the State of Boston Harbor

questions and answers about the new outfall

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Massachusetts Water Resources Authority

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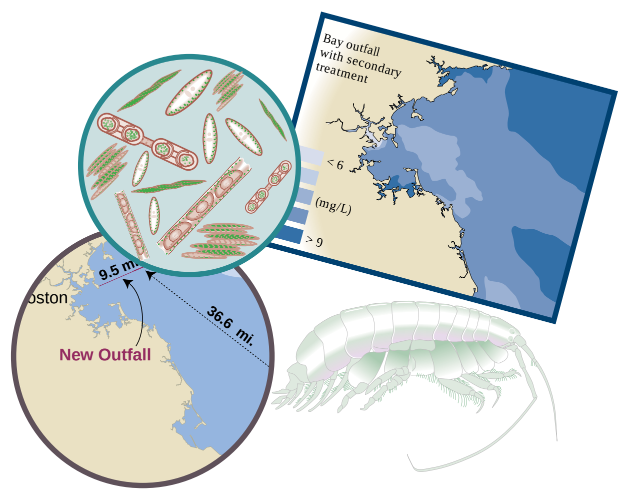

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executive summary

The continuing improvements in the waters of Boston Harbor have been described in the State of Boston Harbor reports over the last few years. Elimination of sludge discharges into the Harbor, prevention of floatable pollution, and system improvements including the start-up of the new primary treatment plant in 1995, have visibly improved the Harbor's environment. Already, reductions in the amounts of pathogens, toxic metals and petroleum products in the primary effluent have been accompanied by fewer swimmers' advisories at Harbor beaches, evidence of healthier animal communities on the Harbor floor, and a lower incidence of liver disease in the Harbor's flounder.

In August 1997, the Massachusetts Water Resources Authority (MWRA) began the next phase of the Boston Harbor Project—the implementation of secondary treatment. Beginning in 1998, a long outfall will discharge secondary effluent into Massachusetts Bay instead of into the shallower waters of the Harbor. This outfall relocation will allow the Harbor to continue recovering from the poorly treated sewage that it received for more than a century.

A draft of the new discharge permit for the Deer Island Treatment Plant will be issued soon. The development of the permit has revealed continuing questions about the new outfall and its potential impacts on Massachusetts and Cape Cod Bays. This report addresses frequently asked questions about this outfall, including the overarching concern: Could the Bays become degraded by sewage effluent as Boston Harbor once was? The answer is no, for these three reasons:

(1) Cleaner Effluent: The secondary effluent that will be discharged to the Bay will be much cleaner than past discharges due to:

Source reduction: Fewer pollutants are being allowed to enter the sewer system, in part through stricter oversight of industrial dischargers. Now, only a small portion of toxic metals entering the treatment plants are from industrial sources.

Improved treatment: Secondary treatment will remove even more contaminants before discharge and meet stringent state and federal water quality standards. While primary treatment removes 50% to 60% of the total suspended solids in wastewater, secondary treatment removes more than 85% of these solids. Oxygen-depleting substances will also be more than 85% removed, compared with 40% removed by primary treatment.

Toxic contaminants will be up to 90% removed, compared to 50% by primary treatment. Pathogens are significantly reduced by secondary treatment. With less solids in the wastewater, disinfection is more effective.

(2) Better Dilution: A four-year scientific and engineering study, regulatory review, and extensive public participation determined that a discharge site 9.5 miles northeast of Deer Island would be the best location for the health of both the Harbor and the Bay. The outfall, equipped with 440 diffuser ports over the last 1.25 miles, will dilute the effluent in water 100 feet deep in the Bay, compared to a depth of only 30 feet in the Harbor.

Computer modeling results indicate that the effluent will have very limited impacts near the outfall in Massachusetts Bay, and virtually no effect on Cape Cod Bay. Surface chlorophyll a, a measure of algal blooms, will increase only in the immediate outfall area, and will be reduced significantly in the Harbor.

(3) Constant Monitoring and Contingency Planning: MWRA's National Pollutant Discharge Elimination System (NPDES) permit for the new treatment plant and outfall, which will be one of the most comprehensive and protective permits ever issued, will require that state and federal water quality criteria not be violated as a result of the discharge. In addition, MWRA is required to conduct an outfall monitoring program that is linked to its Contingency Plan, an action plan that incorporates water quality conditions that trigger MWRA action. These trigger parameters are based on permit limits, state water quality standards, and expert scientific opinion.

Five years of baseline monitoring have revealed much about the Bay system's natural variability, information that will help distinguish between natural and outfall-related phenomena once the outfall is on-line. Through vigilant monitoring, problems can be detected and addressed.

The outfall's impact has received extra scrutiny because of the important role that Cape Cod Bay plays in the life of the endangered North Atlantic right whale. Although no effects are expected, MWRA's intensive monitoring is designed to detect any outfall-related environmental changes that might affect the whales' feeding grounds.

While there are many sources of pollutants to the Bays system, most of the Bays region supports a healthy marine ecosystem. MWRA's secondary treatment and the better dilution provided by the new outfall will contribute to an overall improvement in the health of the Harbor and Bays.

PART I

introduction

The ongoing transformation of a once-degraded Boston Harbor to a valued regional resource is a story of environmental recovery. The Harbor's progress over the past decade is due to ambitious anti-pollution projects, especially MWRA's new Deer Island sewage treatment plant which serves 43 Boston area communities. When secondary sewage treatment is entirely on-line in 1999, sewage treatment in the greater Boston area will finally be in compliance with the federal standards prescribed in the 1972 Clean Water Act.

MWRA is now making progress toward two major milestones at the treatment plant: the three-part phase-in of secondary treatment from 1997 to 1999, and completion of the 9.5-mile effluent outfall into Massachusetts Bay. Secondary treatment will remove even more solids and toxic contaminants from primary-treated wastewater. The new outfall will reach deep water where over 400 diffuser ports will rapidly disperse treated effluent into the marine environment.

Minimizing adverse effects of wastewater discharge on the marine environment includes three fundamental strategies:

1 aggressive source reduction: preventing pollutants from entering the waste stream and, in particular, enforcing strict limits on industry's discharge of toxic contaminants to the sewer system;

2 improved treatment: removing contamination from wastewater before discharge; and

3 effective dilution: mixing wastewater quickly with large volumes of seawater to achieve very low concentrations of any remaining contaminants in the marine environment.

Despite the benefits of improved treatment, the relocation of the outfall has raised questions about the effects of discharging effluent into the waters of Massachusetts Bay. This year's State of Boston Harbor report is principally devoted to the major questions asked about the new outfall.

boston harbor quality update

Boston Harbor is an estuary that is part of the Massachusetts Bays system. Conditions in the Harbor, including treatment plant discharges at the existing, nearshore outfall locations, measurably affect the Bay as a result of strong tidal flushing. Improvements in the Harbor generally also improve Massachusetts Bay.

Better wastewater management, including fewer untreated combined sewer overflow discharges and reductions in contaminants entering the sewage system, has substantially lowered contamination in the Harbor. Figure 1 shows that MWRA's improvements to the reliability of disinfection since 1989 have greatly reduced the pathogens discharged to the Harbor. Figure 2 illustrates improvements in removal of solids (and associated toxic pollutants) from the wastewater. Studies of contaminants in mussels placed near Deer Island, for example PAHs (Figure 3), confirm that environmental levels of toxic chemicals have also decreased.

Dramatic reductions since 1989 in toxic metals contained in the effluent discharged from MWRA's treatment plants are shown in Figure 4. Figure 5 shows that industry's discharge of toxic metals into the sewers now constitutes only a small portion of the total metals loadings. A challenge for the future will be to decrease household and other non-industrial contributions to toxic metal loads in the wastewater received by MWRA treatment plants.

The benefits of better wastewater treatment and management are most apparent along the Harbor beaches, downtown along the walkways of the Inner Harbor, and near the former sludge discharge site in President Roads. Unsightly sewage-related floating matter has been practically eliminated. Figure 6 shows that, for the most part, the number of swimmers' advisories (beach postings) due to contaminated water have declined since the mid-to-late 1980s.

Bottom-dwelling animal communities, for example, the shrimp-like amphipod Ampelisca, have increased in abundance and diversity (Figure 7). The health of winter flounder has improved as shown by the decline of flounder liver disease since the mid-1980s (Figure 8a). Flounder caught in Boston Harbor are safe to eat, as illustrated in Figures 8b and 8c. PCB levels in flounder fillet are measured at about 100 parts per billion—well below the FDA limit of 2,000 parts per billion. Likewise, mercury levels in flounder fillet are measured at levels 10-fold lower than the FDA limit.

Bacteria counts in Deer Island effluent now rarely exceed permit limits

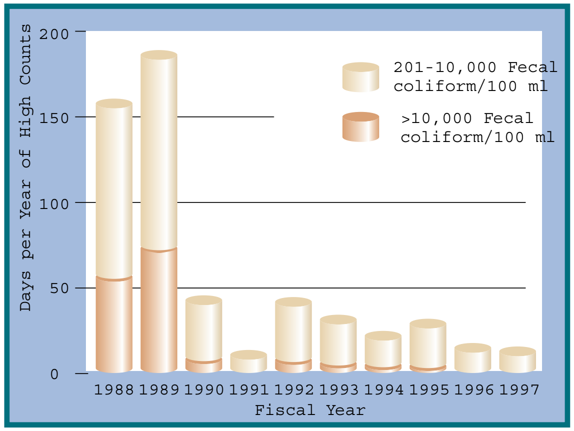


Figure 1. High bacteria counts in Deer Island effluent have decreased dramatically since 1989. Graph shows number of days per year that bacteria in effluent exceeded the permit limit of 200 colonies per 100 ml. Extremely high (greater than 10,000) bacteria counts, once common, have been eliminated. (MWRA monitoring data).

Solids discharged to Boston Harbor

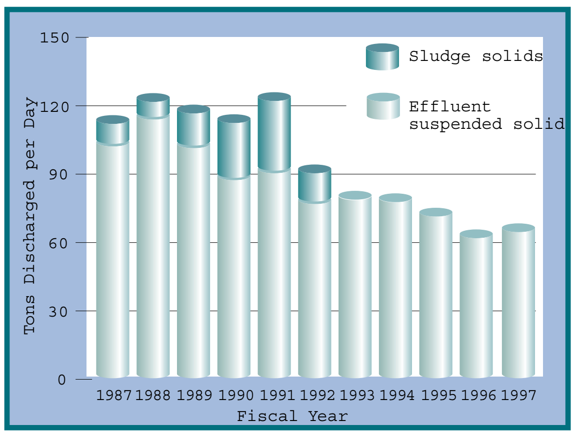


Figure 2. The amount of solids discharged to the Harbor from Deer and Nut Island treatment plants has decreased to about half that discharged in the late 1980's, after the elimination of sludge discharges and improved primary treatment. (MWRA monitoring data).

PAHs in mussels near Deer Island decreased

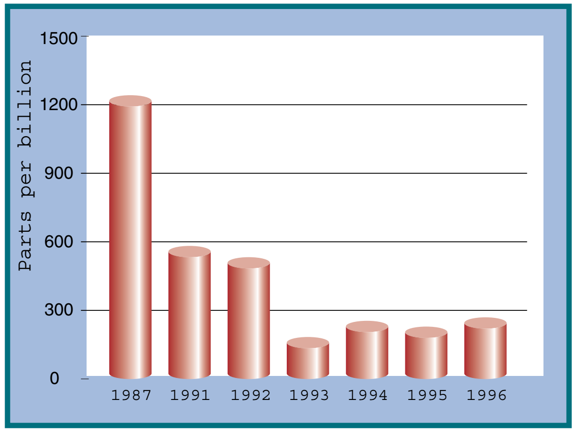


Figure 3. Low molecular weight polynuclear aromatic hydrocarbons, which are potentially cancer causing chemicals created by combustion of fossil fuels, are measured in mussels deployed and grown near Deer Island. Levels of PAHs in mussels have remained relatively low since 1993 (Mitchell et al. 1996, data for 1996 from Mitchell et al.,report in prep.).

Metals discharges to Boston Harbor from MWRA treatment plants declined

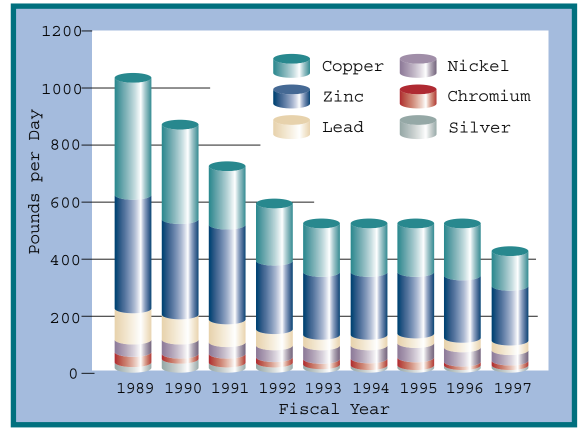


Figure 4. Metals loadings to Boston Harbor from the Deer and Nut Island treatment plants have decreased dramatically since the 1980s. Decreases in FY 1992 reflect the elimination of sludge discharges into the Harbor (MWRA monitoring data).

Industrial metals are a small part of total metals entering treatment plants (Pounds/day)

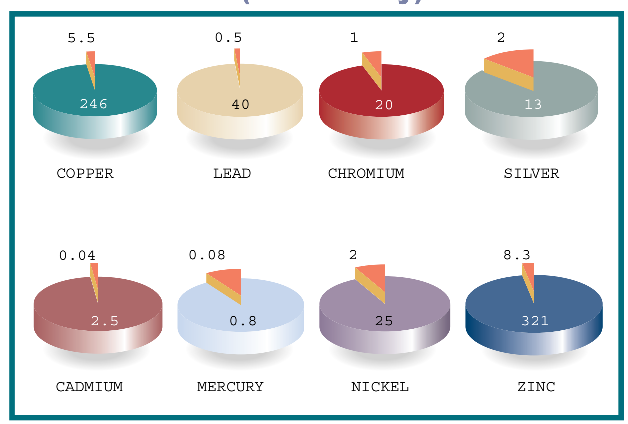


Figure 5. Industrial metals loadings in influent to the Deer and Nut Island treatment plants before treatment are only a small portion of the total. The wedges show, for various metals, the pounds per day originating from industrial sources as compared to the total loading in influent (MWRA monitoring data).

boston harbor quality update

Water at Harbor beaches is cleaner

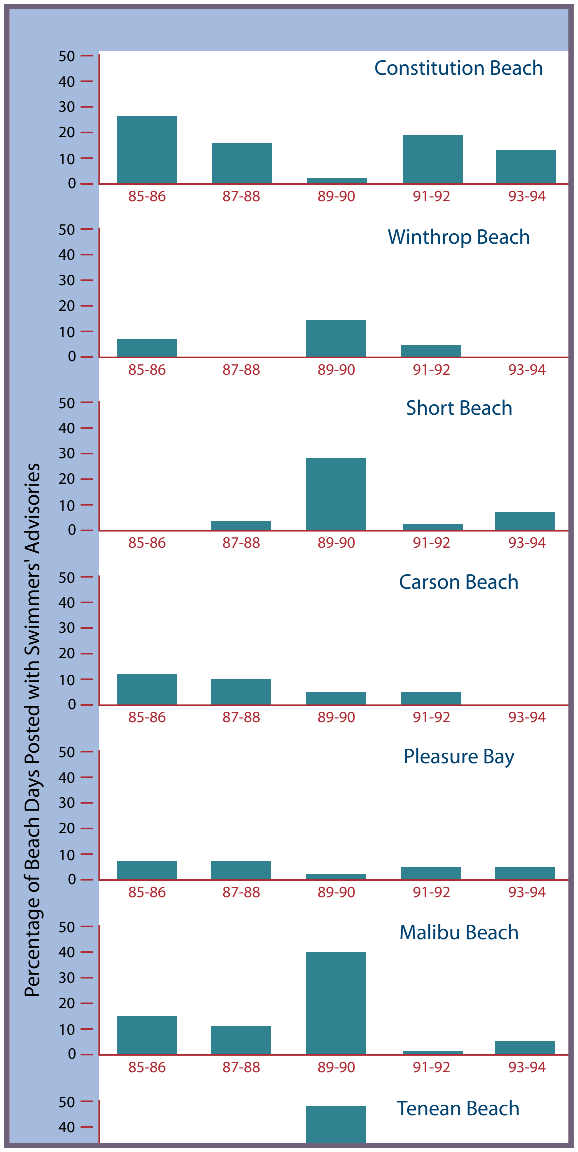
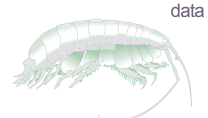


Figure 6. Swimmers' advisories have decreased since the late 1980s. Storm drain contamination and leaking local sewers remain a problem at Wollaston Beach. (Data from Metropolitan District Commission beach monitoring program.)

