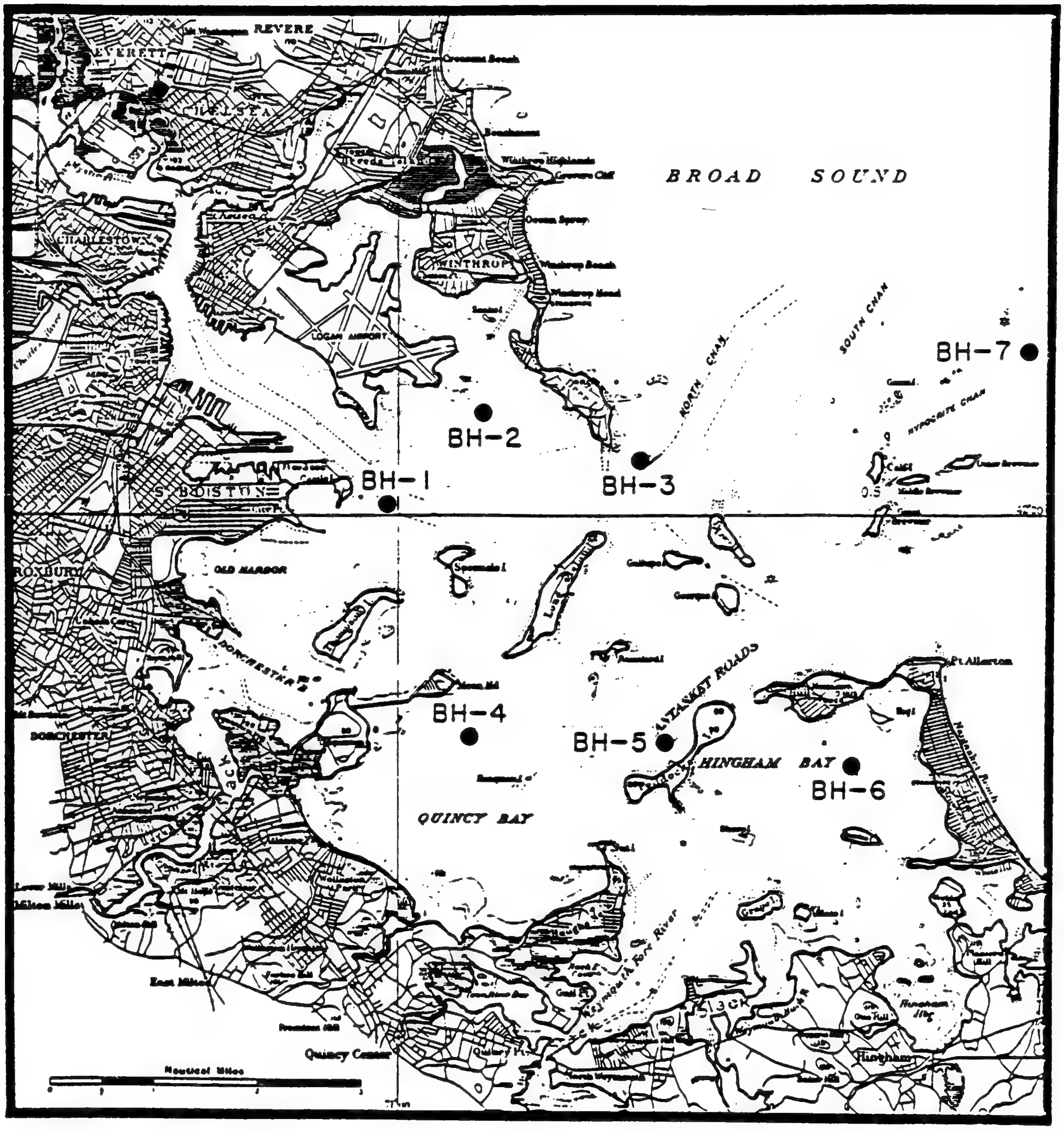

Figure 1. Locations of Boston Harbor (BH) Sampling Stations.

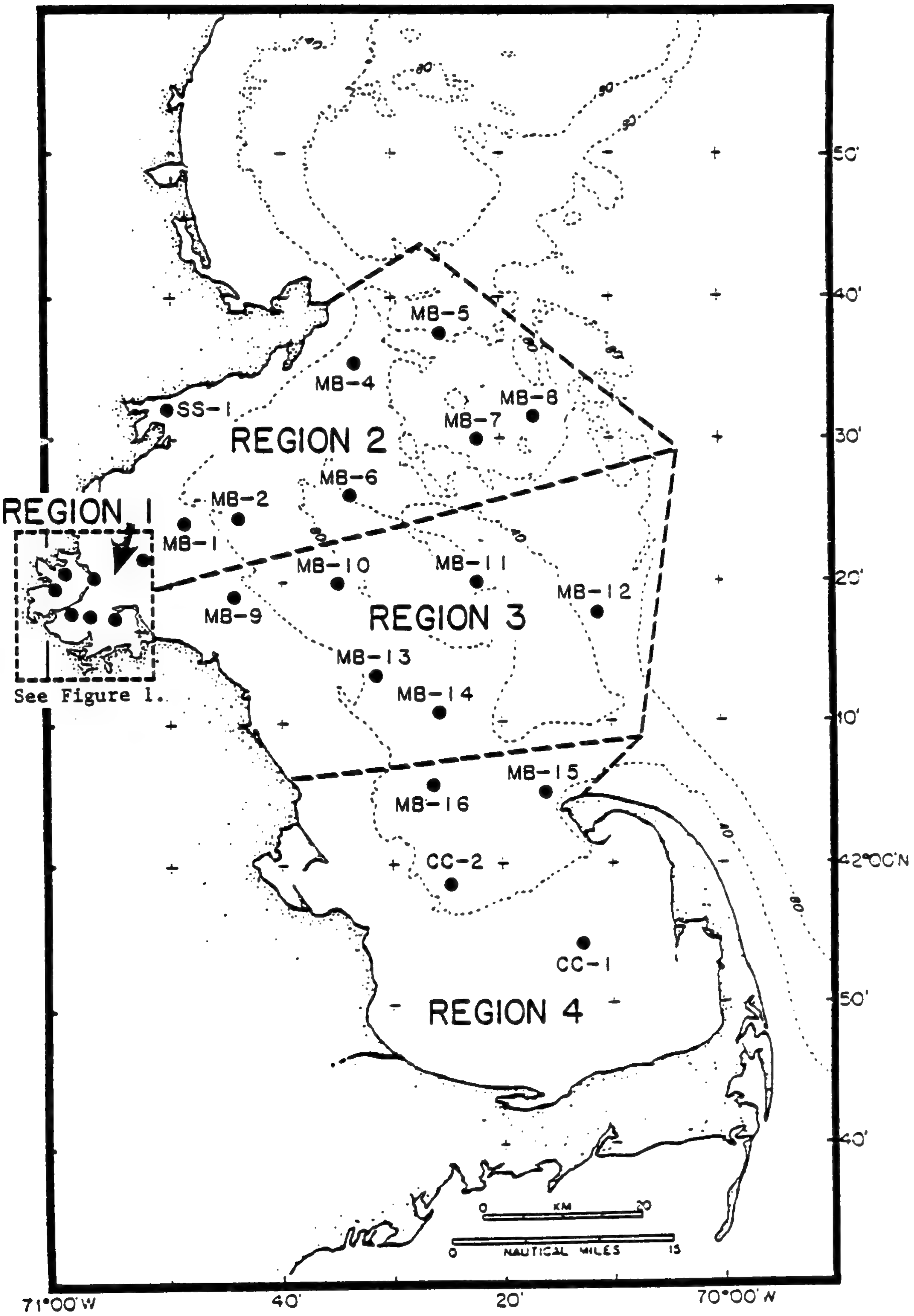

Figure 2. **Locations of Massachusetts Bay (MB) Sampling Stations.**

TABLE 1. SUMMARY OF ORGANIC POLLUTANT DATA IN SEDIMENTS

	Region			
	1	2	3	4
PAH (μg/g)				
Mean	180	1.6	1.0	1.0
Range	(2.4-880)	(0.3-3.5)	(0.2-1.9)	(0.6-1.4)
PCB (μg/g)				
Mean	0.14	0.031	0.010	0.021
Range	(0.07-.33)	(0.005-0.083)	(0.002-0.025)	(0.005-0.031)
Coprostanol (μg/g)				
Mean	5.6	0.20	0.12	0.08
Range	(1.2-15.9)	(0.03-0.45)	(0.05-0.19)	(0.07-0.10)

Now, this is indeed what we found in our recent and previous studies. PCBs and presumably other chemicals are found in higher concentrations in the depositional basins. A multi-station design (Figure 2) in Boston Harbor and several different regions in Massachusetts Bay and Cape Cod Bay was used to examine distributions of toxic organic compounds. Companion studies were conducted to determine concentrations and benthic biological parameters. The biological studies were conducted by Dr. Peter Larsen at Bigelow Laboratory.

As Table 1 shows, we found that of course, the concentrations of PAHs, PCBs, and coprostanol, the sewage indicator, are very high in the Harbor. There is a large range in the Harbor as I mentioned previously. Region 2 (Figure 2) is the northern area of Massachusetts Bay. Concentrations of toxics in this region are elevated over other offshore areas. Ranges of PAH concentrations at several stations in Region 2 reveal values which approach some found in Boston Harbor. These stations are located in small depositional basins (Stations MB6, 7, and 8).

As we look at sediment results farther offshore and to the south in the region of Stellwagen Basin, we find higher values of PCBs and PAHs in these depositional areas. In general, we find the elevated PCBs are found in northern Massachusetts Bay. The data suggest that sewage inputs either from the Harbor or from some of the northern communities, such as South Essex, Lynn, may be deposited in these regions.

Two depositional areas, Stations MB-6 and MB-8, exhibit some of the higher values in the offshore region. Values are low compared to those in the Harbor, but are high for similar offshore regions elsewhere. One of the problems we have in evaluating these data is that we do not have a firm handle on the trends of contaminants in the region because not many surveys have been done which occupy the same stations over time. A survey was conducted by New England Aquarium in 1976. However, our study represented the first statistically rigorous sampling where replicate samples and analyses were obtained at each station. We really do not have any statistically valid trend analyses to show whether concentrations are increasing or decreasing at these stations over time.

We are seeing relatively higher concentrations at several stations, which are perhaps related to the proximity of the "foul" area, (near Station MB-6) a dumpsite for dredged material. Potential offshore transport of pollutants from the Harbor may be occurring as well. We strongly suspect that catch basins exist offshore that are acquiring and accumulating elevated levels of organic contaminants.

We use many source indicators to interpret geochemical data, one of which is related to the composition of PCBs. We find that in the Harbor, trichlorobiphenyls (PCBs with three chlorine atoms) are prevalent and are related to sewage inputs. Such PCB compositional plots are useful in examining likely sources of PCBs (such as those which may be sewage-related). Station MB-6 is located far offshore. However, PCB compositional plots indicate that sewage input is evident. We have come to the conclusion, based on PCB compositional plots and on levels of coprostanol in the sediments, that there are sewage-related deposits quite far offshore, tens of kilometers from the possible sources.

I would now like to put these values into perspective. I showed you that the concentrations of PCBs in the Harbor are, at the high end, close to 0.5 part per million, or maybe more. Some known problem areas in the nation (for example New Bedford Harbor) have very, very high values. Outside of the New Bedford Harbor situation, we see that levels in Boston Harbor are similar to what we find in Buzzards Bay, in New York Harbor and in Commencement Bay. Thus, the Harbor contains fairly typical PCB levels of polluted estuaries.

We have attempted to compare the Massachusetts Bay findings with some other well-studied areas. One such area is the New York Bight Apex. If we calculate an offshore budget for the PCBS (say the amount of PCBs in sediments) and determine PCB distribution on a per-kilometer basis, we find that in comparing the New York Bight to Massachusetts Bay, the loading of PCBs per square kilometer are similar: about 0.9 kg/km^2 on the average for Massachusetts Bay and about 1.2 for the New York Bight.

Although actual individual dump sites in the New York Bight are more heavily contaminated than dump sites in Massachusetts Bay (for instance, "the foul area"), as far as overall pollutant loadings is concerned, the total amount of PCBs in Massachusetts Bay is considerly higher than in New York Bight Apex (Table 2).

Making a similar comparison for PAH compounds in each system (Table 3), we find that the amount of PAHs in the New York Bight Apex and offshore Massachusetts Bay are very similar on a square-kilometer basis (50-60 kg PAH/km^2 on the average).

In Boston Harbor, the PAH values are much higher than they are for other well known polluted estuaries, indicating that a severe PAH problem exists in the Boston Harbor area. On a square kilometer basis, the PAH loadings are 2 to 10 times higher than similar loadings in other harbor areas.

There is also a considerable database on selected animals in the Harbor and Bay areas. Table 4 presents the levels of PCBs in a limited number of samples from our study. Looking at these data from the perspective of the ability to harvest (FDA levels) and not from the perspective of environmental health (similar to those aspects that Bob Murchelano will address later), only the winter flounder in Boston Harbor approach FDA limits of about 2 ppm. These limits, however, are still an order of magnitude lower in concentration than FDA limits.

Elevated levels of PCBs are found, as well, in lobsters and crabs. Whether these observed levels are increasing or decreasing, we do not know. One of the missing pieces of the Boston Harbor environmental puzzle is a valid trend analysis on contaminant body burdens in the area. What we have presented today is, more or less, a snapshot of the status of toxic organic levels in the Harbor at present.

TABLE 2. COMPARATIVE PCB BUDGETS - MASSACHUSETTS BAY VS. NEW YORK BIGHT APEX.

	ng/g dry weight	ng/cm^3	ng/cm^2 [a]	g/km^2	Areas (km^2)	kg PCB
New York Bight Apex[b]						
Dredged Material Dumpsite	200	400	800	8000	6	48
Sewage Sludge Dumpsite	200	400	800	8000	16	128
Christianensen Basin	200	400	800	8000	130	1040
Outer Bight Apex	1.0	2.0	4.0	40	850	34
			Total PCB (kg) =			**1250**
			kgPCB/km^2 =			**1.24**
Massachusetts Bay[c]						
Region 2	31	62	124	1240	2310	2864
Region 3	10	20	40	400	1810	724
			Total PCB (kg) =			**3588**
			kgPCB/km^2 =			**.87**

a - 2 cm thick

b - Data Sources = Boehm, 1982; Boehm et al., 1984; MacLeod et al., 1981; O'Connor et al., 1982; Part 2 of this study

c - Define Source

TABLE 3. COMPARATIVE PAH BUDGETS - MASSACHUSETTS BAY VS. NEW YORK BIGHT APEX.

	ng/g dry weight	ng/cm3	ng/cm2[a]	g/km2	Areas (km2)	kg PAH
New York Bight Apex[b]						
Dredged Material Dumpsite	5000	10000	20000	200000	6	1200
Sewage Sludge Dumpsite	3000	6000	12000	120000	16	1920
Christianensen Basin	10000	20000	40000	400000	130	52000
Outer Bight	100	200	400	4000	850	3400
			Total PAH (kg) =			**58520**
			kg PAH/km2 =			**58.5**
Massachusetts Bay[c]						
Region 2	1600	3200	6400	6400	2310	148000
Region 3	960	1920	3840	38400	1810	69500
			Total PAH (kg) =			**217500**
			kg PAH/km2 =			**52.8**

a - 2 cm thick

b - Data Sources = Boehm, 1982; Boehm et al., 1984; MacLeod et al., 1981; O'Connor et al., 1982; Part 2 of this study

c - Define Source

TABLE 4. SUMMARY OF PCB CONCENTRATIONS IN EDIBLE TISUES (ppm, wet weight).

	Boston Harbor Area	Massachusetts Bay
Winter Flounder	0.1-1.0	-
Dab	-	0.01-0.02
Lobster	0.05-0.1	-
Cancer Crab	0.2-0.3	0.05-0.1

In Massachusetts Bay, we find that PCB levels in the dab, a flat fish (winter flounder were not sampled offshore) are much lower than they are in Boston Harbor. This finding is not surprising. PCB values in crabs in Massachusetts Bay are fairly close to Boston Harbor, illustrating that PCBs are probably transported offshore. To what extent this transport is occurring, we do not know, but it is impacting the levels of PCBs in crabs.

In summary, I have quickly presented our knowledge of the types of organic concentrations offshore. As I mentioned before, one of the existing data gaps pertains to our knowledge of the other components of potential pollutant inputs into the system. We know a reasonable, yet incomplete amount about sewage inputs. Although a considerable number of analyses have been performed, we do not know, on a mass balance basis, what pollutants are coming out of the rivers and are coming out of the many combined sewage overflows.

