RHODE ISLAND
DEPARTMENT OF ENVIRONMENTAL MANAGEMENT

Narragansett Bay Water Quality: Status and Trends

Prepared by the Rhode Island Department of Environmental Management
for the Governor's Advisory Council on the Environment

July 1998

INTRODUCTION

It is often said that Narragansett Bay is Rhode Island's greatest natural resource. This estuary, where salt water mixes with fresh water from rivers and streams, creates an extremely productive habitat for diverse populations of fish and shellfish. At the same time, it supports a wide range of recreational activities such as swimming, boating, fishing, and shellfishing. These activities, as well as many others, contribute to a thriving Bay-related tourism industry supporting more than 15,000 jobs, resulting in more than $80 million in wages, and stimulating $390 million in economic activity (1994). Commercial fishing and shellfishing in the Bay yield more than $25 million to the people who harvest these sustainable natural resources. To a great extent, the value of Narragansett Bay in terms of the quality of life that it provides and the dollar value it yields is dependent upon the quality of the Bay's waters.

The Bay is quite large, covering approximately 147 square miles with an undulating shoreline that creates a string of sheltered coves where water circulation is restricted. These characteristics, and other factors such as the location of urban areas on the Bay's shoreline and within its watershed, make it impossible to characterize the water quality of the Bay in simple terms since the water quality varies greatly from the upper Bay to the lower Bay and even from one cove to another.

As difficult as it may be to characterize, the water quality problem is infinitely more difficult to control. The Narragansett Bay watershed covers a land area of 1,657 square miles, more than ten times the area of the Bay itself. Only 40% of the Bay's watershed is in Rhode Island; the remaining 60% is in Massachusetts. The sheer size of the watershed and the fact that it includes 100 cities and towns in two states increases the difficulty in controlling pollutants entering the Bay, adversely impacting its water quality.

It has been more than a quarter century since the enactment in 1972 of the Clean Water Act, which created an array of programs designed to improve water quality. The Rhode Island General Assembly has also established similar laws during the past twenty-five years. In addition, major water and Bay protection and restoration efforts have been undertaken by local governments, environmental organizations, and others.

The objective of this report is to explore the extent to which these laws and the resulting programs improved water quality in Narragansett Bay. This is a complex task since there are various types of pollutants entering the Bay.

The term "pollutant" is a general term that, in the case of contaminants to the Bay, can include metals, nutrients, organic waste, and other constituents. Some of these have been more easily controlled than others. In addition to the various types of pollutants, there are also two general categories of pathways through which pollutants can enter the Bay. One of these pathways is called "point source," which means that the pollutant originates from specific and identifiable discharge pipes or smoke stacks. The other pathway is called "non-point source," which means that the pollutants enter the Bay through more diffuse means, such as failed septic systems. Greater success has been achieved in stemming point source pollutants than non-point source pollutants. Therefore, water quality trends for the specific types of pollutants must be described separately in order to accurately describe the trends and existing conditions.

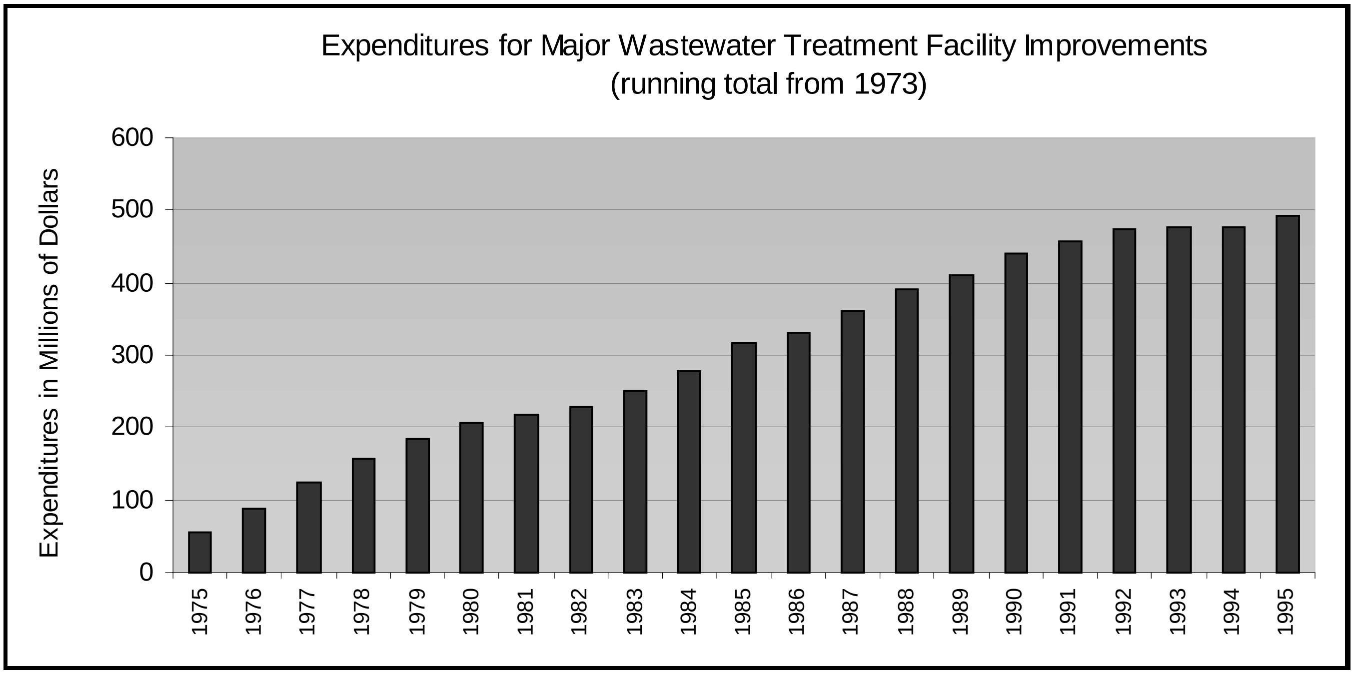
The trends described in this section include: the amount of organic waste discharged into the Bay from municipal wastewater treatment facilities, metals flowing into the Bay, disease-causing bacteria and viruses in the water, and soluble nutrients entering the Bay from these treatment facilities.

ORGANIC WASTE

Organic waste (primarily human waste) discharged into the Bay can have dramatic environmental impacts, even if it has been partially treated. The breakdown of this waste in the water may deplete the amount of dissolved oxygen to such an extent that there is not enough oxygen remaining for fish to survive, resulting in localized fish kills. This may occur in coves or rivers where water circulation is limited and the oxygen-depleted water is not quickly replaced by oxygen-rich waters that may be further off-shore. As a result of a fish kill, dead fish wash ashore, decompose, and create an odor that can be overpowering. Oxygen depletion caused by an excess of organic waste in the water can also cause other noxious smells. Malodorous decomposition of naturally occurring organic matter can result when oxygen levels fall and decomposition without oxygen (anaerobic decomposition) exists. Historical records show that during the 1800s the odors rising from the Providence River flowing through the city sometimes became so intense that people walking nearby fainted from the stench.

Rhode Island's long-standing programs to improve the wastewater treatment facilities over the past twenty-five years have been extremely successful in removing organic waste from the effluent entering the Bay.

Figure 1



Fortunately, Rhode Island's long-standing programs to improve the wastewater treatment facilities over the past twenty-five years have been extremely successful in removing organic waste from the effluent entering the Bay from wastewater treatment facilities. Figure 1 indicates the amount of money from federal, state, and municipal sources used to undertake major improvements to municipal wastewater treatment facilities in Rhode Island since 1973. This clearly shows a sustained level of effort on the part of Rhode Islanders to reduce the amount of human waste discharged into the Bay.

