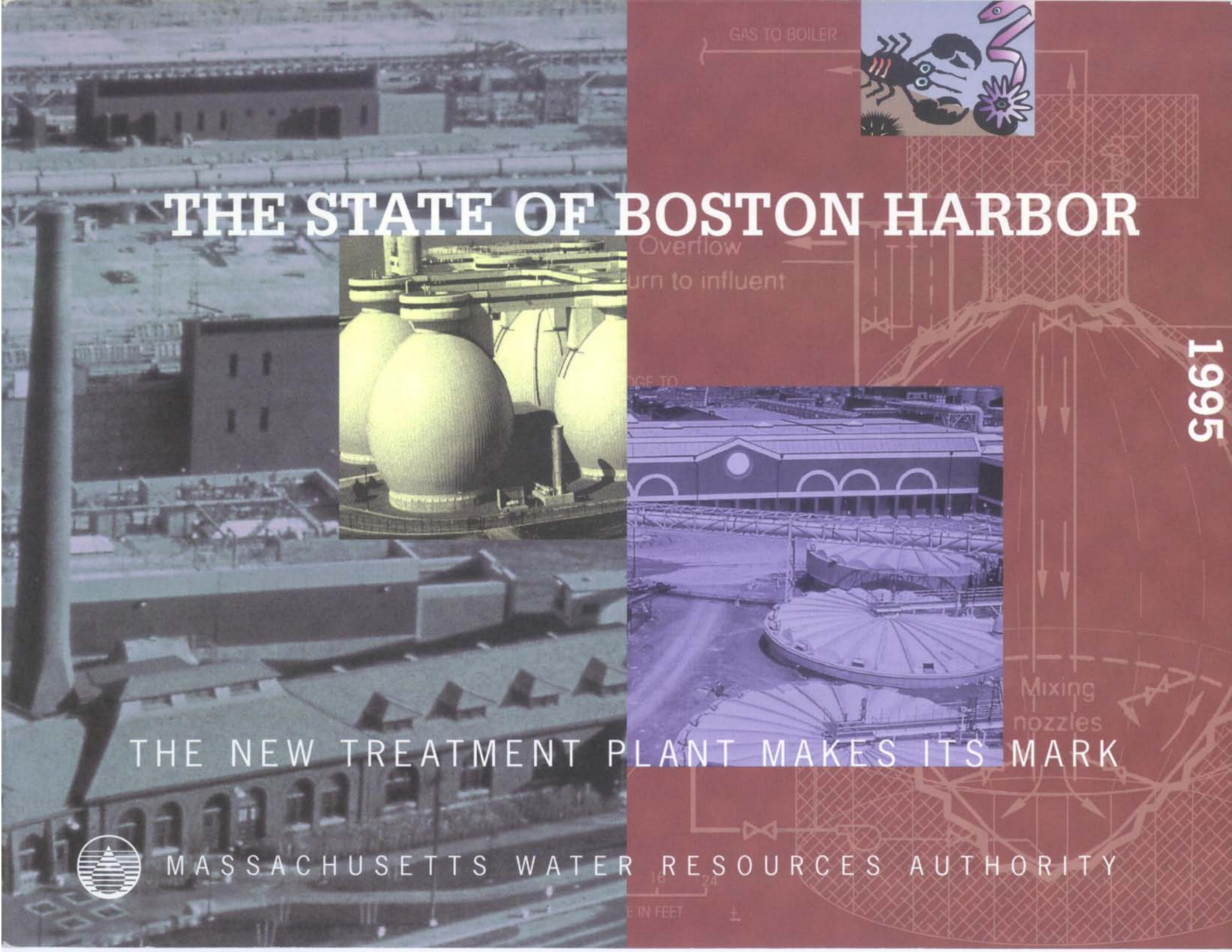
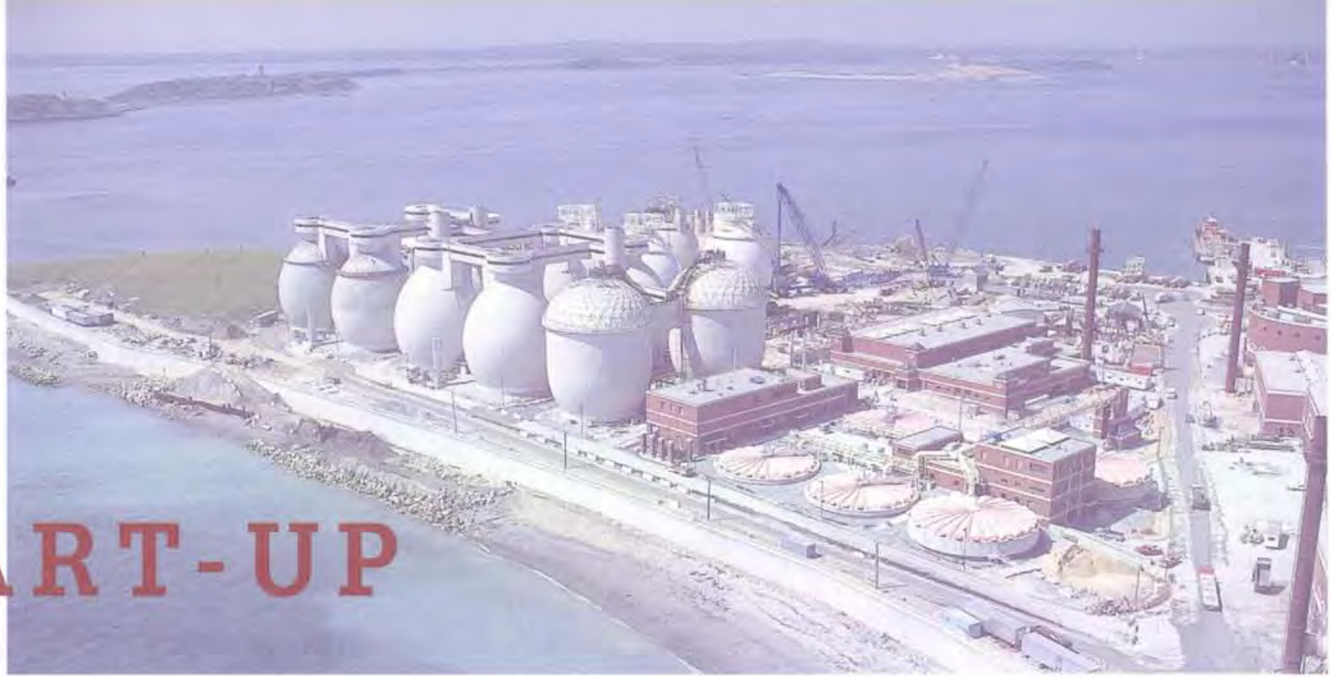
THE STATE OF BOSTON HARBOR



1995

THE NEW TREATMENT PLANT MAKES ITS MARK

MASSACHUSETTS WATER RESOURCES AUTHORITY



START-UP

MODERN WASTEWATER TREATMENT IS TECHNICALLY SOPHISTICATED. MWRA's new Deer Island facility, with advanced computerized controls and innovative treatment technologies, is a dramatic contrast to the faltering system it replaces. The "start-up" process actually lasted several months before wastewater was first introduced into the new plant. Contractors and engineers at Deer Island tested 2,225 pieces of equipment, including hundreds of pipes, pumps and valves; and checked out 11,000 instruments, 3,200 computer controls, and 34,000 computer control circuits.

TRAINING: The construction of the new plant is important—but the most critical part of the successful operation of this facility is a skilled work force. Before start-up, MWRA staff underwent months of specialized training. Managing this modern facility requires new skills, especially compared to those required in order to keep an antiquated plant barely functioning. In the old days, when workers often had to bring tools from home to repair broken equipment, training programs were virtually nonexistent. Understanding that a dedicated and experienced staff (which already had over 4,000 years of collective accumulated experience) was indispensable, MWRA committed to enhance the skills of staff through a $15 million ongoing training and apprenticeship program. Employees are trained in operations, maintenance, and safety. They attend computer classes and other workshops, as well as manufacturers' training in preventive maintenance for hundreds of pieces of new equipment.

PROCESS INFORMATION CONTROL SYSTEM: At the heart of this new facility is a computer system which both monitors and controls the treatment process, and cues staff to perform troubleshooting, process adjustments, and maintenance. This is a great advance over the old plant, which was monitored and controlled manually and suffered for decades from underfunding and neglect of basic maintenance. Now, trained operators work at computer consoles where the "Process Information Control System" (PICS) helps them monitor the treatment process, open and close valves, and start and stop pumps. PICS alerts staff to emergencies, reminds them when specific equipment needs preventive maintenance, and keeps the facility in compliance with its operating permit. System efficiencies are now being employed so that only about 400 staff are required to run the plant, as compared to the 500 workers originally projected.

THE STATE OF BOSTON HARBOR 1995

THE NEW TREATMENT PLANT MAKES ITS MARK

NOVEMBER 1996

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EXECUTIVE SUMMARY

THE STATE OF BOSTON HARBOR report is an annual summary of the condition of Boston Harbor. It analyzes a number of indicators—scientific, environmental, aesthetic—that tell us how much the Harbor has improved and what steps are needed to restore it to full health.

1995 was an important year for the Boston Harbor Project because, on January 20, MWRA started up the new Deer Island primary treatment plant—a key milestone of the Boston Harbor Project. Perhaps the most compelling way to describe the benefits to Boston Harbor of this achievement is to contrast the performance of the new plant with the old for each step of the treatment process. Chapter One of this report compares the old and new by describing the six stages of the treatment process:

PUMPING - This critical first step of the treatment process moves wastewater from the 43 sewer communities into the treatment plant. Ten new pumps have replaced these most troublesome components of the old plant, allowing MWRA to transport sewage from the collection system to the treatment plant much more reliably. The old pumps frequently broke down, causing sewage to back up and overflow into the Harbor. The new plant will eventually be able to pump at the rate of 1270 million gallons per day.

GRIT REMOVAL - Heavy particles like sand and coffee grounds were regular culprits in wearing down equipment in the old plant, and accumulated in the old settling tanks and digesters. The new vortex grit chambers are the largest of their kind in the United States and will improve grit removal efficiency.

SOLIDS REMOVAL - Larger settling tanks in the new plant, "stacked clarifiers," have dramatically increased the plant's ability to remove solids and scum from wastewater. In FY96, Deer Island's solids discharge into Boston Harbor dropped to 61 tons per day, down from 71 tons per day in the previous year, and compared to 126 tons per day in 1986.

SLUDGE AND SCUM DIGESTION - Digesters break down solids collected during the treatment process, destroying pathogens and producing methane gas to help heat and power the plant. The new egg-shaped digesters allow better mixing, improve production of methane, and minimize maintenance costs that troubled the old plant. When digestion failed at the old plant, the low-quality sludge that resulted could not be made into fertilizer pellets, but the new digesters have resolved that problem.

DISINFECTION - Effective disinfection depends upon how long harmful bacteria in wastewater are exposed to sodium hypochlorite before discharge. The new plant has improved the disinfection process by doubling the contact time from 15 minutes to 30 minutes, providing more effective bacteria kill and using less sodium hypochlorite in the process.

GASES AND ODORS - In the old plant, gases and odors escaped freely into the atmosphere. In the new plant, the primary settling tanks are covered so that gases are trapped until they are treated with chemicals that remove the odors.

There has never been a quick-fix way to reverse the decades of accumulated pollution in the Harbor. The 1995 start-up of the new primary plant was an important part of this effort. Other key milestones, such as the elimination of scum and sludge discharges into the Harbor, improved disinfection, and an 80% decrease in toxic contaminant discharges into the region's sewers were important beginnings to the Harbor's recovery.

In addition to documenting the achievements of 1995, the State of Boston Harbor report also looks ahead to future improvements in remaining water quality problems in the Harbor. Dissolved oxygen concentrations in certain pockets of the Inner Harbor do not meet state water quality standards during the summer, and the Inner Harbor can have high amounts of phytoplankton that in some summers turn the water reddish brown. Combined sewer overflows still discharge untreated sewage to the Harbor during heavy rains.

When the secondary treatment facilities become operational at the end of 1996, still more solids will be removed during the wastewater treatment process. In 1998, a new 9.5-mile effluent outfall tunnel will carry the cleaner effluent into Massachusetts Bay where 55 diffusers, resembling giant sprinkler heads, will disperse the discharge into the deep waters of the Bay. Combined sewer overflows will be greatly reduced. By the turn of the century, discharges into the Harbor will be a small fraction of what they are now, allowing a healthier, more diverse marine ecosystem to re-establish itself.

Like other projects MWRA has done and will do, the new primary treatment plant described in this report is an integral part of the overall objective of the Boston Harbor Project: to restore Boston Harbor to an environmental standard that the citizens of the Commonwealth want and deserve.

INTRODUCTION

THIS 1995 STATE OF BOSTON HARBOR REPORT focuses on a major accomplishment of the Boston Harbor Project: the start-up of the new primary wastewater treatment facility on Deer Island. The following pages describe the steps of primary treatment at Deer Island (summarized in Table 1), and contrast the improvements at the new facility with the performance of the old plant it replaces. Designed with capacity for the future, the state-of-the-art facility already provides improvements in treatment that benefit the environment and dramatically increase efficiency and reliability of operation; also, the plant is a better neighbor than its former often foul-smelling predecessor. The second part of the report provides an update of the health of Boston Harbor, reviewing problems caused by sewage pollution and how the Harbor is responding to pollution control projects. The latest data on beach water quality, the health of marine life, and aesthetics are reviewed.

Finally, we project how the Harbor will look in 2005, after all the major components of the Boston Harbor Project (see inset) are complete.

THE BOSTON HARBOR PROJECT was ordered in 1985 by U.S. District Court Judge A. David Mazzone, who ruled that wastewater discharges into Boston Harbor from the outdated and malfunctioning MDC Deer Island Treatment Plant violated the Clean Water Act of 1972. The Boston Harbor Project, at $3.4 billion, includes construction of:

- Primary and secondary wastewater treatment facilities
- Odor control facilities
- Disinfection facility
- Egg-shaped sludge digesters
- Effluent outfall tunnel
- Tunnel from Nut Island to Deer Island
- New and rehabilitated pumping stations

By the end of 1995, the Boston Harbor Project was 80% complete.