Therefore, we cannot really address, from a toxic organics viewpoint, the overall management questions, "What will happen if we turn off a certain pollutant source? What will happen to concentrations over time during a recovery of the system?" The residence times of contaminants in sediments and in the water column, which can only be computed from a knowledge of inputs and ambient concentrations, are very poorly known in relation to well studied systems where the sources have been studied with greater detail. We need to know just where the various pollutants are coming from and what will happen if we turn one or more of these sources off or place it elsewhere?

We know very little about water column particulate organic pollutant concentrations as they relate to established EPA water quality criteria. Little is known regarding fluxes from the Harbor to Massachusetts Bay. Even in our surveys on Massachusetts Bay and Boston Harbor, we are looking at temporal snapshots, so we have to infer from where the materials are coming. Looking at the coupling between the Harbor and the Bay, we know very little about the extent of offshore transport of pollutants originating in Boston Harbor.

Furthermore, we know very little about the fate of sewage plumes and associated pollutants. Sewage is discharged on the ebb tide, and we assume that it goes eastward into Massachusetts Bay. But we do not know where or how much of it may "slosh" back over a tidal cycle and be deposited into Boston Harbor.

We do not know very much at all about temporal trends in pollutant concentrations. Monitoring data are almost totally lacking to determine if pollutant concentrations are on the increase over the last ten years. We are just beginning to get that information, and we certainly cannot make any assessment of how our various management decisions (such as, upgrading sewage treatment to secondary treatment) will affect the system until we have that type of information. We also have very little information on other contaminants (such as pesticides) of concern other than PCBs, PAHs, and heavy metals. More than 100 other compounds are on EPA's priority pollutant list, many of which are far more toxic than PAHs and PCBs, and we have very little data on those types of compounds. Finally, we must know more about the physics of the Boston Harbor system to address mass balance questions. Only with these additional pieces of information can we begin to understand how, if, and over what time frame will various costly environmental management options affect the recovery of the Boston Harbor estuary (Table 5).

TABLE 5. INFORMATION NEEDS

1. RESIDENCE TIMES OF CONTAMINANTS IN SEDIMENTS AND WATER COLUMN.

2. POLLUTANT MASS LOADING DATA ON SEWAGE EFFLUENTS AND STORM WATER RUNOFF.

3. WATER COLUMN PARTICULATE POLLUTANT CONCENTRATIONS AND FLUXES OF PARTICULATES FROM HARBOR TO MASSACHUSETTS BAY; FATE OF SEWAGE PLUMES.

4. TEMPORAL INFORMATION ON CONTAMINANT TRENDS; OTHER CONTAMINANTS OF CONCERN.

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HEPATIC HISTOPATHOLOGY OF WINTER FLOUNDER FROM BOSTON HARBOR

by

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I was planning on sitting in the audience today until Betsy (Dr. Betsy Brown) found out that I was attending this seminar.

I would like to show you representative hepatic lesions of winter flounder from Boston Harbor. I have told colleagues at the Weymouth Fish Disease Laboratory in England that I initiated this study to test a hypothesis. The hypothesis was that the dumping of tea, as practiced by the colonists and as instigated by my colleagues' ancestors, compromised fish health in Boston Harbor. I may have to accept this hypothesis, so bear in mind that tea is still one of the possible causes of these lesions.

Actually, the hypothesis that I wanted to test (I am grateful that Leigh, Mr. Leigh Bridges didn't lead into it in his presentation) was whether one disease which is associated with poor environmental quality, possibly predicts the presence of another in another tissue. That one disease is fin rot.

Fin rot is a disease of winter flounder that I have studied for many years. Even though Carl (Dr. Carl Sindermann) is here, I am going to say that it was under his "gentle prodding" in the early 1970s that I became intimately involved in studies of fin rot in the New York Bight. I was trying to find out what caused this elusive disease. I still do not know what causes it nor does anyone else.

However, one thing did appear quite clear from our studies, to me at least, fin rot was a symptom of unfavorable environmental conditions. When I was asked by Harriett Diamond (Coastal Zone Management (CZM), Commonwealth of Massachusetts) to review some documents for the 301(h) waiver in Boston Harbor, specifically in the area of biological effects, I saw tabular data which revealed that approximately 46 to 47 percent of winter flounder from the Deer Island area of the Harbor had fin rot.

This finding signified that perhaps other aspects of the animals' health were compromised. Therefore, and as Leigh mentioned, in April 1984 after a joint meeting in Boston with staff of CZM and the Division of Marine Fisheries (DMF), I was sent 100 jars containing formalin-fixed livers of Boston Harbor winter flounder (collected by DMF staff). I did not see the fish, only their livers as fixed tissues in jars of formaldehyde. I did not know where the fish came from in the Harbor or if, in fact, they came from the Harbor. Boston Harbor is a large area, and all areas of the Harbor are not the same. I would like to show you some pictures and photomicrographs today and will begin with the disease which led to the finding of the Boston Harbor winter flounder liver tumors.

Figure 1 was taken by Mr. John O'Reilly of the Sandy Hook Laboratory many years ago, in the early 1970s. Because it probably is one of the better photographs, I have used it repeatedly. It shows a winter flounder with large portions of its anal and dorsal fins missing. One can see the missing parts; however, if one does not know this fish, the dorsal fin normally extends much more than as shown. Quite a bit of fin tissue is missing in this fish. In closer view, one would see that there is considerable resolution and that the tissue is healing. Rather than a gaping wound, new tissue has grown to seal off the environment from the tissues of the fish.

Figure 2 presents an old graph, and I do not know what years it represents. However, it most probably summarizes data acquired in the early 1970s when we were studying the distribution and prevalence of fin rot disease in the New York Bight winter flounder. In addition to the distribution and prevalence of the disease in winter flounder, we also studied its cause or etiology. Unfortunately the latter is much more difficult to resolve.

We designated areas that we knew, on the basis of obvious characteristics, that had compromised environmental quality, such as, Sandy Hook and Raritan Bays. We then selected an area that was near these areas, was accessible to us, and was relatively "pristine": Great Bay on the south shore of New Jersey. We made surveys over the years to contrast the prevalence of fin rot disease in these two regions. With the assistance of Dr. Joel O'Connor of the National Oceanic and Atmospheric Administration Ocean Assessments Division, we made some statistical evaluations which substantiated that a difference in prevalence existed between the two areas. We did not know what specifically caused the difference; we only knew that there was a difference.

For the last five years at least, we have been involved in much offshore surveillance, that is, looking at lesion prevalence in fishes from depths greater than 91 feet and over a broad geographic area. Figure 3 shows that the area surveyed extends from the Delaware Bay all the way to the Merrimack River. These studies were done in concert with bottom fish stock assessment surveys of the Woods Hole Laboratory. We decided to add disease observations to the procedures necessary to determine age, growth, fecundity, and predator-prey relationships. We surveyed two offshore areas and several inshore ones. We selected these areas for certain reasons, of course, and then on the basis of many thousands of observations, looked at the distribution of diseases like fin rot.

All data gathering and statistics for this were done by a colleague at the Sandy Hook Laboratory, Mr. John Ziskowski. The diseases noted do not necessarily compromise fish health, but are primarily markers. They are markers because there is evidence in some parts of the world of an association, which might be more than casual, between the numeric prevalence of these diseases and poor environmental quality. This is not illogical.

Upon completing these studies, we plotted the distribution of fin rot, lymphocystis, ulcers, ambicoloration, and a few other conditions, in the geographic areas surveyed. We quite clearly saw that the prevalences of the diseases were discontinuous. Higher prevalences occurred in areas adjacent to high population densities. That is not unusual. We could have predicted that at the beginning; however, we had to substantiate our hypothesis with data.

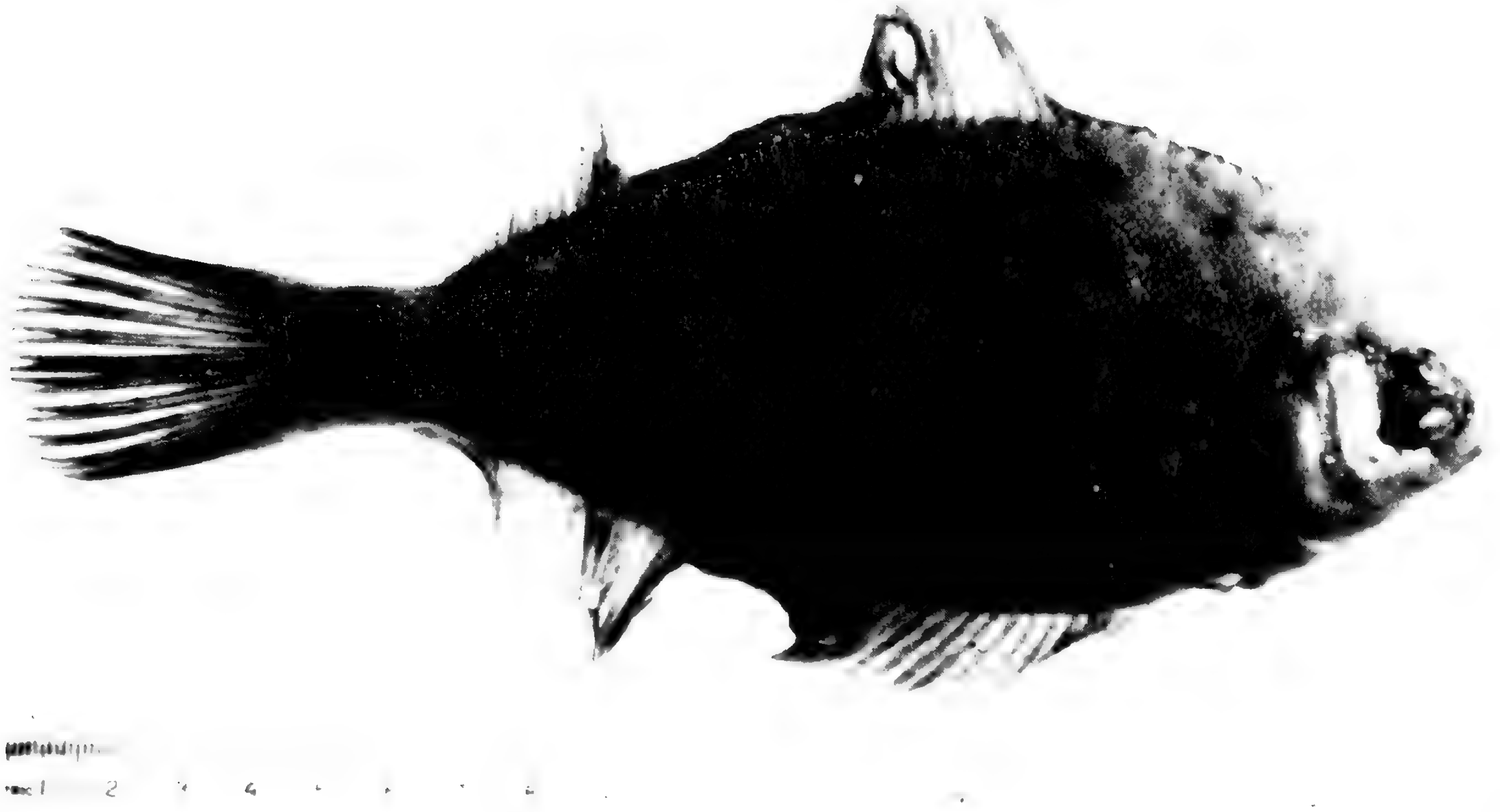

Figure 1. **Winter Flounder with Fin Rot Disease.**

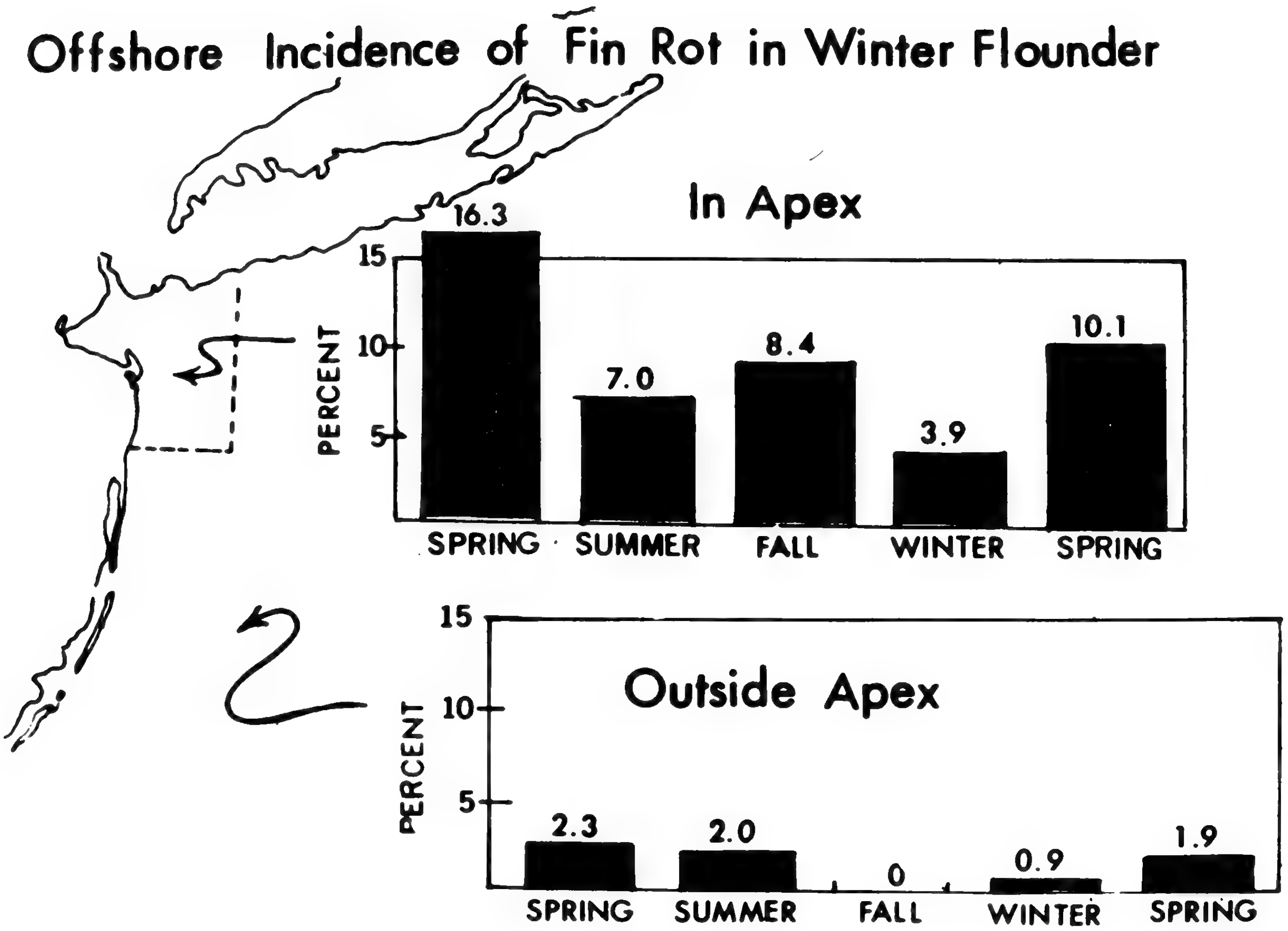

Figure 2. Prevalence of Fin Rot Disease in Winter Flounder from the New York Bight Apex and Offshore Areas Outside the Apex.