Figure 2

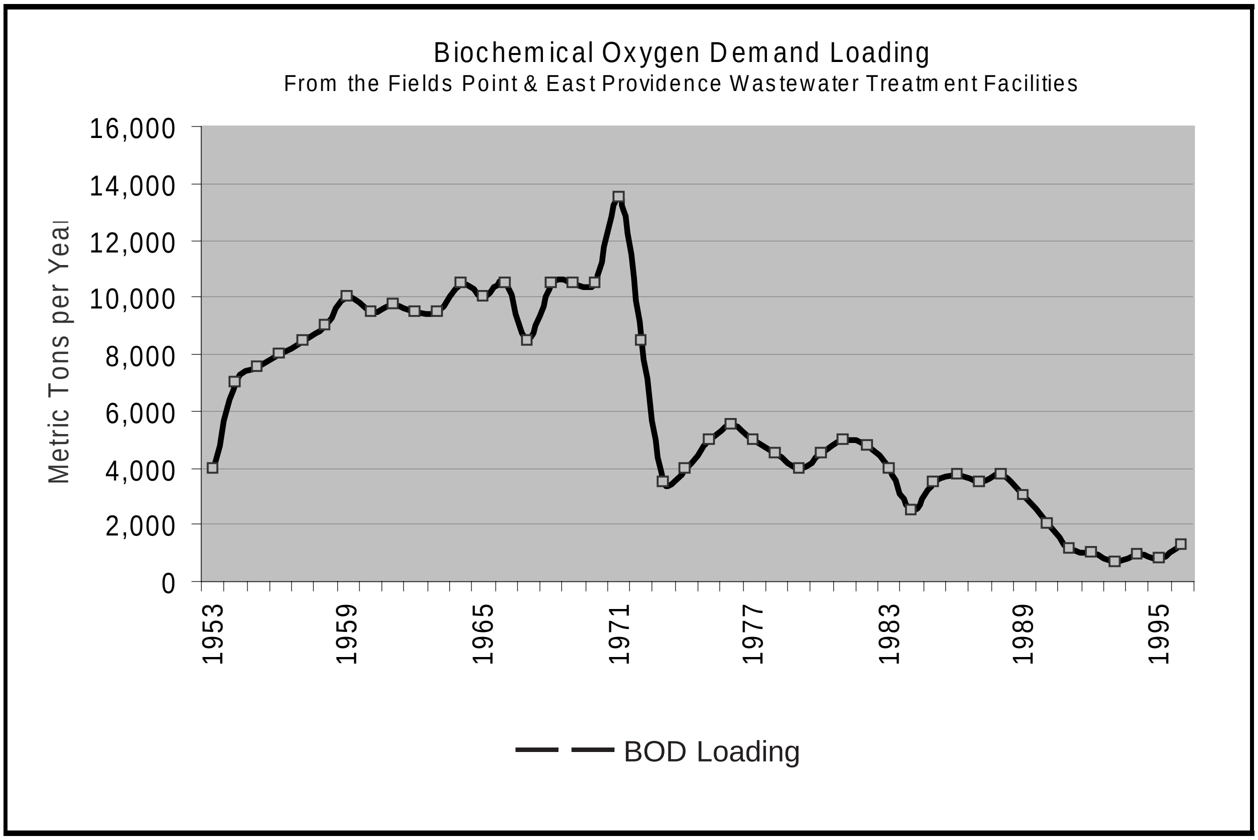


Figure 2 indicates environmental benefits resulting from such improvements, represented as a reduction in the Biochemical Oxygen Demand (BOD) loading from the three upper-Bay wastewater treatment facilities. BOD is simply a measure used to determine the amount of oxygen in the water that would be required to decompose the organic waste discharged into the water. When the BOD loading is high, more oxygen from the water would be used to decompose the waste, increasing the risk of depleting the oxygen so that fish kills result. When the BOD loading is low, less oxygen is consumed and fish kills are less likely. This dramatic reduction in loading of biochemical oxygen demand shown in Figure 2 is linked directly to the improvements made to the wastewater treatment facilities.

The trend shows an increase in BOD loading from these facilities from 1953 to 1971. A dramatic reduction in BOD occurred in the early 1970s when the wastewater treatment facility operated by the Blackstone Valley District Commission converted to secondary treatment. The upturn in BOD loading immediately following was caused by a failure of the Fields Point waste-water treatment facility during the mid-1970s , resulting in the discharge of raw sewage into the Bay. However, the facility was taken over by the Narragansett Bay Commission which made major improvements leading to a reduction in the BOD loading. Now, wastewater treatment facilities represented in this figure achieve between 90% and 97% efficiency in removing the BOD loading. The overall treatment at these facilities is rated as “excellent” by the Department of Environmental Management.

However, this Bay-wide description of BOD loading does not tell the entire story. A number of coves and embayments around Narragansett Bay including the Pawtuxet, Providence, Seekonk, Kickemuit, and Palmer Rivers, as well as Greenwich Cove, Apponaug Cove, and Warwick Cove experience seasonal dissolved oxygen depletion due to decomposition of plants growing in the water column and on the bottom. Excess nutrients, often from wastewater treatment plants, result in rampant growth of plants that can die, decay, and cause fish kills. The suburbanization of land bordering the lower Bay increases the possibility of such problems in coves and embayments since septic systems, lawn fertilizers, stormwater discharges and other nutrient sources increase with development. The growth rate for the state's suburban and rural areas was projected to be 20% during the 25 year period between 1985 and 2010. The projected growth rate for the state's cities was 2.6% during the same time period. Such population trends increase the likelihood that some parts of the Bay will be impacted by non-point sources of pollution from septic systems, road run-off, and lawn fertilizers. (See Nutrient section for more details.)

Significant strides have been made in reducing the point sources of BOD loadings from waste water treatment plants. This has been achieved through the upgrading of wastewater treatment facilities. More needs to be done to address non-point sources, such a farms and failed septic systems, which can degrade smaller coves that have restricted water circulation.

METALS

The waters of Narragansett Bay contain small natural amounts of dissolved metals, called trace metals. Some of these are essential for the natural development and growth of estuarine plants and animals. However, larger concentrations in the Bay can be toxic to the plants and animals living there and possibly to the people eating them.

The input of metals into Narragansett Bay has been linked closely to the state's unique history: the development of textile mills along tributaries to the Bay beginning in the late 1700s; people moving to the cities at the upper reaches of the Bay as jobs were created in the textile industry; development of a machine tools industry to support the rapid industrialization occurring during the 1800s; the booming Civil War production of armaments in factories on the tributaries of the Bay; expansion of the jewelry and silver industries; and (more recently) state and federal laws to control the pollutants flowing into the bay.

> The layer upon layer of sediments that accumulated (and still accumulates) on the floor of the Bay, in the salt marshes, and behind the dams of the rivers flowing into the Bay provide a picture of the pollution history of the Bay.