TABLE 1: THE PRIMARY TREATMENT PROCESS AT DEER ISLAND

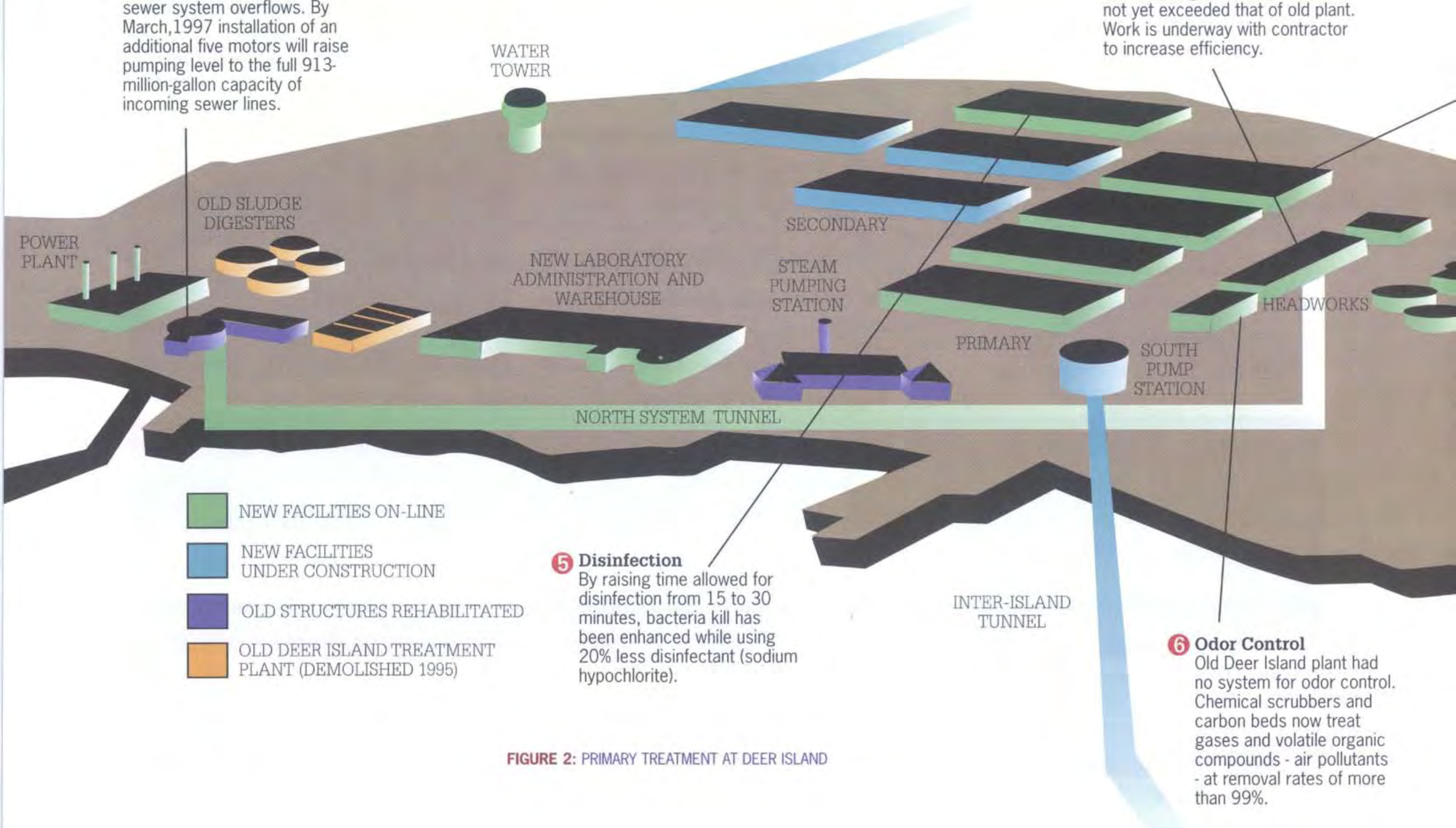
Treatment Step	What it Does	New Plant Improvement	Benefits
1 PUMPING	Pumps sewage up to the treatment plant from the final tunnels of the collection system.	New, modern pumps—improved reliability, less maintenance, lower costs.	The more sewage that can be pumped out of the collection system into the plant, the less untreated sewage enters the Harbor through CSOs, improving nearshore water quality for swimming, boating, and shellfishing in the Harbor.
2 GRIT REMOVAL	Removes sand, coffee grounds, and other heavy particles from sewage.	New vortex separators for improved removal efficiency.	Better overall plant operation because lower grit loads reduce wear and tear on equipment. Less equipment maintenance.
3 SOLIDS REMOVAL	Removes sludge and scum from sewage by gravity settling.	Increased capacity and better removal equipment in the settling tanks.	Reduced discharges of solids that cloud the water, deplete dissolved oxygen levels and cover the bottom with muck and contaminants.
4 SOLIDS DIGESTION	Reduces solids volume by converting a portion to methane gas and water.	Egg-shaped digesters improve mixing, increase gas production, and reduce cleaning and maintenance costs.	Methane recycled for plant heating and hot water; reduced cost of shipping digested sludge to sludge-to-fertilizer plant.
5 DISINFECTION	Kills harmful bacteria with sodium hypochlorite.	Increased sodium hypochlorite disinfection time in new basins. More effective bacteria kill.	Less disease-causing bacteria; safer swimming and boating; fewer shellfish bed closures; reduced chemical use and cost.
6 ODOR CONTROL	Removes odors and volatile organic compounds from the treatment process "off-gases."	Enclosed settling tanks and equipment; modern air quality pollution control equipment.	Less odor and reduction of air pollutants.

CHAPTER ONE

PRIMARY TREATMENT AT DEER ISLAND

1 Pumping
Five new electrically driven pumps have helped reduce sewer system overflows. By March,1997 installation of an additional five motors will raise pumping level to the full 913-million-gallon capacity of incoming sewer lines.

2 Grit Removal
Available grit removal has been increased to 913 million gallons although removal efficiencies of new vortex grit chambers have not yet exceeded that of old plant. Work is underway with contractor to increase efficiency.



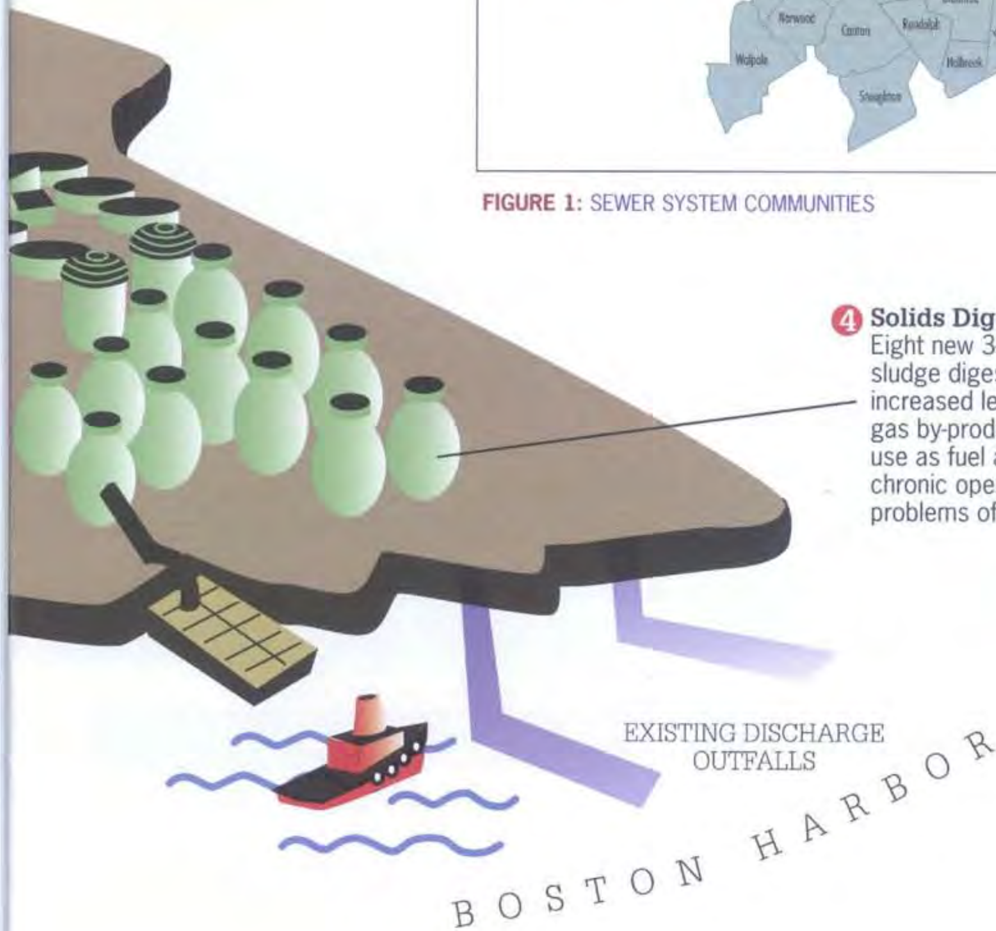
5 Disinfection
By raising time allowed for disinfection from 15 to 30 minutes, bacteria kill has been enhanced while using 20% less disinfectant (sodium hypochlorite).

6 Odor Control
Old Deer Island plant had no system for odor control. Chemical scrubbers and carbon beds now treat gases and volatile organic compounds - air pollutants - at removal rates of more than 99%.

FIGURE 2: PRIMARY TREATMENT AT DEER ISLAND

❸ Solids Removal
Forty-eight new, 1.6 million gallon primary treatment tanks have decreased solids loads entering Boston Harbor from 138 tons in 1986 to 57 tons in 1996.

FIGURE 1: SEWER SYSTEM COMMUNITIES



❹ Solids Digestion
Eight new 3-million gallon sludge digesters have increased levels of methane gas by-product available for use as fuel and eliminated chronic operational problems of old digesters.

MORE THAN 2 MILLION PEOPLE AND 5,500 BUSINESSES ARE SERVED BY THE MWRA SEWER SYSTEM, which collects, transports and treats wastewater from 43 communities in the greater Boston area. Locally owned sewer pipes discharge into MWRA's large "interceptors," and the wastewater is carried to two treatment plants: one at Deer Island which treats sewage from the North System, and the other at Nut Island which treats sewage from the South System (FIGURE 1). Both plants now discharge primary treated effluent into the waters of Boston Harbor.

In 1997, the new facility at Deer Island will treat sewage from both the North and South systems, and the Nut Island Treatment Plant will be decommissioned. Sewage flows from the South System will be screened at a new headworks at Nut Island, and sent to Deer Island through the new inter-island tunnel. The new Deer Island Treatment Plant is designed to ultimately provide primary and secondary treatment to the wastewater from both the North and South systems.

On January 20, 1995, a major milestone in the Boston Harbor Project was reached, as the new primary treatment plant began operations. The new sewage treatment process at Deer Island is a series of steps (FIGURE 2) intended to remove contaminants from wastewater as it passes through the plant. These steps reduce the contamination of Boston Harbor by wastewater effluent discharges, protecting the environment and public health. The main elements of the primary treatment process, which are described in the first part of the report, are shown here.

This chapter describes these steps in detail, explaining how the new facility improves upon past performance; a description of secondary treatment looks to the future.

1 PUMPING: lifts the sewage from the sewerage system to the treatment plant.

Sewage from the North System is carried by gravity through progressively larger pipes from users' streets toward Deer Island. Along the route, the wastewater flows through "headworks" facilities which screen out large objects and remove grit. After the headworks, sewage flows under Boston Harbor to Deer Island, through tunnels 11 feet in diameter built in 1968. The sewage arrives at the plant about 112 feet below ground, and must then be lifted from the tunnels up to the treatment plant. A major challenge to the system is to provide the pumping necessary to lift hundreds of millions of gallons of wastewater each day from the tunnels to the plant. If pumping fails, sewage backs up into the system, and can overflow into the Harbor and rivers, or even into streets and homes.

At the former plant, which was built in 1968, antiquated diesel engines drove old pumps. The engines often failed, and were difficult to repair because replacement parts were no longer available. Sewage backups and frequent combined sewer overflows into the Harbor and rivers resulted (see text box below).

COMBINED SEWER OVERFLOWS: A combined sewer is an antiquated system in which storm drains and sanitary sewers from homes and businesses flow into the same pipes. A combined sewer overflow (CSO) is an overflow that occurs when the volume of stormwater entering a combined sewer system in wet weather overwhelms the capacity of the system. The resulting mixture of stormwater and inadequately treated sewage overflows into the receiving water. Many of the larger CSO outlets in the MWRA system provide disinfection and rudimentary removal of some pollutants.

BETTER PUMPING CAPACITY AT DEER ISLAND REDUCES CSO FLOWS

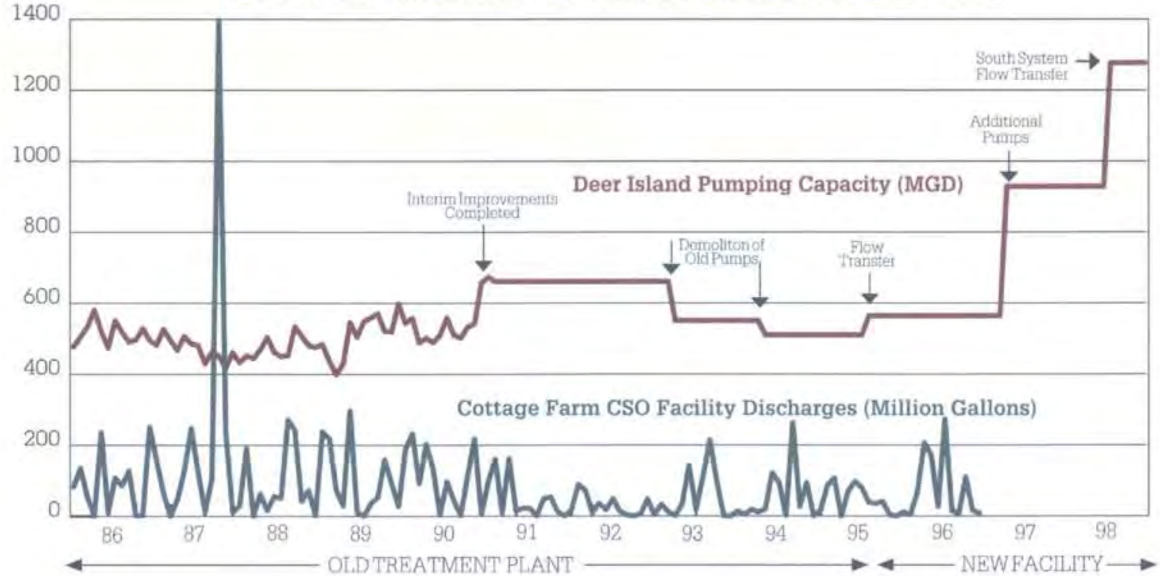


FIGURE 3: Past changes in the pumping capacity at the old Deer Island plant and changes at the new Deer Island facility are charted. Cottage Farm CSO Facility discharges into the Charles River are shown as an example of the relationship between combined sewer overflows and pumping effectiveness at the Deer Island plant.

OLD PLANT: Pumping capacity: Before 1988, the original diesel pumps at Deer Island failed frequently. Pump failures and repairs are reflected in the up and down variation on the graph, with an overall declining trend until late 1987.