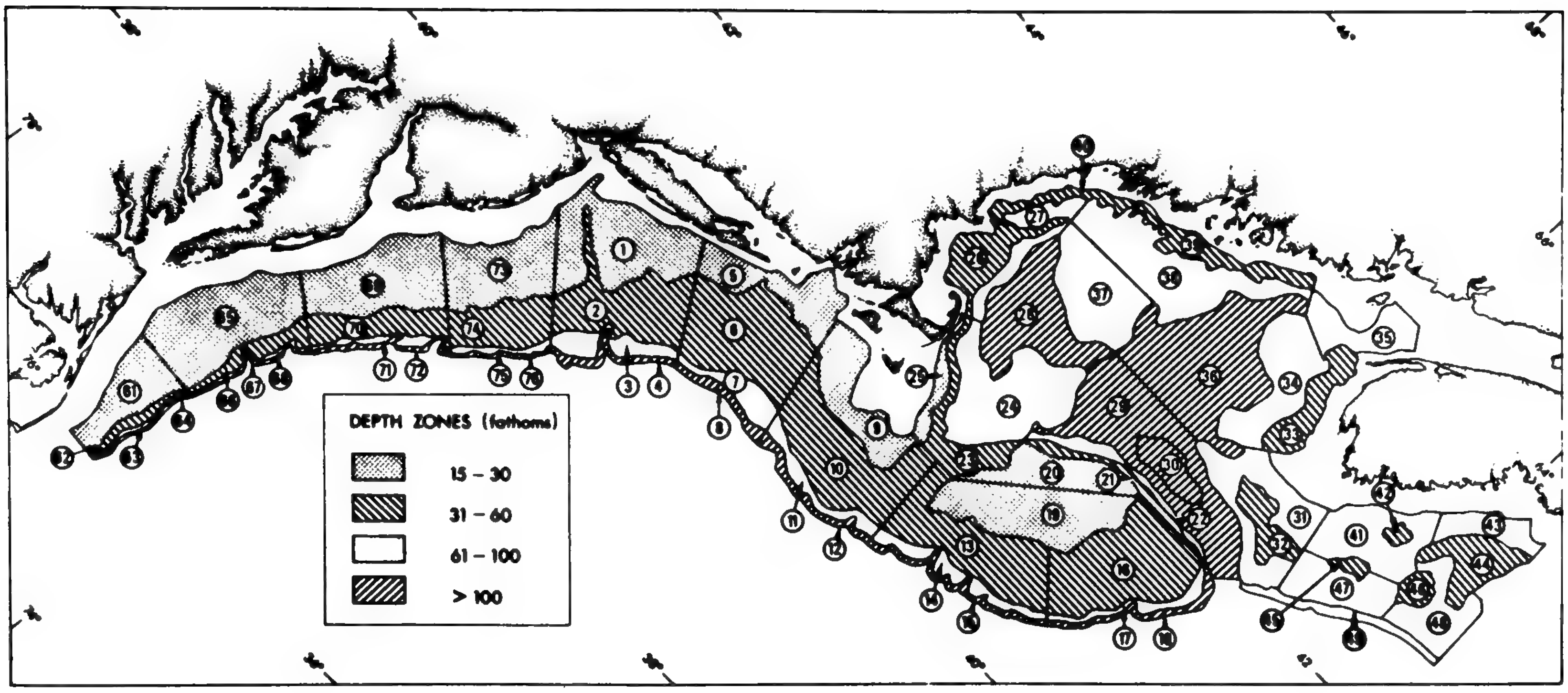

Figure 3. **Area Surveyed for External Fish Diseases and Anomalies During Conduct of Fish Stock Assessment Cruises in the Northwest Atlantic.**

On the basis of this study, which showed that certain diseases seem to be more prevalent in areas where there is compromised environmental quality, we decided to look at other more metabolically important tissues. Perhaps we would find other evidence of disease.

One of the biomedical disciplines that we use very extensively at the Oxford Laboratory is an observational one called histopathology; however, it is not the only discipline of pathology. Histopathology can be very useful in the study of fish diseases, especially when other disciplines are poorly developed. We were intent on examining metabolic tissues such as the liver. I looked first at fish livers from Narragansett Bay and Long Island Sound. I found certain lesions which were significant and which were, as Leigh Bridges has said, identified as carcinomas (cancers). Then the opportunity to examine livers of winter flounder from Boston Harbor was provided. I did not pre-select Massachusetts with any malice in mind, but went there because winter flounder from the Harbor had fin rot. When I examined the liver tissues sent to me by DMF, I found the tumors I wish to present today.

The resources made available to me for sampling Boston Harbor winter flounder are those of the DMF. As Leigh has mentioned, I have used the FC Wilbour at least five times. I was very fortunate to be able to trawl effectively; unfortunately, the boat is not adequate for doing much laboratory-oriented work. Trawl catches from Boston Harbor are essentially monotypic. When the cod end is opened and dumped on the deck, the catch is composed almost exclusively of winter flounder. I desperately wanted to find other fish from this area to examine; however, I could not because they were not present.

Our laboratory table, at least on the first cruise, was quite rudimentary consisting of an abandoned boat hatch and a lobster pot. Mr. Vincent Durso, a staff member from DMF, assisted me as we necropsied fish at the naval shipyard in Charlestown. We laboriously examined fish after fish looking for gross lesions.

Figure 4 illustrates a fish liver in which the functional cells of the liver, such as the hepatocytes, contain large vacuoles. Low magnifications of sections of liver with these highly vacuolated cells show that they cause the liver surface to bulge outwards. The gross appearance of the lesion, therefore, would be that of a tumor.

This vacuolated cell was very common in livers of winter flounder from Boston Harbor. It was present in winter flounder from Narragansett Bay and Long Island Sound also, but never to the extent evident in Boston Harbor fish. On the basis of other cellular changes that were present, I began to think that the vacuolated cell was somehow part of the progression to neoplasia.

Most of the guidance for naming these lesions is based on research done primarily with rodents by veterinary and human pathologists. For legal implications of what is found in studies of experimental carcinogenicity, the rat is the most acceptable surrogate. Terminology that is used to describe lesions in rats is the terminology used in

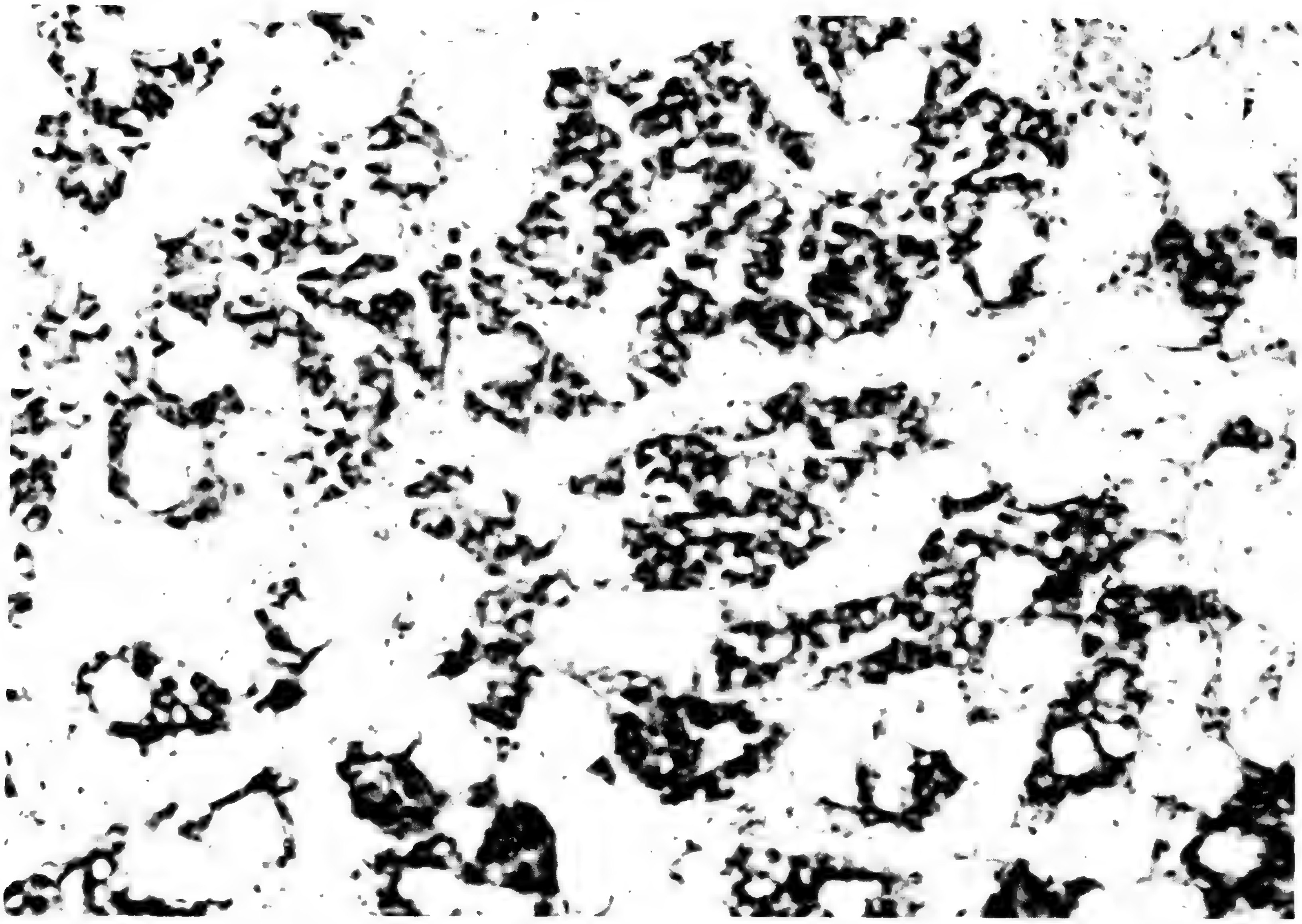

Figure 4. Vacuolated Hepatocytes in Liver of Winter Flounder from Boston Harbor.

the courts. The lesions I will describe are named to correspond with terminology suggested for rodent hepatic lesions induced by experimental carcinogens.

There is a sequence of changes in the liver which takes place from the action of a carcinogen. One of the early lesions (although there is some debate on this) is the formation of chromatically-altered foci, or changes in color of the parenchymal cells.

Figure 5 shows an area of chromatic change in the center of some hepatocytes with cytoplasmic inclusions (probably containing fat). The cells have greater affinity for the stain than adjacent cells. This is significant and should not be ignored. The lesion is called a basophilic focus because its color is blue after staining with hematoxylin and eosin (H&E). These chromatically altered foci can be quite large and easily seen at low magnification. In fact, some of these foci can be detected with a hand lens, regardless of whether they are basophilic or eosinophilic (red with H&E).

Figure 6 illustrates a lesion at low magnification visible not only with a hand lens, but with the naked eye. One easily can recognize a distinct tumor in this photomicrograph with a well-defined outline. As you will see later, this lesion is not very different from the one in the preceding figure, but its cellular characteristics and well-defined configuration elevate it to something more in the nomenclatural heirarchy of these lesions. It is designated a hepatocellular adenoma; the hepatic cords outside the tumor are compressed. The cords in the tumor are virtually at right angles to the cords outside the tumor. As the mass increases in size, it does so at the expense of adjacent tissue. When this happens, and when certain other characteristics are evident, the lesion is designated a hepatocellular adenoma. With mammals, and man primarily, it would be considered a benign lesion. Unfortunately designation as benign or malignant in fish is not possible using only histologic criteria. If I showed a higher magnification, we could see evidence of cell replication from the presence of mitotic figures.

Vacuolated hepatocyte foci are common in livers of Boston Harbor winter flounder and frequently contain other cells in the vacuolated cell areas. These cells are chromatically, cytologically, and organizationally different from the vacuolated cells. In many instances, they have the appearance of early neoplasms. Seventy-seven percent of the winter flounder examined from Boston Harbor have vacuolar cell lesions. That is a very significant number, especially because there appears to be a relationship between the vacuolar lesions and the neoplastic ones. If the presence of vacuolar cells signifies eventual transformation to neoplastic cells, 77 percent is a very alarming number.

Figure 7 shows some chromatically different cells together with vacuolated cells. Some pathologists might not designate the lesion as neoplastic, probably because they have not examined adequate numbers of histologic sections to interpret the significance of the lesion with respect to other neoplastic ones. In Figure 7, the neoplastic cells are trying to form bile ducts. Their destiny, if they are derived from precursors of duct epithelial cells, is to form bile ducts.

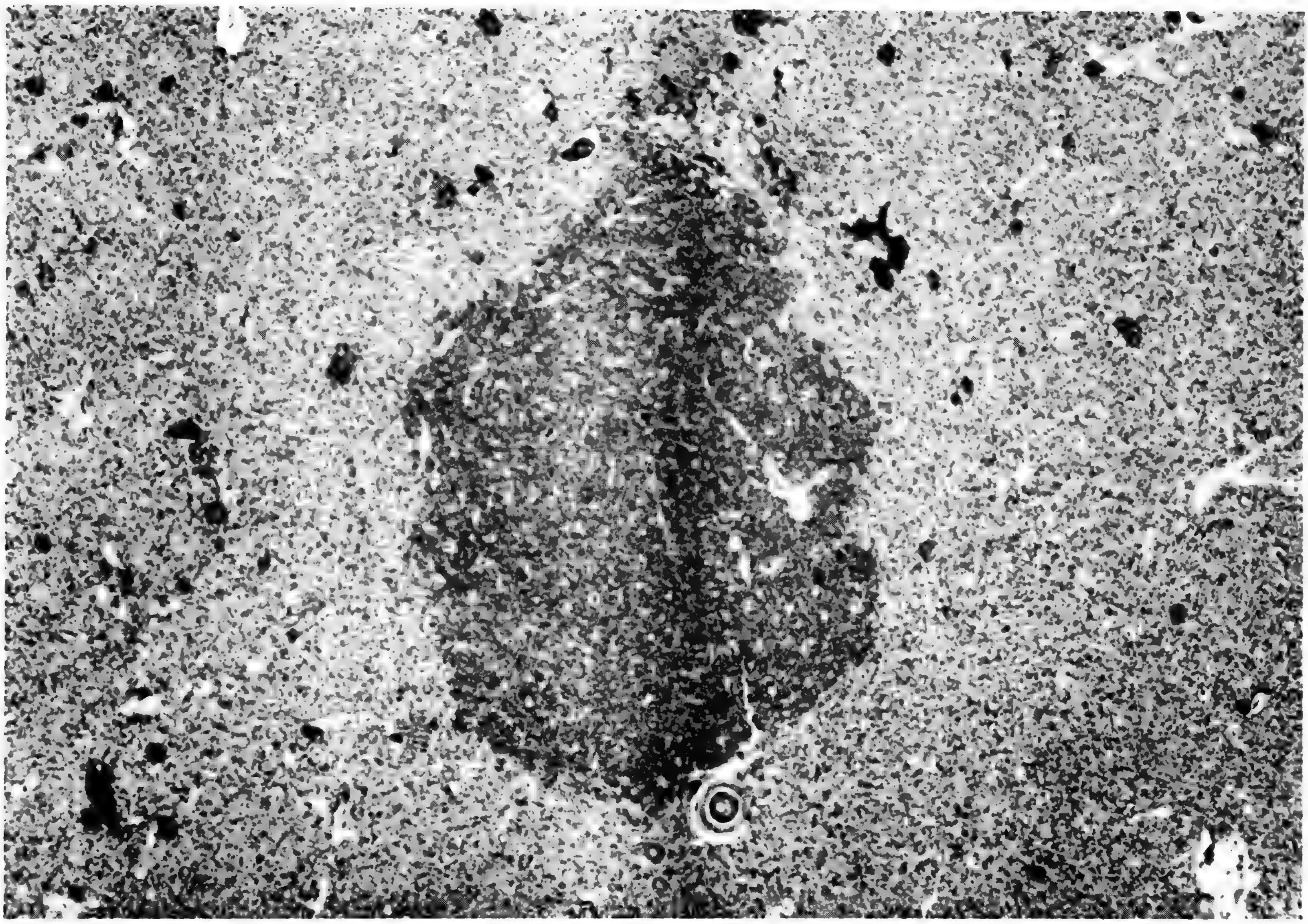

Figure 5. Basophilic Focus in Liver of Winter Flounder from Boston Harbor.