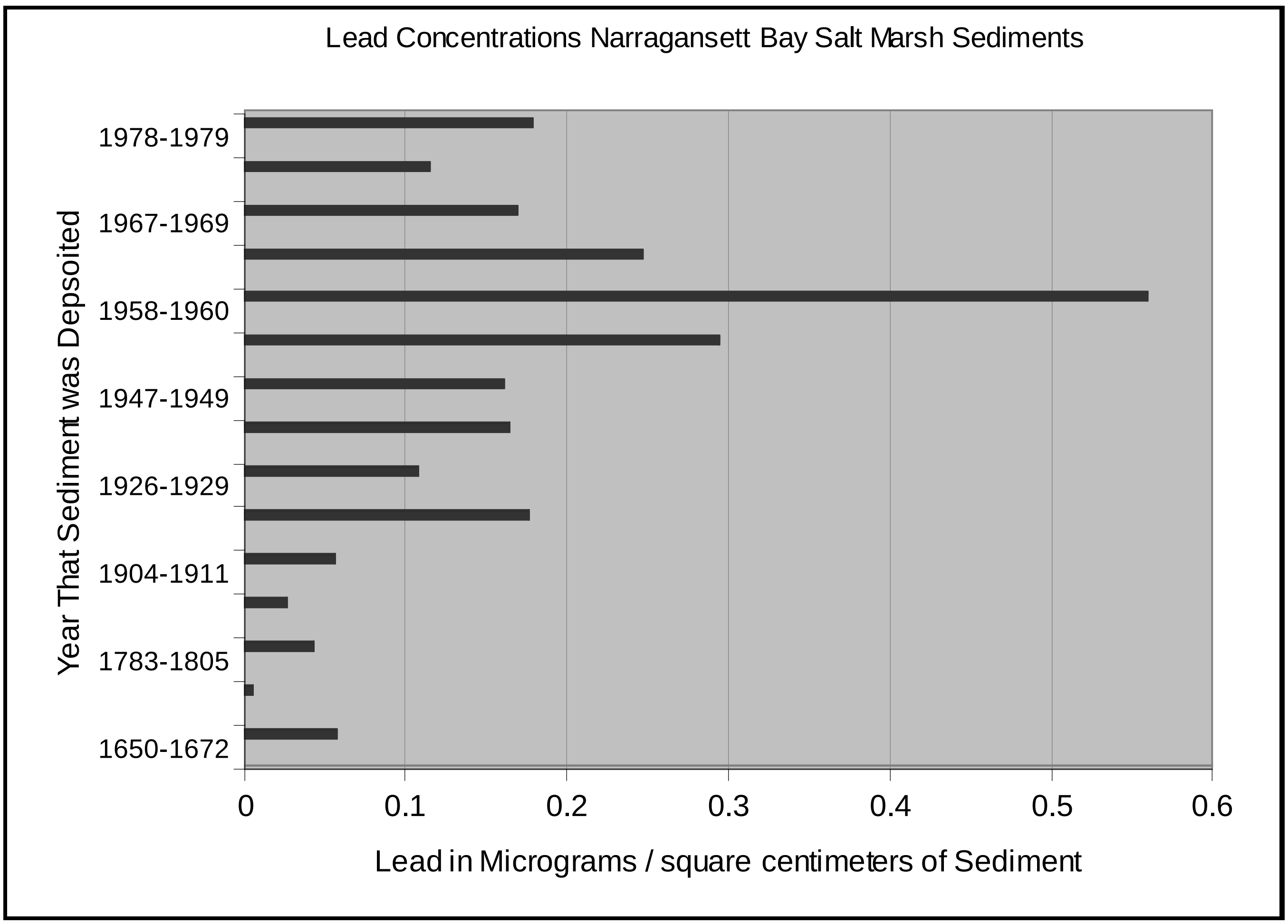
All of these phases in Rhode Island's history resulted in a change in the amounts of various metals washing down the rivers and deposited in the sediments on the floor of the Bay and the salt marshes along the shore. Each year, newer sediments were deposited upon older, creating a stratification of the Bay's pollution history.

The layer upon layer of sediments that accumulated (and still accumulates) on the floor of the Bay, in the salt marshes, and behind the dams of the rivers flowing into the Bay provide a picture of the pollution history of the Bay. Layers of sediment can be analyzed to determine the metals present, aged to determine the period when they were deposited, and then correlated with the specific aspects of Rhode Island history to reveal the types and extent of pollution that resulted from specific periods. These sediments provide a view of the state's history and are of practical significance today since these historic sediments can still impact the water quality of Narragansett Bay. The disturbance of these sediments during dredging projects and storms brings back old pollution problems as these historic sediments become re-suspended in the water.

A look at one particular metal, lead, in these historic sediments reveals the link between heavy metal contamination in the Bay with Rhode Island's history and urbanization. It also reveals how buried pollution problems can reappear under certain circumstances. Figure 3 shows the amount of lead contamination in different levels (and ages) of sediment in a Rhode Island salt marsh. Each sediment level is a page in the state's history that reflects the human activities occurring near the Bay at the time and the extent to which those activities contributed to the amount of lead contaminating the Bay's waters and being incorporated into the layer of sediment deposited.

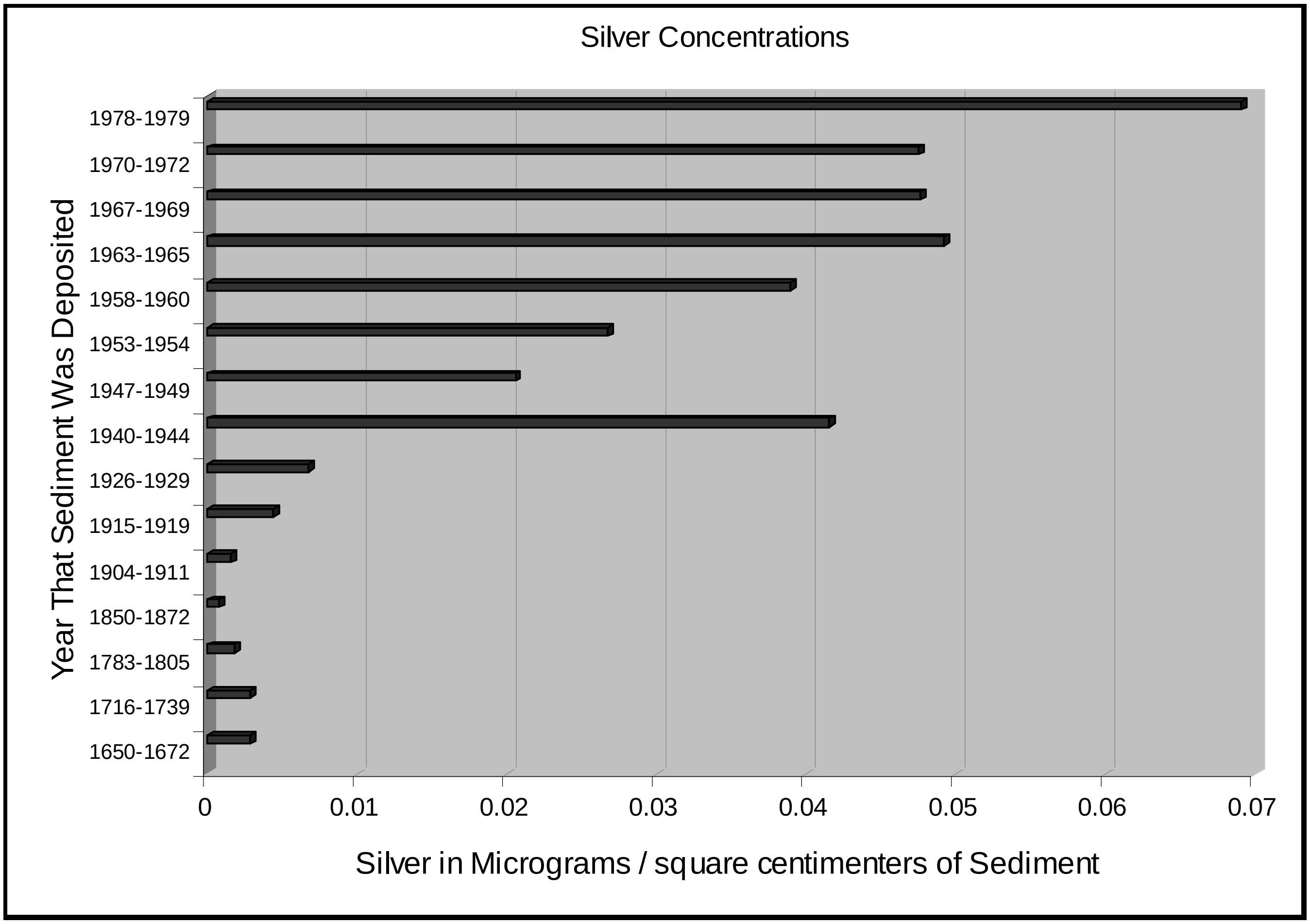
People added very little lead contamination to the Bay until the Industrial Revolution when lead was used to help fix the dyes as part of textile manufacturing in the Narragansett Bay watershed. But an even greater impact resulted from the manufacture of machinery, contributing still more lead to the rivers flowing to the Bay. The addition of lead to gasoline resulted in lead becoming an important contaminant from automobile tailpipes. This contaminant adhered to tiny particles that settled from the air onto surfaces and, when it rained, washed into streams and rivers that flowed to the Bay. It is estimated that in 1923, when lead was first used as a gasoline additive, Rhode Island registered vehicles emitted approximately 100 tons of lead. These emissions grew ten-fold to 1000 tons annually until 1974, when new cars were required to run on unleaded gasoline. The increase in the amount of lead detected in the salt marsh sediments (Figure 3) reflects all these land-based human activities. A large increase in the amount of lead in sediments deposited during the late 1950s probably reflects the added contamination resulting from two large hurricanes that may have washed more contaminants from the roads and re-suspended older sediments as the storm surge and hurricane waves stirred up older, more contaminated sediments. The more recent decrease in lead deposition reflects the removal of lead from gasoline, pretreatment requirements imposed on Rhode Island manufacturers, and more efficient wastewater treatment facilities including the installation of sludge presses at the Fields Point wastewater treatment facility after World War II.