COTTAGE FARM CSO DISCHARGES: Like other combined sewer overflows, discharges at the Cottage Farm CSO,near the Boston University Bridge in Cambridge, occur when rainfall exceeds the capacity of the sewer system, and the capacity of the sewer system is closely related to the pumping capacity at the treatment plant. The monthly volume discharged depends both on the amount of rain that fell and how well the sewerage system was functioning. The figure shows the effects pumping inadequacies can have on the environment: in the spring of 1987, a very large storm coincided with a breakdown in pumping at the Deer Island plant, forcing a backup of flow into the system. Many hundreds of millions of gallons of combined sewage had to be discharged from the Cottage Farm CSO Facility into the Charles River to avoid sewage flooding buildings and streets. Another problem was "dry weather overflows"–discharges from Cottage Farm (for example, in August and September 1988) that occurred when Deer Island pumping failed, even if there was no rain.

From late 1987 to the fall of 1990, the interim improvements gradually improved pumping capacity at Deer Island, adding new electric pumps to the old diesel pumps. From 1991 to late 1992, pumping capacity was consistently high, coinciding with a period of low discharges from Cottage Farm. The last dry weather overflow was in 1990. By 1993, capacity unavoidably declined as the old diesel pumps were demolished to make room to install new pumps for the new treatment facility.

NEW FACILITY: In January 1995, flow from the North System was transferred from the old plant to the newly built primary facility on Deer Island with its five new pumps. In late 1996 three more pumps will be added to the new facility, further increasing capacity. The final jump in capacity will be in 1998 as two more pumps are added before receiving additional flow from the South System through the inter-island tunnel. The ultimate pumping capacity at Deer Island will be 1270 million gallons per day.

The five new electrically driven pumps (FIGURE 4) that began operation in January, 1995 are not yet functioning at full capacity, but have been highly reliable, operating 99% of the time. In contrast, in their last years of service, each of the old diesel pumps were only operational 50% of the time. The new pumps are also operational at the Winthrop Terminal on Deer Island which lifts sewage into the plant from the original 1898-vintage sewage drain lines that first reached Deer Island.

By 1998, ten new electric pumps will be installed plus six new pumps at the Winthrop Terminal, so that the plant's capacity of 913 million gallons a day (mgd) will be enough to handle all projected North System flows even if two pumps are out of service for maintenance or repairs. The history of pumping at Deer Island since 1988 is shown in FIGURE 3.

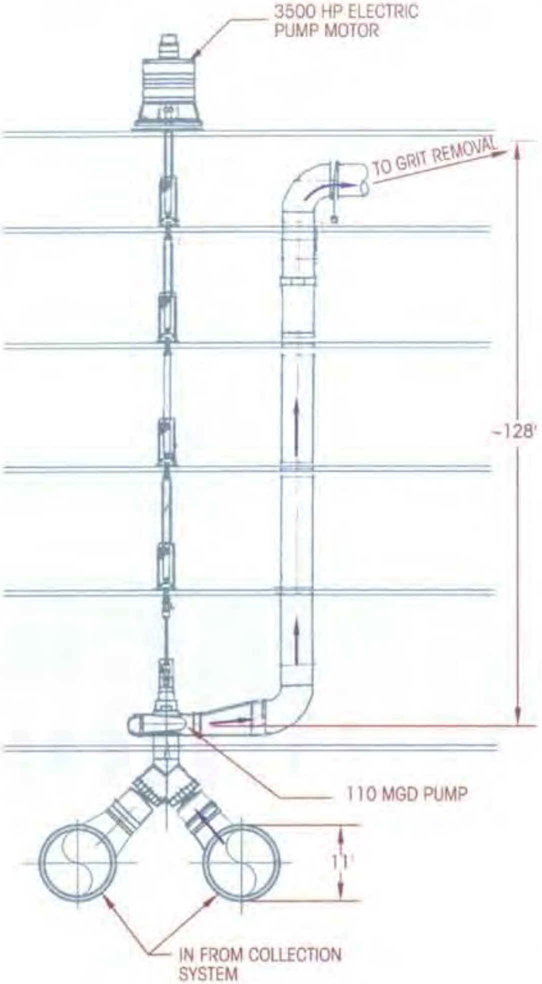


FIGURE 4: THE PUMPING SYSTEM

2 GRIT REMOVAL: Grit chambers remove heavy particles to extend equipment life and improve the performance of the solids-handling system.

Grit, consisting of sand, coffee grounds, and other heavy particles, is removed before wastewater enters the primary treatment settling tanks. While grit itself would not significantly pollute the Harbor, grit can reduce the effectiveness and service life of treatment plant equipment. Constant grit accumulation increased the maintenance requirements of the old Deer Island plant's settling tanks and digesters.

Grit is removed at a number of places in the sewage collection system, including headworks located in Boston and Chelsea that prevent grit from accumulating in the tunnels that deliver sewage to Deer Island. Additional grit removal takes place on Deer Island to prevent grit from collecting in the on-island equipment.

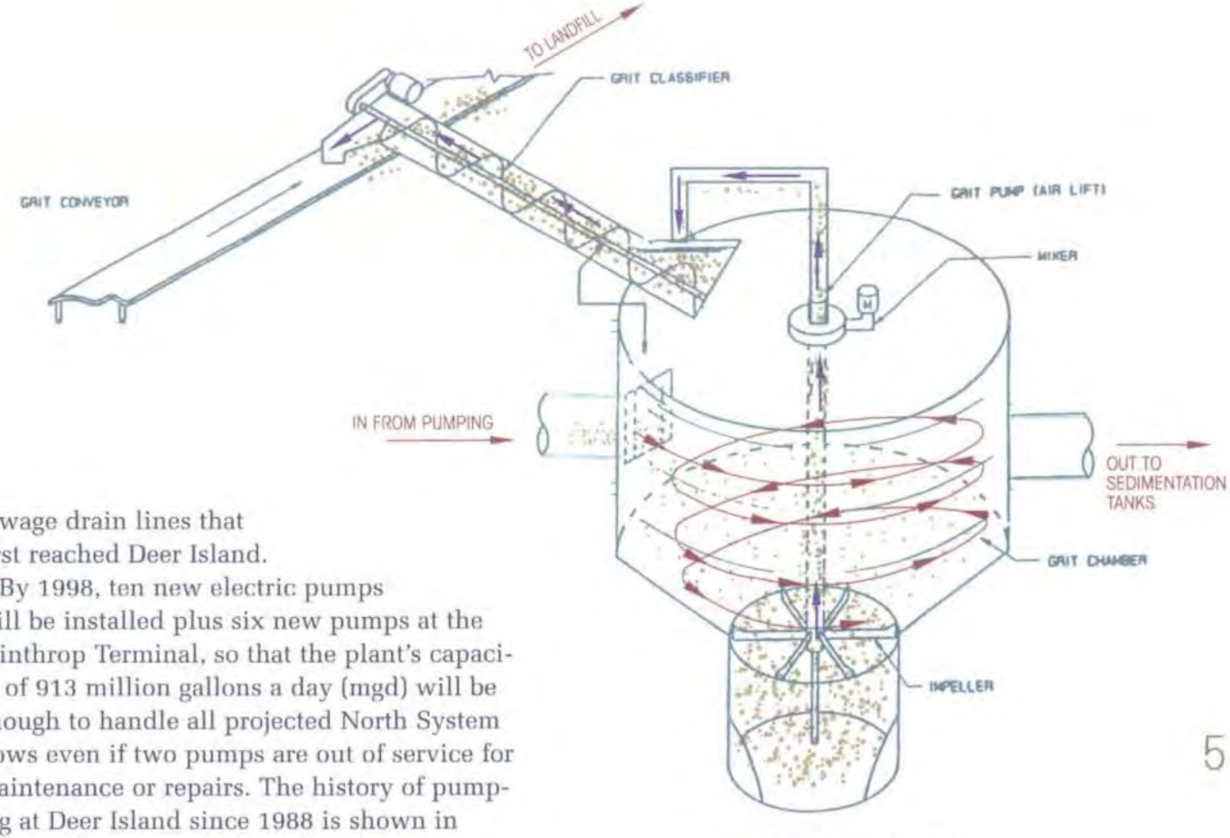


FIGURE 5: GRIT REMOVAL

The new vortex grit chambers (FIGURE 5) on Deer Island are the largest of their kind in the United States, with a total capacity of 913 million gallons per day. This system uses less land space than conventional grit facilities, which is why it was chosen for Deer Island. Grit removal efficiency is still not at the level expected in the specifications for the new plant, but MWRA is working with the equipment contractor to improve performance.

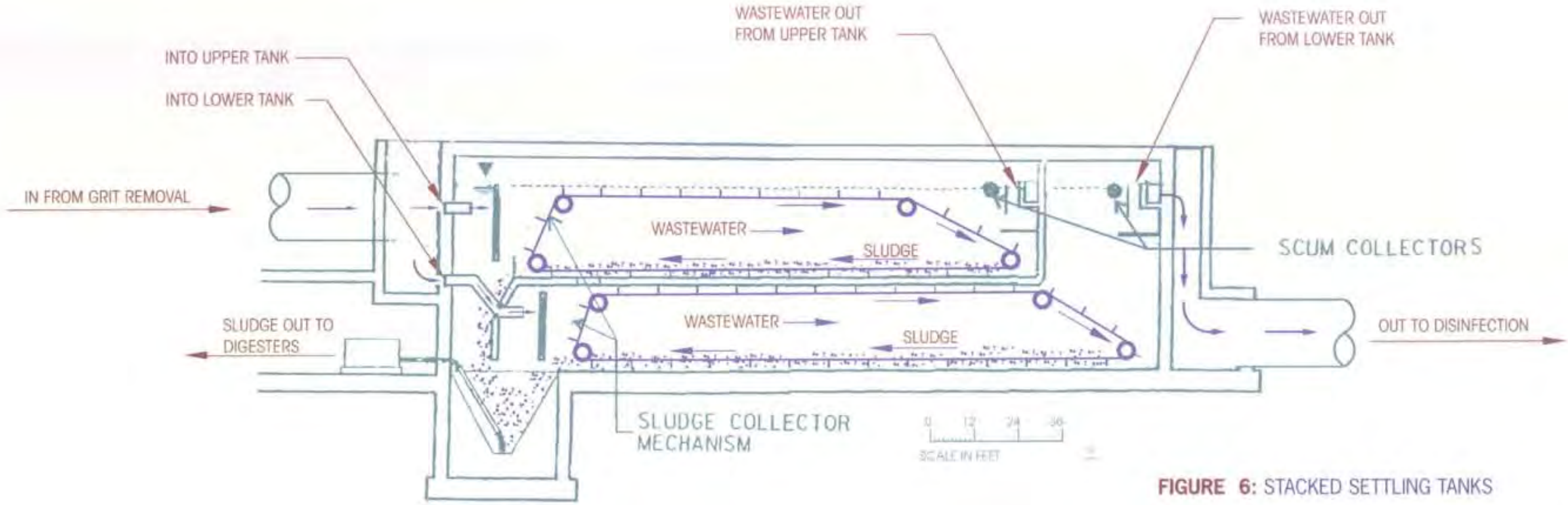


FIGURE 6: STACKED SETTLING TANKS

3 SOLIDS REMOVAL: Sludge and scum are drawn from sewage in large primary treatment settling tanks.

After grit removal, the wastewater flows continuously into the primary settling tanks (also called clarifiers). Once the flow slows down, as the wastewater slowly moves through the tank, heavy particles sink to the bottom of the tank as sludge. Anything that floats—plastics, fats, cooking oils, and sticks— and collects on the surface is called scum, which has a high grease content. Moving paddles draw the accumulations of scum and sludge from the tanks for pumping to the next phase of solids treatment. Sludge and scum, if discharged to the Harbor, would cause cloudy water, oxygen depletion, buildup of sediments, and sediment contamination.

Because there are only about 200 acres of land available on Deer Island, the new plant utilizes the technology of stacked settling tanks (FIGURE 6) pioneered in space-conscious Japan. Two-story tanks provide twice the area for solids to settle while taking up the same amount of land space as single-level tanks. Deer Island is the second sewage treatment plant in the country to use this technology, which is the largest of its kind in the world.

The longer wastewater is retained in the settling tanks, the more solids are removed. The process is similar to letting a glass of chocolate milk stand—the longer the glass stands, the more suspended chocolate particles sink to the bottom.

The efficacy of primary treatment is measured by the surface overflow rate (SOR). The ideal SOR for primary treatment is between 800 and 1200 gallons per day per square foot of settling area. Larger tank area, in comparison to the old plant, means longer settling times and slower SOR rates. If the SOR is too slow, however, bacterial growth in the tanks can produce corrosive and foul-smelling gases which mix solids back into the wastewater. On the other hand, if the SOR is too high, not enough solids will be removed from the wastewater. The new plant's 48 stacked settling tanks (12 in each of the primary treatment Batteries A, B, C, and D) have a greatly increased settling area compared to the old settling tanks, enabling the plant to maintain a desirable SOR (FIGURE 7), even during wet weather when the plant is receiving sewage at a high rate.

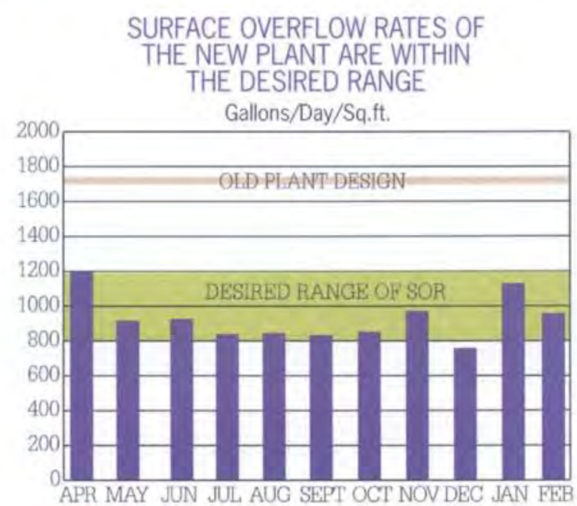


FIGURE 7: Perhaps the greatest advantage of the new plant is its ability to provide a high level of treatment, as measured by the surface overflow rate (SOR), during periods of high flow. Except for the period of initial operation, the plant has operated at an SOR within the desired range for optimum performance. The old plant was designed with an SOR that exceeded the desired range during average flows.

DISCHARGE OF SOLIDS FROM DEER ISLAND HAS DECREASED

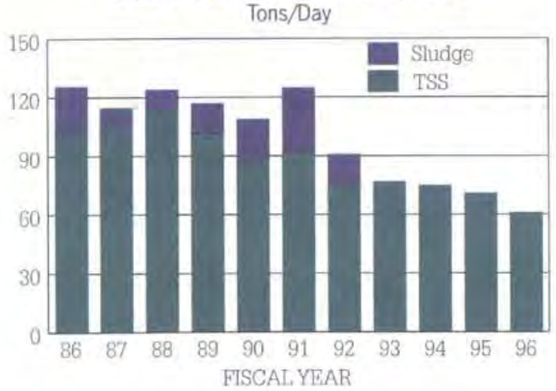


FIGURE 8: Solids input to Boston Harbor from Deer Island decreased dramatically with the start-up of the new Deer Island Treatment Plant in January 1995, and when the new egg-shaped digesters came on-line in August 1995. The ending of sludge discharges in December 1991 is credited with many of the Harbor improvements observed today.