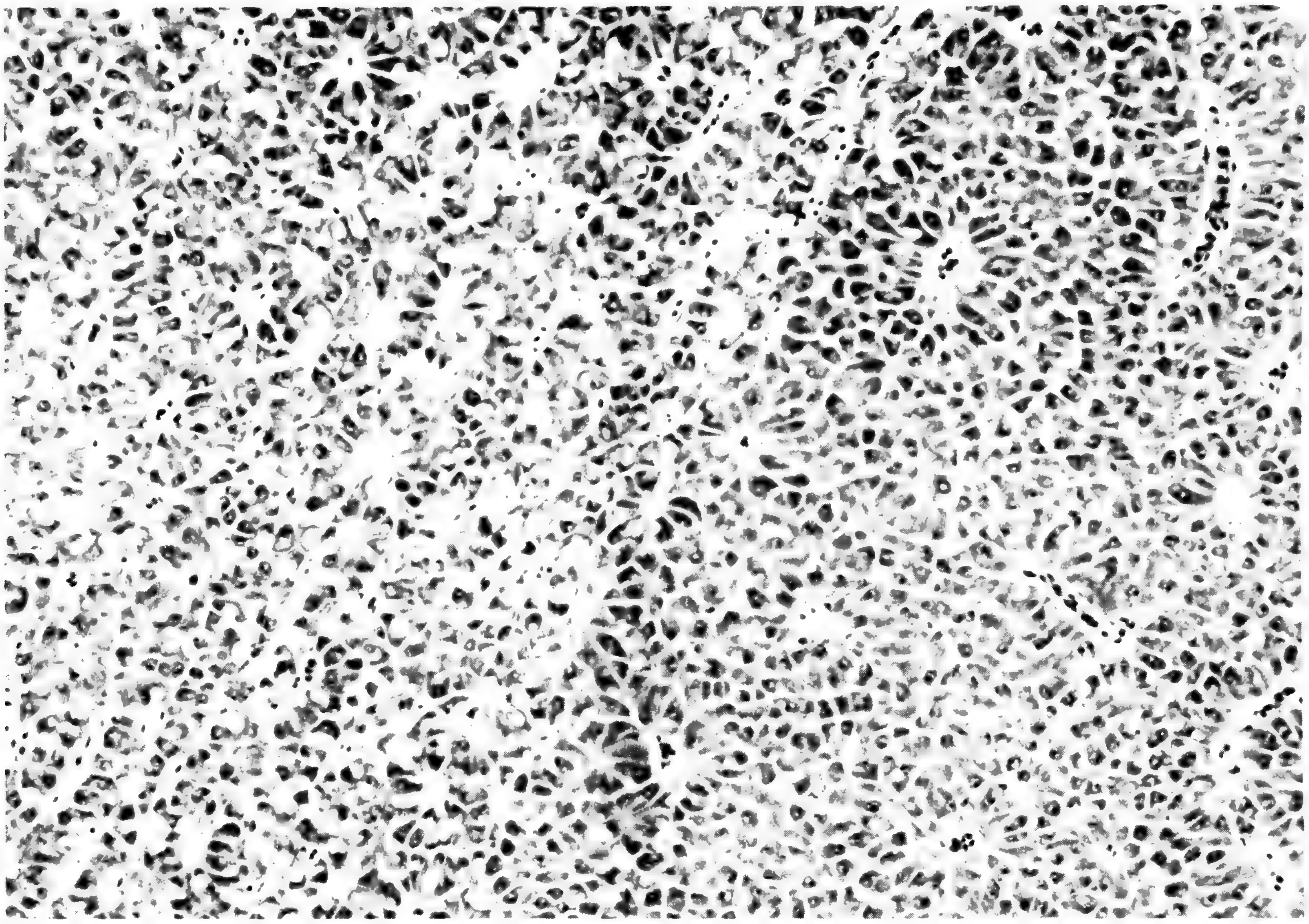

Figure 6. Hepatocellular Adenoma in Liver of Winter Flounder from Boston Harbor.

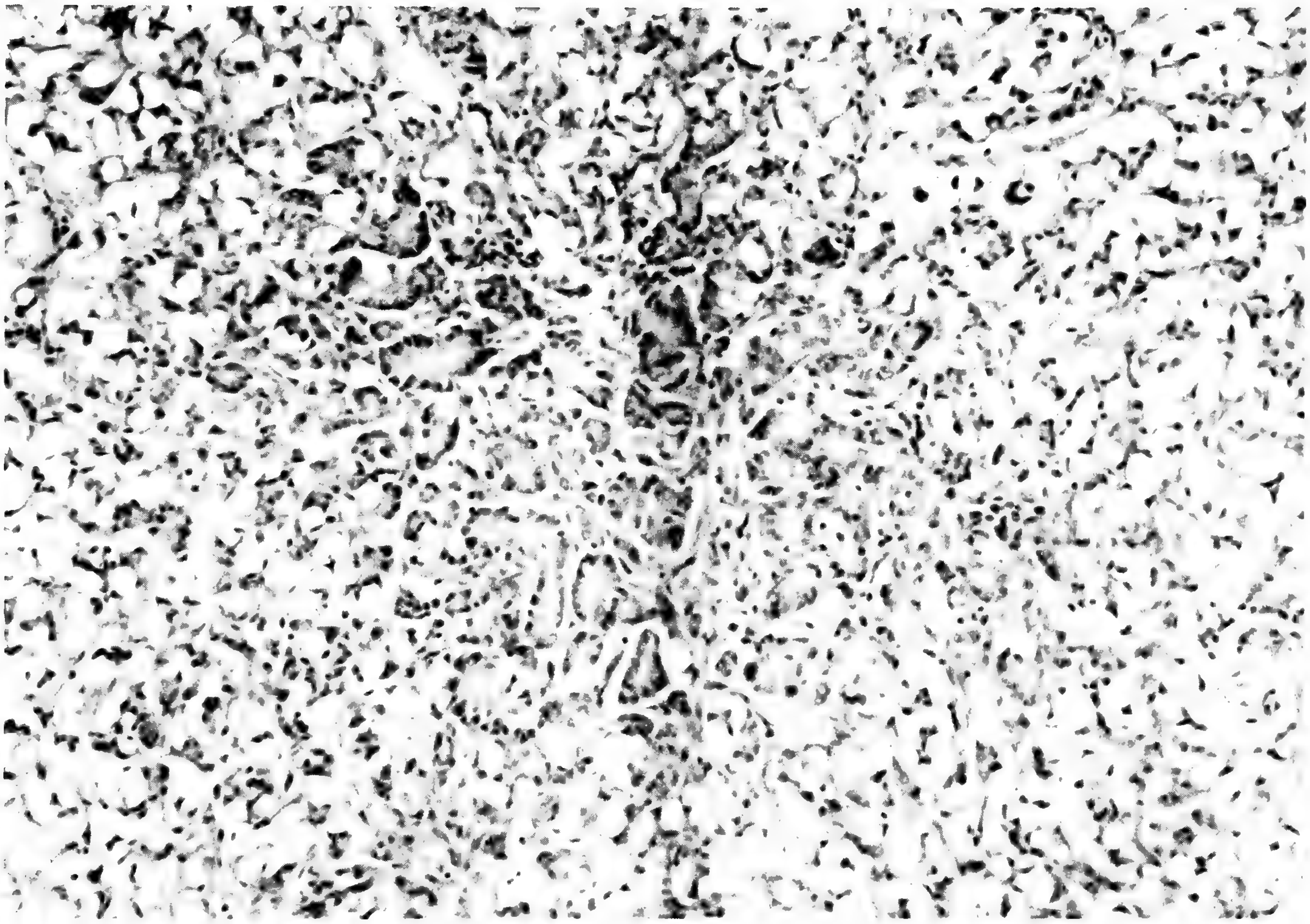

Figure 7. Early Cholangiocarcinoma in Vacuolated Hepatocyte Focus in Liver of Winter Flounder from Boston Harbor.

Figure 8 illustrates a cholangiocarcinoma. When these lesions are large, as is evident in many histologic sections, they are grossly apparent. There are many morphologic variants of the tumors I have shown.

Some neoplasms are well-differentiated and relatively uniform in architecture. However, there are morphologic variants of cholangiocarcinomas that are very bizarre. The morphologic patterns of the neoplasms resemble those induced in rodents with experimental carcinogens.

Figure 9 shows a carcinoma that a pathologist would characterize as anaplastic. An anaplastic neoplasm is one whose constituent cells are not well differentiated and which do not resemble those of normal tissue. Numerous mitotic figures are present, some very large and containing excess numbers of chromosomes (polyploid). All of these features are characteristic of lesions which generally are metastatic; however, whether these lesions metastasize presently is unknown.

Figure 10 illustrates chromatically distinct cells in cardiac muscle that are not inflammatory cells, that is they are not leukocytes. If one looks at the lesion at higher magnification, the cells resemble hepatic tumor cells, cells of a hepatic carcinoma. This could be the first metastasis documented in these fish. This finding suggests that these fish have a lesion which is biologically or behaviorally comparable to that of warm-blooded animals and, therefore, might take the same course.

I will finish by showing you the gross lesions last because they will impress you more than the photomicrographs. If you have ever seen a normal winter flounder liver, you know that it is essentially homogeneous in color, usually coffee-brown, although the color depends on the nutritional status of the fish and the time of the year. The liver in Figure 11 is not normal. Almost all of the discrete, nodular areas are tumors. The specific kind of tumor is unknown until one examines the tissues microscopically. I also have shown you the worst-case situation to impress you. I did not show you pictures of livers with only a few nodules; however, they are quite common.

Boston Harbor winter flounder with tumors look normal like their cohorts. One could easily ask whether the lesion has any significance on the health of the fish. There is much to do to resolve what the lesions ultimate effect is, either for individual fish or populations of fishes.

In closing I would like to acknowledge the assistance provided me by Dr. Clyde Dawe formerly of the National Cancer Institute, and now at Harvard Medical School and Woods Hole. Dr. Dawe first described hepatic neoplasms in wild fish from polluted water and his assistance and interest have been invaluable. He has made all of the collecting trips with me, in fact, he made one trip without me because of lack of funds for my travel to Boston from Maryland. Thank you.

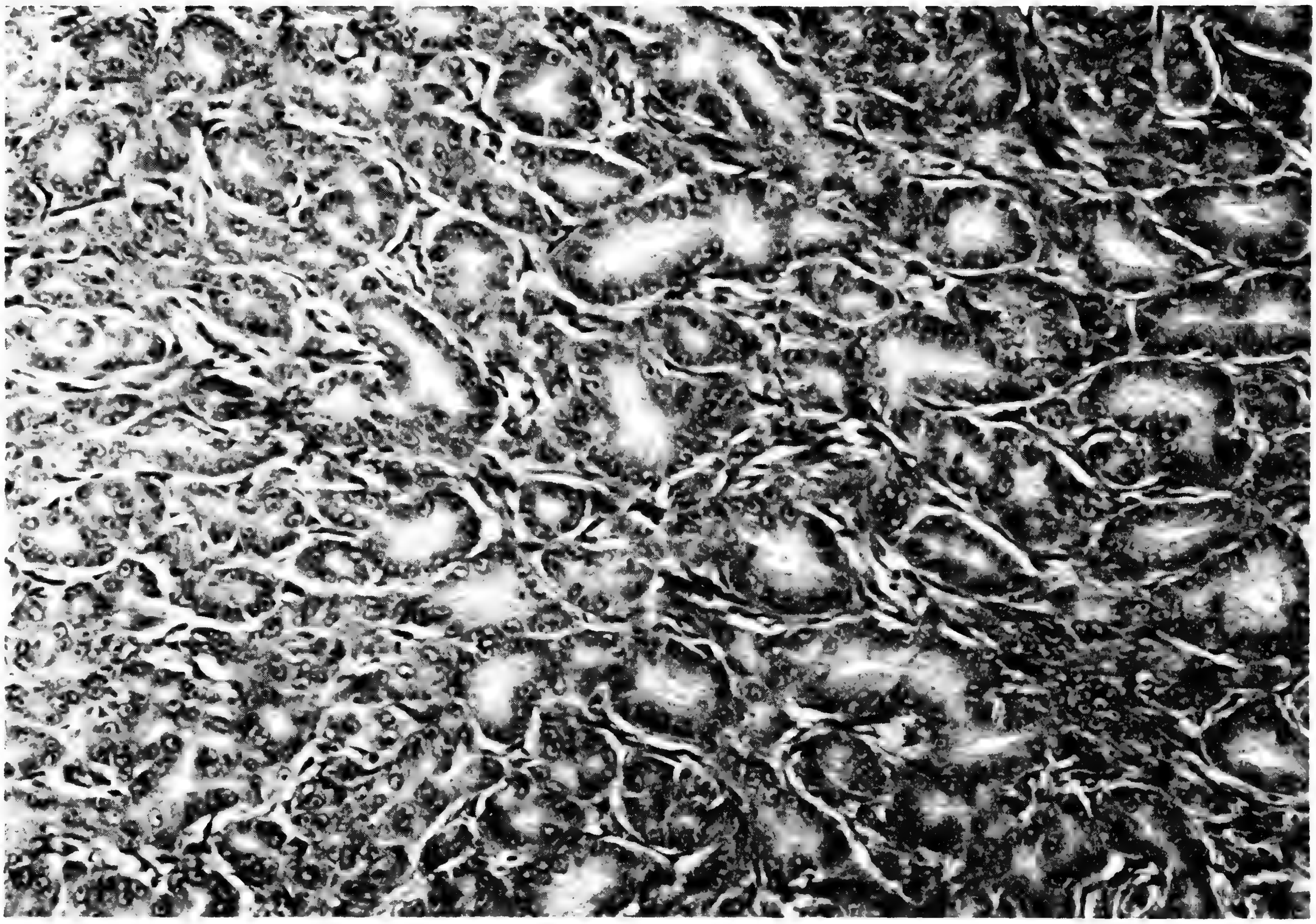

Figure 8. Cholangiocarcinoma in Liver of Winter Flounder from Boston Harbor.

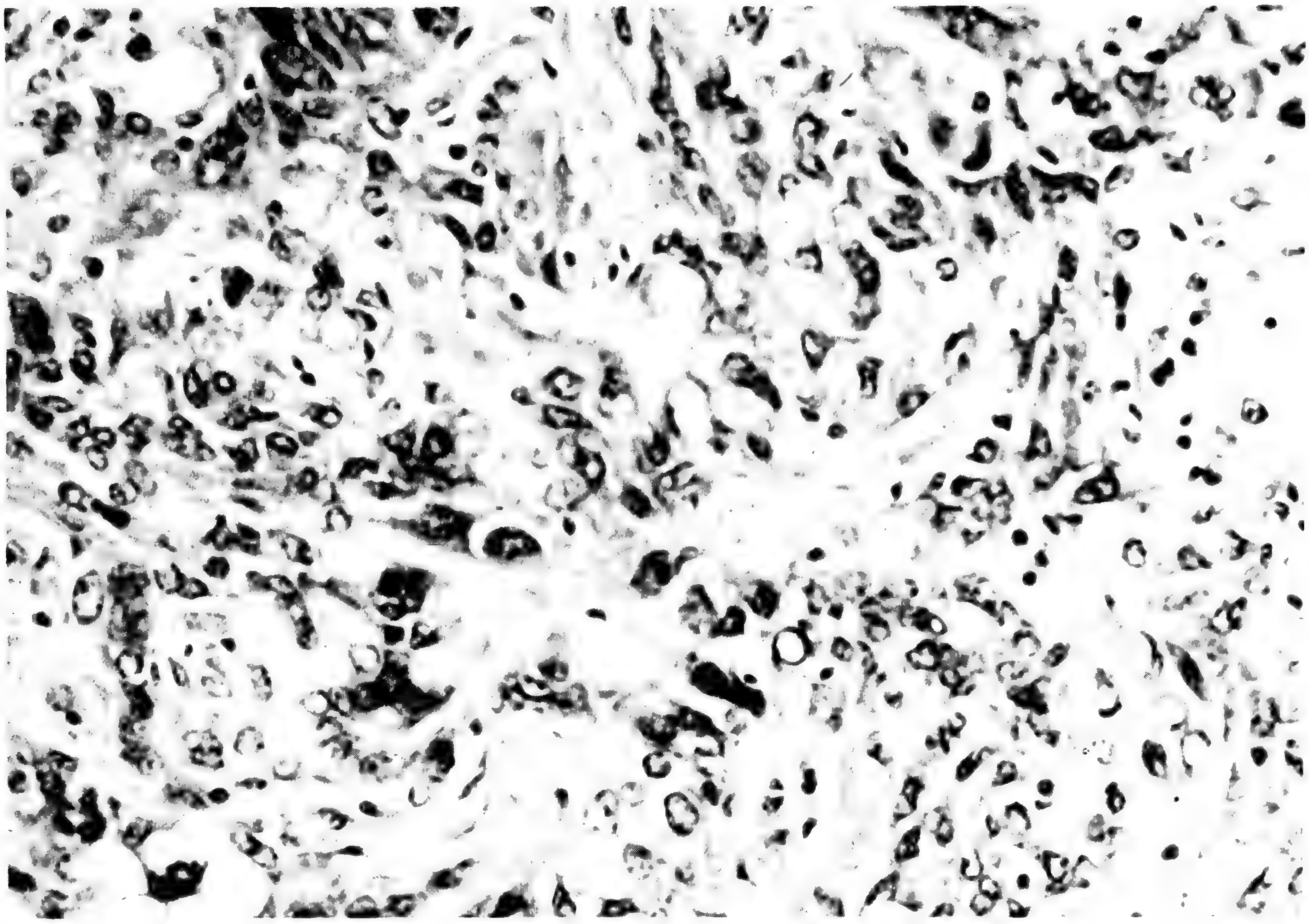

Figure 9. Anaplastic Adenocarcinoma in Liver of Winter Flounder from Boston Harbor.

