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).

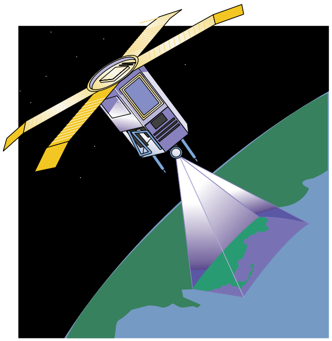
Sampling is most intensive in the immediate discharge area (within three miles of the diffuser). In addition, sampling stations more than 30 miles away in Cape Cod Bay are included (Figure 24). Since the inception of the monitoring program, 3.4 million data records have been collected and stored in MWRA's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

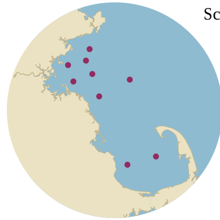
The most frequent measurements are by moored instruments that collect data at one location at intervals only minutes apart. In the critical area around the outfall, oceanographic vessels frequently collect water and sediment samples for detailed chemical and biological analyses. At sites distant from 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.

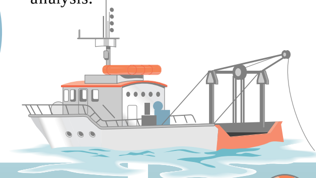


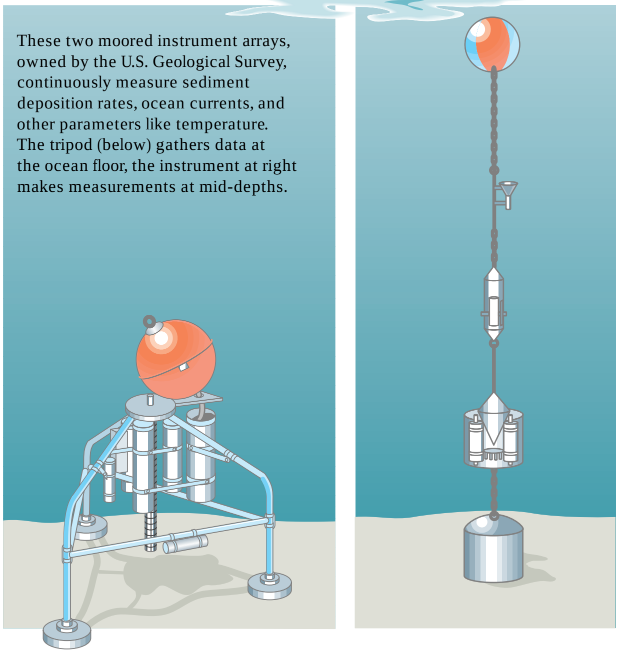
Satellites like SEASTAR collect climate data and measure parameters such as chlorophyll *a* over hundreds of square miles.

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



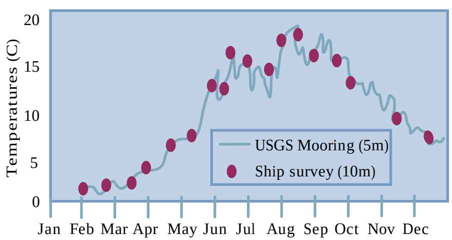
Scientists on oceanographic ships collect water, plankton, fish, shellfish, and sediment samples for MWRA throughout the Bays for laboratory analysis.





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.