Figure 3



The historic record of silver in the sediments of a Narragansett Bay salt marsh mirrors the development and growth of the jewelry industry in Rhode Island. Although the jewelry industry began in the late 1700s along with the textile industry, it did not grow as rapidly, so the increase of silver in saltmarsh sediments occurred later than the increase of lead in the same sediments. This is reflected in Figure 4 which shows the amount of silver in cores taken from a Rhode Island salt marsh. The analysis of these core samples also indicates that silver deposition continued to increase even as lead deposition was decreasing. This is a result of steady growth of the jewelry industry in Rhode Island after World War II.

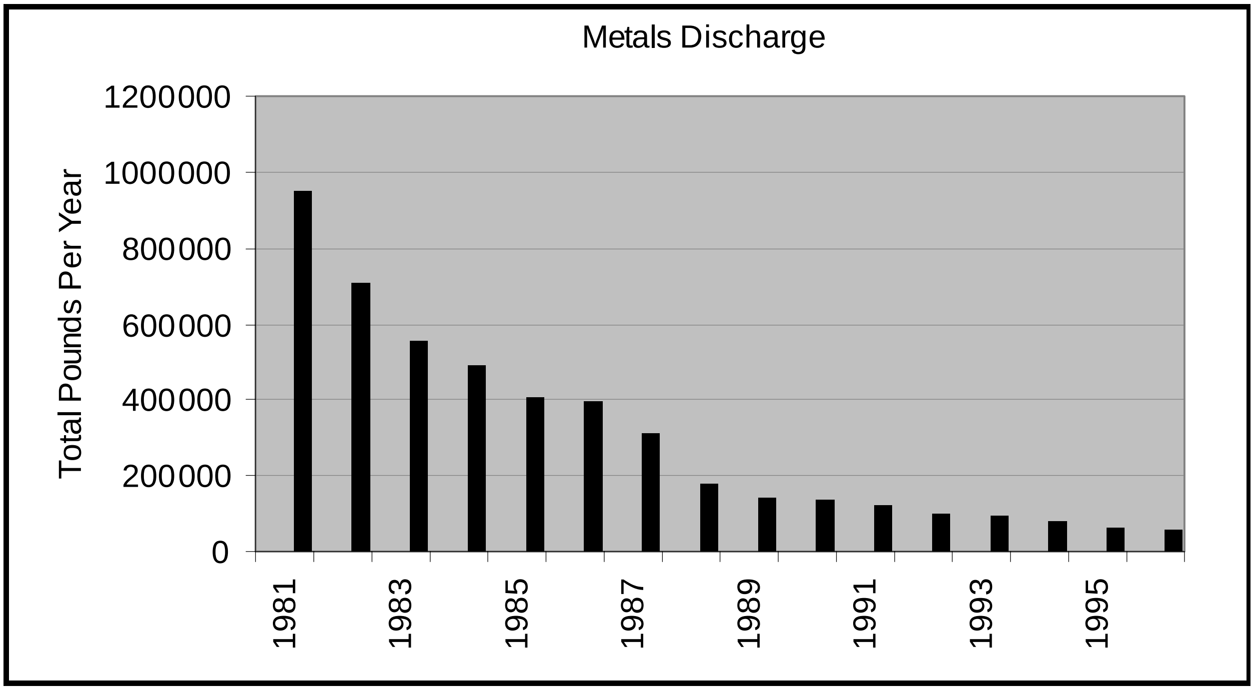
Figure 4



However, Figures 3 and 4 do not show the improvements that have been achieved in the control of metals discharged into Narragansett Bay during the past fifteen years, since the analyses reflected in those figures was done in the early 1980s. During the past twenty-five years, federal and state regulatory programs have required many commercial dischargers to pretreat their processing water reducing the amount of metals and other toxic substances before releasing it to the wastewater treatment facility. Figure 5 indicates the reductions in the metals discharges that have been achieved at the Fields Point wastewater treatment facility during the past twenty-five years. If core samples were taken from the salt marshes today and analyzed, they would probably reflect these reductions of metals discharged.

The dramatic reduction in metals entering the Bay is one of the successes resulting from effective state and federal water pollution laws and regulations which caused the development and implementation of innovative technologies to control such pollution.

Figure 5



DISEASE-CAUSING ORGANISMS

A wide range of bacterial and viral illnesses can be transmitted via human waste in surface water. Such illnesses include gastroenteritis, Salmonella, and infectious hepatitis. The pathogens causing these diseases as well as other bacterial and viral pathogens can enter Narragansett Bay from both point and non-point sources. Some of the point sources include wastewater treatment facilities (WWTFs), combined sewer overflows (CSOs), and storm drains. Non-point sources of pathogens may be individual septic systems (ISDSs), runoff, and discharges of human waste from boats.

Viral and bacterial pathogens can enter Narragansett Bay from both point sources and non-point sources.