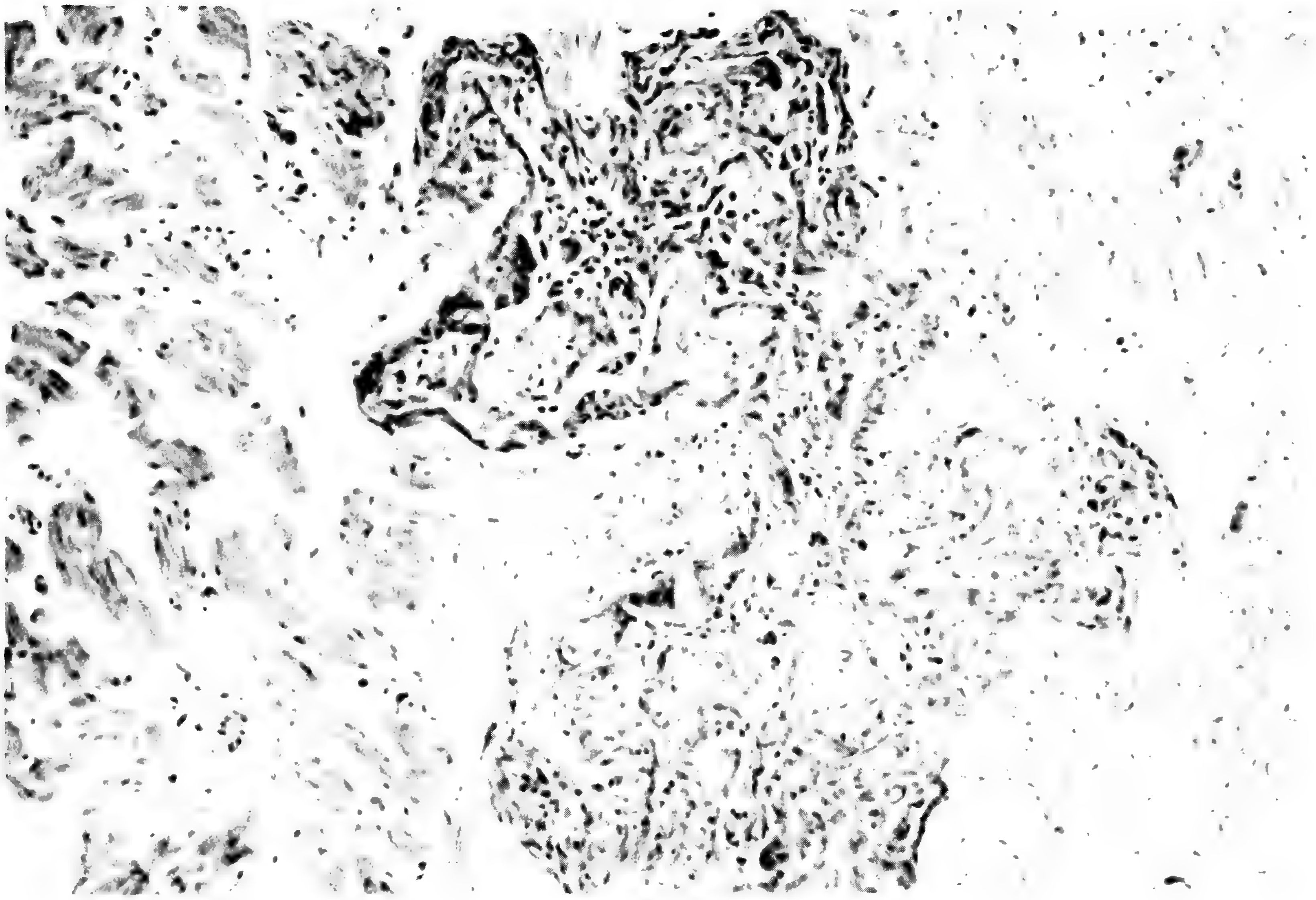

Figure 10. Possible Metastatic Hepatocarcinoma in Heart Muscle of Winter Flounder from Boston Harbor.

Figure 11. Multinodular Liver from a Boston Harbor Winter Flounder.

Question and Answer Discussion

Dr. Brown: We have time for a few questions.

Question: Bob, did you say that 77 percent of the fish that you collected had cancer?

R. Murchelano: No. I said that 77 percent of the fish in Boston Harbor have vacuolated hepatic parenchymal cells. Because I believe that the origin of the neoplastic cells is related to the vacuolated cells, then there is a potential for many more fish with liver cancers than has been noted.

Question: You have shown us a string of precursors to the development of hepatic carcinomas.

R. Murchelano: No, not necessarily. I showed you a string of precursors which are implicated in studies of experimental carcinogenesis in rodents. I believe that the vacuolated cell is associated in some way with neoplastic cells. The winter flounder have other lesions similar to those of rodents. There is some speculation as to whether these other lesions, the basophilic and eosinophilic foci, and the hepatocellular adenoma, are steps in the transition to the carcinoma. No one knows that for certain.

Question: Have residue analyses been performed on these fish?

R. Murchelano: Leigh mentioned that analyses have been conducted for PCBs on livers and flesh; that is it so far. I have bile stored that I want analyzed as soon as possible. I also have gonadal tissue stored for analysis.

Question: Does the incidence of cancer vary with age in Boston Harbor?

R. Murchelano: I did not tell you about the internal bias I used during sampling. I biased my collection for fish over 35 cm in length. I did that for two reasons. One, if induction requires a long latency period, as is well known in some cancers, the longer the time, the better. Second, it is well-known that immune mechanisms, both cellular and humoral, are compromised with age. I do not want to convey that I have exhaustively studied this lesion. The only thing that has been done so far is a morphologic study. There is a lot more that must be done.

Question: Do you know anything at all about the length of life of these fish versus some that don't have the tumor?

R. Murchelano: No. Leigh may have mentioned something about that, but I do not know how life span may be compromised.

Question: Bob, I take it from the last statement of your presentation that fin rot disease does not go hand in hand with these liver tissue carcinomas.

R. Murchelano: No, it does not. If you asked me to tell you how many winter flounder had fin rot, how many had tumors, and how many shared the two phenomena, I could not tell you. I have not even looked at the size distribution of the fish with tumors except roughly within the size ranges that I have collected. I have been totally involved determining the identity of the lesion, and that has been affected by consultation with people who know.

C. Sinderman: I wondered if you had started the long-term experiments that lead to the induction of these lesions?

R. Murchelano: No.

C. Sinderman: Is that a part of the plan?

R. Murchelano: I can plan all kinds of things, but I can not effect them. I have a long list of plans.

C. Sindermann: It would seem quite important to get it going.

R. Murchelano: One of the things that is of considerable interest is the stomach contents of this animal. As was mentioned this morning, in every collection I have made, the stomachs contain only polychaetes. We have bounced a benthic grab off the bottom several times, but did not obtain any worms. I would like to have the polychaetes analyzed for various organic contaminants. If anyone knows anything about the histology of the worms, someone ought to look at them for lesions. The worms certainly are a preferred food of Boston Harbor winter flounder.

Dr. Brown: Thank you very much.

MULTIPLE USES AND MANAGEMENT

by

Mr. Richard Delaney
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Massachusetts Office of Coastal Management
Boston, MA

I want to extend my thanks to NOAA and EPA for hosting this forum this afternoon, to the scientists and fellow colleagues on the panel who have provided some interesting information and expertise to the session, and to the rest of you for enduring six hours of Boston Harbor pollution talk. We in Boston have been dealing with this for a while now, and, of course, misery loves company, so I am pleased to see you all here and interested in our problems, and hopefully part of the solution.

I will focus not so much on the pollution aspect or the technical side, but will talk more about the Harbor and its multiple uses and the management challenges that it presents. I would say that in many cases, the management challenges are as complex and as perplexing as the scientific challenges.

The message, however, will be that while the competing demands for use of the Harbor are increasing dramatically and the complexity of managing those competing demands is also increasing, I do believe we are making some significant progress. I say "we" collectively to mean local, state, and Federal officials, and interested groups working together to make some significant progress in managing these competing demands in a reasonable and balanced fashion. As always, there is still much more to do.

I will start with the one use of the Harbor that has been a dominant theme today: the use of the Harbor as a receptacle for sewage waste which seems to dominate the news in Boston. In fact, it was in the news in Boston 50 years ago this week. On June 11, 1935, the Massachusetts legislature passed a law that was basically one page long, saying that oil, its byproducts, refuse, and other material shall be prohibited from being dumped into Boston Harbor.

Interestingly enough, almost 50 years later that same legislative body, the Massachusetts legislature, passed another law which you heard about this morning. That law created the Massachusetts Water Resources Authority (MWRA), the purpose of which was to put into place a mechanism that would have the fiscal, technical, and administrative capability of carrying out the cleanup of the Harbor and reversing 50 or 150 to 200 years of using the Harbor as a receptacle for waste. I am not sure if that means we are making progress, going backwards, going sideways, or sinking under the whole thing. But it is an interesting juxtaposition. One similarity in the two bills is that they were passed by the same state legislature. In fact, there may actually be some senators and representatives who were there in 1935 who, are still there with us.

The differences are striking. A one-page bill compared to what was about 150 pages of narrative to create the MWRA. The size of Boston Harbor has changed dramatically over the years. The numbers of people and agencies involved in dealing with the Harbor has increased dramatically. What is most instructive of those two bills is that the complexity of this issue has dramatically increased technically, politically, and fiscally.

It is probably even more instructive to go back 100 or 200 years to some of the early citizens of Boston who really did live beside perhaps what would be more truly classified as an estuary than today's Harbor. There were more mud flats and salt marshes, and more fresh water exchange with the Harbor, which, at that time, was not coming through sewage discharges either.

One or two hundred years ago, people perceived the Harbor not as an estuary, unfortunately, but as a place to discard their wastes, to fill in, and to create more land. The early rudimentary pipes that came from individuals' homes bringing wastes into the nearest stream and to the Harbor were eventually culverted and covered over. We are left today with a legacy of antiquated systems upon which we are trying to make adjustments to clean up the Harbor.

Today, we have made some progress. There has been a decision about the 301(h) waiver. We are changing to secondary treatment barring any reversal of that because of a successful challenge in the court, which I hope does not happen. That, of course, means a number of things including a better level of sewage treatment. But it also requires us to look for a site with twice as much acreage. It will mean an increased amount of sludge as the byproduct of the treatment, and increased difficulties in finding a location somewhere adjacent to the Harbor where we will be able to successfully site a treatment plant. One of the management steps the state has taken to solve some of the sewage problems is the creation of the MWRA, which is charged now with finding a site for the new plant and moving forward with its implementation.

Another part of the cleanup strategy in the Harbor will be dealing with CSOs, and I know all of you people in Washington hear the acronym CSO and think of the Coastal States Organization, which is what you should think of. It is the foremost group for representing coastal issues here in Washington with a very excellent staff. Unfortunately, in Boston we think of CSOs as the combined sewer overflows that contribute in some cases almost, at least by some estimates, as much as half of the contaminants to our Harbor. We need the MWRA, in combination with our state agencies and significant federal help, to address the CSO problem. Fortunately, we have had a 30 million dollar appropriation to deal with perhaps the worst of the CSOs, for example, at Fox Point coming out from underneath the main dock at the Savin Hill Yacht Club in Dorchester. That one will be cleaned up, renovated, and put back into operation.

Another component of our cleanup strategy involves the pretreatment of sewage before it goes into the system. That will be a critical part of the operation no matter what level of treatment, where the plant is sited, or how we deal with our sludge.

As an example of the political, economic, and management difficulties of this issue, the MWRA recently discussed increasing its enforcement and monitoring efforts in the pretreatment program. In reaction this week, the Associated Industries of Massachusetts, a group of the major industries in the state, held a meeting where they cried that pretreatment is too costly, is unnecesary, is not scientifically justified, is not technically justified, and is going to hurt business in Massachusetts. We are again caught in that conflict between the quality of the environment and the health of the economy. None of these decisions are easy.

The sludge decision, which will be a fourth component of our strategy and on which we have been working diligently in recent years, will involve major policy decisions, all of which will require sound technical advice. We are hoping to be able to create a composting operation with the sludge; yet that has some technical difficulties. Another option is to incinerate the sludge, which is one of the standard procedures, but one that creates air pollution and may threaten our health and the citizens of Massachusetts. A third option would be to dispose of the sludge in the ocean, which has a possible negative ramification in terms of the food chain and the quality of our waters. What we have been talking about and hoping to pursue with some of our scientific expertise in the state is a true multi-media assessment of the impacts of these options so we can use a good data base to make public policy decisions.

Another use of Boston Harbor is the fisheries: shellfishing, finfishing, and lobstering. It has been part of our history and part of our heritage to look to the Harbor for that kind of a use over the years. Unfortunately, at this point we literally have millions of dollars of unharvested shellfish in Boston Harbor and elsewhere in the adjacent waters; but, because of the contamination, an economic resource that is going untapped.

Fishing is a great economic and natural resource that needs support and is under tremendous pressure from pollution. Another kind of pressure, an economic and management pressure on the industry, is that the piers and docks vital to sustaining this industry are in a state of disrepair in Boston Harbor. The uses of that shorefront and those docks as lobster or fisheries landing facilities are being changed to non-water related uses, such as office buildings on the waterfront.

As you can see, a tremendous user conflict has to be resolved. Our preference is to maintain the water-dependent, water-related use for the fishermen. The state is working to find ways to support the industry through grants to local towns to rebuild those piers and set aside property for the fishing industry. We have a situation right now where the Governor, the Cardinal, the Mayor, and everybody else is involved in trying to find a place for the lobstermen to land their lobsters because they have been recently evicted from their current pier. It is a major concern and another major use that needs some very careful management.

A third and related use of the Harbor relates more to the shoreline uses. As I mentioned just a minute ago, the concern is to use this very unique piece of property for activities related to the waterfront. We made our first attempt at managing this when we developed the Coastal Zone Management (CZM) Plan in our state back in 1978. As a component of that, we identified certain ports as "designated ports" where we have directed our state policies towards encouraging maritime-related uses. The standards are set in such a way that we encourage those kinds of industries to happen there as opposed to another place along the coastline.

Most recently, and one of the more encouraging notes for us, is that in December 1983, the legislature passed a law that amended what we think is the oldest coastal regulatory law in the country: the tidelands license that our state has been issuing to people who do activities and build docks and piers along our coastline since the colonial days, back in the 1640s. At that time, the colonial government began to look at use of the shoreline and, in effect, tried to encourage people to use the waterfront to build docks and piers at their private owners' expense to promote the East India Trading Company and all the marine commerce that the colonists needed.

That law had two basic interests it was protecting. One was to ensure that those projects built were structurally sound, and the other was that the structures did not interfere with overall navigation of the Harbor. Recently we have been able to add a third interest, which is called the public interest. Under that title, we are now able to condition projects so that they serve a proper public interest as opposed to just a private interest or gain. Definition of that "proper public interest" has changed over time from maritime commerce, which is still appropriate, but also now it includes the use of the waterfront for public access, physical and visual aesthetics, for supporting the fisheries, and for water dependent uses. This is an attempt to fend off the trend of non-water-related uses that are coming to the waterfront. Under this license, a proper public purpose is further defined to make sure that a project built along the waterfront notes the water quality and does not contribute to the degradation of that water quality.

A fourth use that is becoming more popular, of course, is the Harbor as a recreational facility. The numbers of marinas, private sailboats, and motor boats that use the water is increasing tremendously. We have been blessed with a number of Harbor islands that are now a state park, the Boston Harbor Islands State Park. The state recently has invested millions of dollars in upgrading those parks and providing a commuter boat for citizens to get to them. We have renovated a historic fort on George's Island. We are rebuilding a major wharf right in the downtown waterfront area both as a visitors' center and to encourage more use of the islands. However, the obvious conflict or irony is that these wonderful islands are surrounded by very contaminated water. Thus, the cleanup process goes hand-in-hand with increased use of the islands as a recreational base.

The Harbor also has not been used to its fullest advantage as a means for a water-based transportation, even though historically it was very active. There are photographs of literally hundreds of two and three-masted ships that would sail into Boston Harbor from nearby ports. Today, we do not see the same numbers of ships, but the numbers are increasing once again, and we have in just this morning's newspaper announced yet another boat being added to the fleet of commuter boats going back and forth between Boston and the South Shore communities.

Another aspect of the Harbor which is not particularly a use of the Harbor, but is an occasional necessity, is the recurring need to dredge certain parts of the Harbor. One of the speakers earlier this morning talked about this management problem. We have traditionally taken the dredge materials out to what is called the foul area some 12 miles off Marblehead and disposed of it there. We recently found that some of that material is not staying in place. We are now involved with the U.S. Army Corps of Engineers and EPA in doing some oceanographic analyses to study sediment transport from the foul area. Because much of this dredge material is highly contaminated, finding an appropriate site for it is another management issue.