Solids removal from the wastewater increased after interim improvements, and have further improved after the new plant came on line in 1995. In 1986, the former plant discharged 126 tons of solids (including sludge) per day into Boston Harbor; and in 1994, the year before the first new facilities went on line, 77 tons per day. In 1995, as the new plant went into start-up operation, it discharged 71 tons of solids per day, and after February 1996, only 61 tons per day (FIGURE 8), bringing the Deer Island plant into full compliance with its interim legal limit for effluent quality.

4 SOLIDS DIGESTION: Digestion breaks down sewage solids, destroys pathogens, reduces the amount of organic waste, and produces methane gas burned for heat and power in the facility.

After sludge is collected from the bottom of the settling tanks and mixed with scum, it is pumped to thickeners where water is removed.

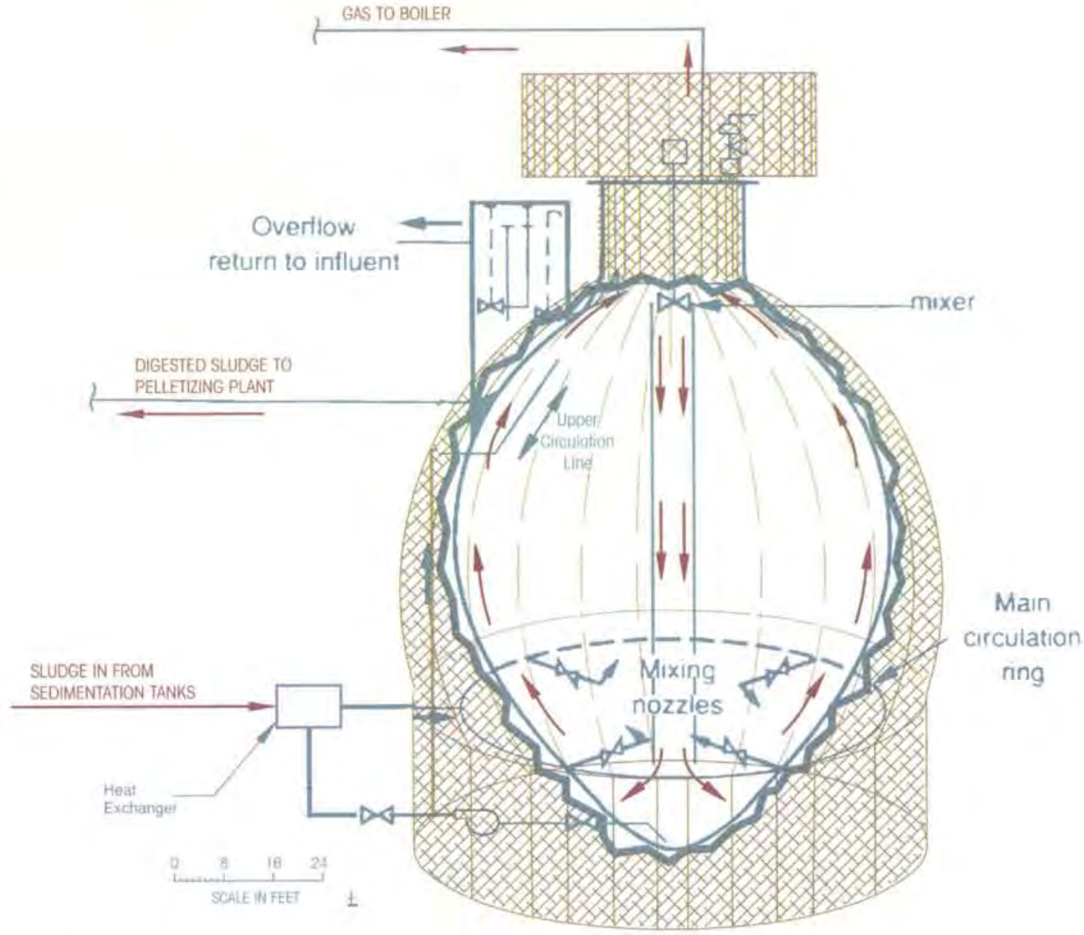


FIGURE 9: THE SLUDGE DIGESTERS

Then, the thickened sludge is pumped into the egg-shaped digesters to undergo anaerobic digestion, meaning digestion without oxygen.

Digestion greatly reduces the numbers of pathogens in the sludge, and stabilizes it for further processing. Microorganisms grow during the digestion process, using the sludge for food. These microbes generate heat and break down the organic matter in the sludge, producing methane gas. The gas can be used for heat and power at the plant. The digested sludge is barged to the sludge-to-fertilizer plant at the Fore River Staging Area, where fertilizer pellets are then produced for agricultural uses across the country.

One dozen 140-foot high eggs make up the most prominent feature of the new Deer Island plant. These egg-shaped digesters are fairly common in Japan and Germany, but relatively new to the United States. The cake-pan shape of the previous digesters in the old plant caused several stagnant areas with poor mixing that reduced digester efficiency. The egg shape is ideal for mixing (FIGURE 9), and the narrow top lessens the accumulation of scum. Grit is easily cleaned out from the tapered bottom, reducing maintenance costs and minimizing problems resulting from solids buildup.

Sludge in the process of digestion is a living biological system, which can be upset. Plant

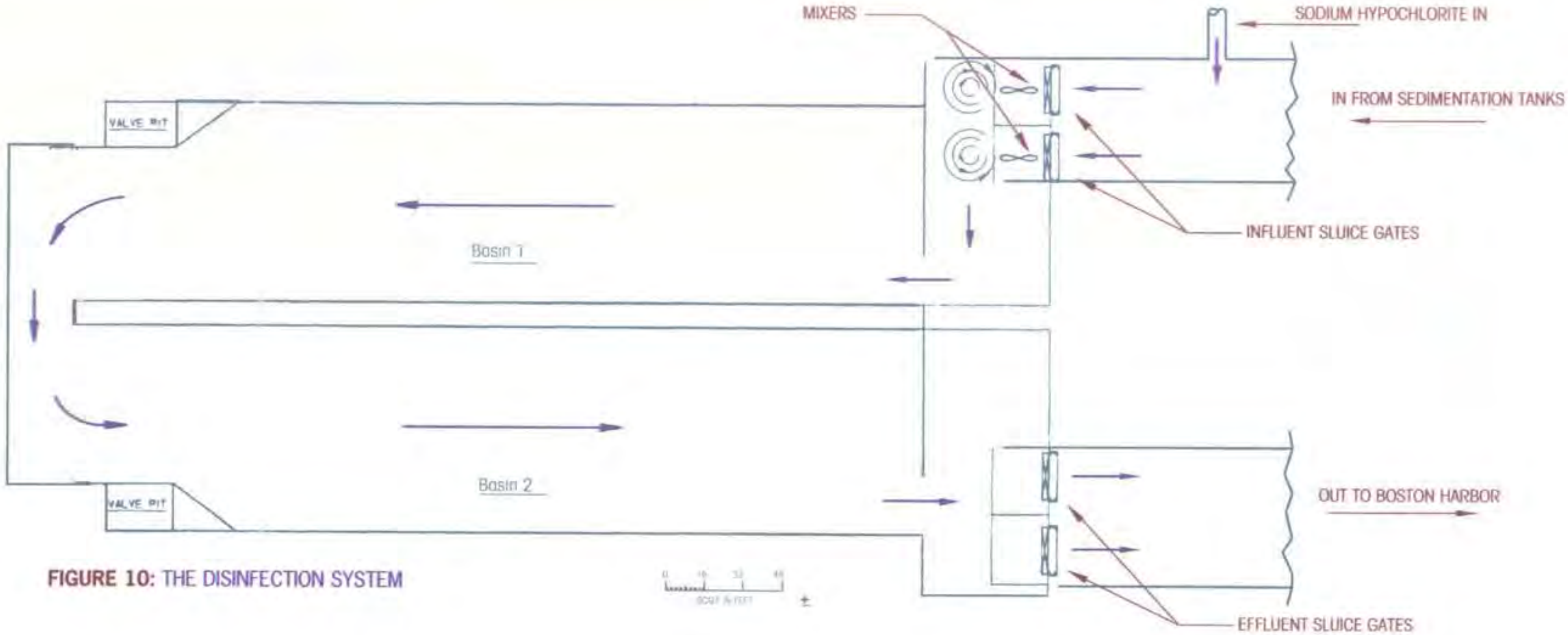


FIGURE 10: THE DISINFECTION SYSTEM

operators must actively manage the digestion process to maintain maximum efficiency. The old Deer Island digesters had problems with accumulated grit, scum, and poor mixing, and were overburdened with too much sludge volume. One symptom of a malfunctioning digester is that the sludge becomes acidic. Chemical "antacids" such as lime and soda ash are often used to neutralize these acids. The old digesters required over 25,000 pounds of soda ash in a year—the equivalent of an antacid tablet 13 feet in diameter and five feet thick! The new digesters have performed very well to date and have not required this treatment.

The new digesters are designed to handle both scum and sludge. The old plant's digesters had inadequate capacity, so until 1988, scum, which requires longer digestion, was discharged directly to Boston Harbor. The resulting unsightly slicks on the Harbor were eliminated in 1988 when scum was landfilled. The new digesters have eliminated the need for landfilling all but a small amount of scum screenings.

Prior to MWRA's opening of the sludge-to-fertilizer plant late in 1991, an even more egregious feature of the old plant was the absence of any disposal location other than the Harbor itself for the digested sludge output of the old digesters. Digested sludge—18 tons per day, on average—was combined with the old plant's effluent for direct discharge into the Harbor. That practice ended entirely in December, 1991. Many of the visible improvements to the condition of Boston Harbor that have been noticed by fishermen, boaters, tourists, and beachwalkers result from nature's recovery from the old plant's scum and sludge treatment limitations and disposal practices.

The new digesters have greatly improved methane gas production. Problems at the old plant's digesters led to a 10-year halt in gas production, increasing fuel costs by about $1,000,000 per year. The new digesters have been producing about 50 tons of gas per day, and gas production is expected to increase.

5 DISINFECTION: Disinfection destroys disease-causing bacteria and viruses found in sewage that would threaten public health if beaches and shellfish beds were contaminated.

Untreated sewage carries large numbers of potentially disease-causing pathogens originating in human waste that would be a health hazard if discharged into recreational or shellfishing areas. Like most wastewater treatment plants, Deer Island uses a form of chlorine (sodium hypochlorite, the active ingredient in bleach) to disinfect wastewater before discharging. Unfortunately, sodium hypochlorite is toxic not only to microbes but also, in high enough concentrations, to aquatic life. The toxicity of sodium hypochlorite, to say nothing of its high cost, makes it important to minimize the amount of hypochlorite used to obtain effective disinfection.

Solids and organic matter in sewage interfere with the ability of sodium hypochlorite to kill microorganisms. Therefore, the more solids present, the more sodium hypochlorite must be added. An important result of improved treatment, which removes more solids, is that less hypochlorite is required for disinfection.

A second important factor influencing disinfectant use is called contact time. The longer the wastewater is exposed to sodium hypochlorite, the less hypochlorite needs to be used for effective disinfection. At the old plant, sodium hypochlorite was added just before discharge, and the contact time was the time it took the wastewater to travel to the end of the outfalls (about 15 minutes). The new facility uses large disinfection basins (FIGURE 10) which increase the contact time to 30 minutes.

Better solids removal and a modern disinfection system have allowed Deer Island to use about 20% less sodium hypochlorite, saving about $1.2 million from March 1995 to February 1996, and discharging less hypochlorite into the environment.

Most importantly, FIGURE 12 shows that effluent from the new facility has consistently met the permit limits for bacteria (measured as fecal coliform counts) and is protecting the public health.

6 ODOR CONTROL: Odorous hydrogen sulfide gas is removed by chemical "scrubbers."

As wastewater flows to and through a sewage treatment plant, bacteria start to decompose the organic materials in the wastewater, producing hydrogen sulfide (which smells like rotten eggs) and other unpleasant odors. These gases accumulate and are released into the air during the treatment process.

In the old plant, the primary settling tanks were outdoors, uncovered, allowing odors to escape freely into the air. To contain these gases, the new primary settling tanks at Deer Island are enclosed. Hydrogen sulfide and other gases are directed to an odor control facility and, in a process called chemical scrubbing, are exposed to chemicals that oxidize the gases so as to eliminate the odor. For any gases that escape the scrubbers, or for occasional volatile organic compounds (air pollutants), carbon bed absorption filters have also been installed as a final step in the air quality control at the plant (FIGURE 11).

There are five new odor control facilities planned for Deer Island, three of which are now in operation. Thus far, the system has performed reasonably well, considering that the volume of hydrogen sulfide gas has been higher than anticipated. After a few initial

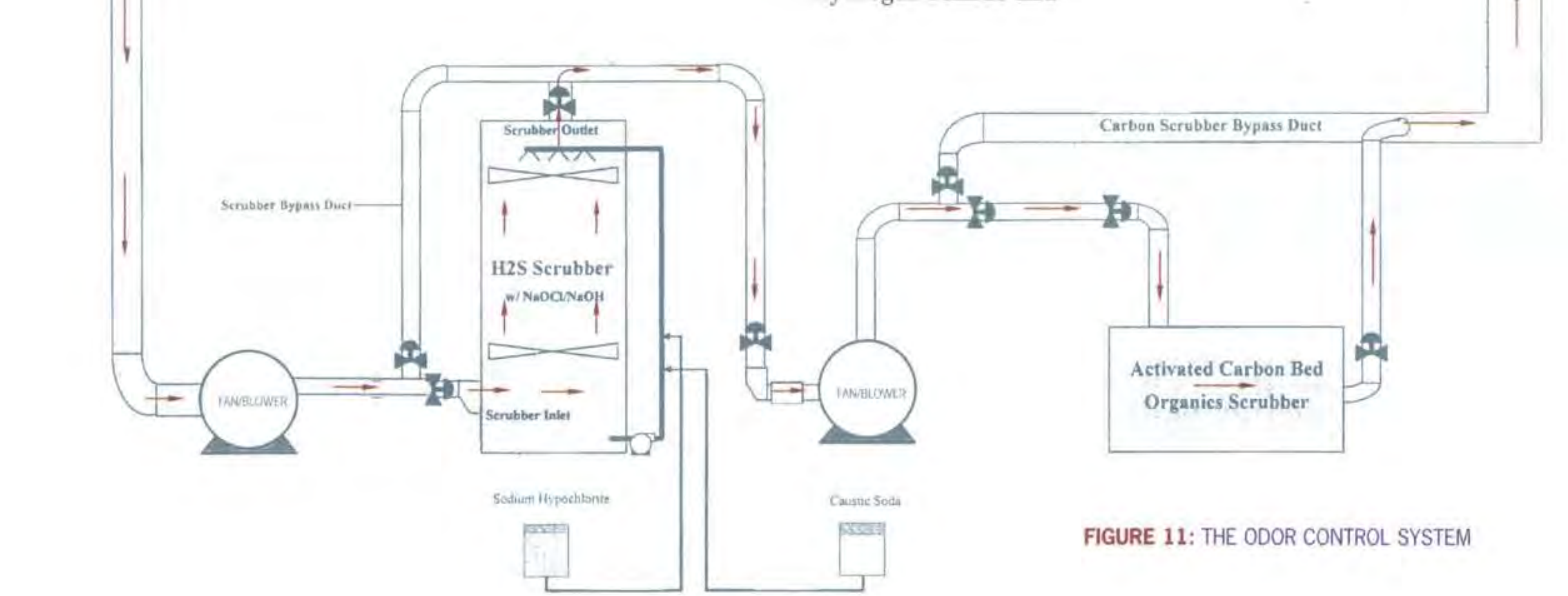


FIGURE 11: THE ODOR CONTROL SYSTEM

modifications, the plant has been able to remove more than 99% of the hydrogen sulfide released during the treatment process.