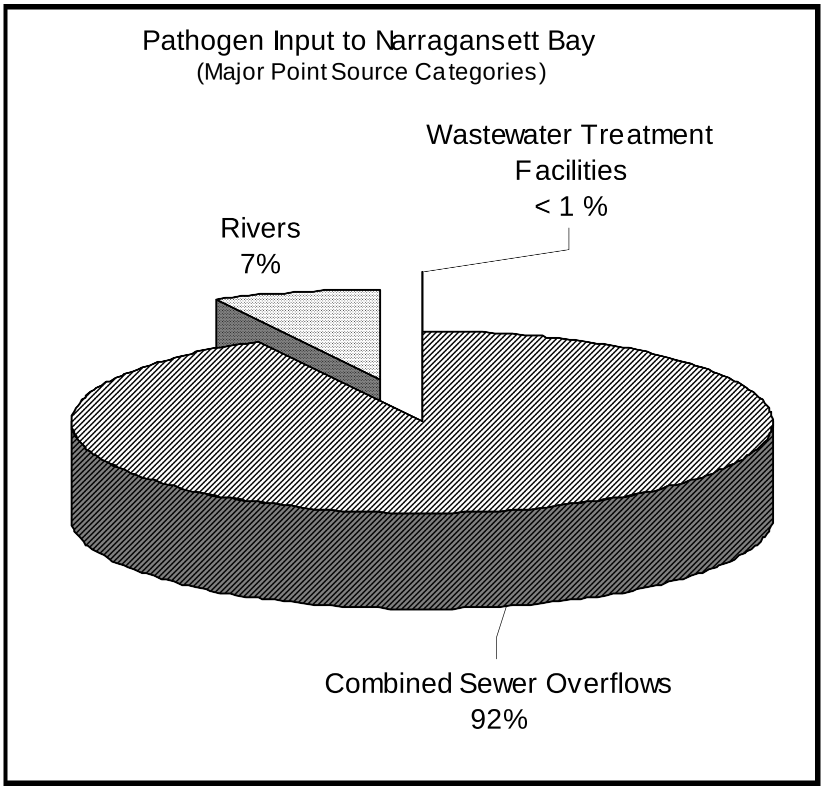
The relative contributions of these sources change as management strategies are designed to eliminate specific sources. For example, as part of a multi-year effort to address the discharge of human waste from boats in Narragansett Bay, DEM has worked with coastal municipalities and marinas to construct pumpout facilities so that boaters have a environmentally responsible means of discharging human waste. By 1997, 34 pumpout facilities and one dump station were installed around the Bay. Now, all of the boats with toilets in Narragansett Bay during the summer can be serviced by pumpout facilities. This can result in a significant reduction in the release of pathogens to the Bay. The focused management program was developed to create a system of pumpout facilities for boats in the Bay and to support the State's application to the Environmental Protection Agency for designation of the entire Bay as a "No Discharge Area" and virtually eliminating boater waste as a non-point source of pathogens. Pumpout facilities have been extremely successful in Block Island's Great Salt Pond, an 800-acre area with 1,000 boats during summer weekends and up to 2,000 on holiday weekends. The pumpout facilities have so improved water quality during the summer that the upper part of the Great Salt Pond can be opened for shellfishing, even at the height of the summer season.

Likewise, the systematic upgrading of wastewater treatment facilities in the Narragansett Bay watershed has significantly reduced bacterial pathogens entering the Bay from point sources. (The chlorine treatment used at WWTFs for disinfection is very effective at killing bacterial pathogens but less effective at treating viral pathogens.) Figure 1 reflects the long-term commitment of funds to this effort. One of the main functions of wastewater treatment plants is to effectively treat human waste as a means of reducing the transmission of disease to people who swim or boat in water bodies receiving human effluent or who eat fish or shellfish caught in those waters.

Figure 6 indicates the major point sources of pathogens into Narragansett Bay and the relative importance of those sources. This chart clearly shows that WWTFs have become a minor source of pathogens to the Bay. At the same time, it indicates the relatively large contribution of CSOs to the loading of pathogens.

Combined sewer overflows (CSOs) are the discharges resulting from the combined sanitary sewers and storm drains that were constructed near the turn of the twentieth century to manage both stormwater and sewage in the metropolitan Providence area. During heavy rains when the stormwater flow exceeds the capacity of the wastewater treatment facility, all of the flow exceeding treatment facility capacity (including the untreated human waste) is discharged directly to the Bay via the combined sewer overflows.

Figure 6



The yearly input of pathogens to the Bay resulting from the raw sewage in CSO discharges varies, depending upon the size and frequency of rain events that result in storm flows exceeding the capacity of the wastewater treatment facilities. The Narragansett Bay Commission, which operates the Fields Point Wastewater Treatment Facility, estimates that 3.2 billion gallons of untreated waste are discharged into the Bay yearly from the 86 CSOs in its management district. (There are approximately 120 CSO inputs including those associated with other cities bordering the Bay.) One proposal is to spend nearly $400 million in three phases to abate the metropolitan Providence CSO problem and dramatically reduce the pathogens discharged into the Bay, just as the investment in upgrading WWTFs reduced the Biochemical Oxygen Demand loading from those facilities (as indicated in Figure 2). Addressing the Providence CSO problem could significantly improve water quality since more than 70% of the CSO inputs to the Bay are in the Narragansett Bay Commission's management area. The first phase of these improvements is now being planned by the Narragansett Bay Commission.

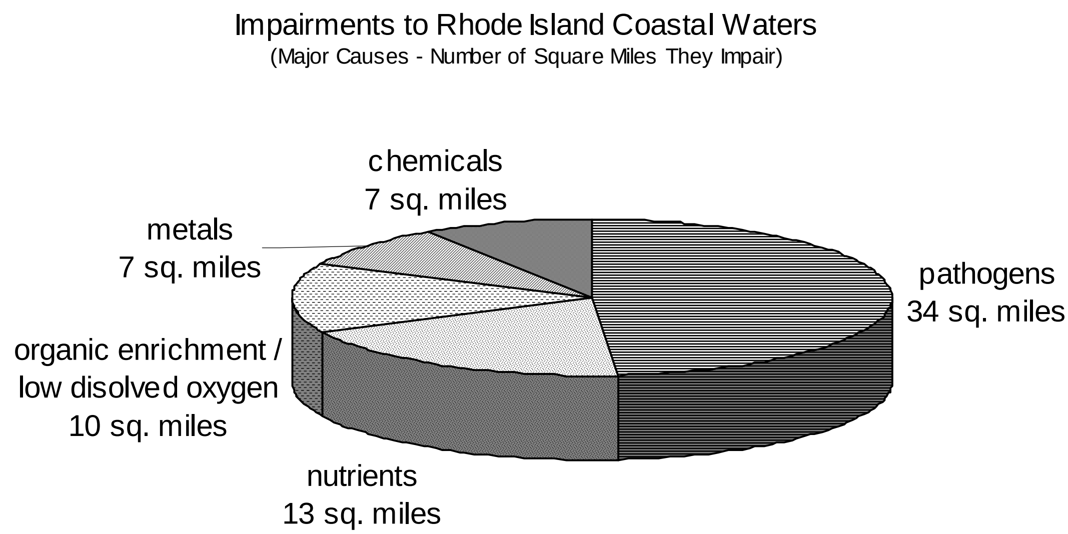
Heavy rains in June of 1998 highlight the impacts that the existing antiquated sewage/stormwater system can have on the water quality of Narragansett Bay. Unusually heavy rain for more than a week overwhelmed the wastewater treatment plants with stormwater, causing the bypass of raw sewage directly to the Bay. The resulting public health threat temporarily closed much of the Bay to shellfishing and swimming as far south as the southern tip of Prudence Island. Although such events are uncommon (the last such massive closure from rain was in 1992) they indicate the extent to which a combined sewage and stormwater system jeopardizes the water quality of the Bay and threatens recreational and commercial uses of this valuable resource.

It is clear that high levels of bacterial contamination in parts of Narragansett Bay restrict some human uses, including swimming, fishing, and shellfishing.