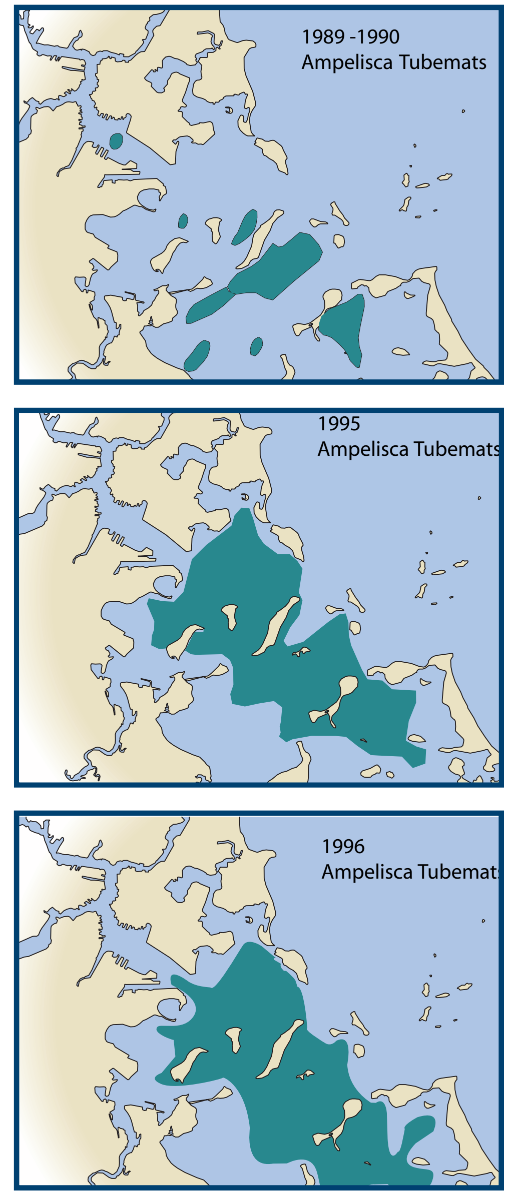
Figure 7. Ampelisca tube mats have increasingly colonized Boston Harbor since sludge discharges stopped, especially in the area of the Harbor that was most severely affected: the northern Harbor. These crustaceans increase the amount of oxygen in the sediments and are a favored flounder prey. (Data through 1995 from Hilbig et al., 1996. 1996 data in prep, Hilbig et al.)



Ampelisca abdita

This tiny crustacean is pollution-intolerant. Ampelisca lives in tubes that it builds into the sediment; these tubes form thick mats that provide shelter for other small animals (illustration after Bousfield,1973).

Healthier animal communities on the Harbor floor



Less liver disease, lower contaminant levels in winter flounder

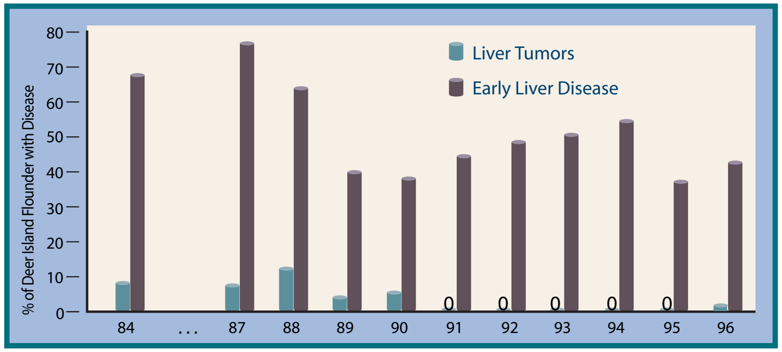


Figure 8a. The reduction in liver disease, including cancer, in winter flounder has followed the banning of DDT and PCBs, and the decreasing discharge of PAHs from wastewater. (1984 flounder liver lesion data from Murchelano and Wolke 1985; 1987 data through 1995, from Mitchell et al. 1996, 1996 from report in prep.)

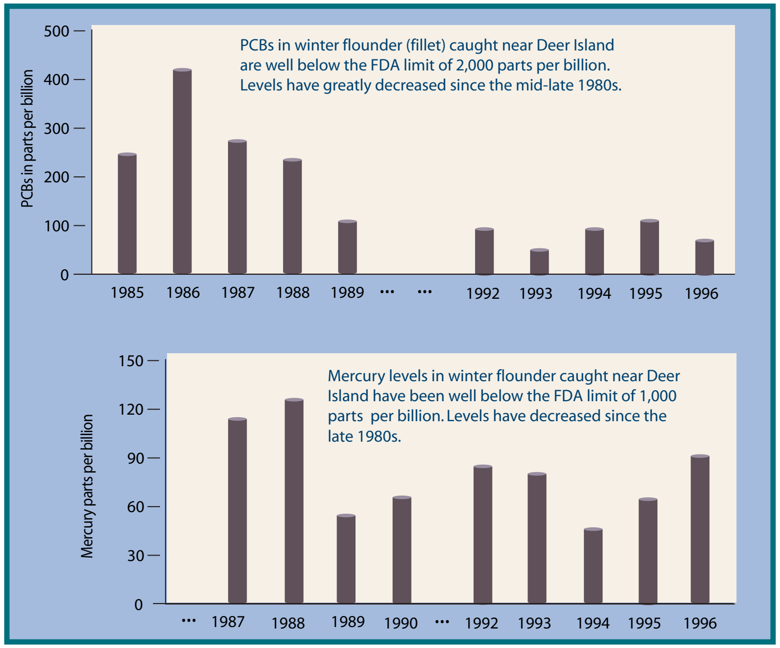


Figure 8b,c. PCBs and mercury in flounder caught off Deer Island have been well within guidelines for human consumption since the mid 1980s, and have decreased since the late 1980s. (toxic chemistry data from National Status and Trends Program 1987; 1985 - 1991 data are from Schwartz et al. 1991 and 1993; 1992 - 1994 data from Hillman and Pevens 1995, 1996 data from Mitchell et al. report in prep.)

PART II

The New Outfall: Frequently Asked Questions

Despite these documented improvements in Boston Harbor, its history of problems invites the question, “Could the Bays become degraded by treatment plant effluent from the new outfall?” Observers, experts, citizens, and marine scientists have generally concluded, "No." Three important reasons are: (1) the effluent to be discharged into the Bay will meet the secondary treatment standard and thereby be much cleaner than the primary effluent and sludge that were discharged into Boston Harbor until 1991; (2) there is much greater dilution at the discharge site in the Bay than in the shallower waters of the Harbor; and (3) there will be constant monitoring of MWRA's effluent and the water quality in the Bays.

Throughout the report, we discuss results of scientific studies which have increased our understanding of the Bays ecosystem and how pollution impacts can best be prevented. In addition, we point out areas of scientific uncertainty. Continual monitoring, linked to a flexible, evolving response plan, will help assure that MWRA is accountable for examining and re-examining areas of uncertainty. By obtaining and using new scientific information in its planning, MWRA and all others interested in the health of the Bays can work together to provide the best protection for invaluable marine resources.

Questions about the new outfall discussed in this report are:

- How was the Massachusetts Bay site chosen?
- How will the new outfall benefit water quality?
- Will the discharge be very contaminated?
- How healthy is the marine ecosystem of the Bays?
- How will the discharge affect the health of the Bays?
- What about the right whale?
- Will we know if the outfall is causing a problem?
- What will be done if a problem occurs?

how was the Massachusetts Bay site chosen?

After a four-year long process including oceanographic and engineering studies, regulatory review, and extensive public participation, the 9.5-mile site for the outfall discharge was found to be the best location for the health of nearshore and offshore waters.

The outfall siting process began in 1986 with the appointment of the Facilities Planning Citizens Advisory Committee (FPCAC), which included 27 participants representing agencies, environmental groups, community officials, and other interested individuals. The FPCAC developed criteria used in the siting process, and reviewed and commented extensively on the environmental impact reports.

At the outset of the siting process, the United States Environmental Protection Agency (EPA) ruled acceptable only those sites that (1) could provide an initial dilution of 50 parts seawater to one part effluent; (2) were far enough from shore so that particles could not be transported directly to shore on the next incoming tide; and (3) avoided sensitive and unique resources.

The existing Deer Island and Nut Island discharge locations (Figure 9a) at the mouth of Boston Harbor did not meet any of the above criteria—for example, the dilution there is only 14 parts seawater to one part effluent. Therefore, because of insufficient depth and dilution, Boston Harbor was not chosen as a site for the new outfall.

Seven potential sites, from a location in Broad Sound to a site 10 miles offshore, were evaluated in detail by MWRA and EPA independently. Sites more distant than 10 miles were eliminated from consideration because construction would not have been feasible at a reasonable cost. Siting studies were done in 1987 and 1988, including engineering studies by four different leading engineering firms as well as the Massachusetts Institute of Technology and the Georgia Institute of Technology. Oceanographic work was done by Battelle Ocean Sciences, the New England Aquarium, MIT, and the US Geological Survey. Biological, chemical, and physical oceanographic information to support the siting analysis was collected in Broad Sound, Nantasket Bight, and western Massachusetts Bay.

Along with oceanographic measurements, a computer model of pollutant transport in Massachusetts and Cape Cod Bays was used to predict likely effects of prospective outfall discharges: any discharge site had to show the ability to attain compliance with state and federal water quality criteria. Other criteria to evaluate potential sites were based on discussions with citizens and scientific advisory groups, and included protection of commercial on-the-water activities, maintenance and enhancement of aesthetics, and avoidance of areas of important habitat.

The computer model predicted that water depth and current patterns would produce the most effective dilution of effluent at three of the most distant candidate sites. These predictions were confirmed by oceanographic field studies.

After an extensive period of regulatory and public review and comment, the Final Supplemental Environmental Impact Statement confirmed that the 9.5-mile site (Figure 9b) was the optimum location for the outfall because it is in an area of strong random offshore currents, has a sufficient water depth, and would be feasible to construct. In 1988, the EPA published its Record of Decision on the outfall site, which also required MWRA to conduct monitoring of the effects of the ocean discharge on the Massachusetts Bay environment.

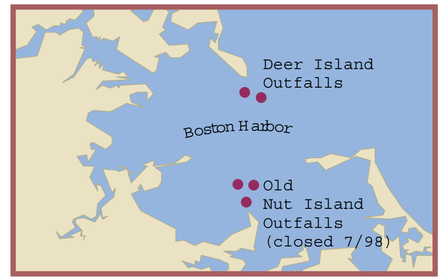


Figure 9a. Present outfall locations in Boston Harbor

Figure 9b. Future outfall location in Massachusetts Bay

Schematic views of outfall and diffusers

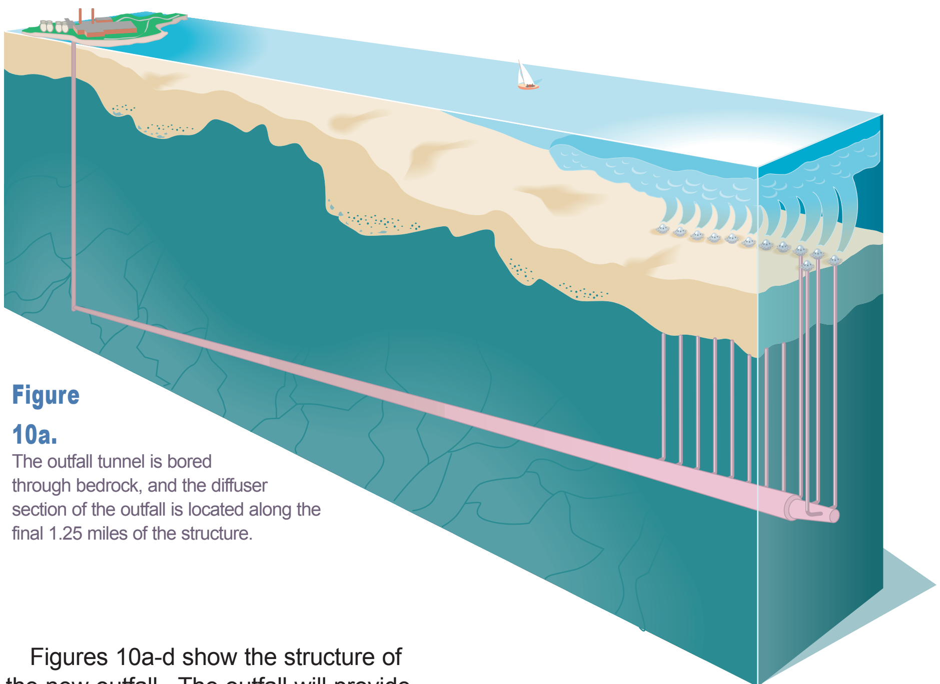


Figure 10a. The outfall tunnel is bored through bedrock, and the diffuser section of the outfall is located along the final 1.25 miles of the structure.

Riser

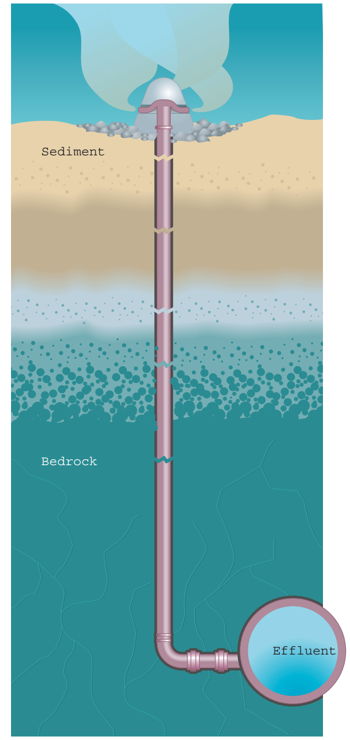


Figure 10b. The 55 risers carry effluent from the deep rock outfall tunnel up to the diffuser heads at the seafloor.

Diffuser head

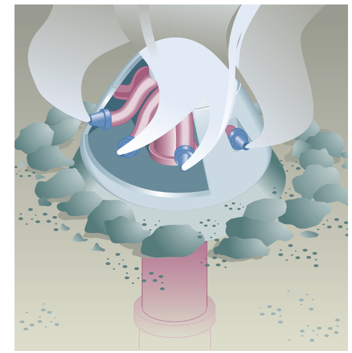


Figure 10c. The diffuser heads each disperse the effluent through eight ports.

Figures 10a-d show the structure of the new outfall. The outfall will provide a larger measure of environmental protection than the existing outfalls. Currently, wastewater is discharged within Boston Harbor from two short (less than a mile long) outfalls at Deer Island and three short outfalls at Nut Island. Because all wastewater treatment will be consolidated on Deer island, it was necessary to build a larger outfall and to locate the discharge in deeper water. Since the continental shelf off the East Coast has a very gentle slope, the outfall had to be relatively long.