Needless to say, I have just given you a smattering of the different kinds of competing uses. There are many more perspectives of the Harbor and many competing uses. There is an increasing demand for more management and attention to these issues, and I think the institutional response is getting better. It had been ignored for sometime. The City of Boston, like other ports around the country, had turned its back on the Harbor. Now we have rediscovered it, and the governmental institutions are trying to catch up on managing the Harbor as a resource.

The legislature has recognized the value of the Harbor by passing the Water Resources Authority Act earlier in 1983. It also passed a Coastal Protection Act, which established the Office of Coastal Zone Management as a permanent entity in the state. This Act essentially told the citizens and all the agencies that it was time to move forward in some comprehensive fashion based on a set of policies that were adopted by the state under the CZM Act and to work together to achieve some success in the Harbor.

The Governor, certainly, has recognized the need for a coordinated effort in the Harbor; he has created a sub-cabinet, which is composed of key members of the various cabinets and key agencies. The prime focus, and the only focus, of this group is to work to bring all of the competing interests together through one office to make more efficient and effective decisions.

The agencies clearly are aware of the need for sound management decisions. You have seen by the turnout today by the Division of Marine Fisheries and some of the other state agencies that there is an ongoing effort. We recently have created and organized a group of key individuals from the Division of Marine Fisheries, Department of Environmental Quality Engineering, Public Health Agency, and from CZM to work together to facilitate communication, to examine the ongoing research around the Harbor, and to help develop goals and strategies so we can more effectively work as a state with EPA, NOAA, and the private educational institutions in making progress.

To end on an "up" note, we have heard a lot of disturbing comments about contamination and about competing uses, but I clearly and honestly believe we have reached a point where a lot of people are concerned and a lot of good talent and expertise are being focused on the Harbor. We are very pleased to see the Federal Government doing the same thing, with both NOAA and EPA creating estuary programs. It is certainly going to be a step in the right direction. We hope that the budgets in the U.S. Congress can continue to reflect that kind of a priority.

We need funds for research. We need funds for good coastal management, and we need to have the CZM act reauthorized. There is a true need for the federal-state partnership to continue in this area. Meetings like this today are encouraging and I hope they continue.

I will be glad to answer a question or two if you have some. Yes, Sir?

Question and Answer Discussion

Question: Isn't Boston Harbor the place where you have an LNG terminal?

R. Delaney; Yes, it is and, in fact, traffic in Logan Airport is redirected at that time. All Harbor traffic is cleared out the Harbor. There are six tugboats that surround the LNG tanker when it comes in. It does go under the Mystic River Bridge and has to go under at the right tide. If it goes under at high tide, we are all in trouble.

Question: I haven't heard anything about rehabilitation of the major problems of your bays, estuaries or Harbors in Massachusetts. What thoughts have you given to rehabilitating these locations?

R. Delaney: Rehabilitation in terms of removing the contaminated sediments in the harbors?

Question: Well, whatever.

R. Delaney: We are really not quite at that point yet. I guess we are looking at, at least in Boston Harbor, stopping or reducing the amount of pollution being contributed to the Harbor by upgrading treatment plants, by finding a solution to our sludge problems, and by repairing our combined sewer overflows. At that point we may be able to look at some rehabilitation, and that is, I'm sure, many years down the road.

For example, in another area in Massachusetts, New Bedford Harbor, we have a similar and very disturbing PCB contamination problem in the sediments in the bottom of that harbor. It has become a Superfund site. We are now involved in developing with the EPA the strategy for rehabilitating that situation. It's very, very difficult. It's very expensive, and the scale of that is unbelievable. In fact, I think the solution might be that the best we can do is just cap the PCB hotspots in the Harbor and not go the alternative route, which is to try to remove essentially several square miles of acreage in the bottom of that harbor, and in the process churning up and resuspending many of those contaminated sediments.

So, no, we are really not at the stage where we have active--unless some of my staff can help me out--rehabilitation projects going on.

Question: In earlier years we received a certain amount of tax funds for research. Do you see anything like this coming out in Massachusetts where funds can come from local and state government for this use?

R. Delaney: Yes. Possibly. One of the most recent bills that we passed--and I mentioned this--is this Chapter 91 Amendment. It is the license that is issued by the state to someone, a project proponent, who is going to do some work in the tidelands. Traditionally, as I mentioned, that license has been given fairly cavalierly and without any major fee.

The newest regulations that we are about to promulgate will increase that fee significantly so that the true value of that property, that undervalued coastal property, is reflected in the license. One of our hopes is that that money can then be redirected back at related projects like research on the waterfront and acquisition of waterfront property.

Dr. Brown: Thank you.

PANEL DISCUSSION

B. Brown: There are many areas where we still have information gaps that are important in making management decisions in the Boston Harbor/Massachusetts Bay area. I'd like to ask some of the speakers to address what they think are the data gaps still missing. I'll start with Gene Gallagher.

G. Gallagher: I think the physical oceanography of Boston Harbor and Massachusetts Bay is first and foremost. It was pointed out to me during the break that there are existing models of the circulation in Massachusetts Bay. The major one that has been used is called CAFE. It was developed at MIT, and used by the MDC section 301(h) waiver.

We need more sophisticated modeling efforts for understanding the currents in Boston Harbor and Massachusetts Bay. We need to know the sources of the pollutants, but we also need to know the mechanisms of transport. We must understand the physical oceanography to look at the exchange between the Inner Harbor in Boston and the Outer Harbor as a major source of pollution as well as the exchange processes between Boston Harbor and Massachusetts Bay.

The reason sophisticated models are needed is that what we know about circulation is very complex. The Harbor is very shallow, and also circulation is dominated by tidal forcing and wind effects. So we need models to incorporate wind sheer stress.

In the last 5 or 6 years, there have been tremendous advancements in the field of physical oceanography in putting together both finite element difference models which could handle wind sheer stress. I think the major thing limiting our understanding of Massachusetts Bay is the physical oceanography. Once we begin putting those pieces together, it will help us look at coupling the output. If we know the output of pollutants, we will know more about determining where they are going and their effects.

B. Brown: Leigh Bridges?

L. Bridges: Well, from the point of view of the fisheries, I think our understanding of the contamination problem manifested by the carcinoma in flounder has to be broadened. The second species that needs to be looked at is lobster, and that should be done immediately. Moreover, I think Dr. Murchelano indicated that the fish that have been studied, to date, have been looked at or sampled on the basis of trying to find a flounder in this condition.

We have to establish a sampling program that would be less biased in terms of discovering what percentage of the population is affected. Secondly, we should determine, if possible, what long-term effect pollution might have on the population of winter flounder and lobster if they are affected. At this point in time, we don't know whether they are affected, but quite possibly that they are.

From the contaminant point of view, more sediment analysis has to be done to find out the contaminant levels in the sediments, where the hotspots are, and what the sources of the PAHs are. Currently, we have no knowledge of what those sources are.

B. Brown: What do you know about the shellfish populations in terms of the presence of neoplasia?

L. Bridges: I would have to plead a little ignorance because we've harvested shellfish in Boston Harbor for a great number of years, even though it has been polluted. They are depurated by use of untraviolet lights and then, they are marketed. There is a very strong demand by restaurants in the Boston area and the North Shore for Harbor shellfish. When the shellfish come out of the depuration plant, it is believed that they are an excellent quality product. And of course, when you depurate shellfish, you're depurating in terms of bacteria. You are not getting out viruses or viral infections within the animal.

Tufts University scientists have recently found out that many of the shellfish throughout our state have a form of blood cancer or abnormalities in the blood system, which they feel are either precancerous or cancerous. I think there is some debate as to how far this goes back historically because apparently they have found this condition in New Bedford Harbor shellfish. However, our people indicate, that this condition was not prevalent in 1976. So we really don't know a lot about shellfish pathology. And one of the things that the state agencies need is more expertise in pathology.

M. Barber: Is there a sensitivity to testing of lobster flesh and shellfish? Earlier on, someone said that citizen involvement would help as far as any known problems dealing with getting monies. Is there a citizen sensitivity, either from the fishing community or the citizens themselves, about not wanting to know what's in the flesh?

L. Bridges: There's been a lot of publicity about the problems in Boston Harbor and the problems in New Bedford Harbor with PCBs. There is a resistance within the industry, particularly the lobster industry, as a result of the New Bedford Harbor problem. When you have a contamination problem that affects an economically valuable resource, then producers of that resource resist actually finding out the root of the problem, because when the public becomes concerned, the consumption rate drops drastically after media publicity.

For example, this spring the flounder fishery in Boston Harbor, suffered from a drop in participation by anglers because of the adverse publicity on the flounder themselves. I don't want to get into the question of whether the carcinoma in Boston Harbor is a problem as far as human health is concerned. That's not my expertise, and I don't have any background in that. The adverse publicity has affected the flounder fishery in Boston Harbor this year, and it has affected the lobster industry in the past in the South Shore in terms of PCBs. So it is a factor; there's no question about it.

I think part of the problem is that the producing industry feels that every time a contamination problem comes to the forefront--in the 1970s, it was mercury--the fishing industry is the one that suffers. There is no remedy to the situation of polluters who are causing the problem. I think the fishing industry in New Bedford took the two polluters in New Bedford to court and lost. They sued them for damages on the potential harvest that was lost, and they lost. They had no recourse, no remedy from the court.

M. Barber: Was that a state court?

L. Bridges: That was a Federal district court.

B. Brown: Paul Boehm, is there anything you'd like to discuss or Gordon Wallace, either one, on potential data gaps that you can identify?

P. Boehm: I think Gene hit on some of the major data gaps as far as circulation and fluxes from the Harbor to Massachusetts Bay. The whole issue of pollutant mass loadings is important. The contributions of the sewage effluents and the sludge effluents versus the combined sewage overflows, river discharges, and concentrations of toxic organic compounds in the Charles River is substantial. And Gordon showed some overall flow calculations, about 35 percent of the water flow from rivers. If the trapping efficiency of Boston Harbor is 3 percent for the sewage, then something doesn't add up. There's a lot going on that's causing both the higher levels and the whole range of problems we're seeing here other than just the sewage situation.

In terms of management decisions, there's a major effort focused on the MDC. Maybe that's the story; that's what the public believes. Maybe that's the right answer right now. But I really don't think it's the whole story. In terms of one of the biggest data gaps, it's just the contributions from all the sources and what else needs controlling.

J. Thomas: I'd like to add something concerning that. With regard to the Charles River, there's a lock at the base of the Charles River. It's usually assumed that most of the contaminant material goes with the particulate phase. I would assume that the locks should cause some sedimentation of the particulates in the Charles River above the locks. Perhaps if we want to protect the Harbor, we can certainly make the Charles worse. Do you have any comments on that one way or the other?

P. Boehm: It gets really down to the Charles permanently so that nothing gets out. I really don't have any comments on it--maybe Gordon knows something more about the flux from the Charles.

G. Wallace: I've only taken one sample behind the dam of the Charles River. This was a monograph we were working on. The metal levels there indicated that the Charles was not a significant source, at least for metals, going into the Harbor. I think you're absolutely right. There is a high suspended load and much material is effectively trapped behind the dam and, therefore, is not getting into the Harbor. But, what I've said is based on one sample taken at one time. Certainly, more needs to be done before any quantitative statements can be made.

P. Boehm: I think that the bulk of all the material would enter the system during a heavy rainstorm; a time when people gather information least.

G. Wallace: I'd just like to echo what Gene and Paul said about physical oceanography, because none of us can look at geochemical cycling and transport unless we understand the basic physics of the system. That's going to be a big concern for management. I've already mentioned the problems with copper. Some of the other metals are at or would violate the revised clean water standards. In addition, unless we know what to expect if we go to secondary treatment and reduce that particulate loading on the Harbor water quality and, therefore, can predict what the maximum permissible loading was, we're potentially faced with building an extended outfall which is not a trivial undertaking. I don't know what the cost would be; I would imagine it would be in the hundreds of millions of dollars.

Question: Somebody mentioned that there are a lot of academic institutions in that area, and yet there doesn't seem to be a tremendous amount of involvement in that area in terms of research. Is this because the area is small, or the problem is not recognized? Why do you think this is the case?

G. Wallace: May I answer that? I'm glad you asked. MIT, for example, is a Sea Grant organization that has tried to put a comprehensive program together for the Harbor, and it just wasn't interesting to any of the funding agencies. We've only been there for 3 years, and we have several grants now that are actively involved with work in the Harbor in one aspect or another.

Most people at MIT, in terms of my field of geochemistry, are interested in offshore, blue-water work. That's the same for Woods Hole. And that's where additional funding has gone. The suffering that goes along with trying to get funding for inshore coastal work is incredible. For some of us, it's hardly worth the effort in terms of ease of funding and acquiring the funds. It's an extremely complex environment that requires a multi-disciplinary approach. It requires generally large funding bases to do meaningful studies that address the kinds of questions being asked here. I find that financial support is really tough to come by with the current status of funding to the agencies.

P. Boehm: Your question really has to be directed to the funding agencies not to the universities. I think this is a system that everybody--including most Federal agencies--has assumed is somebody else's problem or it's getting a very limited approach like in the 301(h). There's been a lot of 301(h) activity, but research activity extends to the zone of initial dilution. Many chemists have linked one 301(h) study with another one several miles away.

Question: In the Chesapeake Bay area, a lot of environmental legislation goes all the way back to the environmental impact statements. It has been a matter of people putting pressure on legislatures. Of course, the Federal legislature is close by and convenient, but there has been a great sense of awareness of the environmental quality and also the economic value. Of course, there is a lot more inland area, inland water too. Do you think that is an area that could be developed in Massachusetts, an area of interest, and possible societal pressure?

R. Delanay: I think it will be, and it has to be. Obviously, from what we've heard today, there is a tremendous need for more research. Both the early comments are true, however. Historically, the research money was not being directed at that area from the state or the Federal government, for that matter, or from other sources. And until the University of Massachusetts program focused its attention physically, put itself on the Harbor front and focused attention on the Harbor, we really didn't have a forum or a place to direct that. But I think more will follow; the ball is rolling now.

K. Castagna: I'd like to add something to that. It's my perception that there's a constituency to clean up Boston Harbor. I don't doubt that. There's been a tremendous amount of public and newspaper interest on the plight of Boston Harbor and the plight of the Metropolitan District Commission (MDC) to operate and maintain adequate sewage treatment facilities for the 43 communities who are serviced by that facility. I don't think we mentioned that, but 43 cities and towns are serviced by the MDC.

Many engineering studies have focused on the Metropolitan District Commission sewage system. There's some misconception in the public's mind between engineering studies and overall environmental research. This type of forum is very interesting to bring out the fact that there are a lot of unanswered environmental questions for which we need answers. In the Boston area, the public might believe that when you study Boston Harbor for 15 years or more without much action, why spend more money in research when we want action?

Many unanswered questions need research. There's also a correlation between those unanswered questions and very wise management decisions that are coming up. I think we need to bring forth the message more clearly that there are a lot of unanswered questions from an overall environmental point of view.

M. Barber: Along the same lines, how does the public health question affect recreation and citizen involvement? Is there any swimming in Boston Harbor at all? Are the beaches in Massachusetts Bay open or closed? What is the situation there and how can it be used to advantage?

R. Delaney: There is swimming. However, when very heavy rain falls in the summer and these combined sewer overflows overflow and discharge waste into the adjacent water, the beaches are closed at that time. This is a serious concern. In fact, we've set as priorities the rehabilitation of those particular CSOs adjacent to the swimming beaches; this is one of our criteria.

But for the most part, the swimming outside of Boston Harbor extends, by some definitions, from Winthrop through ten major towns, and small cities such as Chelsea, Revere, Quincy, and along the Massachusetts coastline. In addition to the city, at least eight, and perhaps ten, towns have frontage on the larger Boston Harbor and Massachusetts Bay. But for the most part, the pollution, problems with swimming beaches are really just in the immediate areas close to the CSOs.

Question: I have a couple of questions. From a national perspective and in order to be able to set priorities, there's only so much money in the kitty, so how would you compare Boston Harbor to other estuaries along the east coast or the northeast coast? I won't say nationally, but how does Boston Harbor compare? If you don't know the answer to that question, what criteria must we use to be able to prioritize where the money has to go so we can correct or mitigate, in one way or another, what is happening in some of these estuaries? Is Boston Harbor worse off, for example, than Raritan Bay? Is Boston Harbor worse off than Searsport, Maine, or the Gulf of Maine, or Chesapeake Bay? Maybe it's not a fair question to ask.