Shellfishing Beds

The opening or closing of shellfishing beds reflects the improvement or degradation, respectively, of water quality in specific areas of the Bay. Increased suburban development near the shore of the mid-Bay, lower Bay, and tidal rivers flowing to the Bay has resulted in more contamination from septic systems, runoff, and other sources, while the antiquated combined sewer overflows and urban wastewater treatment facilities servicing the urbanized upper Bay communities continue to contaminate the upper Bay. Figure 7 reveals that pollution from pathogens impairs more square miles of the state's waters than any other contaminant, negatively impacting 34 square miles of Rhode Island's estuarine waters (including other coastal waters besides Narragansett Bay).

Figure 7



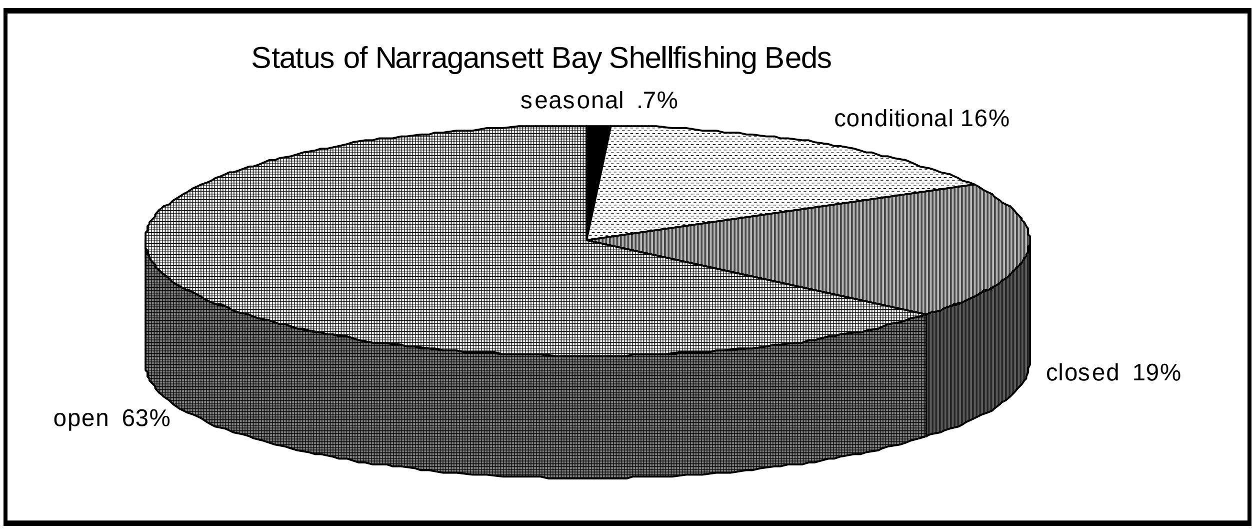
In response to these pollution pressures, the State has attempted to reduce pathogens in the Bay by helping to fund the construction of pump-out facilities for marine toilets and controlling other sources of point source (such as combined sewer overflows) and non-point source pollution. The level of success in controlling pathogens has been mixed. In some coves, shellfish beds that had been closed are now conditionally open due to improvements in controlling bacterial contamination and due to the ability to better monitor the quality of the water so that the area can be closed temporarily when bacterial contamination reaches an unsafe level. However, uncontrolled bacterial contamination continues to keep approximately 19% of Narragansett Bay shellfish beds permanently closed and additional beds are only conditionally open at times when bacterial contamination is low. As Figure 8 indicates, 63% of the Bay's shellfish bed acreage is open for shellfishing.

In 1994 and 1995, more than 5,500 acres of shellfishing beds were reclassified from "prohibited" to "conditionally open". In 1995, however, more than 4,500 acres of shellfishing beds were closed in the vicinity of wastewater treatment plants, providing a larger buffer area to protect public health.

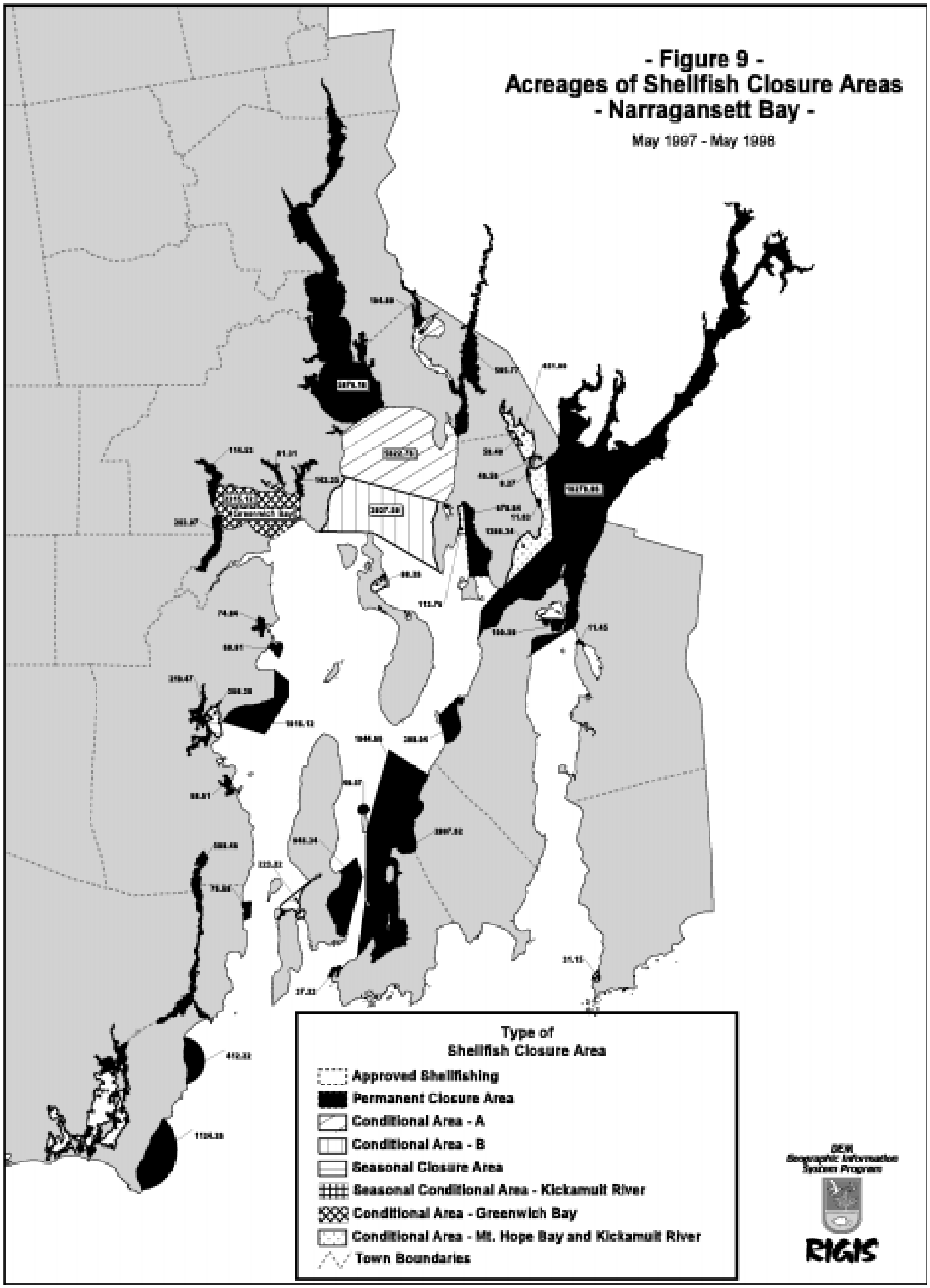
The map in figure 9 shows the status and location of the Bay's shellfishing beds. It graphically reveals the relationship between urbanized/industrialized areas and impaired waters that result in the closure of shellfish beds of the Providence River, upper Narragansett Bay, and Mount Hope Bay. However, this map also reveals the smaller but growing trend of the negative impacts caused by the suburbanization of land bordering Greenwich Bay, Pettaquamscutt River, and Island Park resulting in the closure of shellfish beds nearby. Suburban communities often depend upon individual septic systems instead of municipal sewerage. The failure of septic systems can release pathogens into nearby Bay waters (or into streams flowing to the estuary), and impair the water bodies to such an extent that shellfishing beds must be closed.