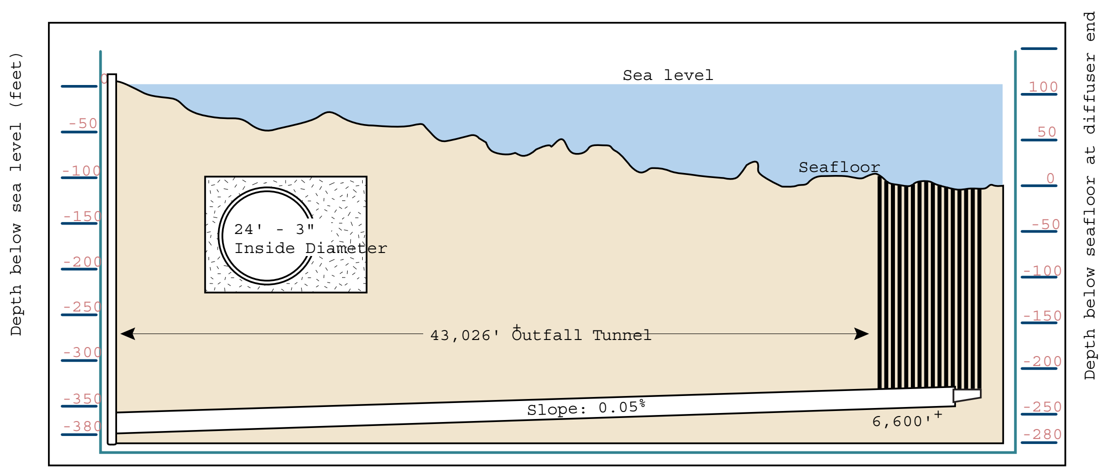


Figure 10d. Cross-section diagram of outfall pipe

NOTE: Diagrams not drawn to scale

how will the new **outfall** benefit water quality?

Rapid mixing with a large volume of seawater will quickly dilute the constituents of the effluent to background levels.

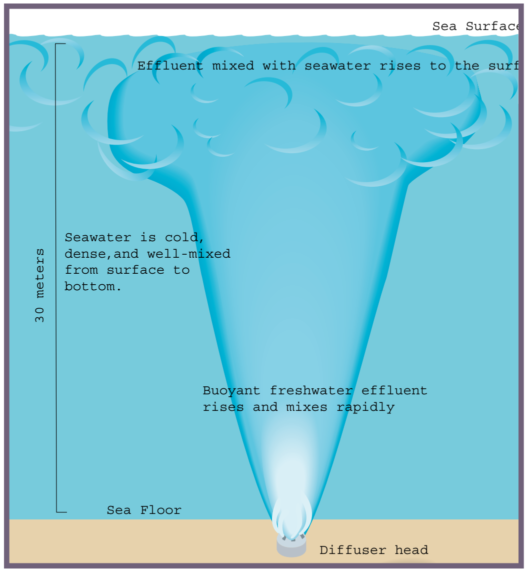
The new outfall is designed to maximize mixing and dilution of effluent. At the present time, treated wastewater effluents from the Deer Island and Nut Island treatment plants are discharged near shore within Boston Harbor. Strong tidal currents eventually carry the effluent into Massachusetts Bay, but each incoming tide brings some of the effluent back into the Harbor. Because the Harbor is shallow (on average only 30 feet deep), the effluent plumes receive little dilution and reach the surface, where they are visible. With onshore winds, the effluent can reach the shoreline. By contrast, the new offshore location is in an area where circulation is greater and more variable, providing better mixing.

The new outfall (illustrated on the previous page in Figure 10a-d) will carry effluent 9.5 miles (15 kilometers) off shore to a location where Massachusetts Bay is 100 feet (30 meters) deep. The effluent will be discharged through 55 diffuser heads each with eight outlets (ports), creating a diffuser that altogether will be 1.25 miles (2000 meters) long. The long diffuser area and multiple ports will effectively disperse the effluent to maximize dilution. The initial dilution of the effluent at the new location will be about 150 to 1, compared to the present dilution near Deer Island of 14 to 1.

Because effluent is mostly fresh water, it is lighter than seawater. Buoyancy causes the effluent to rise toward the ocean surface, rapidly mixing with the surrounding water. This vertical mixing causes the density of the effluent plume to increase, and the mixed effluent becomes about as dense as seawater. This mixing happens within a few minutes, and within a distance of tens of meters from the diffuser.

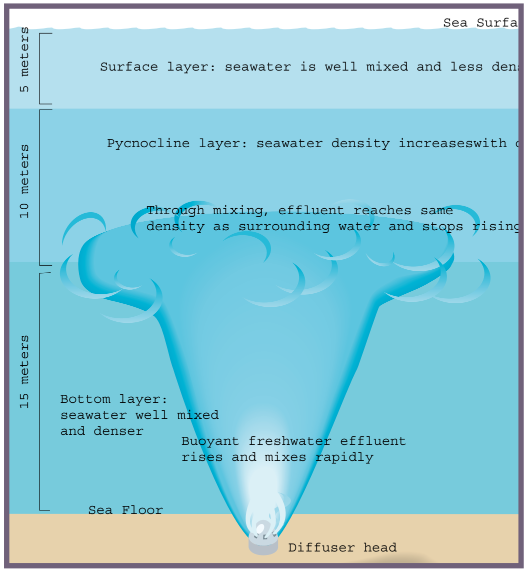
In the winter, the effluent plume, after mixing, will reach the surface. In the summer, effluent will be trapped below the surface because it quickly takes on the same (denser) characteristics as the bottom water (Figures 11a and 11b).

After initial mixing, whether the plume surfaces or not, it will be mixed horizontally by currents at the new outfall site. These currents vary in direction, helping to further disperse the effluent. The outfall is distant enough from shore so that even shoreward currents will not carry the effluent close to beaches or shellfish beds.



Diluted effluent rises to surface in winter

Figure 11a. What ultimately happens to the effluent plume depends upon seasonal effects on the density of ocean water in Massachusetts Bay. Seawater density is controlled by temperature and salinity. Warmer temperatures and lower salinity make seawater lighter, while cooler temperatures and higher salinity make seawater heavier. In the winter, the waters of the Bay are about the same density top to bottom and are well mixed. When the seawater has a relatively uniform density top to bottom, the effluent plume will rise to the surface as it mixes.

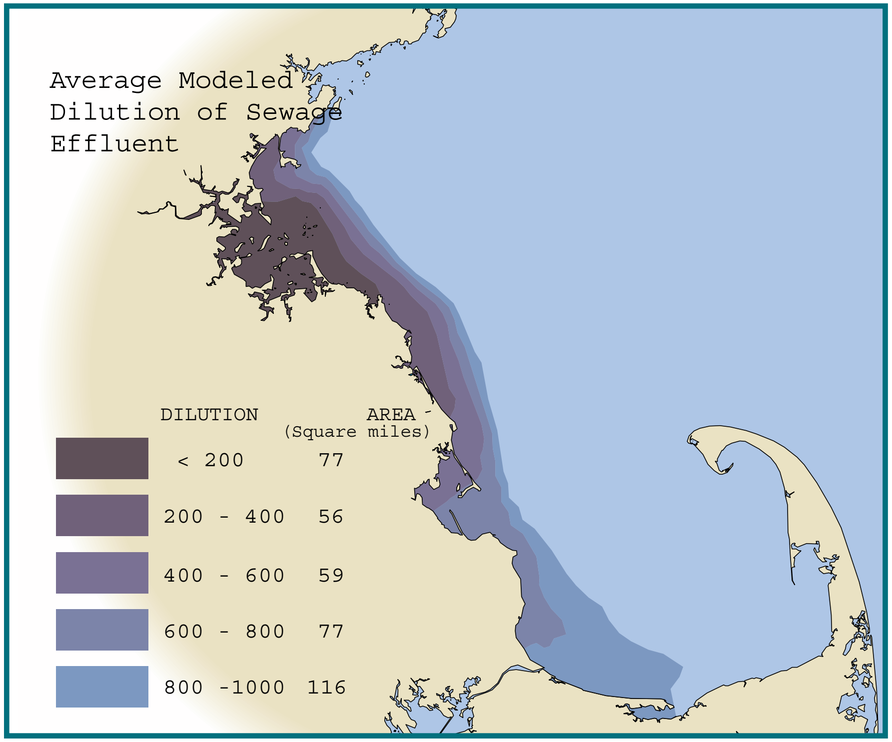


Diluted effluent trapped beneath surface in summer

Figure 11b. In the summer, the surface water is warmed and becomes increasingly lighter, setting up a layering effect. The level where the density change is most abrupt is called the pycnocline.

Effluent becomes increasingly dense as it mixes with seawater, and will rise up only to the depth where it is no longer lighter than the surrounding water—at the pycnocline. Thus the effluent plume will be trapped below the pycnocline. At the outfall site, this is about 50 feet (15 meters) below the surface.

Dilution contours, Harbor outfall location



Dilution contours, new Bay outfall location

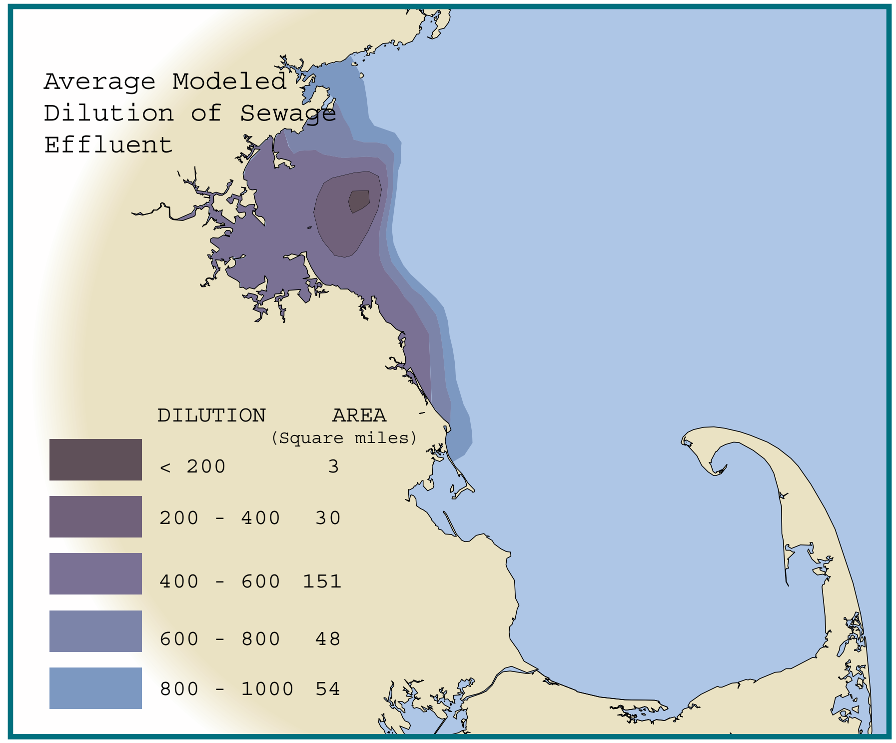


Figure 12a.

Figure 12b.

Moving the outfall offshore greatly reduces the area most affected by effluent. These two figures show the results of computer model predictions of effluent dilution during winter conditions at the present and future outfall locations. At present (12a), 77 square miles all of Boston Harbor and the South Shore to Cohasset Harbor, now have a dilution factor of less than 200-fold. At the future outfall location (12b), only 3 square miles, immediately above the diffusers will have a dilution of less than 200-fold. The dilution model assumes concentrations in effluent are the same for both Harbor and Bay outfalls: this is true for nutrients. The illustration does not take into account the effect of improved treatment in lowering the concentrations of contaminants in effluent. Model predictions based on winds and currents, winter 1990-1991. (Model created by R. Signell and H. L. Jenter of the U. S. Geological Survey and A. Blumberg of HydroQual, Inc.)

will the discharge be very contaminated?

The secondary effluent discharge will meet stringent state and federal standards to ensure that it will not pose a threat to either human health or the health of the environment.

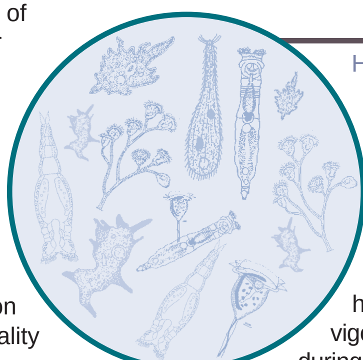
Treatment is a critical step in minimizing adverse effects of sewage discharges. The centerpiece of the Boston Harbor Project is the state-of-the-art primary and secondary treatment plant nearing completion on Deer Island. This massive, multibillion dollar project was built to comply with strict environmental regulations in order to protect human health, the health of the Harbor, and the ecology of the Bays system.

The secondary-treated wastewater to be discharged into Massachusetts Bay is very different from the inadequately treated primary effluent and sludge that were discharged into Boston Harbor for decades. As shown in Table 1, while primary treatment removes 50 to 60 percent of the total suspended solids in wastewater, secondary treatment increases the removal of solids to 85 percent or more.

Table 2 shows the levels of toxic pollutants in primary and secondary treated effluent, and the predicted concentrations in the area around the new outfall after dilution compared to water quality standards.

After secondary treatment (Figure 13), the concentration of toxic pollutants in the effluent is very low–measured in parts per billion or parts per trillion. Levels of many of these pollutants in the secondary effluent are already low enough to meet regulatory standards for receiving water. In fact, after dilution at the new outfall, most contaminants are 10 to 1000 times lower than water quality standards allow.

Nutrients are the only components of sewage entering the treatment plant that are not significantly reduced by secondary treatment. Therefore, MWRA carefully monitors the potential effect of nutrient issues on the Bays system, and nutrients have received particularly intensive scrutiny by regulatory agencies.



Helpful Microbes

Tiny microbes including bacteria, ciliates, and rotifers, as seen here through a microscope at about 500-fold magnification, are the key to secondary treatment. These helpful micro-organisms feed vigorously on the wastewater during treatment, breaking down and removing contaminants.

Tables 1 and 2. Secondary treatment at the Deer Island treatment plant, combined with dilution at the new outfall, will ensure that levels of toxic contaminants in the receiving waters are well within water quality standards. The table shows selected toxic constituents of wastewater that are regulated by EPA. For most constituents, the final concentration in the receiving water will be far lower than EPA criteria (for details see end note, p.26).

Table 1. Comparison of primary and secondary removal of pollutants

Pollutant	Primary removal	Secondary removal
Total suspended solids (TSS)	50-60%	85+%
Biochemical oxygen demand (BOD)	25-40%	85+%
Toxic contaminants	0-50%	50-90%
Nutrients	5%	10-15%
Pathogens	0-50%*	80-99+%*

*These numbers indicate removal before disinfection. Disinfection further reduces pathogens to safe levels.