G. Wallace: Well, one of the things we have to consider is probably the largest single discharge of sewage occurs within the estuary itself, which is generally not the case in any other estuaries along the east coast or at least in terms of the volume of water being impacted. Another criteria I'd use is the economic value. Are the fisheries resources lost and are the recreational and aesthetic values affecting real estate values? How do we put a number on that?

Question: Well, I guess what I'm asking is the same question that was asked at first. What criteria and data gaps do we have, in a sense? But I've heard today, for example, we use Capitella, we use chemical contaminant loads, we use neoplasias, we use disease symptoms or even disease effects, perhaps even parasitic loads. This is an expert panel whose charge, I would assume, is to try to address questions like this not necessarily just for Boston Harbor, but thinking in a holistic way, just where are we supposed to be going if indeed pollution is affecting our health or resources.

L. Bridges: I don't know if I can answer your question, but in Massachusetts when the original Federal Water Pollution Control Act was passed, a great deal of emphasis was on building sewage treatment plants throughout the state. The principal activity centered on freshwater streams, lakes, and ponds. Basically, I think the ponds and streams in Massachusetts have been fairly well cleaned up, and the condition is certainly much improved over what it was in the early 1960s. But in the coastal areas of the large industrial cities like Boston, Salem, South Essex, and the New Bedford area, this isn't the case. As far as I'm concerned, decision-makers put their heads in the sand because they figured, well, all we have to do is dump sewage out in the ocean, and the ocean will assimilate this waste.

The technology that's been applied inland to clean up the inland waters really has not resulted in any improvement along the coast. Moreover, what we've experienced in Massachusetts as an industrial state is extreme development along the coast. For example, on Cape Cod, where people spend their summers because it's a beautiful place to be, within the last year or two, the number of acres of shellfish flats closed because of bacterial contamination is increasing from about 2,000 to close to about 5,000. The amount of housing being built on Cape Cod, and a whole host of problems brought on by increased use of Cape Cod, is one of the things that's happening in Massachusetts. And I'm not sure that it's happening elsewhere in the country or on the east coast.

G. Gallagher: I would like to comment on how we set priorities. We don't know enough about Boston Harbor to really have a ranking of how it compares in terms of pollution levels to Elliot Bay and Puget Sound. One way we might consider ranking funding is trying to get to just a basic rudimentary understanding of the various systems.

Puget Sound is fairly well understood, but could use a lot more research. For example, in the main basin of Elliot Bay, we know essentially what controls the phytoplankton bloom. It was modeled pretty well in the winters of the 1960s.

Narragansett Bay had a good base of funding through NOAA-Sea Grant, so they were able to put together a fairly good model of the tides there. Jim Kramer and Scott Nixon put together a very nice simulation model to explain the blooms in Narragansett Bay. They have good data on the copepod populations so they know the relative effect of the zooplankton population. They had a good data base to work with before they even began considering pollution levels and how they affect the biological community.

We don't have that in Boston Harbor. However, we have heavily polluted sediments, we have people fishing for winter flounder that tend to congregate around the plume outfalls. We have a heavily polluted system, but we don't have a good understanding at all of this system. We need funding from somewhere. I think a Federal source would be nice. Boston Harbor is not unique. Fred Nichols started working in San Francisco Bay in the 1970s at a point similar to where we are now with Boston Harbor. A good review of what's known about the biological communities in San Francisco Bay up until the early 1970s, such as the knowledge about San Francisco Bay until the mid-1970s was as woeful as it is about Boston Harbor right now. They have made a fairly heavy effort in the last 10 years in San Francisco Bay and have a pretty good understanding of the situation. We don't have that in Boston Harbor/Massachusetts Bay. So rather than try to rank it, I think maybe getting a basic knowledge of the processes would help an awful lot. And that, unfortunately, takes some pretty hefty funding.

P. Boehm: Well, I'm going to be bolder. I admit that we have to know more about the processes to make the management decisions. We have discussed processes, fluxes, and circulation. In terms of ranking criteria if we're talking about fish disease and pollutant concentrations, granted, we don't have as large a data base as other estuaries. I would rank the Boston Harbor area as bad or probably much worse than most estuaries outside of the superfund, New Bedford Harbor, maybe Commencement Bay area. Although Commencement Bay has some comparable levels.

So, granted, we don't know much about the implications of these pollutant levels, but Dr. Murchelano has told us, that he's never seen such a high level of incidence. I think we have a feeling that we're dealing with a system that's pretty badly degraded--much more degraded than some of the estuaries, certainly, being studied by EPA in the estuaries program.

A. Rosenfeld: You said neoplasia is probably one of the most dramatic criteria or clues, at least, that the place is dramatically contaminated. This should not be the only criteria. Other criteria may be equally significant or as important as neoplasia. The criteria depend upon biases as to what is the most important adverse effect.

Right now, I think Boston Harbor is only using neoplasia, liver carcinomas more specifically, in winter flounder as a major criteria for saying it is badly degraded. At least you are, Paul, in addition to some of the other criteria, such as certain pollution levels. But what are these pollution levels in comparison with Raritan Bay, for example?

R. Murchelano: Whether we establish criteria in terms of how much attention an estuary, body of water, or land should receive in a society, a democratic society by fiat, by presidential decree, by legislative action, by referendum, by whatever we want--it's bound to vary. Somebody has to arbitrarily designate for the benefit of society overall, what things are most important. That's incredibly difficult. I understand that. That's basically your question.

But let's go back even further than that. Why study the phenomena to death? By virtue of the fact that we know polluted bodies are polluted. If they're polluted by anthropogenic activity, then we should do pollution abatement and pass legislation that affects pollution abatement and quit the studies.

I don't think anyone would disagree that disease in a room, in a body of water or in a piece of land that is constricted, and thus where animals are contagiously close, is going to be one consequence of pollution. So if that is a given and it is not illogical, then we should make the effort for pollution mitigation and legislation that stops the pollution.

K. Castagna: I'd like to mention something. From strictly a hardware point of view, the Metropolitan District Commission wastewater system is extremely antiquated. They operate one plant that is over 30 years old and under capacity. We do not have enough capacity in that plant for the type of flow that reaches that plant. That's the south system, Nut Island Wastewater Treatment Plant. The other plant was constructed in 1968 and has had chronic functioning and operations problems due to pumps installed there. As far as the level of treatment, it's still at a primary level and, as we know, nation wide, other than the waivers that have been granted, secondary treatment is the law of the land.

Cheryl discussed the history of the waiver process. Boston is one of the few municipalities left in the country that discharges raw sludge through an outfall pipe. So that has to stop. That needs to cease. The CSOs need to be abated. I'm trying to say that from a hardware point of view, it's an antiquated system that we know enough about, in comparison to other major metropolitan cities, to know the hardware needs to be changed. So there's a duality here. I feel that the research needs to monitor improvements of the different types of hardware that we install over the years. But I don't think we need more research to begin to implement that.

From a hardware point of view, it's in a very sad state. I would rank it very badly compared to other metropolitan areas nation wide. Our regional administrator with EPA has said that quite often. From the EPA's regional point of view, we want pollution control equipment, funding it along with the different processes: the environmental review process, the finishing of the facilities plans, the designs of the new treatment plants, the designs of sludge management, disposal techniques that are agreed upon, and more. There's a lot to be done. And we don't need to rank it any further to begin some of that action.

C. Breen: I have to add something to what Kathy is saying about the practical hardware standpoint. When we talk about new facilities for the Metropolitan District Commission, we're talking about more than just end-of-the-pipe type equipment such as treatment plants or combined sewer overflow treatment facilities. Basically, the system is in such a state of antiquation that a number of major pumping stations and interceptors also need repair or replacement. And right now, they're causing not only pollution in the Harbor, but pollution in the local freshwater bodies along their routes because, as Kathy mentioned, 43 communities extend west of the Harbor. Thus we need the hardware not only to improve or lessen pollutant loading into the Harbor, but to keep the sewage out of people's basements and local streams.

G. Wallace: I'd just like to expand on that. I can't let that comment pass unscathed because I think it's a little bit more complex than just pollution abatement. Pollution abatement is fine if you're working as a marine scientist and you're concerned about the health of the marine environment. What about the marine ecosystem? They have to go hand-in-hand. I'm appalled, for example, at the 301(h) progress, which does not consider the ramifications of the increased toxicity of the sludge, for example, because the wastes are going to be generated. How they're handled and where they're transported or where they end up may be slightly different in each case, but it certainly should go into the overall decision process.

I think--and this viewpoint has been made more and more often by people such as Ed Goldberg and Charlie Osterberg recently at the APU meeting in Baltimore--we need some reasonable management plan for judging where the waste is going to go. The marine environment has to be considered as a possible repository of that waste. It obviously has to be done with some rationale so that we don't reach concentrations that presumably induce toxic fish disease and other sublethal effects that we can't even begin to address because we don't have the expertise to do so.

There has to be a balance--a rational management plan and some accommodation for disposing wastes in adjacent coastal marine regions. Therefore, we need the information. We can't stay in this condition of ignorance about what is going on geochemically, biogeochemically, and biologically in the nearshore processes.

The waters are going to continue to receive the wastes; there's no doubt about that. Even if we go to secondary treatment, some wastes will go into that system. We need to know how the wastes are transported, where they are going to end up, and what the likely biological effects might be.

The only way we're going to get those answers is by tackling more complex problems associated with the inshore areas as opposed to blue-water areas. The blue-water system is a much simpler, nicer system. I've done both. It's very nice to go out into the middle of the Sargasso Sea and look at vertical profiles. The variables are not nearly as complex. When I move inshore and try to look at the nearshore fluxes, I've got a real mess on my hands. It's much more difficult, and the variables that we have to consider are much greater in number.

Question: Somebody has to decide at what point we have enough information to make an investment. What that means is that somebody has to decide what abatement is, because some people may be thinking that by investing money, they are going to be obtaining abatement, whereas other people may be saying that you're not going to get any abatement at all. And somewhere along the line, somebody has to make the decision about when to make the investment.

There hasn't been any absence of willingness on the part of Congress to spend money on these problems. But there has been more spending of money on problems and not solving them. It seems to me that there has got to be a basic agreement reached between the scientists who are willing to say, "Yes, the information is good enough to spend a certain amount of money," and the politicians who are willing to say, "We really shouldn't just go out and dump hundreds and hundreds of millions of dollars into secondary treatment plants without knowing how they are going to be affected."

The only thing that would be worse than not spending that money would be spending it and not having any improvements for the public to see. And I have a very definite feeling that what is going on in Boston is that that meeting of the minds is a long way from having happened. What I hear many people saying that we need more information about circulation and about sources.

We have other people on the panel saying that by July 10th, we're going to make a decision where we will put a multi-hundred million dollar secondary treatment plant that's going to have an outfall located, as best as I can tell, about where the existing outfall is.

Somewhere in between there is room for resolving some issues. I began to hear a little bit about this with recent comments such as, "yes, we have to meet some of the interim problems along the way." But it seems to me that there still is considerable emphasis on heavy hardware coming from a lot of people who see the need to solve the problem in the public eye by building a plant on site. Whereas, in fact, a lot of the improvements we may be seeing from the scientist's point of view are going to come from these interim solutions that we are looking at now; solutions that may, in fact, be erroneous. But we don't know yet. So I get the idea that you folks haven't really come together yet from the information side to the money-spent side.

L. Bridges: Along that line, one thing that hasn't really been brought out today is that when the waiver was being considered, the state licensing agency, DEQE, actually supported the granting of a waiver at one point. And I don't want to speak for them, but my impression is that one of the reasons they did was that they felt that the technology involved in secondary treatment would not cure the problems caused by the huge amount of waste in the Boston Harbor. Namely, there were no effective pretreatment programs for complex organic compounds. And it is my understanding that that was one of the considerations. Rich, you correct me if I'm wrong. That is one of the reasons why they were in support of the waiver application. Is that correct?

R. Delaney: Basically, I think you described the situation pretty accurately. For a number of years, we have been in that state of when do we make the decision? When's "D" Day? We've been having this ongoing debate about primary or secondary treatment and what is the best dollar value for us to make. Meanwhile, frankly, the political pressures and the frustrations and the deterioration of the Harbor continues to build to a point where a decision had to be made. There is still ongoing debate about primary versus secondary, but the decision has been made. And we are going to go forward with that.

That decision is only one step or one part of the overall solution, the overall strategy. We need to deal with the other components--pretreatment, combined sewer overflows, sludge, and the treatment plant. From a hardware perspective, there are at least four parts to that, and we've described it as number four in terms of primary and secondary. But now we've made a decision, we've still got to complement it by addressing the other three. That's not always easy because a large amount of dollars that are needed to go forward.

K. Castagna: I'd like also to say that, from EPA's point of view, we never saw the only solution to the Boston Harbor pollution problem as the building of the new wastewater treatment facility. We see it, as Rich said and as the Commonwealth sees it, as a multi-faceted pollution problem that needs many remedies before we'll see improvements, one of which, for the nearshore areas, for the beaches, has to be the combined sewer overflows into the Harbor and sewage sludge in the Mid- to Outer Harbor.

I think what's gone wrong with the wastewater treatment end of it is that it is the most expensive part of the "hardware" solution. I consider the hardware solution the construction of CSO facilities and the construction of adequate sludge management facilities; multiple or sludge management can be used. Ocean discharge, ocean disposal will be one of the options evaluated for the sewage sludge. Sludge management will be examined in light of many alternatives. There will be a new environmental impact statement in the summer of 1985 on the issue of sludge disposal for this system.

But from the public point of view, a tremendous amount of controversy has centered on where the plant will go. One reason the controversy is so intense is that the existing plants are extremely bad neighbors because, as I said before, of their antiquated condition. They generate odors, noise, and traffic. I would describe it as a horror show to live near some of those plants. The focus in the media has been on the plants because of this controversy and the cost, but from our regional perspective, we feel a new plant is the only solution. We feel it's one of many steps needed in Boston Harbor.

C Breen: I hate to do this, but I just have to comment on something that Rich Delaney said about the decision being made on the waiver. It is true that EPA issued that tentative denial of the waiver in April and that the MDC did not respond within the 45 days that they had to contest that decision. But, as I mentioned in my talk this morning, the next step in the whole process is for the EPA to issue a draft discharge permit.

When that draft permit is issued and goes out for public comment, the MDC, the new Water Resources Authority, or some other party will have an opportunity to contest the decision or to begin negotiations on the permit's actual final effluent limitations. Rich is correct in saying that the Commonwealth stands behind and supports EPA's decision for denial, but the Commonwealth's position doesn't speak for the new Water Resources Authority.

G. Gallagher: If I might make one comment, I think you set up a false opposition. You said the scientists are saying, "we need more study," and the policy people are saying, "Well, okay, go to secondary sewage treatment," and the decision will be made July 10th about the site. I don't think they're incompatible. The scientists are saying we need more study, and I think that was a lot of the reason that I, for one, felt that the EPA had very little choice in turning down Boston's application for a section 301(h) waiver. The knowledge of physical oceanography 7 miles out in the Harbor, which is the old diffuser site, is so inadequate we really don't know where the sewage plume would go. Drogues released at one time a year with one wind-forcing condition would be washed to the northwest; drogues released at another time of the year would be washed to the southwest. We really didn't know what the physical oceanography is.

And when we are that uncertain about the physical oceanography of a site out in Massachusetts Bay, we have to give the environment the benefit of the doubt. In reviewing the work, I don't think the waiver could have been granted to the MDC.

Our knowledge is so rudimentary about the environment where the proposed diffuser was to be built that if Boston was allowed to stay with primary sewage treatment, the distribution of the rocky areas in a transect going 7 miles out is virtually unknown, although some preliminary side scan sonar work was done in the early 1970s by Edgerton's group at MIT. That's about the state of our knowledge in mapping where there are sediment patches and rocky patches.

Without a good side scan sonar or good depth sounding device, we wouldn't know when we put down a box corer whether we would be landing in soft sediment or in rock. Our state of knowledge is that poor. When our state of knowledge is that poor, I don't think the scientists are going to be saying, "Build the outfall out there." You know, build it out there and we'll decide after we've done more studies whether we need to go to secondary.

Question: Whether you go to secondary treatment or not, there has to be a discharge of some things some place. You need to decide discharge location whether you do physical oceanographic work or not. How much more physical oceanographic information would you need to make a decision about where you would want the discharge? It is going to have to be discharged.

G. Wallace: We've been discussing that because we've been involved in the South Essex sewage district and their potential attempts to reapply after their permit denial. To address the scientific concerns, we put together a package that would address EPA's concerns, which now would include farfield and nearfield effects. To do that, we have to understand the circulation of Massachusetts Bay. This would have to be done on a basis of where we have at least enough data to examine the principal influence of the major forcing factors. That would require seasonal deployment of current meters. For example, in the South Atlantic Bight, extensive information has been gathered for the Department of Energy program over a number of years.