Greenwich Bay, identified in Figure 9, is a 4.9-square mile arm of Narragansett Bay that supports one of the most productive shellfish beds on the entire East Coast. The quahog harvest from this relatively small shellfish bed is worth approximately $1 million yearly at the dock and stimulates approximately $4 million in the state's economy. Nearly 90% of all the shellfish harvested from Narragansett Bay during the winter months is taken from Greenwich Bay. Therefore, the closure of this area to shellfishing in 1992 due to high bacteria levels focused the state's attention on the sources of pollution that caused the closure. A coalition of federal, state, and municipal agencies, the University of Rhode Island along with environmental advocacy groups and volunteer citizen water quality monitors identified the major sources of contamination. Corrective measures included improvements to a farm bordering a brook that flows to Greenwich Bay, construction of sewers to eliminate the pollutants that originated from nearby septic systems, and the use of alternative septic systems where there were no sewers. Such improvements, coupled with diligent water quality monitoring and a mechanism for closing the shellfish beds temporarily after storms, has allowed the embayment to be open to shellfishing. Such focused efforts to identify and control sources of water pollution can be successful and the Greenwich Bay Project serves as a model for other local embayments that may be threatened due to development near the shore.

Figure 8



The long-term objective is to limit pathogen contamination and improve water quality in Narragansett Bay, increasing the acreage of harvestable shellfishing beds.



- Figure 9 -
Acreages of Shellfish Closure Areas
- Narragansett Bay -

May 1997 - May 1998

Nutrients, such as nitrogen and phosphorus, are essential for plants to flourish. If sufficient nutrients do not occur naturally in the soil, gardeners often add fertilizers containing them. Plants in the Bay also require nutrients and respond especially to one particular nutrient — nitrogen.

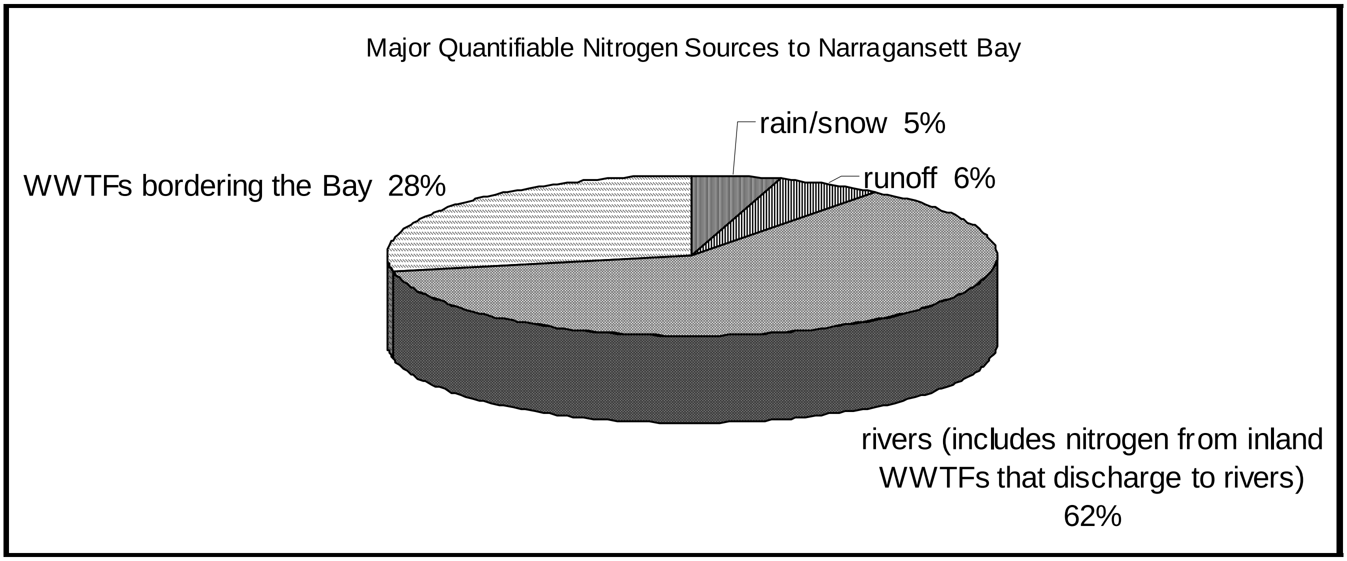
Algae, the most common form of plants living in the Bay, grow rapidly when nitrogen is added to the water, particularly during the warmer months. However, like garden plants that are over-fertilized, algae growth can become excessive when there is too much nitrogen in the water. *Algae blooms* can result.

Rampant algae blooms can degrade the estuarine environment in two ways. First, most algae plants grow very quickly, then die and decompose on the floor of the Bay in a process that consumes oxygen. The oxygen removed from the water because of decomposition results in less oxygen being available to the aquatic animals. This oxygen reduction may lead to fish kills if they cannot obtain enough oxygen from the water to survive. Dead fish wash ashore and soon smell as they too decompose, using up even more oxygen. This occurs mainly in the warm summer months when there is normally less oxygen in the water anyway. (Cold water can hold much more dissolved oxygen than warm water can.) In late summer, oxygen levels can fall so low in some areas of the Bay that essentially all bottom life dies.

Nutrients flowing into the Bay have increased as cities around the Bay grew and land uses changed in the towns and cities within the Bay's watershed

A second potential problem is that over-fertilizing the Bay may actually change the types of plant communities that occur there naturally. By analogy, low-nutrient upland soils will support specific native plants adapted to live in low-nutrient environments. When such soils are fertilized, the former plant community may be gradually replaced by other plants that can take advantage