Table 2. Toxic contaminants reduced by treatment and dilution

	Parts per billion (micrograms/liter)			Parts per trillion (nanograms/liter)		
	Copper	Mercury	Lead	DDTs	TOTAL PAH	TOTAL PCBs[7]
Primary effluent[1]	103	0.3	29.2	31	54,932	57
Secondary effluent[1,2]	21.6	0.1	3.3	3	3,250	12
Concentration after dilution[3]	0.27	0.0013	0.04	0.008	8.93	0.033
Receiving water quality standards[4,5,6]	2.9	0.025	8.5	2.02	42,000	0.045

Secondary wastewater treatment schematic

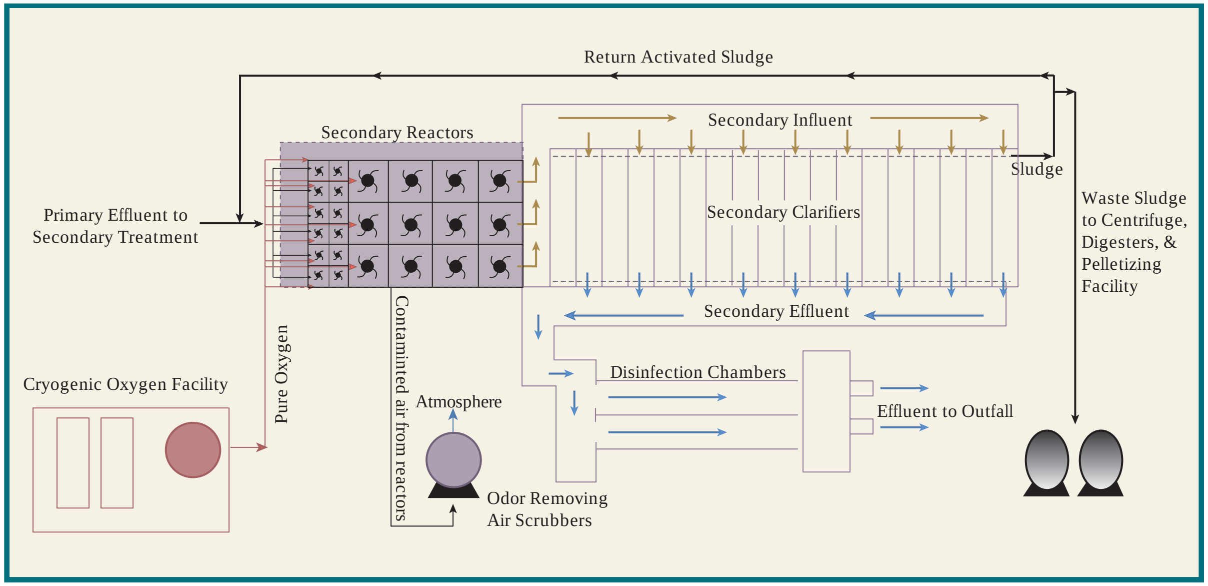
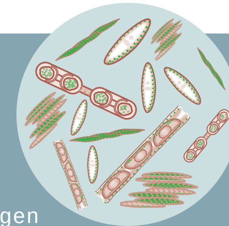


Figure 13. Secondary wastewater treatment follows primary treatment at Deer Island. Primary treatment removes solids by simple physical processes: in settling tanks (clarifiers), heavy solids (sludge) sink to the bottom and lighter solids (scum) float to the surface. These solids are removed; the remaining liquid is primary effluent, which is then undergoes secondary treatment. Within the secondary reactors, the primary effluent is mixed with pure oxygen. The oxygen and mixing stimulate the rapid growth of beneficial microbes (bacteria, protozoans, and other tiny organisms) in the wastewater, which consume more solids and break down contaminants. After about two hours, more sludge and scum are separated out in the secondary clarifiers. A portion of the secondary sludge, rich in beneficial microbes (activated), is returned to the reactors, where it is used to treat more primary effluent. Waste sludge and scum are sent to Deer Island's egg-shaped digesters, to be further broken down by microbes and eventually converted to fertilizer pellets. The clarified secondary effluent is disinfected and discharged to the ocean through Deer Island's outfalls (Figure after D. Duest, MWRA)

nutrients



Nutrients, especially nitrogen and phosphorous, are familiar as the active ingredients in lawn and agricultural fertilizers. Nutrients are also essential for the growth of plants (seagrasses, seaweed, and microscopic floating algae called phytoplankton) in the ocean. In the marine environment, excessive amounts of nutrients, especially nitrogen, stimulate the growth of phytoplankton and seaweeds and can cause nuisance algal blooms like brown or red tides (eutrophication). The eventual decaying of these plants can deplete dissolved oxygen levels in the water and sediment.

Nutrients from the present outfalls exit the Harbor to the Bay in effluent plumes at the surface of the water, where sunlight and nutrients induce abundant phytoplankton growth. One major benefit of the new outfall is that diluted effluent will be discharged at the bottom of Massachusetts Bay, 110 feet below the water's surface. During the summer when there is the most light, the discharge will be trapped by stratification about 50 feet below the surface. Most phytoplankton growth is at the surface, where there is a lot of light. Nutrients from the discharge at the sea floor will generally not reach the surface during the summer, when there is the most potential for excess growth. Therefore, the outfall is not likely to contribute to eutrophication in the Bay.

the seasonal cycle of
the Bays

Fundamental to all the processes in the Bays is the annual seasonal cycle. In order to be able to recognize the effect of effluent discharge on the environment, it is important to first understand the changes that happen naturally. Over the past five years, MWRA's baseline monitoring program and extensive studies by the US Geological Survey and the Massachusetts Bays Program have provided a good understanding of the Bays' seasonal cycle.

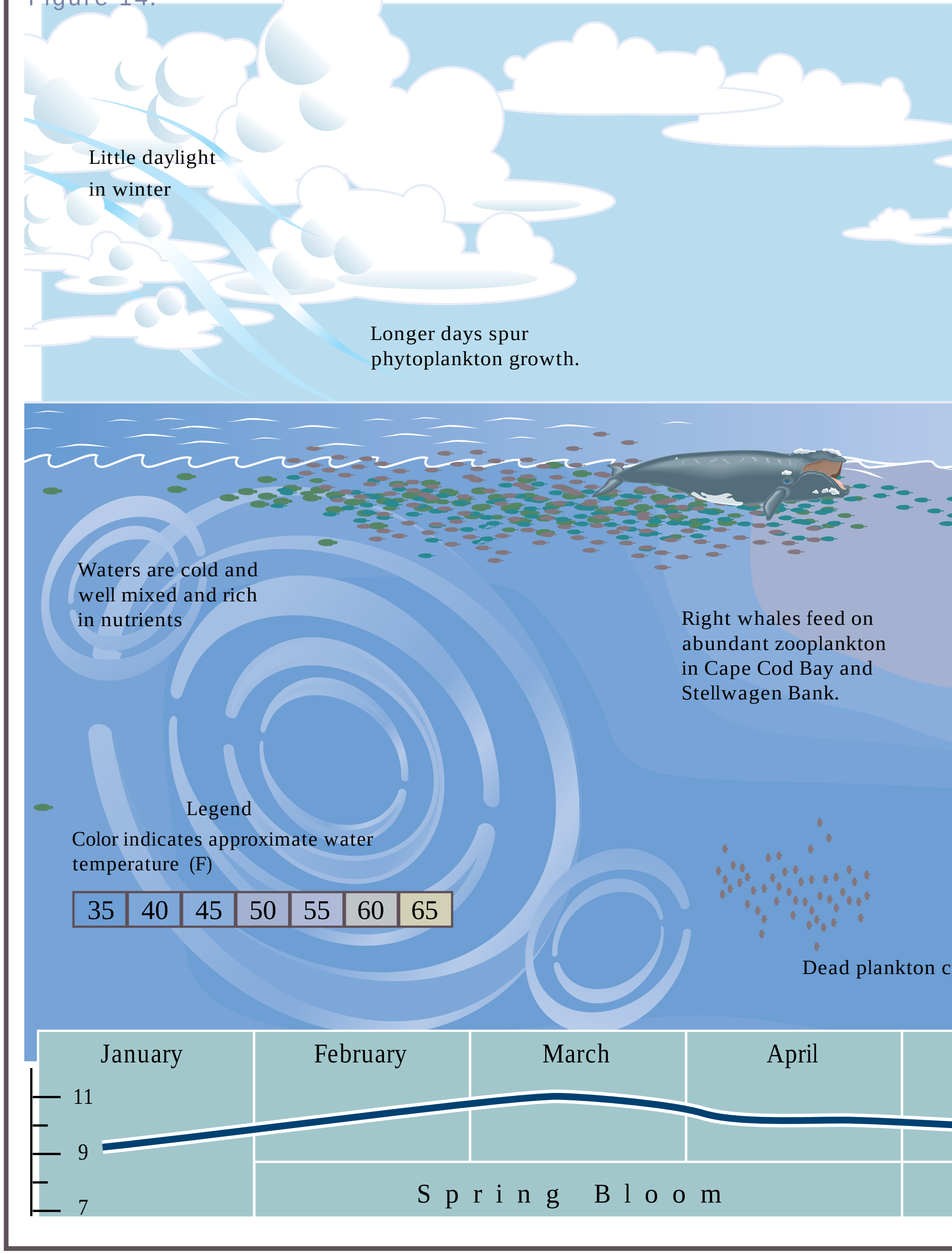
In November through April, winds and cooling mix the waters of the Bays. Nutrients are plentiful, but in December and January the penetration of light into the water is rarely enough to support the growth of phytoplankton (microscopic floating algae at the base of the food web). As the days lengthen in early spring, increases in light and in nutrient levels trigger the rapid growth of phytoplankton.

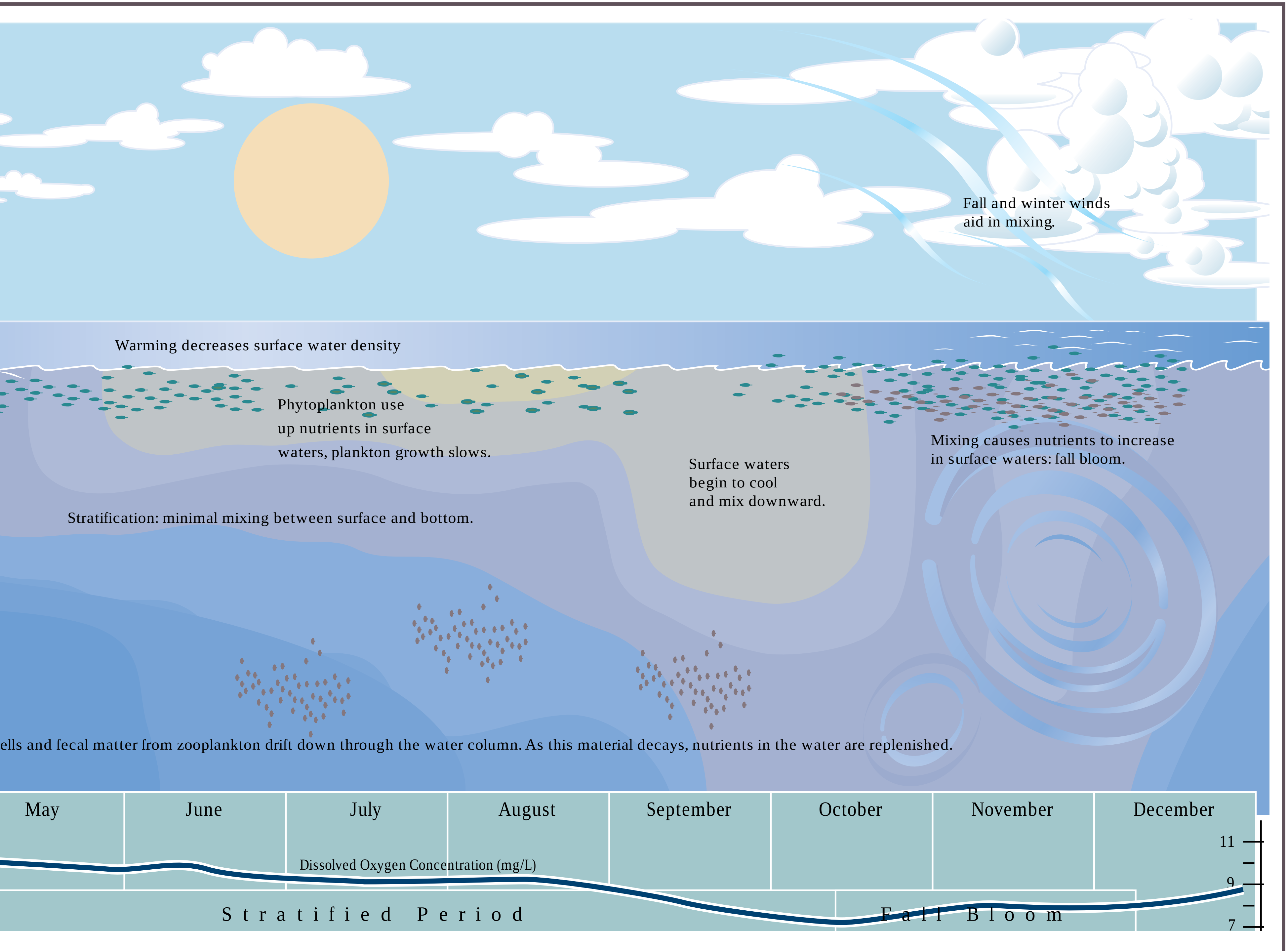
The spring bloom of phytoplankton starts in the shallower waters of Cape Cod Bay, providing food for zooplankton (tiny animals, including juvenile forms of animals like fish and jellyfish, and abundant tiny crustaceans called copepods) carried into the Bays by strong currents from the Gulf of Maine. In turn, the fast-multiplying zooplankton provide food for many marine species including the northern right whale. A single right whale feeding in Cape Cod Bay can consume about one ton of these plankton daily.

Later in the spring, the surface waters of the Bays warm and stratify. The phytoplankton grow abundantly at the surface, where they receive ample light. Because vertical mixing is prevented by stratification, the nutrients at the surface do not get replenished from the bottom waters. The phytoplankton use up the nutrients in the surface water and die, eventually sinking to the bottom and providing food to the bottom-dwelling animal communities which show a growth spurt in mid-summer.

In the water column, bacteria use up dissolved oxygen through their respiration as they consume the dead plankton; the lowest dissolved oxygen levels in the Bays occur from August to October. In the fall, cooling of surface waters and strong winds allow mixing throughout the water column, bringing fresh nutrients to the surface, stimulating a new growth of phytoplankton—the fall bloom. By mid-winter, light levels have declined, ending the fall bloom. The plankton die and decay, releasing nutrients. Nutrient levels increase throughout the water column, preparing the Bays for the next spring bloom.

Figure 14.




Fall and winter winds
aid in mixing.
Warming decreases surface water density
Phytoplankton use
up nutrients in surface
waters, plankton growth slows.
Surface waters
begin to cool
and mix downward.
Mixing causes nutrients to increase
in surface waters: fall bloom.
Stratification: minimal mixing between surface and bottom.
ells and fecal matter from zooplankton drift down through the water column. As this material decays, nutrients in the water are replenished.
May
June
July
August
September
October
November
December
11
9
7
Dissolved Oxygen Concentration (mg/L)
Stratified Period
Fall Bloom

how healthy is the marine ecosystem of the Bays?

The Bays system supports a rich and diverse ecosystem of normal plant and animal communities, but signs of stress are evident. Stress results from multiple causes, including overfishing and contamination. The highest levels of contamination are nearshore—sources include rivers, the atmosphere, sewer overflows, treatment plants, and past use of disposal areas.

An overview of the Bays system

At the southern end of the Gulf of Maine, the Massachusetts/Cape Cod Bay system extends from the New Hampshire border to the tip of Cape Cod, encompassing about 1650 square miles.

A strong southward coastal current and a large flow of water from the Merrimack River produce an average flow south through the Bays, exiting to the open Atlantic (Figure 15). Strong tide and wind effects produce circulation patterns that are highly variable from day to day.

Rich resources and multiple stressors

The beaches, wetlands, rocky shores, and deep offshore waters of the Bays provide important habitat for many plant and animal communities including commercially important species of fish and shellfish, and rare or endangered animals and birds.

There are a variety of environmental stressors in the Bays system: historical whale hunting and ongoing commercial fishing; disappearance of habitat such as salt marshes; dams that hinder fish migration and spawning; commercial shipping and boating activities; and pollution.