SECONDARY TREATMENT ON THE HORIZON

Secondary treatment uses a biological process to increase the removal of organic pollutants from wastewater, producing an even cleaner effluent.

Scheduled for initial start-up of about 20% of its process elements beginning late in 1996, secondary treatment will significantly improve the quality of Deer Island effluent. Table 2 shows that secondary treatment removes even more pollutants from wastewater than primary treatment.

In the new plant, wastewater will go through primary treatment, followed by secondary treatment and disinfection before the effluent is discharged. While primary treatment is a simple physical process using gravity to settle out solids, secondary treatment is quite different: bacteria are used to break down and consume pollutants remaining after primary treatment. At Deer Island, secondary treatment will be a two-step process: first the wastewater will be aerated to promote the growth of bacteria, and then the resulting bacterial solids will settle and be removed from the effluent. The secondary treatment method to be used at Deer Island is called an activated sludge process.

TABLE 2: COMPARISON OF PRIMARY AND SECONDARY TREATMENT

Pollutants	Primary Removal	Secondary Removal
TOTAL SUSPENDED SOLIDS (TSS)	50-60%	85%
BIOCHEMICAL OXYGEN DEMAND (BOD)	25-40%	85%
TOXIC CONTAMINANTS	0-50%	50-90%

AERATION: In the secondary "reactors" primary effluent will be mixed with pure oxygen. Primary effluent contains two ingredients used in secondary treatment: organic matter and billions of bacteria. The oxygen encourages bacteria to multiply, and the bacteria feed on the organic matter and break down many pollutants. Certain strains of bacteria beneficial to treatment are favored to grow during this process. As the bacteria grow, they form clumps called flocs. These flocs are a mixture of bacterial cells and waste particles sticking together. During aeration bacteria consume many pollutants and incorporate inorganic particles that aren't actually consumed into the flocs.

SECONDARY SETTLING: After aeration, the mixture of bacteria and effluent is transferred to settling tanks, the "secondary clarifiers." Here, the flocs of bacteria and most of the pollutants settle to the bottom of the tanks. The bacteria are sticky and particles of pollutants attach to the bacteria as they settle, removing more contaminants from the wastewater. This mixture of bacteria and particles is secondary sludge. Much of this secondary sludge will be removed and digested in the egg-shaped digesters, but some secondary sludge, now rich in beneficial bacteria, will be returned to the aeration tanks. Here, the bacteria will mix again with more primary effluent and oxygen to grow and consume pollutants in a continuous cycle: the "return-activated-sludge" process.

The first battery of secondary treatment at Deer Island will treat most of the Deer Island flow. The second and third batteries, scheduled to start-up in 1997 and 1999 respectively, will be able to provide secondary treatment to both Deer Island flow and the flow from the South System now treated at Nut Island.

The environmental benefits of secondary treatment are a dramatic reduction in pollution loadings to the ocean, and a cleaner effluent that will require less hypochlorite to disinfect.

HIGH BACTERIA COUNTS IN DEER ISLAND EFFLUENT HAVE DRAMATICALLY DECREASED SINCE 1988

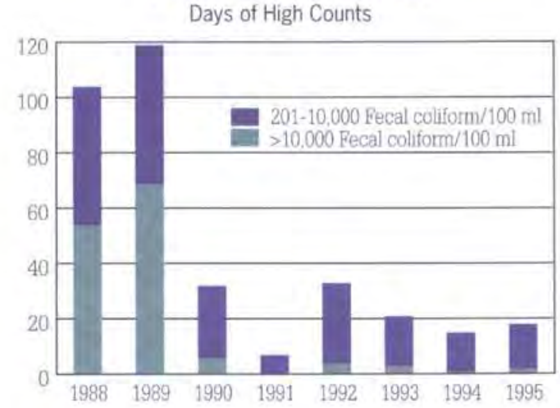


FIGURE 12: This figure shows the number of days from 1988 to 1995 that average fecal coliform counts in Deer Island effluent were higher than the standard of 200 per 100 ml. Two categories of high counts are shown: days when fecal coliform counts were greater than 200 but less than 10,000; and days when fecal counts were greater than 10,000. For comparison, fecal coliform counts in undisinfected effluent average about 5,000,000 per 100 ml.

Because the dilution in the ocean at the Deer Island outfalls is about 20-fold, if effluent counts are 10,000 or less the water quality standard (200) will be met not far from the outfalls, and effects on beaches and shellfish beds will be minimal. However, when bacteria counts in the effluent are very high, over 10,000 per 100 ml, beaches and shellfish beds can be affected. The figure shows that after 1990, the number of days counts exceeded 200 dropped dramatically from more than 100 days per year to less than 40 days per year. Most important for environmental quality is the virtual elimination of days when fecal coliform counts were extremely high: from 69 days 1989 to only 2 days in 1995.

SEWAGE POLLUTION IN BOSTON HARBOR

THE SEWAGE TREATMENT improvements described in the previous chapter have the goal of improving the quality of effluent released into the harbor; MWRA has worked to ensure that these legally-required improvements are cost-effective. This chapter looks at how Boston Harbor has responded to past efforts, and how it may change after recent and future plant improvements. Table 3 summarizes how better sewage treatment will help in the Harbor's recovery.

Although untreated (raw) sewage is over 99% water, it contains numerous forms of waste, mostly human in origin, that need to be removed or otherwise treated before the wastewater can be safely discharged. In the following sections, the major targeted pollutants in sewage are described.

A PATHOGENS: The term pathogens refers to the potentially disease-causing viruses and bacteria that abound in raw sewage.

If not removed by treatment, many of these pathogens can survive in seawater for days or weeks. Sewage-derived pathogens can pose a serious health threat to people who come in direct contact with contaminated seawater by swimming or boating, and to people who consume contaminated shellfish.

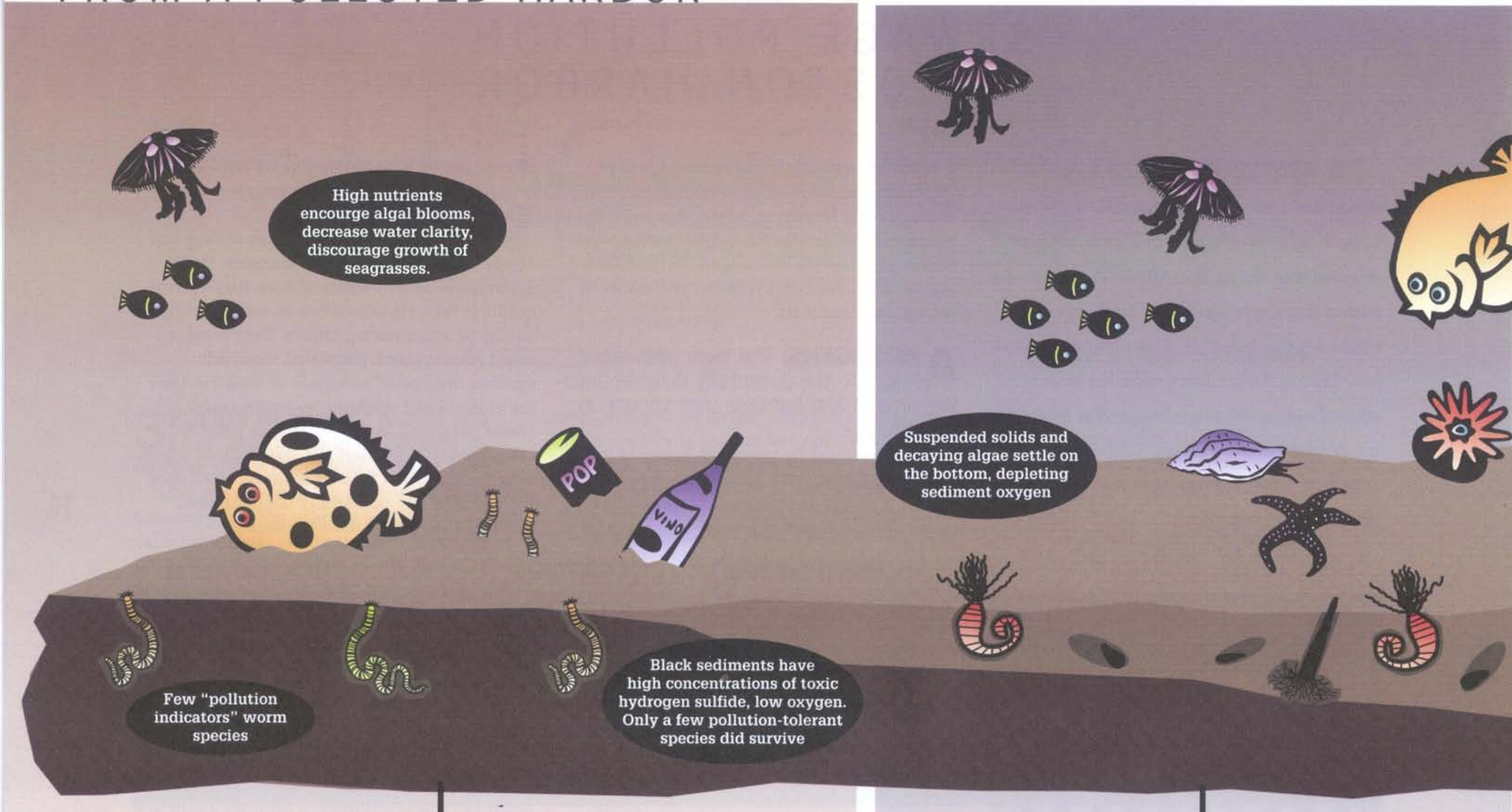
Since pathogens can pose a risk at very low levels which are difficult to measure, their presence is usually inferred from that of fecal coliform bacteria which can be measured more easily. If a monitoring agency finds fecal coliform counts above permitted standards, beaches are posted as unsafe or shellfish beds are closed until coliform levels decrease. All clams harvested in Boston Harbor must be "depurated"—cleansed at a state facility where they are placed in filtered seawater until they have passed any potentially contaminated material that was in their stomachs.

TABLE 3. POLLUTANTS TARGETED BY SEWAGE TREATMENT

Pollutant in Sewage	What it Is	What it Does	Better Treatment Reduces this Pollutant
A PATHOGENS	Disease-causing viruses and bacteria (indicated by fecal coliform).	Unsafe swimming, boating, and shellfishing.	Disinfection; longer holding time will more reliably kill pathogens.
B TOXIC CONTAMINANTS	Heavy metals such as copper and lead; PCBs, pesticides, petroleum hydrocarbons.	At high doses, can be toxic to marine animals and carcinogenic to people.	New primary settling tanks have removed more contaminant solids; industrial pre-treatment programs.
C ORGANIC MATERIAL (BOD)	Food residues, human waste, plant matter. Can be dissolved, solid, or liquid.	Uses up oxygen as it decays; large amounts can deplete dissolved oxygen in the Harbor.	New primary settling tanks have increased BOD removal; more will be removed with secondary treatment.
D TOTAL SUSPENDED SOLIDS (TSS)	Mix of organic particles, silt, and sand suspended in the water.	Clouds water; toxic contaminants adhere to solids which eventually settle to bottom; can smother bottom-dwelling marine life.	New primary settling tanks have increased solids removal; more will be removed with secondary treatment.
E NUTRIENTS	Nitrogen, phosphorous; act as plant fertilizers.	Can cause excessive growth of phytoplankton in the Harbor, which depletes oxygen when it decays.	Primary or secondary treatment does little to remove dissolved nutrients. Greater dilution in Massachusetts Bay will reduce nutrients to background levels.
F FLOATABLES	Floating debris: plastics, condoms, tampon applicators, oil and grease.	Unsightly slicks are aesthetic pollution of the Harbor.	Preliminary treatment/screening; pumping improvements decrease combined sewer overflows which carry floatables into the Harbor.

FIGURE 13

FROM A POLLUTED HARBOR



1985-1990

Deer Island and Nut Island treatment plants discharged primary treated effluent and digested sludge (including scum) into Harbor. Poor pumping capacity at plant caused frequent CSOs in rainstorms. Disinfection failures at treatment plants not uncommon in 1985 and 1986.

Discharges of BOD, solids, nutrients caused low oxygen in some Harbor sediments, preventing normal plant and animal communities from living on bottom. Toxic chemicals in sewage and road runoff probably caused high rates of liver disease in flounder. High PCB levels in lobster tomalley.