A problem with all these waivers is that if the comprehensive studies were done initially to develop the lacking rudimentary, fundamental knowledge, we would have had a pretty good idea right at the start of what could and could not be tolerated. Unfortunately, that information doesn't exist. Just as a ballpark figure, it would cost 3 million dollars. Well, that's a lot of money.

But the cost of just a small South Essex sewage district in going from secondary down to primary or up to secondary is 20 million dollars. So it's a small investment, in terms of taxpayers' money, to gain that information. But it has to be done in the correct fashion.

Question: What is there about the physical oceanography? Suppose you had all this physical oceanographic information and you knew precisely where all the discharge was going to go all the time. With that information, how would you decide whether or not you would need secondary treatment?

G. Wallace: Well, that's not the only information. The other information we need would be the ambient biological and chemical condition. We have to consider a series of criteria.

Question: Yes. That's the problem. We would like to have all of this information: physical, chemical, and biological. But we haven't decided precisely what it is that we want to change from a management point of view. We haven't decided what it is we want to avoid.

G. Wallace: I think they're all equal. We have to get rid of the waste. And the greatest lack that I see in this whole program is the lack of attention paid to the balancing of the terrestrial versus the marine disposable wastes.

Question: You're dealing with the unknowns on land as well.

G. Wallace: Exactly. But we know we have severe groundwater problems. I get calls everyday at the university. "Should I buy this house, it's near hazardous landfills, it's number fourteen in the Superfund sites." "Gee, sir, I don't know." But the point is, we know contaminants are present, and it's happening more and more frequently. And there's going to be more and more pressure to avoid going to landfills, for example.

Question: We know that. What do you want to know about the circulation in Boston Harbor and in Massachusetts Bay that is going to make a difference?

G. Wallace: We need to know the transport and dilution of the toxicants that are going to be diffused.

Question: That's a multiple answer.

G. Wallace: Right.

Question: I think you ought to know the frequency with which you're going to contaminate beaches, and then you want to know the flushing capacity.

G. Wallace: Oh, we want to make sure we don't do those things.

Question: Well, those are the end points. Without having a well-defined end point, a definition of what you want to avoid, all you're going to do is generate a lot of academic information about circulation in Massachusetts Bay that sometime later, hopefully, somebody can use.

G. Wallace: No. I presumed when you asked the question, you knew the answer. So, of course, those are the concerns--to know exactly what the fate of the transport of the pollutants are, what environments are going to be affected, and what biological resources will be impacted. And we can't know this unless we have a pretty good idea where they're going to be transported, what form they're going to be in, and what communities are likely to be affected.

Question: That's all true, but you haven't decided what you want to avoid.

G. Gallagher: A perfect example of where the physical oceanography has been a key in understanding the effects of a pollutant would be in the monitoring of mining and oil drilling on Georges Bank. The physical oceanography was the key to designing the sampling program--to look at whether drilling muds and fluids had an adverse effect on the marine environment. This physical oceanography was mainly done by Brad Buttman of the U.S. Geological Survey in Woods Hole, MA.

There is an area of deposition where most of the fine materials from Georges Bank are transported. Monitoring stations were not only set up around the drilling rig, but also in the deposition area. We're missing all of that information in Boston Harbor. In terms of assessing whether there is environmental damage, we really need to know where the fine materials from one area are transported.

It's not just academic information that's sitting there. It's key to managing an area's resource. When the Canadians begin drilling on Georges Bank, as they might, the physical and geological oceanographic information and sediment transport is going to be a key element to deciding whether there's been an adverse impact due to renewed drilling on Georges Bank. It's not just of academic interest; it's key to management.

B. Brown: I agree with Gene. We need to understand dispersional and depositional processes in Boston Harbor and Massachusetts Bay. We must learn where contaminants are going. For example, are they going to fine-grained sedimentary areas such as Stellwagen Basin, to our living resources, offshore out of the system, or somewhere else. We also need to learn more about chemical conversions of contaminants over time in estuaries and marine systems. These types of information are key to management decisions in Boston Harbor and Massachusetts Bay. We need them to decide issues such as outfalls siting, siting of dredge spoil areas, and methods for placing subharbor tunnels.

Question: I've heard Dr. Wallace comment several times on the need to assess in advance what's going to happen to the waste. I wouldn't want us to be left with the impression that as a general rule there's no one thinking about that. Criteria are being made on how to develop technical recommendations used in a multi-media assessment.

G. Wallace: I'm glad to hear it, but in practice right now it's not being done. The sludge management problem is just totally ignored. Michael Deland, the Region I EPA Administrator, said, "Under law, that's what I'm required to do: only consider water quality considerations, not balance terrestrial."

In the EIS for treatment plant siting that recently came out, the sludge disposal factor was not figured into the siting problem, for logic that escapes me, too complex or whatever; but it was not one of the factors they considered in the initial EIS statement. Perhaps it is now. I don't know its status now.

Question: I'm just reporting that it is not an unknown problem.

G. Wallace: I'm glad to hear that.

C. Breen: Gordon, if I understand your statement about the 301(h) waiver process, the reason, in your words, they were ignoring the impacts of the sludge discharge is that the sludge discharge into Boston Harbor is something that is not supposed to happen, and plans are underway to halt it. A separate EIS on sludge disposal options will be prepared following completion of the EIS on treatment plant siting.

G. Wallace: No. In judging between primary and secondary, you always end up with the higher toxic levels in the secondary treated sludge. That poses a problem with disposal. And the consequences of that activity versus primary sludge disposal and the options we have, therefore, have to be balanced. And that's what was not done.

C. Breen: Okay. Thank you for clarifying that because I thought you were talking about the discharge of sludge into Boston Harbor.

G. Wallace: No.

K. Castagna: I'd like to say that the waiver regulations are written very specifically as to what shall be evaluated when a municipal applicant applies to the EPA to allow for a lower level of treatment other than secondary. Those regulations don't allow for economic analyses, such as how much more secondary would cost than primary. Those regulations also don't allow for the evaluation of what we do then with the residual waste product, meaning sewage sludge. So under regulations in evaluating that waiver application, EPA does not have that variability or viability to go into, say, a cost-benefit analysis and weigh those other conditions.

G. Wallace: I know.

J. Thomas: Maybe I could just shift gears here just a little bit. We heard earlier--I think it was from Paul Boehm, and if not Paul, excuse me--that you're not sure that a trend toward whether or not the system was getting worse or better because the data base was too short in temporal time. We also heard people talk about problems with spatial variation, that they had only sampled in some of the pockets and thus weren't sure whether their samples were truly representative or not.

The question I'm really asking is from this panel--and maybe we can hear from several of you--do you feel that the habitat of Boston Harbor and Massachusetts Bay, the trend, is getting worse, getting better, or don't you know? Do you feel the State of Massachusetts and the Federal Government are getting on top of the problem? Or do you feel that the question is pretty much up in the air? And maybe if you want to include the living marine resources in there as well, we'd be interested to hear some kind of wrap-up statements on that.

P. Boehm: The only trend data that I've seen was presented by Gordon Wallace. That's sort of a long-term trend. It's not really addressing a time frame that we want to look at in years, say one, two, three, or five years.

It's even hard answering the magnitude questions; there's just so little data. The trend question has to be answered by well-designed, statistically valid studies. And as somebody mentioned before, most of the area's information has come from engineering-related studies, end-of-pipe studies, and studies that really haven't addressed longer-term monitoring in a spatial sense. So we can't really answer that question on the time frame we're looking at. Things are getting worse when we look at--I don't know what the duration of Gordon's was--the data at the bottom of your core?

G. Wallace: Supposedly about 1900.

P. Boehm: Between 1900 and now things have gotten worse. That's the type of resolution I would really like to know.

J. Thomas: Is the trend still going downhill or is it leveling off? In discussing Delaware Bay, Jon Sharp came down here several months ago and stated that the lower part of the Delaware River and the upper part of Delaware Bay were actually improving. The agencies in Pennsylvania, New Jersey, and Delaware had gotten together and were starting to, in fact, get on top of the question and to come out on the upper side, to bottom out. So some estuaries around the country have bottomed out and are coming up.

I gather in this case your feeling is that since 1900 it's gotten worse, but maybe now you're either unsure or you don't know if it's bottomed out. Is that a fair statement?

P. Boehm: We have absolutely no idea. Gordon's data on the effluent, if you're talking about concentrations of metals, is good temporal data, and some of those metals are up and down. If you're talking about sources, maybe Gordon can comment on this; some appear to be getting better or worse. But in terms of the health of the ecosystem, I don't think we have a clue.

G. Wallace: I don't see any evidence in the effluent data. Some statements have been made, and perhaps with zinc you could argue that the concentrations have been going down. But even more recent data from 1984, which I've seen a few months of, shows no evidence of a trend in the effluent data versus time, and I've talked to our local statisticians about this. And I even have analytical questions about the quality of that data.

So I certainly don't see any reason why things should be getting better based on the limited evidence we have and on the activity in the Boston area. I would doubt that we could see any improvement, as I said, in terms of metal loading in another five or ten years depending on when those plants go on line.

J. Thomas: How about if I pick on Bob Murchelano in terms of fish disease? If fish disease has been around a considerable time in Boston Harbor as badly as you say--I'm not saying that it's been around a long time, but if it is as bad as you say and that condition has been there for some time--then we would either assume that the disease has not had much effect on the population or that the disease is new. Any comment on that?

R. Murchelano: Well, the latter statement is really a fundamental one as to whether it's had an effect on the population. To really address that and assess that would be incredibly difficult.

In addressing it from the perspective of whether the situation is status quo, has become worse, or will improve on the basis of limited information of this particular disease, there is no way to determine its effect on pollution. This is a very, very small assessor of a phenomena at one point in time, and there's no way of estimating, at least, what its effect is and what its rate of change has been. Those are very, very complex questions.

Whether there should be research to determine that, whether we should undertake research to determine whether those questions are answerable, is very vague in my mind. If we reference the extent or prevalence of analogous diseases, or the same disease in a population from an area which has not been ecologically affected to any large degree, such as Georges Bank, and find the spontaneous rate of this disease is non-existent there, then we have to implicate some article as a source other than genetic. And I bring that out, right to the fore, that a genetic difference in susceptibility from a local genetic stock might be something that pertains. But if we can discount the fact or accommodate to the fact that a reference population does not have any spontaneous occurrence of the disease, then the disease most probably is caused, by virtue of where it occurs--in what tissue, its manifestation, its analogy to homeotherms--by an outside source.

So on that basis alone, if we stop some of the introductions--whether they be via primary, secondary, sewage outfalls, industrial plants, or whatever we want, radioactivity from laboratories, all of these possibilities--and start to control them, then we make a step toward reducing the phenomenon which we have studied or identified. Very pragmatic.

J. Thomas: Could I shift to either Leigh or Richard? How about closure of shellfish beds? Are you closing more and more, and is the area expanding year-by-year? Or is the area getting smaller, staying the same, or shifting from one area to another? Is it increasing or decreasing?

L. Bridges: On a state wide basis we are closing more and more shellfish areas every year, principally because of the reason I mentioned before. Everybody wants to live on the coast. We have more waste being dumped directly into the open waters even from individual septic systems. We've closed another 2 or 3,000 acres of shellfish areas on the Cape.

In Boston Harbor, the amount of closed areas fluctuates, but it remains around 2,800 acres which remain open. Now, Cheryl stated that when the MDC is bypassing sewage everything shuts down, so we have zero acres open in Boston Harbor. And that condition might last for as many as two or three weeks, and then the areas are reopened when the bacterial counts go down and the shellfish are harvested again.

I think that Boston Harbor, as far as the shellfishing and the productivity of the shellfish are concerned, probably has some bearing on the pollution load because Boston Harbor is one of the most productive standing crop shellfish areas we have in the state.

I don't have any information on whether this problem is getting worse. There is no trend information, obviously, but just from the development along our coast, I'd have to believe--and it's strictly no more than a personal opinion based on no scientific data--that the problem is in a lull and may be getting worse. Maybe the Water Resources Authority can begin to turn this around.

But if we go back to what happened in New Bedford Harbor in 1977, the discharge of PCBs had stopped. What we've seen since then is a general degradation of the level of PCBs in the animals within the Harbor. But the level has come down, and it has stabilized, so we're still at a level whereby PCBs are still showing up over the limits of the Federal standards. The point is that since the PCBs have been shut off in New Bedford Harbor, there has been some degradation of the amounts showing up in the animals.

R. Murchelano: I'd like to make another comment which has to do with a question that you very acutely identified. And that was, is this particular phenomenon addressing the one which I know best: the one involving the hepatic lesions? If this phenomenon has existed for a long time, why aren't the populations of animals depressed in that Harbor if the same thing is happening to fish that have cancer as happens to mammals that have cancer? That's a very fundamental question, and obviously there is no way I can address that because there is no body of information. I'll say that for the first time.

But that's really not the only important thing. Some individuals here were at that hearing with me held at the House Committee on Merchant Marine Fisheries. Congressman Breaux from Louisiana said it, and I think he said it best of all the individuals that I've heard address this topic of Environmental Degradation and Biological Effect, and that is, "The fish are telling you something, but you're not listening too well."

And if these fish have a phenomenon which is called cancer, we don't know what it does to them because we haven't worked with fish to the extent that we have worked with mammals with this particular phenomenon. But it should be obvious that whatever is happening to fish, could possibly happen to you as well. So the societal consequences of a phenomena of this nature are more than what I address from a resource agency, concerned with the survival of the fish, legitimately, as well as populations of fish, legitimately, and the use of fish, legitimately. But there's another implication--what happens to other animal species besides fish?

Questions: Well, in terms of the shellfish industry, if it is correct that a large number or percent of lobsters are gathered from the Harbor's and that the Harbor's mean PCB level is greater than allowed by standards, why haven't they closed their lobster industry?

L. Bridges: The mean PCB level--the lobster industry in New Bedford Harbor has been closed since 1979.

Question: How about Boston Harbor?

L. Bridges: When I was talking about PCB levels in lobsters just a few minutes ago, all of my comments referred to New Bedford Harbor, not Boston Harbor. We have no data on Boston Harbor on PCB levels. We're attempting to get some now.

Question: Doesn't the Department of Health concern itself with these things?

L. Bridges: The Massachusetts Department of Public Health closed New Bedford Harbor to all kinds of fishing, an emergency closing.

G. Wallace: I think you're asking about Boston Harbor, concerns about Boston Harbor.

Question: Yes.

G. Wallace: Yes. There are concerns, and analyses of PCBs are going to be done in the immediate future. But it's been a long time coming.

B. Brown: I think that we should probably conclude now. I want to underscore how little we know in the area. When I started working on this workshop today, I thought I was going to have a lot of conflicts. I thought I might have ten or fifteen who would be speaking and, for example, six or seven who know about the sewage management concerns, and many who know about biology and fisheries in Boston Harbor and Massachusetts Bay.

It turns out that we do not have the data like that available for Narragansett Bay, Long Island Sound, the Chesapeake Bay, or Delaware Bay. We don't have the volume of knowledge that they have and the literature that has been generated. Most of the available literature for Boston Harbor and Massachusetts Bay is in the grey literature, not in referred journals.

Clear definition of critical management questions remains to be elucidated. Obviously, the Harbor and its sources of contaminants require attention. A more finely focused understanding of transport, dispersion, and deposition processes is lacking. Physical oceanographic data are lacking. Links between Boston Harbor and Massachusetts Bay must be established. Fisheries are stressed both in terms of their health and harvest. The patchiness of the benthic community and the character of the plankton community remain poorly defined. A well-defined, prioritized, basinwide management approach is badly needed.

The Boston-area community has become increasingly concerned with problems in the coastal waters. Progress is being made toward improving municipal wastewater treatment systems around Boston Harbor and Massachusetts Bay. Continued cooperative efforts among Federal and state agencies, private institutions for research and education, and the public is the only way the Boston Harbor/Massachusetts Bay ecosystem can be managed effectively.

I want to thank all of the speakers today for the efforts they have put into preparing for this workshop. Jim Thomas wants to make some final comments.

J. Thomas: Thank you, Betsy. On behalf of NOAA and the U.S. Environmental Protection Agency, we want to thank you, Betsy, and you, Paul, for organizing such a fine day. And we particularly want to thank the speakers who came down here to Washington from the Boston Metropolitan area and shared with us their expertise and knowledge. And last, but not least certainly, we want to thank those of you who managed to survive and hang on all afternoon. Thank you very much, all of you, for coming.

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