Many sources of pollution, past and present

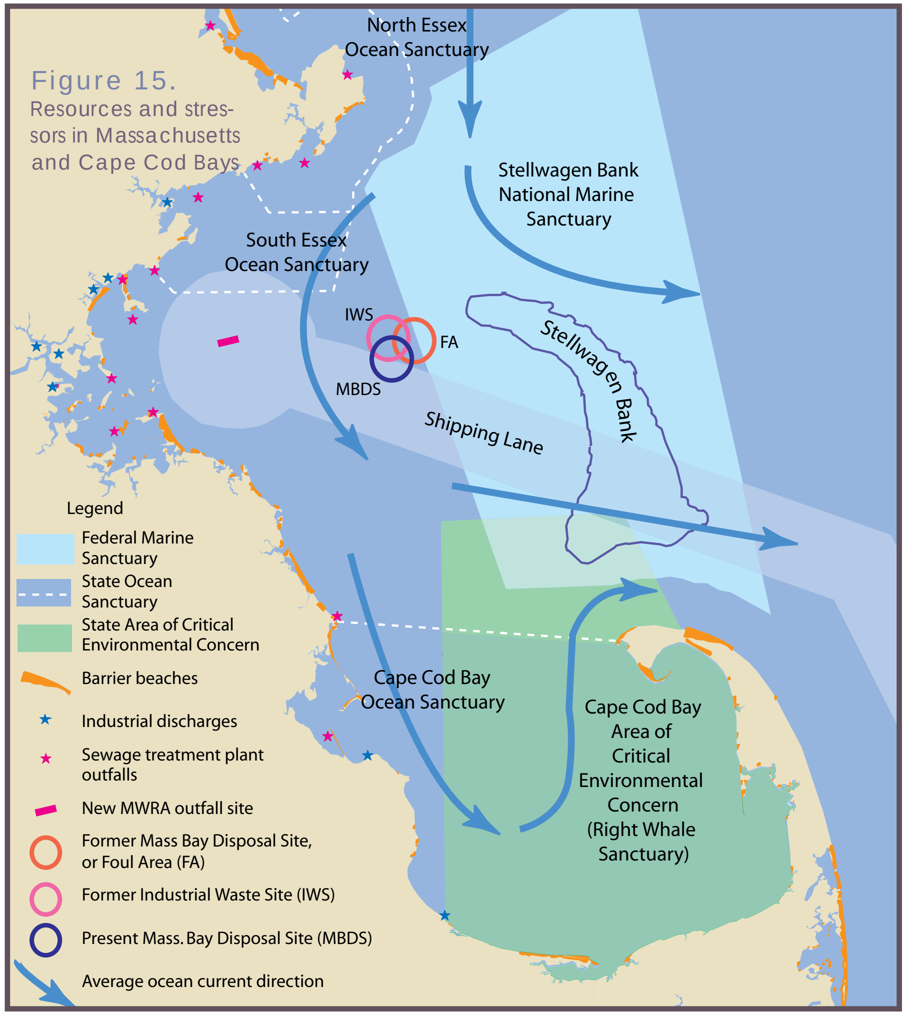
Bacterial contamination of beaches and shellfish beds is a concern along most of the Bays' coastline. The chief sources of this contamination are sewer pipe overflows, stormwater runoff, and leaks from septic systems. Treatment plants are a relatively minor source of contamination.

Levels of toxic contaminants in the water are highest near the coast and, except for a few pollutants like polychlorinated biphenyls (PCBs), generally meet water quality standards throughout the Bays. However, the sediments near urban shorelines like Boston Harbor, Salem Sound, and Broad Sound have significant levels of contamination.

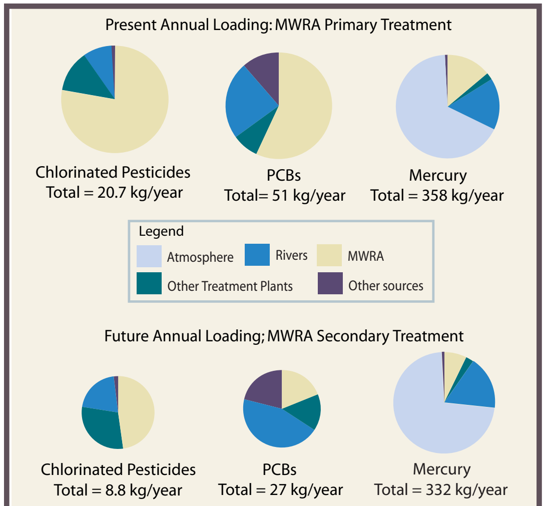
In sediments, as in the water column, contaminant levels decrease with distance from shore except at former waste disposal sites in Massachusetts Bay. Contamination in offshore sediments is not high enough to cause detrimental ecological effects, according to National Oceanic and Atmospheric Administration standards. In fact, monitoring has shown that the bottom-dwelling animal communities are typical of the Gulf of Maine ecosystem.

Toxic organic compounds and metals have many sources. Three examples illustrating this are chlorinated pesticides (especially DDT and its breakdown products), PCBs, and mercury. DDT was banned in 1972 and PCBs were phased

Figure 15.
Resources and stressors in Massachusetts and Cape Cod Bays



Multiple sources of toxic contaminants to the Bays



Estimated existing inventories in Massachusetts Bay

	Chlorinated Pesticides (kg)	PCBs (kg)	Mercury (kg)
Water	39	47	300
Sediment	430-1520	510-1800	40,000-80,000

Figure 16. Annual inputs (loadings) of chlorinated pesticides and PCBs to Massachusetts Bay are small compared to existing accumulations from past sources. The source of mercury is primarily atmospheric. Secondary treatment reduces MWRA's contributions. The pie chart areas reflect the relative amounts of present vs. future loads. (Annual loading data from Mitchell et al. 1997, Massachusetts Bay estimates of existing inventory from data by Shea, 1993, 1996 in prep.; Bothner et al. 1993. Estimates based on model in Shea 1995).

Distribution of silver in surface sediments

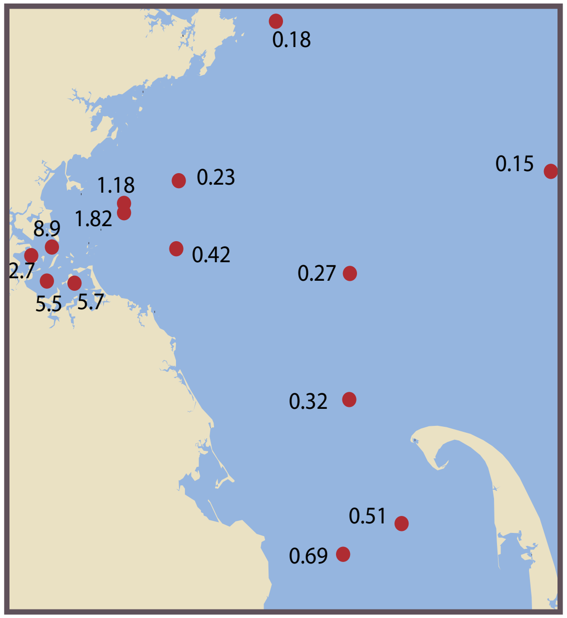


Figure 17. Sediment silver concentrations (measured as parts per million of the mud fraction of sediment) decrease with distance from the coast. Cape Cod Bay has somewhat higher silver concentrations than more northern locations; this may reflect sediment resuspension and transport by currents to Cape Cod Bay (data from Bothner et al. 1993).

Winter flounder liver disease rates

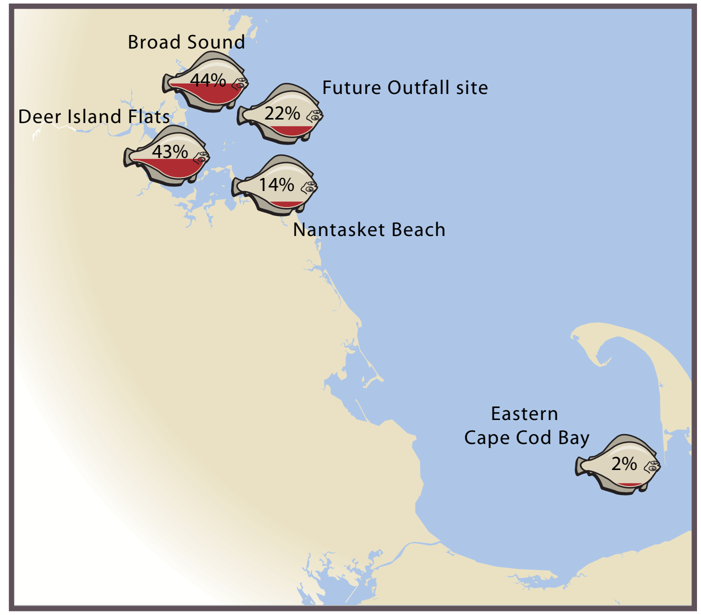


Figure 18. Flounder liver disease is high in Boston Harbor and Broad Sound, and low in Cape Cod Bay. The percentage of flounder showing early liver disease decreases with distance from Boston Harbor—flounder at the new outfall site may be affected by toxic pollutants from the coastal sources or from old waste disposal sites. Improved treatment, continued source reduction, and improved dilution and dispersion at the new location will minimize flounders' exposure to the contaminants (PAHs,pesticides, and PCBs) thought to cause this disease (data from Mitchell et al. 1996).

out of production beginning in 1971. These contaminants can bioaccumulate in marine mammals and fish.

Figure 16 shows that the present inputs to Massachusetts Bay from all sources combined of PCBs and chlorinated pesticides are a small fraction of the amounts that have accumulated from past inputs, when the chemicals were being used in large amounts. Secondary treatment will greatly reduce MWRA's contribution of PCBs to Massachusetts Bay. The amounts of PCBs and chlorinated pesticides entering the Bays will continue to decrease in the future, and are slowly degrading in the environment.

Historical contamination signals

MWRA's monitoring program has revealed that past sewage discharges into Boston Harbor have contributed contaminants to broad areas of Cape Cod Bay as a result of tidal flushing. Past inputs of sewage and sludge in Boston Harbor contained silver, which was historically discharged in large amounts by the photographic industry. A gradient of silver extends from the Harbor to Cape Cod Bay (Figure 17), with higher concentrations in parts of Cape Cod Bay than in other offshore waters. Because the Harbor apparently was the source, these silver concentrations correspond quite well to the modeled dilution of the effluent dispersed into Massachusetts Bay from the existing Harbor outfalls (Figure 12a).

Despite the pattern of silver (and other sewage tracers not shown), the contaminants are not causing significant impacts on the health of marine life in Cape Cod Bay. Bottom-dwelling animal communities in the Bay are typical for the Gulf of Maine as a whole. Data gathered on winter flounder (Figure 18) show that contaminant-related liver disease is at very low levels in Cape Cod Bay compared to the area close to Boston Harbor.

Future decreases in contamination

As MWRA's contribution of toxic pollutants continues to decrease due to source reduction and treatment improvements, the existing gradient of pollutants in the Bay should gradually lessen. In addition, moving the effluent discharge to the new outfall site (see page 9) will reduce the concentration of dissolved contaminants reaching Cape Cod Bay from Boston.

how will the discharge affect the health of the Bays?

Using computer modeling, MWRA has predicted that increased pollutant removals by secondary treatment, combined with improved dilution of effluent provided by the new outfall, will improve the health of Boston Harbor and Massachusetts and Cape Cod Bays.

Computer model

Scientists assisting MWRA have developed a detailed computer model to predict impacts on Boston Harbor and the Massachusetts and Cape Cod Bays from discharges of secondary-treated effluent at the new 9.5-mile outfall location. This forecast is contrasted with modeled impacts from the discharges of primary effluent at the outfall location near Deer Island within Boston Harbor. The model is a time-variable, three-dimensional, hydrodynamic and water quality model called the Bays Eutrophication Model. It was developed by the U. S. Geological Survey and Hydroqual, Inc., the company that also developed water quality models for the Chesapeake Bay and Long Island Sound.

Verifying the model

In the course of developing and testing the model, modeling results were compared to actual environmental observations in the Massachusetts Bay system made in 1989-1992. The model results agreed quite well with observed data, and reproduced the major processes affecting the Bays system: the annual cycle of surface water heating and stratification; the spring freshet associated with the Merrimack River and other northern rivers discharging to the Gulf of Maine; the annual cycle of phytoplankton growth; the annual cycle of nutrients in the surface and bottom waters; and the effect of stratification on the minimum dissolved oxygen concentrations observed in October.

After the usefulness of the computer model was established by these tests, scientists used the model to predict the likely impacts of discharging secondary effluent through the new outfall into Massachusetts Bay. Figures 19-21 show the model predictions for three major components of concern: surface chlorophyll *a*, bottom dissolved oxygen, and particulate organic carbon flux.

Chlorophyll a

Because primary and secondary treatment do little to remove nutrients from sewage effluent, one of the major questions regarding relocation of the effluent discharge to the 9.5-mile site offshore is what effect nutrients would have on phytoplankton growth: would adding nutrients offshore promote blooms of phytoplankton? One important measure of the status of eutrophication in the Bays system is the concentration of chlorophyll *a*, a major algal pigment that is a good measure of phytoplankton abundance.

Figures 19a and 19b show concentrations of chlorophyll *a* at the surface for Boston Harbor and Massachusetts Bay predicted by the Bays Eutrophication Model. The figures show a five-day average in August, when the Bays are stratified. There is a large decrease in surface chlorophyll *a* levels in Boston Harbor and no increase in Massachusetts Bay after the 9.5-mile outfall and secondary treatment are on-line. This is largely because of improved dilution, and because at the new deeper location, discharged nutrients will mostly be below the summer pycnocline in the Bay. Nutrients will not be available to phytoplankton at the surface, where there is enough light to support vigorous growth.

Dissolved oxygen in bottom water

Animals and plants living in the marine environment need adequate dissolved oxygen (DO) in the water for respiration. If DO levels fall too low, fish and other animals may die. Bottom waters, because they are not in contact with the atmosphere, are most likely to experience low DO. Factors that decrease the levels of DO in the water are: high water temperature—oxygen is less soluble at warmer temperatures, and respiration rates of all life increase; too much oxygen-demanding organic matter in the sediment; and stratification of the water

Figure 19. Modeled surface chlorophyll a, August

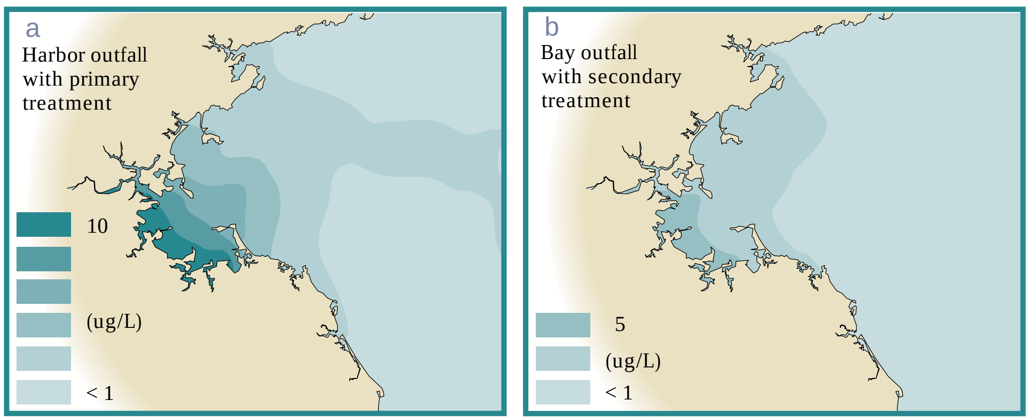
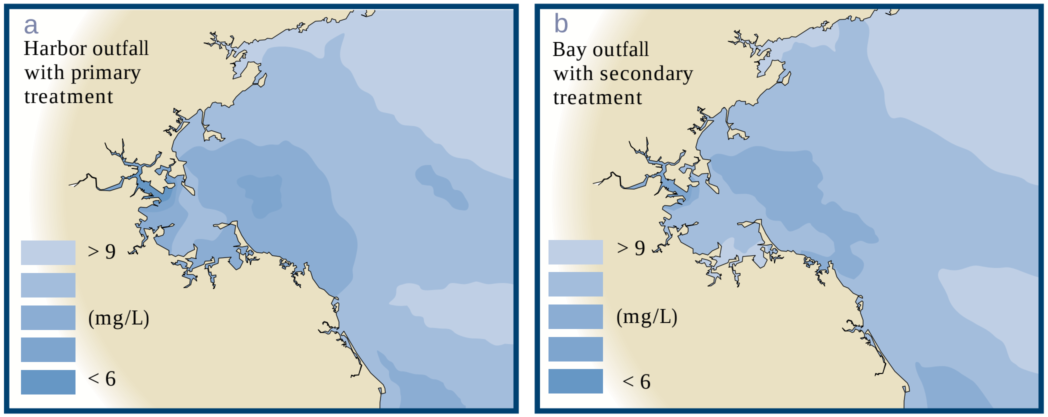


Figure 20. Modeled dissolved oxygen in bottom water, October



column, which prevents more highly oxygenated surface waters from reaching the bottom. Concerns about the outfall related to dissolved oxygen are whether inputs of materials that use up oxygen (measured as bio-chemical oxygen demand, or BOD) and nutrients might cause bottom DO to violate the water quality standard. Monitoring has shown that bottom water DO has occasionally fallen below the standard at the new outfall site. The state standard for DO is 6 mg/l in Massachusetts Bay, and 5 mg/l in most of Boston Harbor.