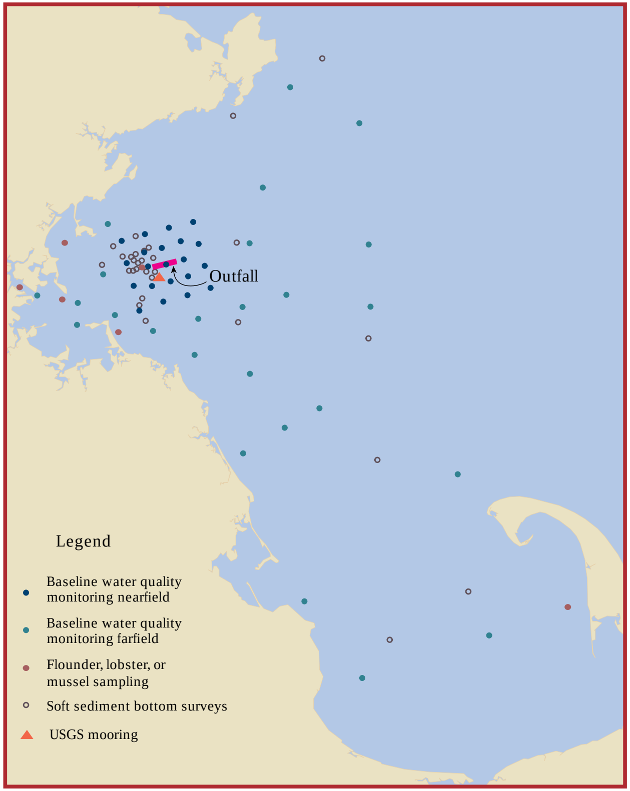


Figure 24. Monitoring stations include water, sediment, and the biota close to and distant from the new outfall site.

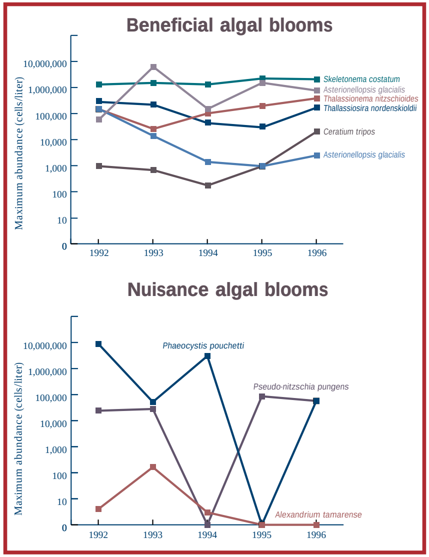


Figure 25. Beneficial and nuisance algal blooms have different inter-annual patterns. Nuisance algal blooms have occurred during the baseline monitoring period. These blooms are less predictable than the normal, beneficial algal blooms which produce food and oxygen. Continued monitoring will enable MWRA 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 (1992-1996)

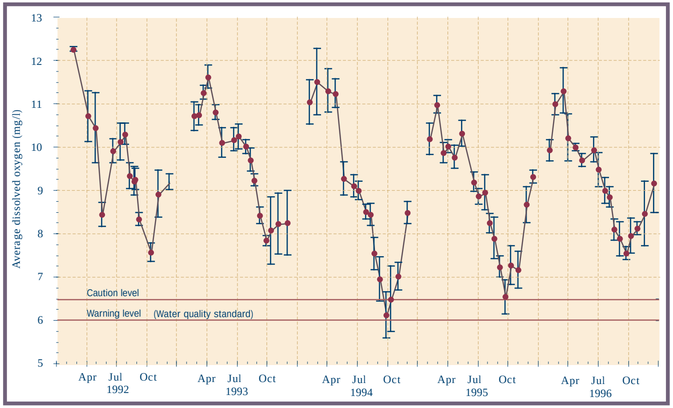


Figure 26. Baseline monitoring shows low dissolved oxygen can occur in bottom waters at the future outfall site. Average dissolved oxygen levels measured during surveys of the bottom waters of the outfall nearfield area show dramatic seasonal fluctuations, as well as varying from year to year. In 1994, 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)

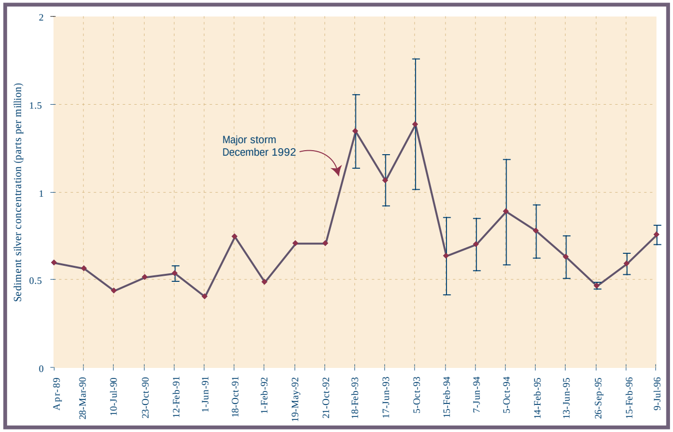


Figure 27. Silver concentrations in sediment near the future outfall site increased after a major storm. A major storm occurred in December 1992, causing resuspension of sediments from shallower inshore areas, which redeposited into deeper offshore areas, including a small muddy area near the future 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).