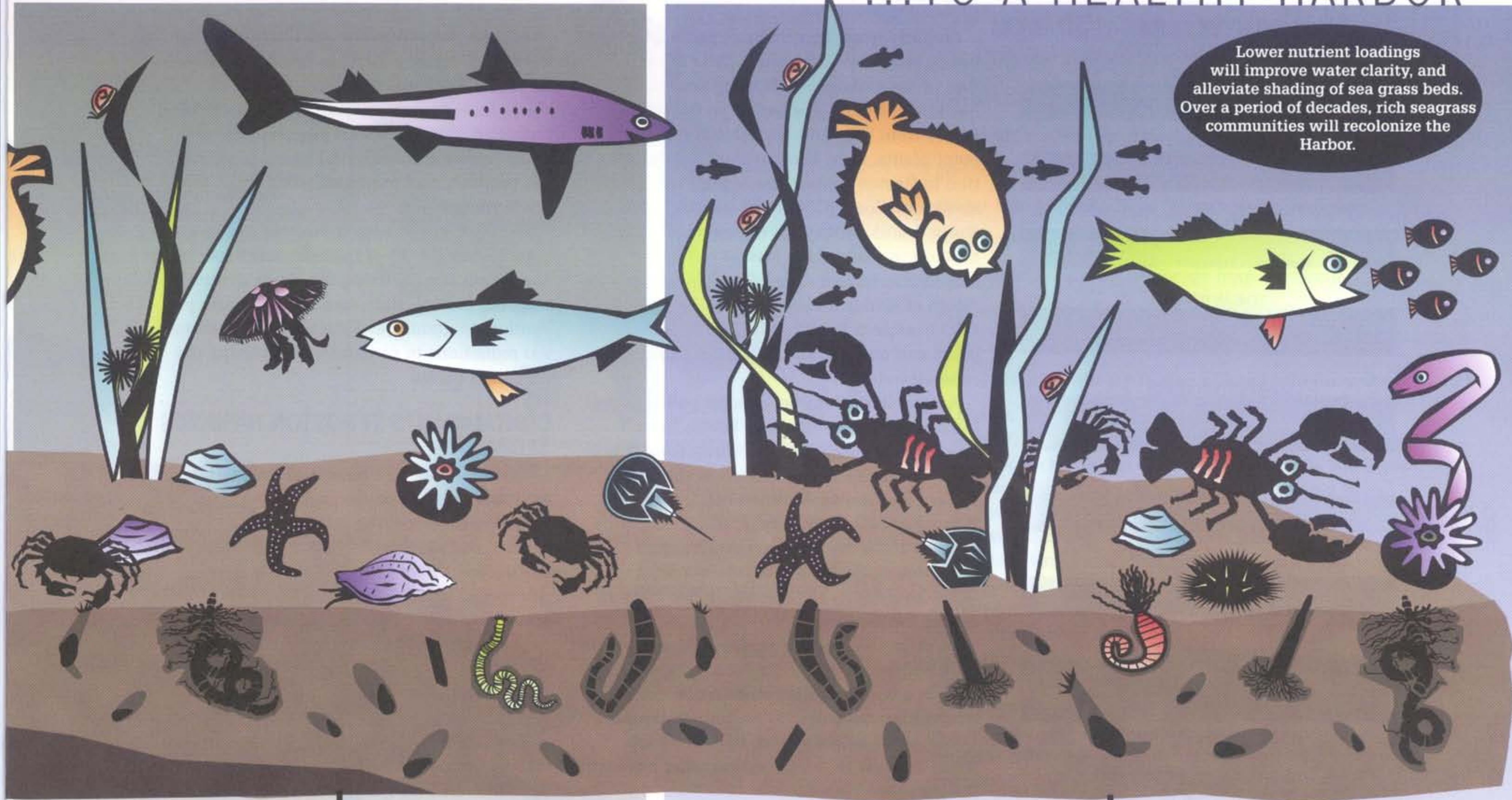
1990-1995

Source reduction programs reduce discharges from industry into sewers, so toxic discharges from treatment plants were reduced by 31%.

Sludge and scum discharges cease at the end of 1991, significantly lowering inputs of BOD and solids. Pumping improvements and better maintenance mean fewer CSOs.

Bottom-dwelling communities begin to reappear at areas heavily affected by sludge. Liver disease in flounder dramatically decreases.

...TO A HEALTHY HARBOR



1995-2000

New primary treatment plant on Deer Island opens in 1995, with improved removal of solids and BOD and improved disinfection. Secondary treatment begins in 1997, dramatically changing solids and BOD loading to Harbor. Water clarity improves. Inter-Island tunnel and outfall tunnel completed. Nut Island decommissioned so discharges to Quincy Bay and Hingham Bay cease.

Bottom-dwelling communities continue gradual recovery, becoming more diverse, sediment oxygenation continues to improve.

2000-2005 and beyond

Full secondary treatment completed. All sewage treatment plant discharges to Boston Harbor cease.

Ecosystem recovery continues with diverse communities of plants and animals returning to Harbor. Contaminated sediments gradually buried under cleaner sediments, and bioaccumulation of toxic chemicals abates in the Harbor.

Although not pristine, most of Boston Harbor will be an example of a normal New England coastal ecosystem.

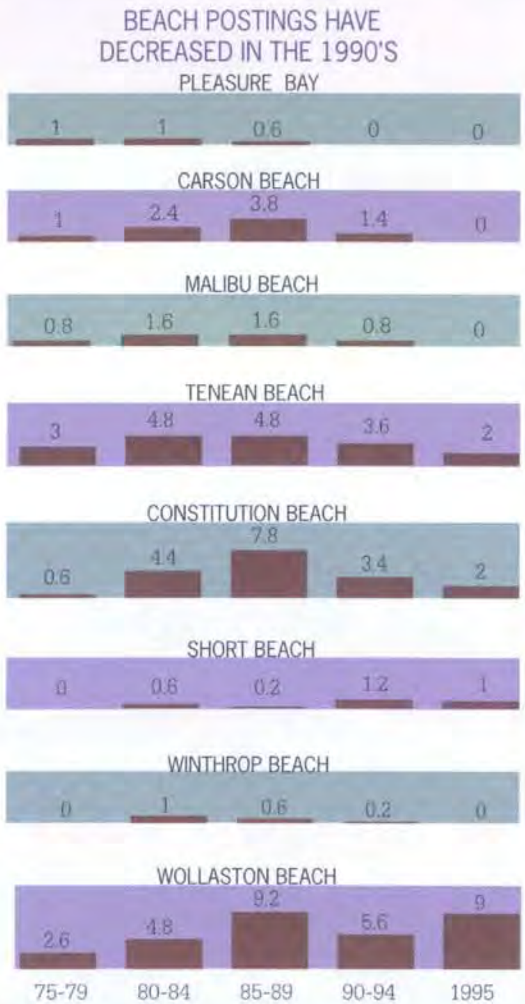


FIGURE 14: The graph shows the average number of beach postings for four five-year periods (since 1975) and for 1995 for MDC Boston Harbor beaches. Different beaches varied greatly in the number of postings, but a general pattern is clear. The numbers of postings were low in the 1970s and increased during the 1980s. During the 1980s the sewerage system, including pumping capacity at the Deer Island plant, was deteriorating.

During the 1990's, interim improvements at the treatment plants, the cessation of sludge dumping in the harbor, construction of three CSO treatment facilities, and increased community attention to local sewer contamination problems had the cumulative effect of improving water quality at beaches.

In 1995, there were only a few beach postings, in part because of lower than normal rainfall, although Wollaston Beach continued to have pollution problems due to contaminated storm drains.

Properly treated wastewater poses little health risk from pathogens. Only a small fraction of the pathogen-indicating fecal coliform bacteria currently discharged to the Harbor comes from Deer and Nut Island sewage treatment plants. Most fecal coliform contamination in Boston Harbor comes from combined sewer overflows (CSOs) and contaminated storm drains. Today's lower average levels of bacteria in areas of the Harbor reflect the cumulative impact of improved pumping, cessation of sludge and scum discharges, new CSO treatment facilities, better maintenance of pipes and outfalls, and improved disinfection of wastewater.

Among Boston Harbor's major public attractions are its miles of sandy beach, from Constitution Beach and Winthrop town beaches on Winthrop Bay to Wollaston Beach in Quincy and numerous town beaches in Weymouth, Hingham, and Hull.

Since 1973, the Metropolitan District Commission (MDC) has monitored fecal coliform levels at its beaches in Boston Harbor during the summer swimming season and used these data to determine whether or not to post beaches as unsafe for swimming (FIGURE 14). The beach data illustrate water quality trends from the early 1970s through the early 1990s, when sewer system improvements began to show in decreased bacterial levels in the Harbor.

B TOXIC CONTAMINANTS: Some chemicals found in sewage can, in high enough concentrations, kill or injure sensitive marine organisms.

These contaminants can accumulate in sediments or in the marine food chain to toxic levels, and pose a threat to human health through the contamination of seafood. Certain toxic chemicals are defined by the Environmental Protection Agency (EPA) as priority pollutants and their discharge is strictly regulated. These include heavy metals, PCBs, pesticides, and other chemicals such as polycyclic aromatic hydrocarbons (PAHs) found in petroleum products and produced when fossil fuels are burned.

The best way to keep industrial and household chemicals out of treated wastewater is to keep them from entering the waste stream. Ongoing federal, state, and MWRA waste prevention programs have already led to substantial reductions in contaminants entering the treatment plants.

CONTAMINANTS IN BOSTON HARBOR'S SEDIMENTS

Contaminants can remain in the marine environment for decades, and Boston Harbor is only slowly recovering from many years of unregulated discharges through sewers, storm drains, and direct commercial or industrial discharge. In the mid-1980s, the Harbor's sediments contained such high levels of contaminants that it was labeled the "dirtiest Harbor in the nation."

IMPROVING CONDITIONS

Even though change is slow, there are indications of improvement in parts of the Harbor. Several recent studies strongly suggest that, as contaminant inputs decline, sediments are already beginning to cleanse themselves. The most noteworthy of these is a study in which U.S. Geological Survey researchers have collected and analyzed surface sediments at four Harbor sites three times since 1977. At these sites, the concentrations of heavy metals decreased between the late 1970s and 1993 (TABLE 4). Other recent studies have confirmed these results, both for metals and for organic contaminants. In 1993, U.S. National Oceanic and Atmospheric Administration research confirmed that sediment contamination and toxicity remains a problem in Boston Harbor sediments. On average, the Inner Harbor contains the most contaminated sediments with concentrations in the Outer Harbor lessening from Dorchester and Winthrop Bays to Quincy Bay. The lowest contamination levels are found in Hingham and Hull Bays.

CONTAMINANTS IN MARINE ORGANISMS

Small animals and bottom-feeders that live on or in the seafloor ingest contaminants in the sediments. Since these organisms are prey for fish and shellfish, the contaminants they contain can become concentrated in the bodies of larger animals. Also, many organisms can absorb these toxic chemicals through the skin. Some sensitive species may not be able to live in sediments with high contaminant levels.

Overall, recent measurements of the levels of contaminants in lobster and winter flounder and the effects of contaminants upon the health of these bottom-feeders mirror the results of the sediment studies, showing recent improvement but remaining contamination.

TABLE 4: DECREASES IN HEAVY METALS AT FOUR SITES IN BOSTON HARBOR, 1977-1993.[1]

Metal	Decrease[2]	Range[3]
CHROMIUM	54%	40-68%
COPPER	31%	21-41%
LEAD	46%	37-55%
MERCURY	37%	24-50%
SILVER	33%	16-50%
ZINC	44%	26-62%

[1]Data and analysis are from Bothner et al. (1996).

[2]Average percent decrease in metals at the 4 sites from 3 surveys between 1977 and 1993, as estimated by an analysis (regression) of metals changes.

[3]The ranges in percent decrease show the margin of error around the analysis.

PCBS IN LOBSTER TISSUES HAVE DECREASED SINCE 1987

Total PCB's parts per million wet weight

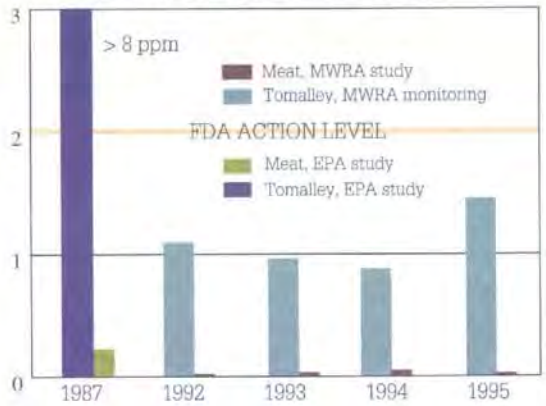


FIGURE 15: Concentrations of polychlorinated biphenyls in Boston Harbor lobster have decreased over the past decade, particularly in lobster hepatopancreas (tomalley). The use of PCBs was banned in the early 1970s. The 1987 data are from an EPA study of contaminants in lobster from Quincy Bay; 1992- 1995 data are from MWRA monitoring. There are no data for 1991. There are several analytical differences between the EPA study and the ongoing MWRA monitoring (which is consistent with other current national programs). Because of these and other differences between the studies, the apparent decrease in PCBs must be interpreted with caution.

LOBSTER: The American lobster sustains a major commercial fishery along the entire New England coast. More lobster are caught in and around Boston Harbor than anywhere else in Massachusetts. In 1990, more than 5 million pounds of lobster were caught in the Harbor, contributing more than $13 million to the local economy.

Because lobsters hunt and scavenge their food from the seafloor, they are exposed to contaminants from the sediments. Contaminants in lobster tissue have been measured by MWRA since 1992. Although Boston Harbor lobsters have somewhat higher levels of contamination than lobsters caught in Massachusetts and Cape Cod Bays, these contaminant levels have declined significantly since the mid-1980s when the state issued a public health advisory against consuming lobster tomalley or hepatopancreas (FIGURE 15). This liver-like organ breaks down or stores toxic contaminants and, because it is an important fat storage organ, accumulates higher concentrations of fat-soluble contaminants like PCBs than the leaner tail and claw meat of the lobster.

WINTER FLOUNDER: Winter flounder have long been a mainstay of the commercial and recreational fisheries in Boston Harbor and Massachusetts Bay. Houghs Neck in Quincy, once home to six boat rental businesses, was known as the "flounder capital of the world."

Like lobster, flounder live and feed on the sea floor, making them vulnerable to contaminants in sediments and in the small seafloor organisms they eat. As with lobster, contaminants in flounder concentrate in the liver. Contaminant levels are generally so low in the flounder's lean filet, even in fish from Boston Harbor, that the meat poses no significant health risk to humans. However, the contaminants in the liver of the Harbor flounder caused the fish to develop several types of diseases or lesions, and served as a warning of excessive Harbor contamination.

In the mid 1980s, the U.S. National Marine Fisheries Service found that most of the flounder in Boston Harbor showed fin rot, 8% had liver tumors, and almost 70% had minor lesions associated with exposure to contaminants. These results helped focus public attention on the problem of pollution in Boston Harbor.