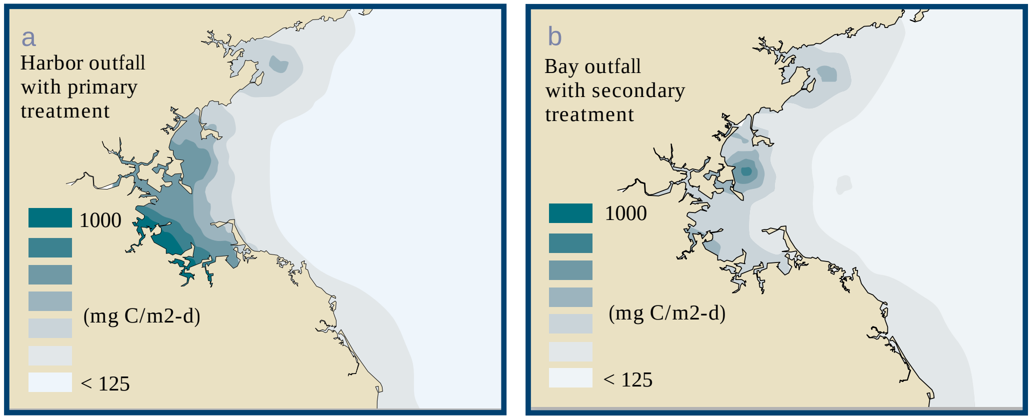
Bottom DO levels are generally lowest in October because the water column has been stratified since April (see page 12). The model shows that with the Harbor discharge and primary treatment (Figure 20a), the lowest DO is in the Inner Harbor, and DO is also depressed near the future outfall area. This offshore DO depression is partly natural, and partly reflects the present export of nutrients and BOD from Boston Harbor. Figure 20b shows that secondary treatment and the long outfall result in improved bottom DO, both in the Harbor and near the outfall. Most of this improvement is explained by increased removal of BOD through secondary treatment.

Particulate organic carbon flux

The animal community living on the ocean floor relies for food on organic matter deposited to the sediment through the overlying water column—the particulate organic carbon (POC) flux. However, deposition of too much organic matter in the sediments can deplete sediment DO. Excess food as POC will destabilize the normal community structure, leading to decreased diversity, as has happened in Boston Harbor. POC can be contributed directly by an effluent discharge, or indirectly by increased phytoplankton and zooplankton abundance, some of which ultimately deposit in the sediments. A concern with the 9.5-mile outfall location has been the potential effect of adding POC to the sediments near the new outfall.

The model shows a high deposition rate in Boston Harbor with the present outfall and primary treatment (Figure 21a). With the new outfall and secondary treatment, POC flux is dramatically reduced in both the Harbor and the Bay (Figure 21b).

Figure 21. Modeled deposition of particulate organic carbon



what about the right whale?

Endangered northern right whales, when visiting Massachusetts and Cape Cod Bays, will be exposed to lower amounts of toxic pollutants and pathogens because of improved wastewater treatment. Hypothesized effects of nutrients on plankton that are food for the right whale are being carefully monitored.

The northern right whale (*Eubalaena glacialis*) is the world's most endangered large whale. From an original population size of at least 10,000 animals, extensive hunting for more than 800 years drove the species to near-extinction. Only about 300 individuals remain in the North Atlantic; fewer in the North Pacific. Despite an international ban on hunting right whales since 1949, the population is increasing at a very slow rate, in contrast to other protected whales which have recovered more quickly.

The explanation of this slow recovery is not known. Natural causes such as competition with other species, or genetic factors like inbreeding, or behavioral factors may be important. Human-induced mortality includes collisions with ships and entanglement with fishing gear. Finally, habitat degradation has been identified as a potentially important cause of the whale population's low rate of increase. Reduction in food availability, physical interference with whales through shipping, mining and dredging activities, and pollution impacts are factors that could degrade whale habitat.

Cape Cod Bay and Stellwagen Bank are important late winter/spring feeding areas for these migratory animals, and have been identified by the National Marine Fisheries Service (NMFS) as critical habitat to be protected. Therefore potential pollution sources like the MWRA outfall must be reviewed under the Endangered Species Act, although the long outfall discharge is distant–more than 16 miles–from identified right whale habitat.

In 1993, EPA conducted a comprehensive Biological Assessment on the potential impact of the MWRA outfall on endangered species and NMFS issued a Biological Opinion. The conclusion was that the outfall was not likely to jeopardize the species. Nevertheless, the critical status of the right whale requires special and continued consideration. Issues that have received ongoing scrutiny include the potential for impacts from pathogens, toxic chemicals, and nutrients, as described below.

Will the whales be threatened by infectious bacteria, viruses or protozoans in the effluent?

Secondary treatment is highly effective at removing pathogens from the wastewater. Secondary-treated effluent is also disinfected more effectively than primary effluent. Improved removal combined with higher dilution will significantly decrease the levels of pathogens in both the Harbor and the Bays. The microbiological water quality will meet human swimming standards and the much more stringent shellfishing standards. These standards should be sufficiently protective of the whales as well.

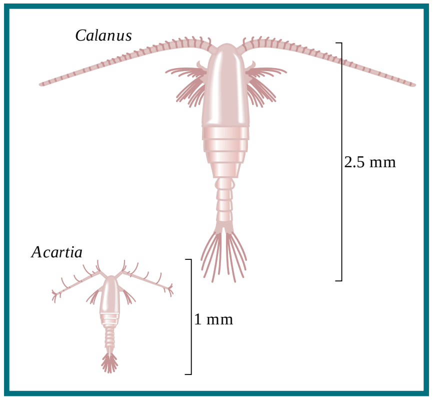
What about toxic and bioaccumulation effects of metals and PCBs?

Levels of these contaminants in the discharge will be so low (page 10) that short-term, acute toxic effects are not a concern. The focus is on average levels of contamination Bay-wide and the effects of long-term chronic exposure, such as bioaccumulation, and the potential for sublethal effects like decreased fertility.

Measurements of organochlorine compounds, like PCBs, in right whales indicate relatively low tissue levels compared to other marine mammals. Although exposure to toxic chemicals may possibly be a factor in right whale reproductive failure, moving the outfall location from within the Harbor to the 9.5-mile location offshore will not increase the risk to whales because the inputs of these contaminants to the Bays system will not be increased. Rather, secondary treatment will substantially decrease any toxic chemicals MWRA contributes to the Bays system.

Will increased nutrients cause decreased food availability?

In order to better understand nutrient issues, it helps to know something about the feeding biology of the north-



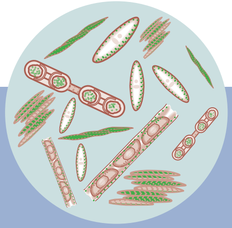
ern right whale (see illustration, Figure 22). Right whales are baleen whales; they feed by swimming open-mouthed through patches of zooplankton, straining millions (about one ton a day) of tiny crustaceans, called copepods, from the water. In the spring, right whales feed in Cape Cod Bay and Stellwagen Bank, where there are intense blooms of large and nutritious copepods like *Calanus finmarchicus*. The whales feed in dense *Calanus* patches, created by wind and current patterns as well as copepod swimming behavior.

Offshore *Calanus* zooplankton communities differ from their nearshore counterparts. Nearshore zooplankton are typified by species like *Acartia*, which are smaller, less nutritious, and apparently do not form the dense patches required to sustain a feeding whale. Different types of copepods eat different kinds of phytoplankton. It has been suggested that the nutrients discharged by the new outfall could cause the Bay environment to favor zooplankton like *Acartia*—not good food for right whales.

Another nutrient-related whale-feeding concern is nuisance algal blooms: will the outfall cause blooms of *Phaeocystis*, which seems to interfere with whale feeding, or brown or red tides which might be toxic? Blooms of *Phaeocystis* and *Alexandrium* have occurred in the Bays, so the question is whether the outfall could worsen them.

To help address both of these food availability issues, MWRA has used the Bays Eutrophication Model (page 16). The model shows that we can expect to see effects of nutrient discharges limited to the immediate area of the outfall, so it is unlikely that there would be any outfall-related changes as far away as right whale habitat. If any changes in phytoplankton or zooplankton do result from the discharge, they would first occur near the outfall. Therefore, MWRA is monitoring intensively for changes in plankton composition there. MWRA also monitors Cape Cod Bay for any significant changes.

plankton



phytoplankton

Tiny floating plants (algae), especially diatoms, that are carried about with ocean currents. These plants (illustrated at right) grow most abundantly near the surface of the water, where they receive maximum light. At the base of the marine food web, phytoplankton grow using nutrients in the water, and are eaten by zooplankton.

zooplankton

Tiny floating animals, including juvenile forms of fish, jellyfish, and shellfish. Very small crustaceans, the copepods (see drawings on left), are often abundant in zooplankton. Zooplankton eat phytoplankton, and in turn are eaten by fish and other marine animals, including northern right whales.

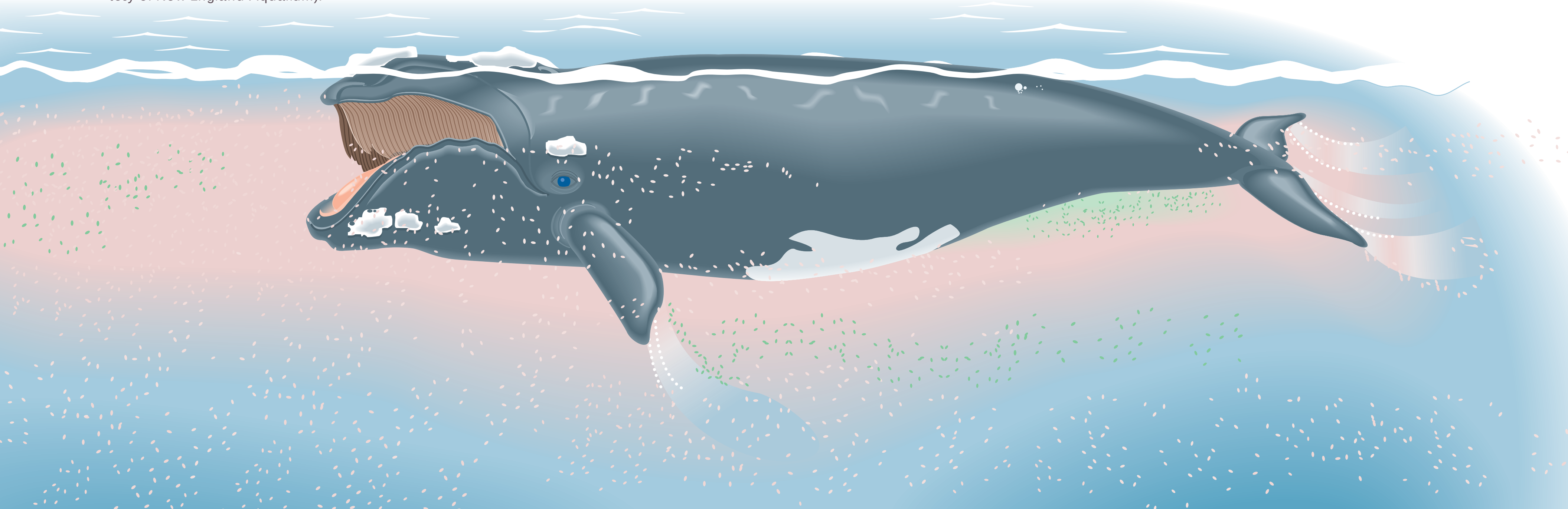


Figure 22. Feeding northern right whale. High springtime nutrient levels in the water, combined with wind and current patterns, stimulate the abundant growth of phytoplankton and *Calanus* copepods in Cape Cod Bay and Stellwagen Bank. The nutritious copepods are found in dense patches, favored by filter-feeding northern right whales. The whales feed in Massachusetts and Cape Cod Bays in the spring before continuing their migration north to the Bay of Fundy. MWRA monitoring will detect changes in phytoplankton or zooplankton communities. (Illustration by S. Hussey, after S. Landry, courtesy of New England Aquarium).

will we know if the outfall is causing a problem?

Baseline monitoring, which has been conducted since 1992, is telling us a lot about natural environmental variability. The more we understand the Bays system, the more quickly and confidently we can determine if an apparent impact is discharge-related. Scientists and regulators have established threshold values of environmental parameters that will trigger MWRA action.

Permit, trigger parameters, and thresholds

MWRA's National Pollutant Discharge Elimination System (NPDES) permit for the new treatment plant and outfall, to be issued jointly by EPA and the Massachusetts Department of Environmental Protection (DEP), will incorporate stringent limits and testing requirements for Deer Island effluent discharges. The permit will be one of the most comprehensive and protective permits ever issued, and will require that state and federal water quality criteria not be violated as a result of the discharge. In addition, MWRA has been conducting an extensive outfall monitoring program, which is linked to an action plan—the Contingency Plan—that incorporates trigger parameters and threshold values for MWRA actions.

Trigger parameters are environmentally significant components of effluent or the marine ecosystem that, if certain (threshold) levels are exceeded, indicate a potential for environmental risk. Examples of trigger parameters for effluent are total suspended solids, biochemical oxygen demand, and toxic contaminants. Examples of environmental trigger parameters are water column dissolved oxygen concentration, chlorophyll *a* concentration, benthic community structure, and liver disease in flounder. Twenty-two trigger parameters are incorporated in the outfall monitoring program.

Threshold values are measurements of trigger parameters selected as indicators of the need for action, and are based on expected permit limits, state water quality standards, and expert opinion. To alert MWRA to any changes, each trigger parameter has thresholds that are defined as caution or warning levels. These thresholds are based on monitoring data collected since 1992 under the guidance of the Outfall Monitoring Task Force, which includes academic scientists, government agency representatives, and citizens groups.

Monitoring comprehensively

Years of study by MWRA, scientists at major universities, research institutions including the Woods Hole Oceanographic Institution, and government agencies including the EPA and Geological Survey, have shown that the combination of improved wastewater treatment at Deer Island and the dilution provided by discharge of effluent into deeper Bay waters will generally benefit Massachusetts Bay and Boston Harbor. Nevertheless, to ensure that any potential unforeseen environmental impacts of the outfall relocation are addressed, MWRA has implemented the most comprehensive marine monitoring program in the nation for a secondary-treated sewage discharge, and will continue post-discharge monitoring after the outfall begins operating in 1998. Actions to be taken by MWRA if any unexpected impacts occur are detailed in the Contingency Plan described at the end of this report.

Massachusetts Bay has become one of the most thoroughly studied marine environments anywhere. As recommended by the National Academy of Sciences' National Research Council, the monitoring program focuses on the potential impacts of nutrients, organic material, toxic contaminants, pathogens, solids, and floating debris. Contaminants are measured and biological observations made in effluent, water, sediment, plankton, fish, and shellfish. Even satellite data is used to measure chlorophyll, temperature, and other ocean conditions (Figure 23).

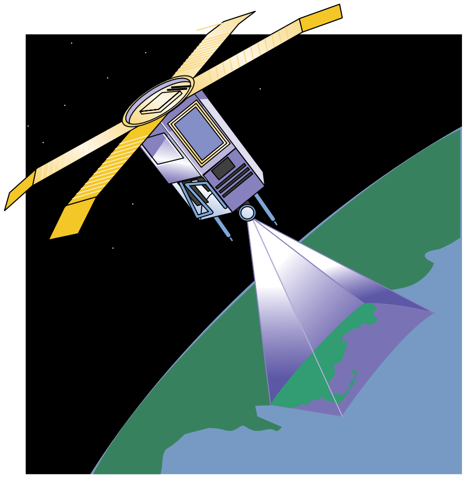
Sampling is most intensive in the immediate discharge area (within three miles of the diffuser). In addition, sampling stations more than 30 miles away in Cape Cod Bay are included (Figure 24). Since the inception of the monitoring program, 3.4 million data records have been collected and stored in MWRA's marine monitoring database, and more than 200 reports written.

Monitoring at all scales

Perhaps the biggest challenge in pollution effects monitoring is to characterize the natural variability in the environment. Within the general patterns of seasonal and habitat differences, the marine environment can be unpredictable. Changes occur in the physical and biological environment that are unrelated to human activities. Plants, animals and plankton in Massachusetts and Cape Cod Bays have what is termed a patchy distribution in space and time; where and when they are found are greatly affected by local winds, currents, sediment types, or animal behavior. This means we must measure local changes, as well as understand broader, general processes.

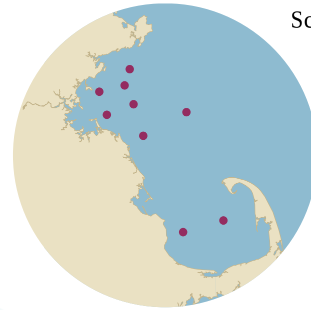
The most frequent measurements are by moored instruments that collect data at one location at intervals only minutes apart. In the critical area around the outfall, oceanographic vessels frequently collect water and sediment samples for detailed chemical and biological analyses. At sites distant from the outfall location, less frequent sampling will enable us to monitor the general health of the area. The big, regional picture, on a scale of kilometers, is generated by satellite images.

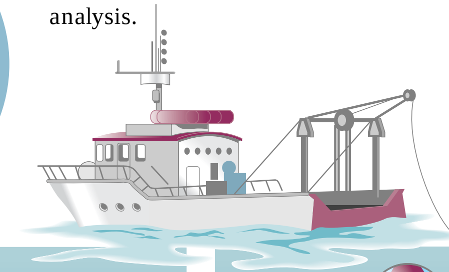
Figure 23. MWRA monitors the Harbor and Bay at all scales; data are collected by satellite, ship, and mooring.



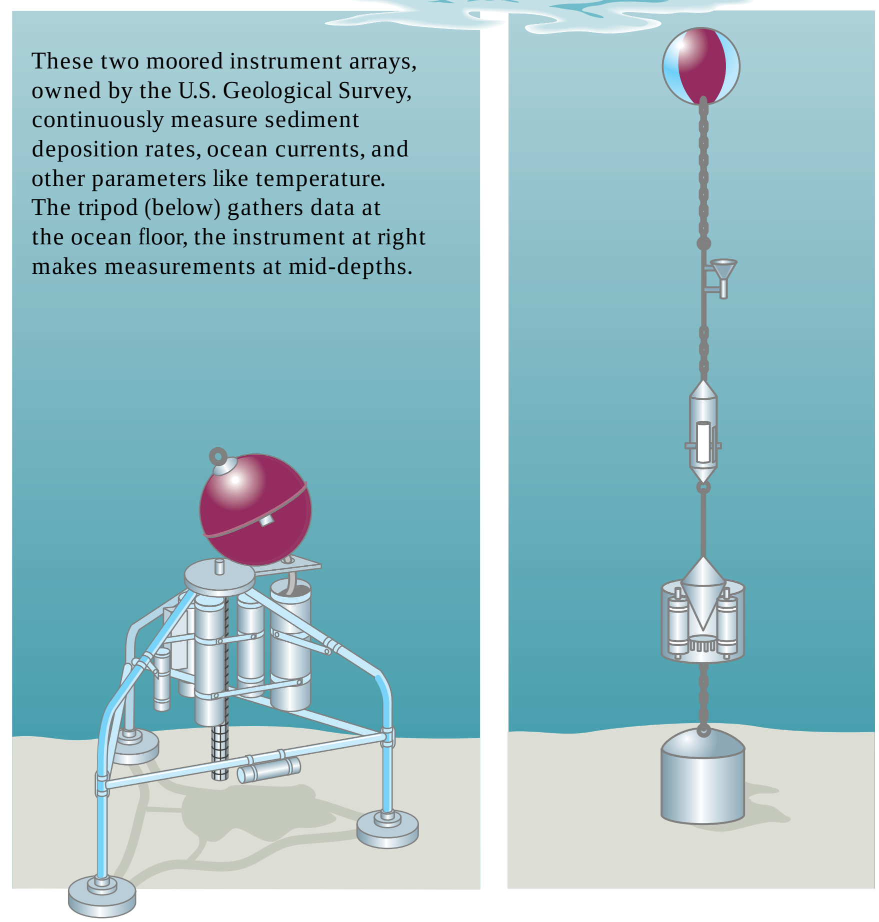
Satellites like SEASTAR collect climate data and measure parameters such as chlorophyll *a* over hundreds of square miles.

This floating buoy owned by the National Oceanic and Atmospheric Administration collects oceanographic data such as wave height, at the surface of the sea.



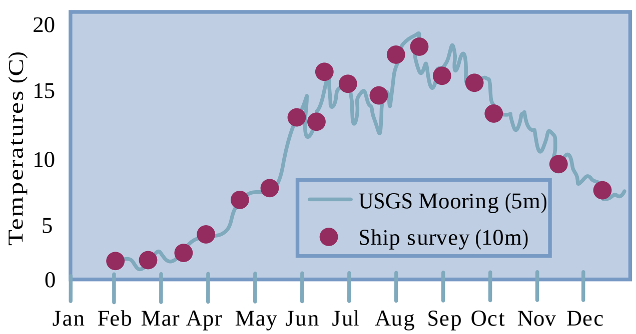


Scientists on oceanographic ships collect water, plankton, fish, shellfish, and sediment samples for MWRA throughout the Bays for laboratory analysis.



These two moored instrument arrays, owned by the U.S. Geological Survey, continuously measure sediment deposition rates, ocean currents, and other parameters like temperature. The tripod (below) gathers data at the ocean floor, the instrument at right makes measurements at mid-depths.

Example of data (water temperature) collected continuously by moored instruments compared to survey data collected by ship.



Monitoring locations in the Bays.

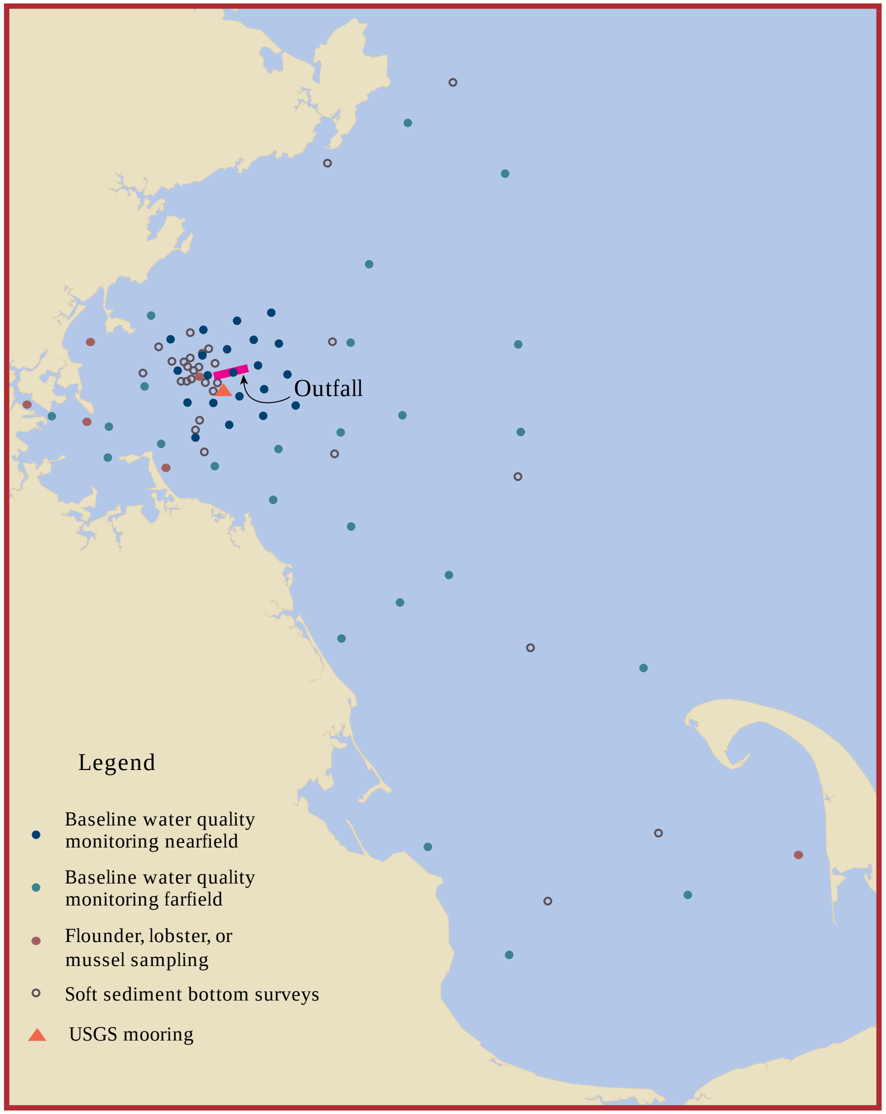


Figure 24. Monitoring stations include water, sediment, and the biota close to and distant from the new outfall site.

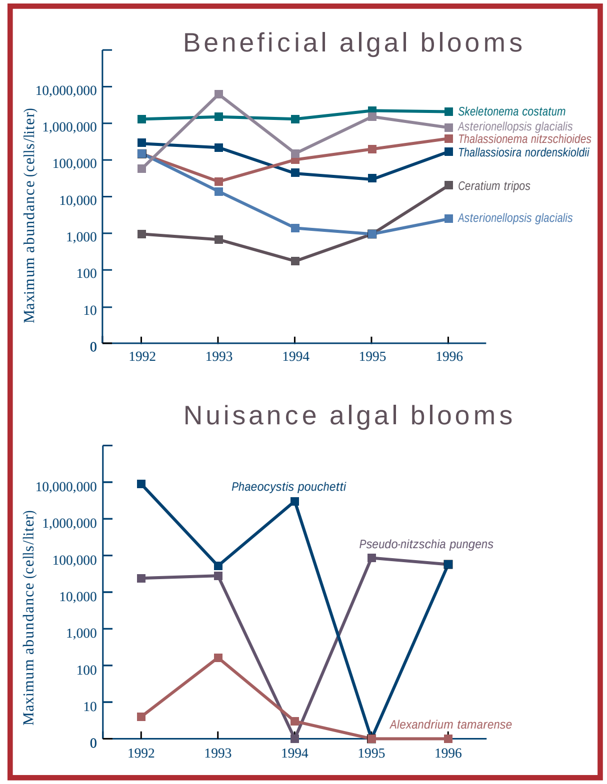


Figure 25. Beneficial and nuisance algal blooms have different inter-annual patterns. Nuisance algal blooms have occurred during the baseline monitoring period. These blooms are less predictable than the normal, beneficial algal blooms which produce food and oxygen. Continued monitoring will enable MWRA to detect whether changes in algal blooms are related to the outfall (MWRA monitoring data).

Indicators of the Bays' health vary naturally

Baseline monitoring has shown that, within the overall seasonal cycle, there is intense variation from year to year. For instance, Figure 25 shows differences in abundance of dominant (beneficial) phytoplankton and nuisance phytoplankton in the Bays since baseline monitoring began in 1992. The maximum abundances of beneficial phytoplankton, like *Skeletonema* and *Thalassiosira,* vary relatively little from year to year. By contrast, nuisance phytoplankton like red tide (*Alexandrium tamarense*, the cause of paralytic shellfish poisoning) or blooms that lower bay-wide oxygen concentrations, discolor the water, or produce foul odors, are much more erratic from year to year. Large nuisance blooms are interspersed with no blooms. In 1992 and in the spring of 1997 (not shown), there were large nuisance *Phaeocystis* blooms in Cape Cod Bay and Buzzards Bay. The 1997 bloom apparently interfered with right whale feeding, as right whales left Cape Cod Bay earlier than usual that year (Mayo, 1997). Nuisance blooms can be linked to the larger circulation in the Gulf of Maine: for example, winds, currents and spring runoff during May determine whether red tide enters

Massachusetts Bay or is transported out to sea (Anderson, 1997).

Figure 26 shows another example of natural variability: in 1994 and 1995, average oxygen concentration in the bottom waters of the Bay fell below the caution level. This measurement would trigger more intensive evaluation once the new outfall comes on-line, an example of a natural phenomenon that could have been interpreted as outfall-related.

Another example of a measurement that, if the new outfall were in use, could have been attributed to sewage effluent, was a pattern of silver deposition in the sediments near the new outfall site. Figure 27 shows that silver concentrations spiked up to more than double their baseline value in February 1993 after an unusually severe storm in December of 1992. That storm caused redistribution of silver into the muddy sediments sampled. By February 1994, silver concentrations declined to near-background levels. If the new outfall had been commissioned, it might have seemed reasonable to attribute the elevated silver concentration to the outfall, but now we know that severe storms can create a pattern like this one.

Observations of natural year-to-year variation of phenomena like nuisance blooms and the spike of silver in the area near the outfall site provide an important context for examining changes after the long outfall is commissioned. Information like this will help MWRA, scientific experts, regulators, and interested citizens to know where to look for likely causes of suspected environmental problems.

Dissolved oxygen levels in bottom water at the Bay outfall site

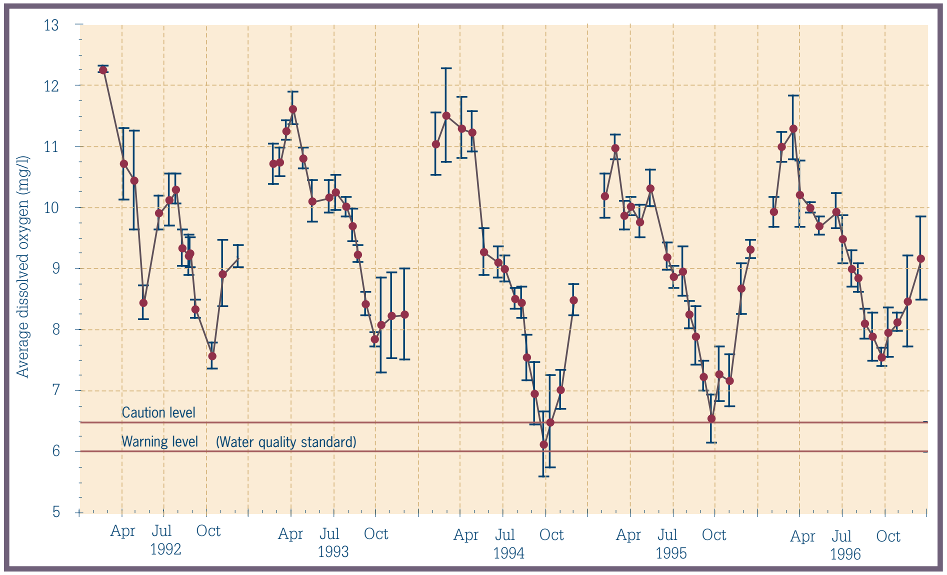


Figure 26. Baseline monitoring shows low dissolved oxygen can occur in bottom waters at the future outfall site. Average dissolved oxygen levels measured during surveys of the bottom waters of the outfall nearfield area show dramatic seasonal fluctuations, as well as varying from year to year. In 1994, the average DO in October almost violated the state water quality standard, and did fall below the caution (6.5 mg/l) level in 1994 and in 1995. Another measurement, the percent saturation of DO, not shown, violated the warning level in 1994 and 1995. These violations are related to the warmer temperatures during those years; in the post-discharge period such low levels would trigger notification of the Outfall Monitoring Task Force (error bars represent one standard deviation; MWRA monitoring data).