Since the 1980s, the improving health of flounder has been associated with the major

POLLUTION-RELATED LIVER DISEASE HAS DECLINED IN BOSTON HARBOR FLOUNDER

Percent of Deer Island flounder with disease

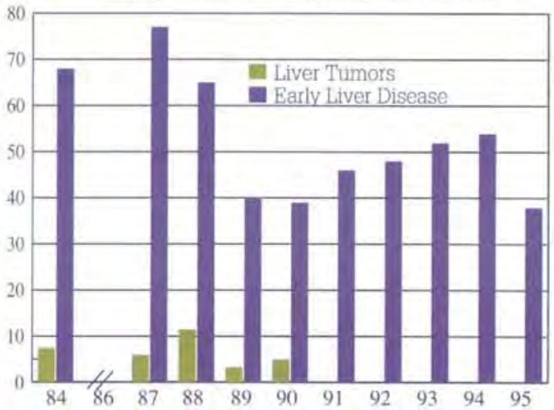


FIGURE 16: Flounder liver disease has declined since the mid-1980s and liver tumors have not been seen since 1991. The early liver disease is a condition called centrotubular hydropic vacuolation, a non-life-threatening condition linked to an animal's exposure to chlorinated hydrocarbons (pesticides and/or PCBs). Data are from a 1984 NOAA study, research by Woods Hole investigators, and from ongoing MWRA monitoring.

reductions in contaminant discharges to Boston Harbor. Woods Hole scientists have found that the numbers of fish showing mild, contaminant-associated liver disease dropped from about 70% of the population before 1989 (when sludge was being dumped in the Harbor) to less than 50% in the following years. Similarly, liver tumors, the most serious contaminant-related disease, declined from about 10% of the flounder population before 1989, to about 4% between 1989 and 1991, to zero in the years since (FIGURE 16). However, Harbor flounder continue to show more signs of contaminant-associated lesions than do flounder from Massachusetts and Cape Cod Bays.

C OXYGEN-CONSUMING ORGANIC MATTER: Once in the Harbor, some components of sewage decay and use up dissolved oxygen (DO).

Aquatic animals need adequate DO in the water to breathe. The amount of DO used up by wastewater as it decomposes is called Biochemical Oxygen Demand (BOD). By removing the majority of the settleable solids from wastewater, primary treatment causes a substantial reduction in BOD. Thus, the increased solids removal at the new Deer Island primary plant resulted in a small but significant decrease in BOD in the effluent.

Low DO is most problematic in the summer because (1) warmer water can hold less oxygen than colder water, (2) the process of decay is more rapid, and (3) the population of aquatic organisms increases and is more active. Bottom waters tend to have lower oxygen levels than surface waters, where oxygen can be absorbed directly from the air. In extreme situations, all the DO can be used up (anoxia), causing fish kills.

While dissolved oxygen levels in Boston Harbor rarely get to zero, DO is frequently lower than the state standard of 5 parts per million, especially in water near the seafloor. In the summertime, low DO in bottom water is particularly frequent in the narrow channels of Boston's Inner Harbor. Dissolved oxygen violations in Boston Harbor over the past 6 years have shown no improvement (FIGURE 17).

D SUSPENDED SOLIDS: These solids are a mix of silts and organic waste particles.

These small particles, tinier than grains of sand, give raw sewage its cloudy, opaque appearance. Suspended solids can have a direct effect on the Harbor by increasing its turbidity (clouding the water), and they are also of concern because of the BOD and/or contaminants they can carry. When these particles settle out onto the sea floor, they can lead to lower DO and contaminate the sediments with toxic chemicals. In extreme circumstances, such as in the vicinity of a sludge discharge, solids can build up so quickly they smother the animals that live on or in the sea floor sediments.

The main goal of primary treatment is the removal of solids. Startup of the new primary treatment plant resulted in a significant reduction in the discharge of these solids to the Harbor. Further substantial reductions in the discharge of solids will occur with secondary treatment, which removes the smaller, so-called "colloidal" solids from effluent; with the transfer of Nut Island flows to the new Deer Island plant; and with the improved diffusion of effluent in Massachusetts Bay in 1998.

SUMMERTIME DISSOLVED OXYGEN VIOLATIONS IN THE INNER HARBOR

Percent of samples not achieving 5mg/l criterion

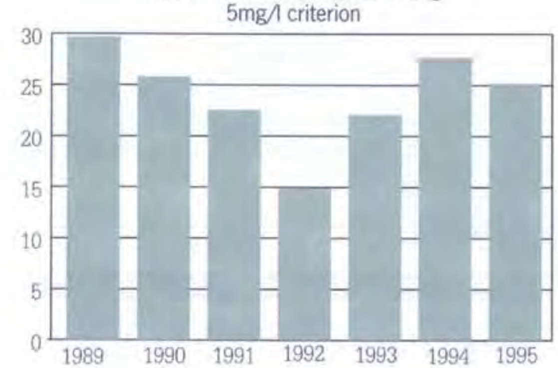


FIGURE 17: Limited river flow into the Inner Harbor combines with BOD inputs, sluggish tidal circulation and high oxygen usage to deplete the bottom waters of oxygen. The bars show the percent of near-bottom DO measurements at Inner Harbor monitoring stations below the state standard. Samples were taken when water temperature exceeded 15 degrees Celsius.

GRADIENTS OF WATER CLARITY IN BOSTON HARBOR

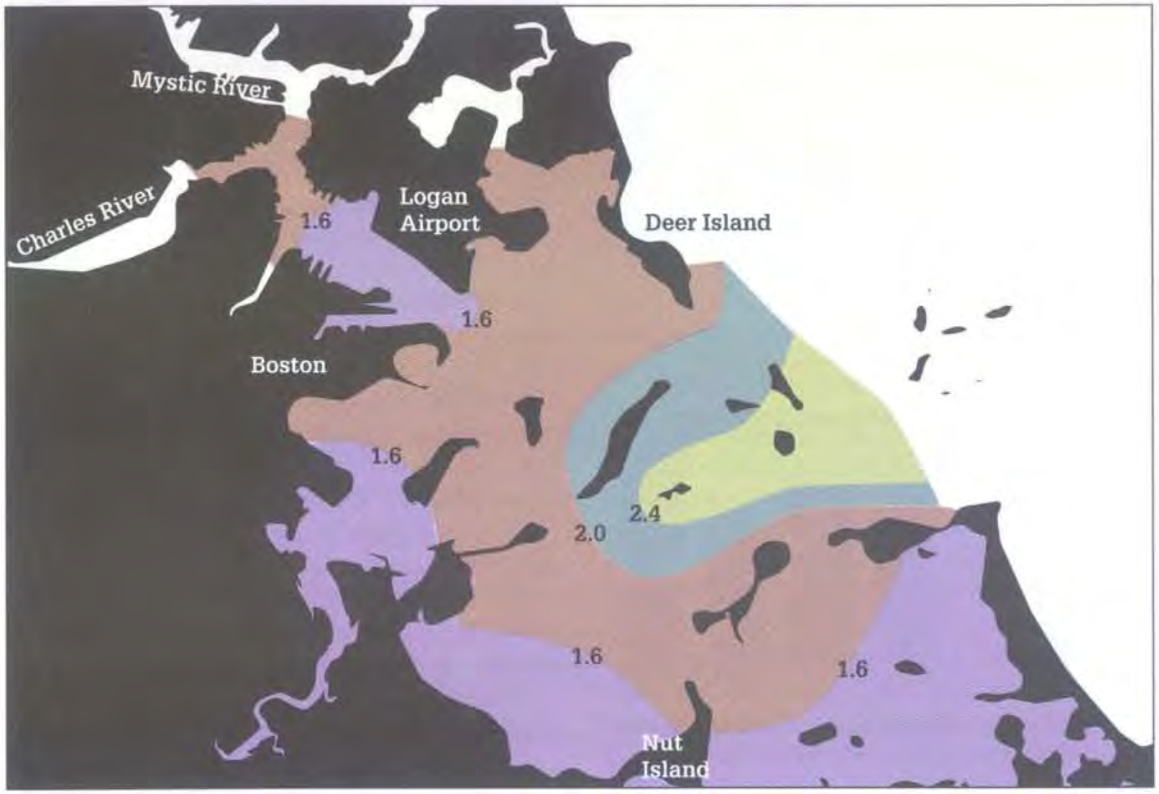


FIGURE 18: On average, water clarity increases from the Harbor's shallow embayments to the deeper ocean out in Massachusetts Bay. Values on the map are depths (meters) of disappearance of a standard white "Secchi" disk lowered into the water, and are average summer values (June-October), 1993-1994.

SOLIDS POLLUTION AND WATER CLARITY

Water clarity determines how the public perceives and therefore uses the Harbor--nobody wants to swim or dive in cloudy water. Before December 1991, black plumes of smelly sludge reduced the clarity of the water to zero at the two discharge sites off Deer Island and Long Island (where Nut Island sludge was discharged until 1991). The water surface at the two sites was also marred by opaque slicks and foam caused by the floating scum discharged with the sludge. Since these discharges stopped, the visible pollution at these sites has disappeared. To date, this has been the greatest improvement in Boston Harbor's water clarity.

Water clarity also determines the extent and depth of light penetration into the water, which in turn affects the growth of ecologically important species of plants, including seagrasses. Not only are seagrasses important habitats for a wide variety of bottom-dwelling fish and invertebrates, their roots also play a role in improving water clarity by helping to bind soft bottom sediments that are otherwise easily stirred up.

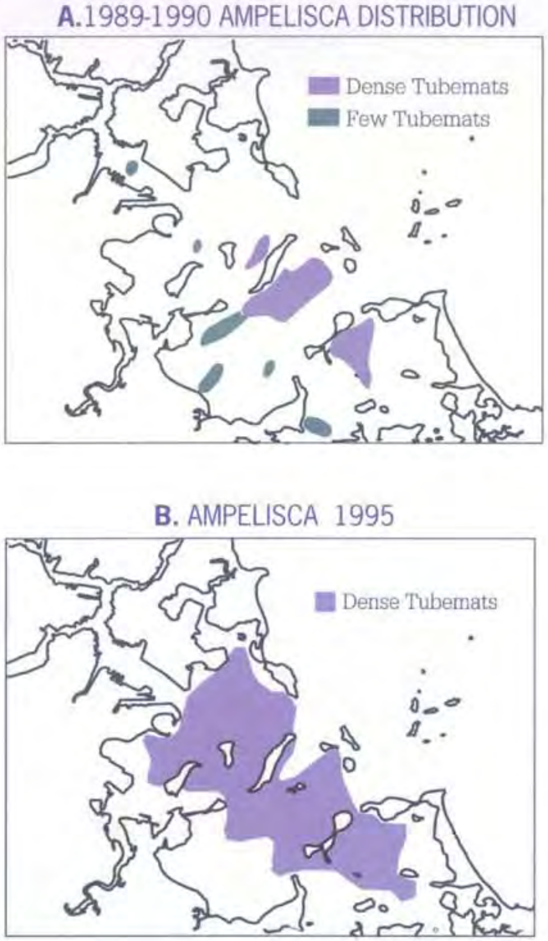
Various factors affect water clarity in Boston Harbor such as concentrations of suspended particles, floating algae (or phytoplankton), and dissolved materials in the water. These solids may occur naturally or enter the Harbor in sewage effluent. The water clarity varies from region to region, being greatest at the mouth of the Harbor where exchanges with the clear water of Massachusetts Bay are greatest, and lowest in the shallow embayments (such as Dorchester and Quincy Bays) where bottom sediments can be stirred up into the water by wave action (FIGURE 18).

Many observers, from marina owners to lobstermen, report improved water clarity throughout the Harbor in 1995. In Boston Harbor, water clarity varies naturally from day to day as sediments are resuspended by strong currents and waves, floating algal blooms appear, and rivers bring in dissolved materials. Because of this natural variability, the routine water clarity monitoring of the Harbor that began in 1993 will need to be continued for several more years before any improvements can be verified by scientific measurement.

SOLIDS POLLUTION AND SEAFLOOR COMMUNITIES

Seafloor communities are susceptible to pollutants because (1) they have little mobility, (2) contaminants collect in the sediments, and (3) sewage solids use up oxygen in the sediments.

In the ocean, the communities formed by species of plants and animals that live on or within the seafloor are known as benthic communities. Because these bottom-dwellers are unable to quickly move from their environ-



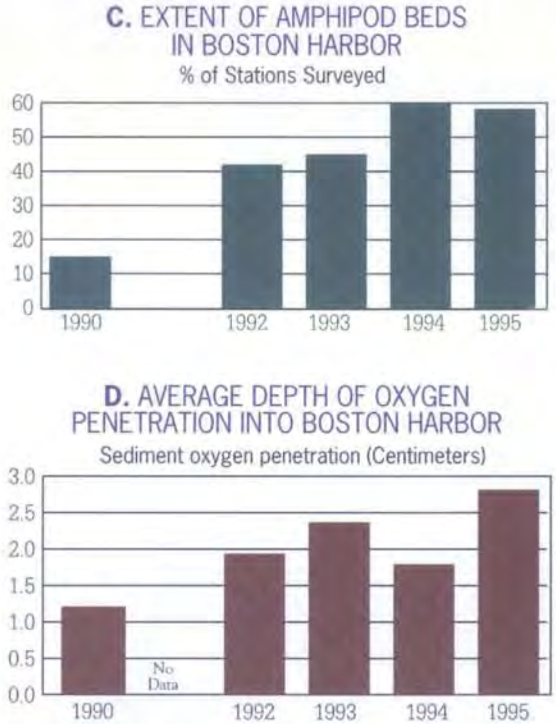


FIGURE 19 (A-D): INCREASE IN AMPHIPODS ON THE HARBOR FLOOR. Boston Harbor's sediment quality has improved enough to be increasingly colonized by shrimp-like amphipods that further extend the depth of oxygenation in the sediments.

ment, they are a sensitive indicator of environmental conditions and are therefore important to the study of ocean pollution.

The tiny worms and shellfish in the benthic community are mainly affected by sewage pollution in two ways. First, toxic pollutants adhere to particles in the water that are then either filtered out of the water by benthic filter feeders or settle to the bottom sediments. Second, the BOD, which also tends to settle on the bottom, can lower sediment oxygen levels when large amounts of it decay, causing stress to the benthic animals.

Studies of Harbor benthic communities made during the late 1970s and early 1980s showed that much of the northern parts of the Harbor was seriously degraded, with very low numbers of a few pollution-tolerant species. The southern parts of Boston Harbor, which were more distant from major sewage discharges and better flushed, had healthier benthic communities.

In more recent years, there have been some improvements in the Harbor's sediments. Although these changes cannot be attributed solely to decreased pollution (major storms and natural cycles can also affect the sediments), they are very encouraging. Since 1991, MWRA's monitoring programs have shown large increases in the numbers and kinds of organisms found near the former sludge discharges, signaling dramatic local recovery. A harbor-wide trend is evident in dense beds of a small shrimp-like amphipod called *Ampelisca*, a food source for winter flounder. *Ampelisca* covered roughly 25% of the Harbor floor in 1989 and 1990 (FIGURE 19A) but increased to more than 60% in 1995 (FIGURE 19B). This amphipod is only moderately pollution-tolerant and is not found in extremely contaminated areas; its growth is likely an indication that the Harbor is recovering from severe pollution (FIGURE 19C).

Ampelisca make tubes in which they live and use to burrow into the ocean floor, further oxygenating the sediments. Thus, the presence of this organism makes the sediments more habitable for other benthic organisms. On average, oxygen penetrates deeper into the floor of Boston Harbor now than when sludge was being discharged, another sign of improving sediment health (FIGURE 19D).

E NUTRIENTS: While nutrients are essential for the growth of plants in the ocean, an excess of nutrients can be damaging.

Nutrients like nitrogen and phosphorous are familiar to many people as the active ingredients in lawn and agricultural fertilizers. In aquatic environments, excessive amounts of nutrients—especially nitrogen—can stimulate the overgrowth of phytoplankton and seaweed.

In poorly flushed systems, blooms of phytoplankton can discolor the water, produce odors, shade out bottom-living seagrasses, and deprive fish and shellfish of oxygen. Despite the fact that Boston Harbor receives large amounts of nutrients from the two wastewater treatment facilities, algal blooms are only a minor problem because the nutrients are added mainly at the mouth of the Harbor which is well flushed.

Boston Harbor shows regional differences in phytoplankton populations with the largest populations occurring in the Inner Harbor which has slower currents and receives inputs of nutrients from the Charles and Mystic Rivers (FIGURE 20).

There is also more algae near Nut Island, presumably because of the nutrient inputs from the Nut Island wastewater treatment facility. No such elevations occur off Deer Island, perhaps because this region is better flushed, and the nutrients are diluted with water from Massachusetts Bay before the algal populations can build up.

At this time, and as would be expected, significant Harbor-wide reductions in algal populations have not been seen. This is because only a small proportion of the nitrogen in sewage is removed by primary treatment.

CONCENTRATIONS OF ALGAE VARY IN BOSTON HARBOR

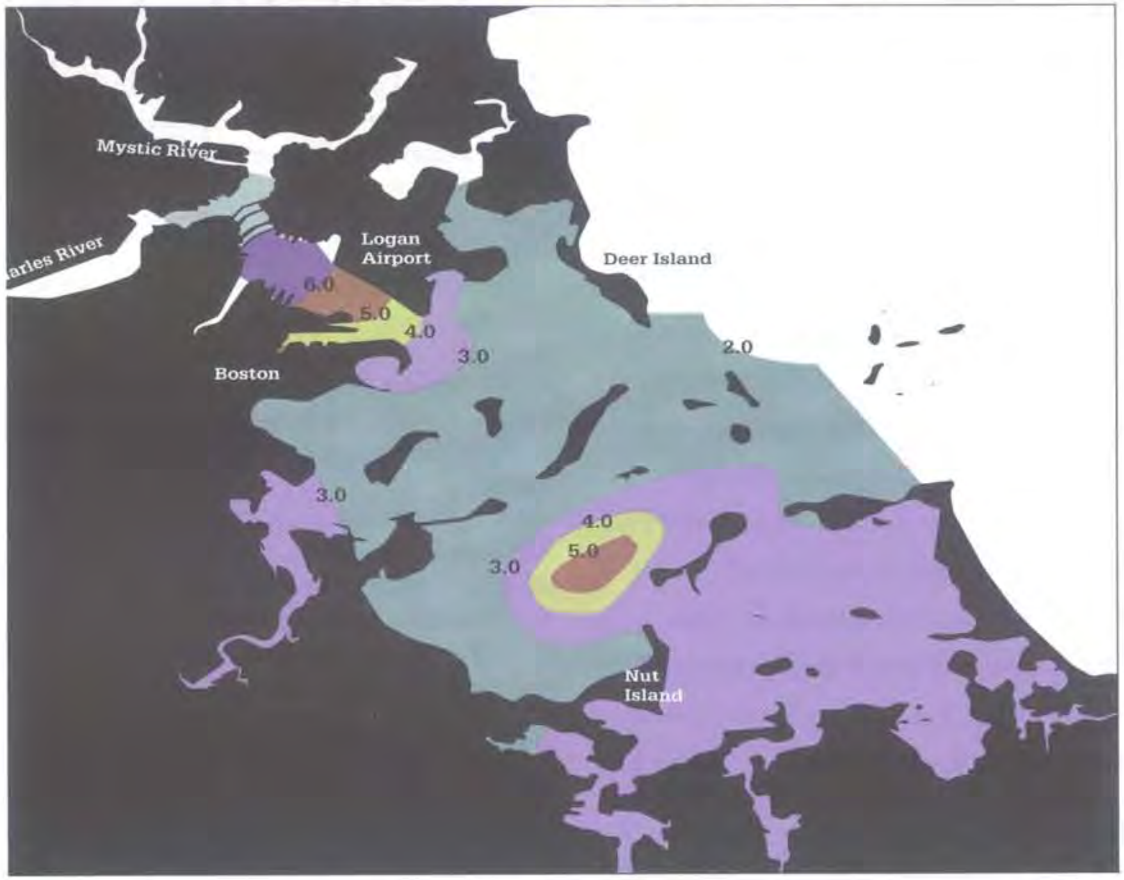


FIGURE 20: Quantities of microscopic floating algae in the Harbor are slightly elevated in the Inner Harbor and off Nut Island, but are generally low in all areas. Values are average summer (June to October) chlorophyll concentrations, 1993-1994. Chlorophyll is a measure of the amount of algae in the water. Units are micrograms of chlorophyll per liter.

FLOATABLES: Plastics and other floating debris cause unsightly slicks on the water.

Floatables are frequently the most visible evidence of polluted water. They include toilet paper, condoms, and tampon applicators, as well as oil and grease. While obviously aesthetically offensive, floatables can include plastic bags or six-pack rings which can entangle or be mistakenly eaten by marine life.

Combined sewer overflows, a major source of floatable pollution, have been greatly reduced in both volume and frequency by an increased pumping capacity at the treatment plants, and better overall sewer system performance. The Interim Improvements to the scum handling facilities and the landfilling of scum instead of mixing it with sludge, greatly reduced the discharge of scum to the Harbor. The removal of sludge discharges in 1991 and the start-up of the new primary plant in 1995 also reduced the amount of floatables entering the Harbor. CSO improvements being phased in over the next ten years will decrease floatables even more.

To complement the decrease in sewage-related floatables, conscientious attention to litter prevention and removal is important to prevent debris from streets or boats from entering the Harbor.

BOSTON HARBOR IN THE YEAR 2005

THE PAST FIVE YEARS have shown reductions in pollutants, and improvements in key environmental quality indicators in Boston Harbor. Over the next five to ten years, the quantities of the pollutants entering the Harbor will be decreased further with secondary treatment, reduced CSO inputs, and relocation of the outfall. With the improved effluent quality and the diffusion of the effluent into the vast bottom waters of Massachusetts Bay, the improvements to the Harbor are expected to be even greater than those observed to date. The following are the types of changes we might expect to see in the Harbor in the years to come.

LESS CONTAMINATION, ESPECIALLY OF THE SEDIMENTS

One of the future changes will be a significant reduction in chemical contamination of the Harbor, especially in its bottom sediments. With continued industrial pre-treatment programs, secondary treatment at Deer Island, and the new effluent outfall tunnel, we expect an 80% reduction in inputs of BOD and toxic chemicals to the Harbor. Less BOD will allow dissolved oxygen levels in the sediments to increase, and bottom-dwelling animals will be able to live and burrow deeper in the sediments. As more animals actively burrow or pump water through the sediments, contaminants will be flushed out to the overlying water and diluted in the ocean. The slow accumulation of cleaner sediments will, over decades, bury remaining contaminants.

CLEARER HARBOR WATER

The Harbor shows a natural cycle—the water is clearer in winter, and less clear in summer. The completion of the secondary treatment process and the relocation of the Deer Island outfall offshore will reduce the quantities of solids entering the Harbor and are likely to further improve water clarity.

Although the factors regulating water clarity are still not well understood, it seems likely that future changes in water clarity will be small to moderate. As with all New England marine systems, the Harbor's water will always contain natural levels of particles from bottom mud and plankton.

LESS SEVERE ALGAL BLOOMS: While we expect the Harbor to still show intermittent blooms of algae, especially in summer, the sizes and duration of these blooms are expected to decrease. Primary and secondary treatments only cause small reductions in the nitrogen in sewage, but the creation of the new outfall offshore is projected to decrease nitrogen inputs to the Harbor by 90%, in turn causing a 50% reduction in the average amounts of algae in the Harbor (Hydroqual 1995). The reductions in blooms are likely to be most pronounced near Nut Island, where there are slightly elevated concentrations of algae.

POSSIBLY SOME UNWANTED ALGAE: One of the consequences of the decreased nitrogen inputs to the Harbor may be the generation of blooms of different forms of algae. Certain algal species can become dominant in systems where the availability of inorganic nitrogen is lowered, a situation that may occur in Boston Harbor when the effluent discharge is removed. One species that can bloom under such conditions is the brown tide organism *Aureococcus* which can harm shellfish and seagrass communities (Nixon et al., 1994). *Aureococcus* blooms have been observed in the last decade in systems such as lower Narragansett Bay, RI, or Peconic Bay, LI., during periods of reduced nitrogen inputs.

A GREATER VARIETY OF ANIMALS AND SEAWEEDS

A healthier ecosystem will be reflected in increased diversity of the animal and plant communities in the Harbor. In a polluted environment, only the few hardiest species of animals and plants can survive. As conditions in the Harbor continue to improve, the number of species living within the system will increase. This increase will be especially visible to divers in the Harbor, but will likely also be apparent to waterfront pedestrians who, at Rowes Wharf or Castle Island, may notice a greater variety of animals and seaweeds on pilings and sea walls.

MARINE MAMMALS: For many people, annual spring and fall sightings of the Harbor seal and Harbor porpoise have become symbolic of Boston Harbor's recovery. Population fluctuations and migration patterns in these larger animals, as with most higher level predators, are generally controlled by availability of prey, cycles of infectious disease, or hunting by humans. The Marine Mammal Protection Act has certainly been the most important factor in protecting the populations of these animals.

In Boston Harbor, we can expect marine mammal populations to follow natural cycles as they do everywhere. Nevertheless, the cumulative effect of improvements in the Harbor for prey species like fish and shellfish should create an increasingly hospitable environment for seals and porpoises.

RETURN OF SEAGRASSES: An additional change that is expected with the new outfall, and may in fact be already underway, is a gradual recolonization of the shallower areas of the Harbor by important seagrass habitats. Research from the EPA and the New England Aquarium has shown that it is likely that seagrasses covered much larger areas of the Harbor in the past than they do today (FIGURE 21). The decline of seagrasses may have been caused by decreased water clarity, growth of algae on seagrass leaves, or disease.

With the predicted decreases in nitrogen and solids inputs to the Harbor, less algae, and increased water clarity (albeit small), seagrass habitats may well recover. In shallow, moderately turbid systems such as Boston Harbor, even small increases in water clarity can greatly increase the area available for seagrass colonization.

The recovery of seagrasses is, however, likely to take decades. Few beds remain in the Harbor to serve as a seed population, and seagrasses release heavy seeds which do not travel long distances. These grasses can also spread by sending out underground shoots (rhizomes), but this too is a very slow process. Colonization rates will depend on whether or not brown tide or equivalent algal blooms occur, and whether artificial transplanting programs are implemented in the Harbor.

BOSTON HARBOR EELGRASS CIRCA 1890 | BOSTON HARBOR EELGRASS CIRCA 1990s

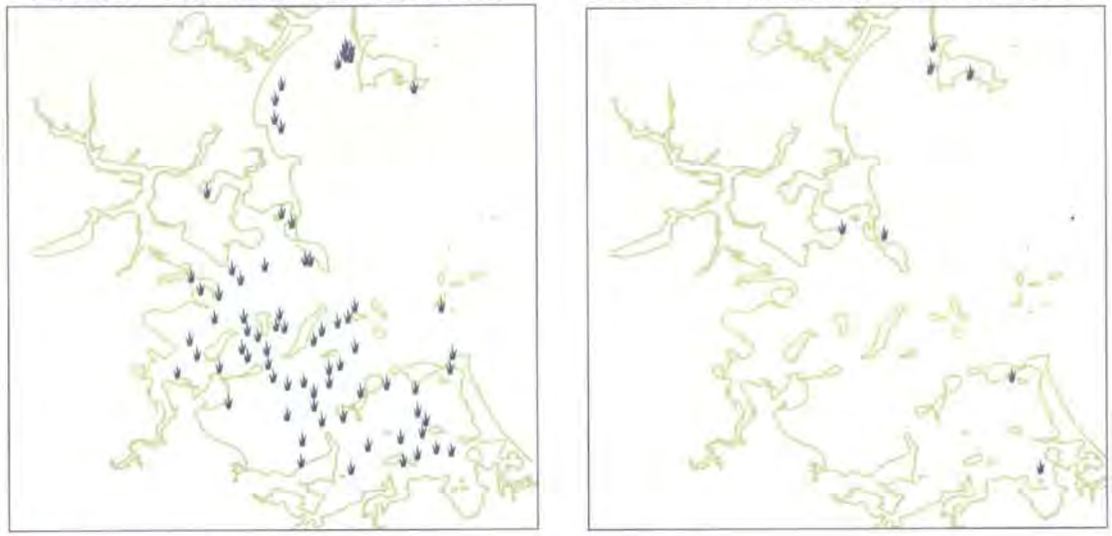


FIGURE 21: HISTORICAL DECREASE OF EELGRASS BEDS IN BOSTON HARBOR
Eelgrass beds dominated the Harbor 100 years ago and may return as the Harbor recovers in the future.

DECREASED THREAT OF LOW DISSOLVED OXYGEN LEVELS

Because of the future decreases in BOD and nutrient inputs to the Harbor, there may be fewer incidents of lowered dissolved oxygen in the bottom waters of the Harbor.

The Inner Harbor is especially susceptible to low DO in its bottom waters because it is relatively deep and has a large input of fresh water from the Charles and Mystic Rivers. In the summer, the water in the Inner Harbor becomes stratified: warmer, fresher, less dense water stays on the surface, preventing the bottom waters from mixing upwards. The bottom water is kept away from the air, and stays in contact with the bottom sediments which deplete the available dissolved oxygen. Average summer DO levels in the bottom waters of the Inner Harbor, now at the minimum standard of 5 mg/L, will increase to more than 6 mg/L according to predictions by computer models.

HEALTHIER FISH AND SHELLFISH

As the inputs of toxic contaminants to the Harbor decrease, and sediments gradually become less toxic, fish and shellfish populations will become healthier. Sediment quality will improve slowly and, because fish diseases can develop three years after exposure to contaminants, a lag time of several years is expected before monitoring shows further improvements in flounder liver diseases.

Although the health of fish and lobster will improve, it is difficult to predict whether their numbers and size will increase over the next ten years. This is because the populations of these animals follow long-term cycles determined in large regions of the ocean distant from Boston Harbor, including the Gulf of Maine. These cycles are governed by natural population fluctuations, climatic changes, and overfishing—none of which can be controlled by activities in Boston Harbor.

IN SUMMARY

One certainty is that in the next five to ten years, the discharges of toxic materials and other pollutants to the Harbor will be a fraction of what they are now. Much of the Harbor, especially the areas offshore near the wastewater treatment outfalls, will be healthier places for the animals and plants living there as well as for the boaters, fishermen and swimmers who utilize this invaluable resource, Boston Harbor.

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