Sediment silver concentrations at the Bay outfall site (1989-1996)

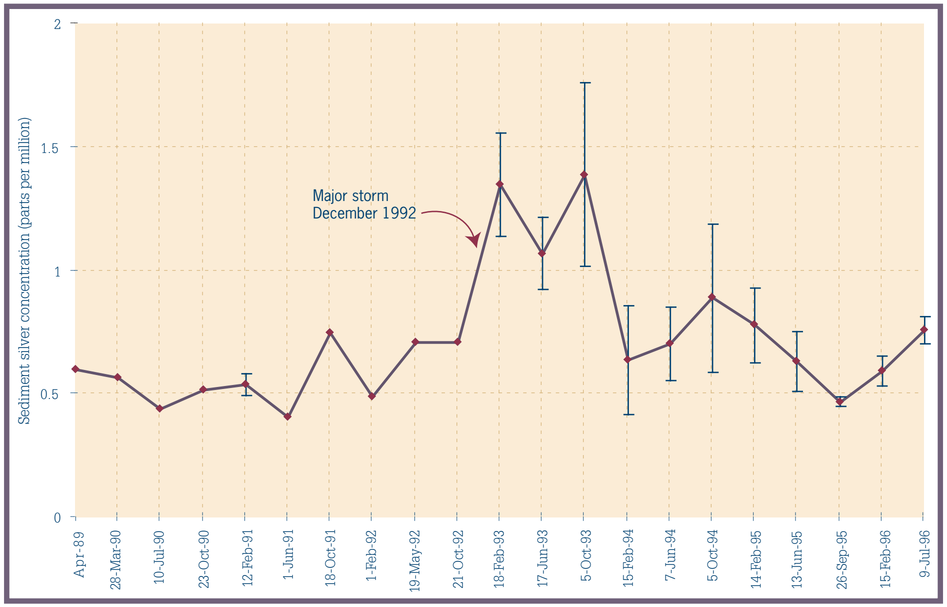


Figure 27. Silver concentrations in sediment near the future outfall site increased after a major storm. A major storm occurred in December 1992, causing resuspension of sediments from shallower inshore areas, which redeposited into deeper offshore areas, including a small muddy area near the future outfall site (average is mean of three measurements error bars show one standard deviation; data from Bothner 1997 in press, Bothner et al. 1997 in press).

what will be done if a problem occurs?

The Contingency Plan describes how, if monitoring results indicate a possible environmental problem, MWRA and the regulatory agencies will act to determine the cause of the problem and what corrective actions should be taken.

The Outfall Contingency Plan

The Outfall Contingency Plan was developed to create a process to identify and respond to water quality changes that potentially could be related to effluent discharges. Even though it is not expected that these discharges will affect the environment adversely, the Contingency Plan describes the criteria and process that MWRA, regulatory agencies, and the Outfall Monitoring Task Force (OMTF) would use to assess potential changes, make information on those changes available to the public, and respond appropriately to avoid harm to the marine environment.

How the Contingency Plan works

The Contingency Plan identifies trigger parameters, conditions that can suggest that effluent quality or environmental conditions may be changing or likely to change in the future. To alert MWRA to different degrees of observed change, each trigger parameter has thresholds that are defined as caution or warning levels. These thresholds are based on monitoring data collected since 1992.

In the event that a threshold is exceeded, the process for responding will vary somewhat depending on whether the threshold is a caution or a more serious warning level (Figure 28). The response to any threshold exceedance, even before the cause has been discovered, will be to decide whether treatment plant operations can be altered to reduce the discharge of the relevant pollutant.

If MWRA discharges have caused a caution level to be exceeded, MWRA will expand its monitoring to closely track any change in effluent quality and environmental conditions, and provide the information necessary to:

1) evaluate the cause and effect of the exceedance; and

2) review applicable trigger parameters and thresholds.

If the threshold exceeded is a warning level, the proposed response will include both early notification to EPA and DEP and the quick development of a Response Plan. A Response Plan includes a schedule for implementing actions such as additional monitoring, making further adjustments in plant operations, or undertaking an Engineering Feasibility Study regarding specific potential corrective activities.

Corrective activities

Corrective activities have been identified in the Contingency Plan (or may be identified in the future) as potential solutions to unexpected impacts in the marine ecosystem from the operation of the outfall. If the effects of effluent discharges must be reduced, examples of corrective activities could include the addition of specific enhanced treatment technologies and increased pollutant prevention and regulation.

How the Contingency Plan is accountable to the public

To ensure that the Contingency Plan provides appropriate environmental protection, every step of the implementation process will be open to public input and review. In addition, MWRA will produce a quarterly Wastewater Performance Report to provide the public with information about plant performance and monitoring results. The report is designed to:

- provide information about key wastewater operations;
- demonstrate day-to-day progress in achieving goals and objectives; and
- compare actual performance against trigger parameters and other important water quality monitoring or plant performance targets.

Once a year, MWRA will also develop an Outfall Monitoring Overview/Contingency Plan report that will be submitted to the Outfall Monitoring Task Force as well as to EPA, DEP, and the Federal Court. The report will also be available to the public. The report will summarize monitoring results and any exceedances, responses related to the Contingency Plan, and corrective activities that have occurred over the previous year. The report will also propose changes to the Contingency Plan, as needed. Changes are expected to be guided primarily by OMTF recommendations.

How the Contingency Plan will be enforced

The Contingency Plan is one portion of many obligations, both state and federal, that MWRA is required to meet:

- The NPDES permit imposes extensive requirements on MWRA discharges, including effluent monitoring, reporting, plant maintenance and operations, and the industrial pretreatment program. Requirements for the combined sewer overflow (CSO) program and sludge-to-fertilizer plant are also included;
- A Federal Court Order guides the construction of the new treatment facilities, sludge-to fertilizer plant, CSO projects, and the industrial pretreatment program, as well as treatment plant staffing;
- The Massachusetts Executive Office of Environmental Affairs and EPA have overseen the development and implementation of MWRA's Outfall

Monitoring Plan, which has also been submitted to the Federal Court.

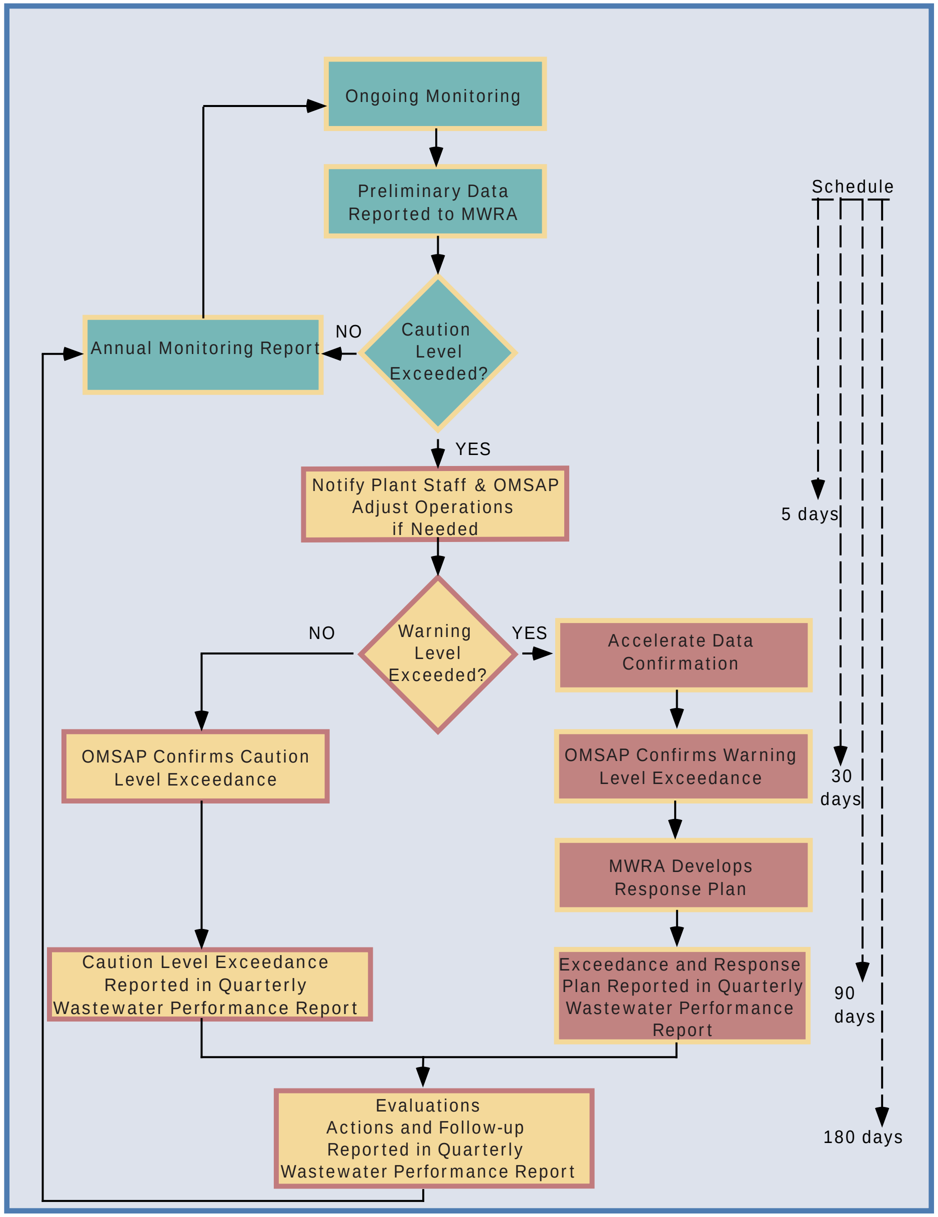
To ensure that even greater oversight and enforcement opportunities are provided, the new draft NPDES permit being developed for public comment by EPA and DEP is expected to include requirements to ensure that the Contingency Plan will be implemented as described and intended.

The Contingency Plan is designed to build on and be consistent with MWRA's regulatory and judicial obligations. The Plan also represents the matching of MWRA's obligations with a clear line of accountability to the Court, regulatory agencies, and the public.

outfall monitoring task force

In 1990, the Massachusetts Secretary of Environmental Affairs formed the Outfall Monitoring Task Force (OMTF) to advise the MWRA. The OMTF, composed of scientists and representatives from government agencies and regional environmental groups, guides MWRA's monitoring program. The Task Force directed MWRA to monitor in four general areas: effluent, water column, sediment, and living resources. The OMTF meets regularly to review MWRA's findings and approves changes in monitoring annually based on new scientific information. The Task Force also sets priorities regarding the environmental issues and questions MWRA should address with its monitoring program. OMTF meetings are open to the public.

Figure 28. Contingency plan process flowchart



endnotes
references

endnotes for Table 2

1 Maximum value measured during Deer Island detailed effluent studies (Butler et al. 1997), except for total PCBs, which are average values.

2 Secondary effluent from Deer Island pilot secondary plant.

3 After appropriate dilution factor (80:1 for copper, lead and mercury available in area nearest diffuser, after initial mixing. Dilution factor is 364:1 for DDTs, PAH, and PCBs, available in the outfall nearfield area.)

4 EPA determines three categories of receiving water quality criteria: acute, chronic, and human health. Different criteria are applied to different types of discharges. Acute criteria are applied to small areas or brief discharges, and specify the maximum concentration of a constituent an organism can be safely exposed to for a short duration. Chronic criteria are applied to large areas or long-term discharges and specify the maximum concentration of a constituent that an organism can be safely exposed to for a long period of time. Human health criteria reflect the concentration of a constituent that fish and shellfish can live in without endangering the health of people who eat the seafood.

5 Water quality criteria for copper, mercury and lead are EPA chronic criteria. Water quality criteria for DDTs, PAH and PCBs are human health criteria.

6 The criterion for fluoranthene is given because there is no established criterion for total PAH.

7 Comparing PCBs in effluent to the water quality criterion is problematic because ambient levels in all Massachusetts waters already violate the human health standard.

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internet web sites

mwra

Information about the MWRA
http://www.mwra.state.ma.us

state and federal

Mass. Division of Marine Fisheries
http://www.magnet.state.ma.us/dfwele/dmf/dmf_toc.htm

Mass. Executive Office of Environmental Affairs (EOEA)
http://www.magnet.state.ma.us/envir/eoea.htm

Departments within EOEA (DEM, DEP, DFWELE, DFA, MDC)
http://www.magnet.state.ma.us/envir/depts.htm

Northern right whale information
http://www.magnet.state.ma.us/envir/rtwhale.htm

Program Offices of EOEA (MCZM, MEPA, DCS, OTA, MassGIS, STEP)
http://www.magnet.state.ma.us/envir/units.htm

MDC beach water quality
http://www.magnet.state.ma.us/mdc/harbor.htm

MDC guide to Boston area reservations, including coastal and Harbor island sites.
http://www.magnet.state.ma.us/mdc/reserv.htm

Boston Harbor Islands National Recreation Area
http://www.nps.gov/boha/

EPA Region 1
http://www.epa.gov/region01/

National Marine Fisheries Service - Northeast Regional Office, Gloucester MA
http://www.wh.whoi.edu/ro/doc/nero.html

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http://woodshole.er.usgs.gov/

Boston Harbor - Mass. Bay Ecosystems - Sediment Bibliography
http://coast-enviro.er.usgs.gov/MassBib/default.htm

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Coastal Ocean Modeling at the USGS Woods Hole Field Center
http://crusty.er.usgs.gov/

A Geologic Map of the Sea Floor in Western Massachusetts Bay, Constructed from Digital Sidescan-Sonar Images, Photography, and Sediment Samples
http://woodshole.er.usgs.gov/data1/CDROMS/massbay.dds3/massbay.html

Gulf of Maine Information System
http://oracle.er.usgs.gov/GoMaine/

Gulf of Maine Red Tides
http://crusty.er.usgs.gov/wgulf/wgulf.html

Ocean engineer Marinna Martini's web page on oceanography tools.
http://marine.usgs.gov/~mmartini/instment/tools.htm

USGS Branch of Atlantic Marine Geology, Sediment Database
http://woodshole.er.usgs.gov/data1/SEDIMENTS/hathaway/readme.1st.htm

USGS Contaminant Transport Studies in Massachusetts Bay
http://crusty.er.usgs.gov/mbay/mbay.html

USGS Stellwagen Bank Information System
http://vineyard.er.usgs.gov/

Northeast Fisheries Science Center - Woods Hole
http://www.wh.whoi.edu/noaa.html

advocacy groups

The Boston Harbor Association
http://www.tbha.org/

Center for Coastal Studies, Provincetown MA
http://www.provincetown.com/coastalstudies/index.html

Charles River Watershed Association
http://www.crwa.org/

Merrimack River Watershed Association
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Cetacean Research Unit - research, education, conservation
http://www.friendly.net:80/user-homepages/b/birdman/

other organizations

New England Water Environment Association (NEWEA)
http://www.newea.org/

Northeast Business Environmental Network (NBEN)
http://nben.org/index.html

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