Figure 10



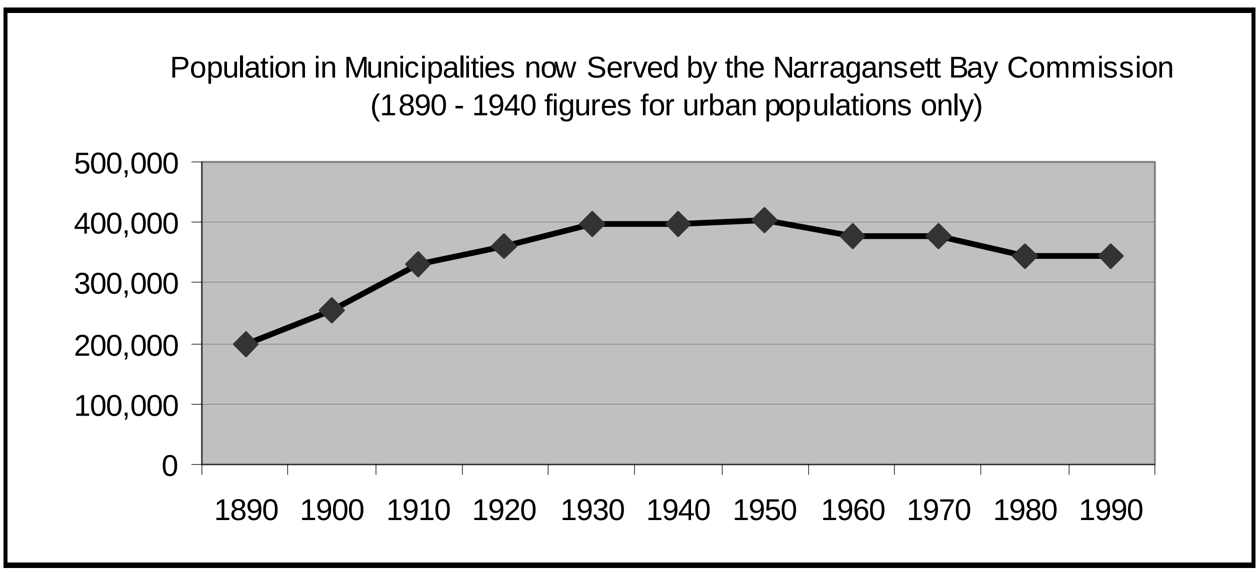
of the newly-fertilized soil. Some researchers now believe that the constant elevated flow of nutrients into the Bay has altered the ecology of this fragile ecosystem by causing a change in the estuarine plant communities and Bay-sediment animal communities. This has occurred in parts of upper Narragansett Bay, Greenwich Bay, the mouth of the Potowomut River and other areas with high nutrient input. One of the obvious changes in the plant community of the Bay could be the replacement of naturally-occurring algae with nuisance algae, some of which are toxic to Bay animals and even to people. Scientists believe that increasing the nutrients in estuaries may result in more frequent outbreaks of these nuisance and toxic species.

Sea lettuce, a common large alga in the Bay, often carpets the bottom in shallow areas where nutrient levels are elevated. This can degrade the environment for other plants and animals that may have inhabited that part of the Bay.   Furthermore, high water temperatures result in the sudden die off of sea lettuce resulting in large amounts of decomposition, lowering dissolved oxygen levels to critical levels.

The nutrients flowing into the Bay have increased as cities around the bay have grown and land uses changed in the towns within the Bay's watershed. Non-point sources of nutrients include: individual sewage disposal systems (ISDSs) that discharge nutrients into the groundwater and, eventually, to the bay; fertilized lawns and farms that leach nutrients to the groundwater or from which nutrients are washed as storm runoff to streams and rivers that flow to the Bay; airborne nutrients that can settle on the surface of the Bay or are washed from the sky by rain and snow. On the other hand, wastewater treatment facilities are considered to be major point sources of nutrient enrichment to the Bay. Figure 10 indicates that sewage from wastewater treatment facilities is a major sources of nitrogen to the Bay. (The large contribution of nitrogen in river water includes the nitrogen from wastewater discharges upstream.)

Sewage inputs of nitrogen result mainly from the normal operation of wastewater treatment plants, since such treatment does not remove nutrients as it lowers biochemical oxygen demand (see in Figure 2 for BOD removal).

Figure 11



The large input of nitrogen to the Bay in sewage can be traced to the creation of a municipal water system in the metropolitan Providence area during the late 1800s and the construction of a sewer system in the early 1900s, making it possible to flush human waste from homes and workplaces to the wastewater treatment plant and then out into the Bay. The amount of nitrogenby wastewater treatment facilities. Figure 11 shows the increase in the number of people living in the urban metropolitan area now served by the Narragansett Bay Commission's wastewater treatment facilities.

As the urban population serviced by wastewater treatment facilities around the Bay (and even in Massachusetts cities on rivers flowing to Narragansett Bay) grew, nitrogen inputs increased. But Figure 8 tells only part of the story since it reflects just the population serviced by the Narragansett Bay Commission's wastewater treatment facilities. Actually, more than one million people throughout the entire Narragansett Bay watershed are serviced by wastewater treatment facilities that discharge effluent to the Bay.

Although it is not possible to calculate precisely the increase in nitrogen loading to Narragansett Bay since prehistoric times, scientists' estimates help to provide some perspective regarding the extent of the "fertilization" of the Bay caused by people. A recent calculation made by URI research scientists is that human activity has increased the nitrogen loadings to the Bay five-fold over the level that existed before colonization. Furthermore, scientists estimate that this level of fertilization has probably doubled the algae production in the Bay.

CONCLUSION

The water quality of Narragansett Bay is the result of many factors, both environmental and human. The Bay's watershed is remarkably vast - 1,650 square miles. It is also one of the most densely populated in the country with an average of more than 1,100 people living in each square mile. The Industrial Revolution in America started on the banks of the Blackstone River, which flows into Narragansett Bay. From the mid-1800s into the early 1900s, sewer pipes carried untreated human waste from the cities directly to the Bay.

Current efforts to improve the Bay's water quality address the historic, social and economic characteristics of this unique watershed. The combined sewer overflow problem, as well as its solution, reflect the urban character of the Bay's watershed. Future pollution control measures must take into account current trends such as the suburbanization of the mid- and lower Bay shoreline that creates non-point pollution problems. More effective monitoring can be used to identify new or previously unidentified sources of pollution that impact water quality and could measure the success of site-specific pollution control strategies.

Twenty-five years of diligent enforcement of Federal and State clean water laws have resulted in profound improvements in Narragansett Bay water quality. This state of the environment report documents many of these, including:

- The upgrading of municipal wastewater treatment facilities has reduced the biochemical oxygen demand that these facilities had placed on the Bay ecosystem. This is accomplished by the removal of solids from sewage and the biological breakdown of organic matter that occurs through secondary treatment at wastewater treatment facilities. Additional upgrading to tertiary treatment is in the design stage in Warwick, West Warwick and Cranston.

- Pretreatment requirements imposed on businesses that use metals through a variety of industrial processes has reduced the amount of metals discharged in their wastewater. Technical assistance provided to these companies by environmental agencies and the development of less polluting technologies have helped to reduce the metals loadings to the Bay. The elimination of lead from gasoline has also had a significant impact on the input of this toxic metal to Narragansett Bay.

At the same time, more remains to be done to achieve the consistently high levels of water quality that Rhode Islanders desire and that Federal laws require.

- In spite of the fact that wastewater treatment plants have reduced the biochemical oxygen demand loadings to the Bay, and have reduced the input of bacterial contaminants through chlorination, these efforts must be expanded upon. Problems continue to result from the combined sewer overflows that cause raw, untreated sewage to flow into the Bay after heavy rains. This problem is associated with the antiquated combined sewer lines and storm drains, not the level of treatment achieved at the wastewater treatment facilities. Another problem not fully addressed is that chlorination treatment is not effective at disinfecting the full range of viral contaminants that can be carried via human sewage into the Bay.

- Nutrient inputs to the Bay, particularly nitrogen, are not yet adequately controlled. Excessive amounts of nitrogen continue to cause instances of oxygen depletion in some coves and other areas of the Bay. Even the secondary treatment achieved at the wastewater treatment plants cannot reduce the high levels of nitrogen associated with sewage. New permits issued to wastewater treatment facilities will, in some cases, require further nitrogen reduction. In unsewered communities, older failing septic systems can contribute significantly to nutrient-loading, and even conventional systems that function properly may do little to reduce nitrogen inputs. In some areas near the Bay, newer technologies may be required that involve nitrogen reducing individual sewage disposal systems. In some areas, non-point sources of nitrogen, such as lawn fertilizers and agricultural fertilizers, may need to be controlled to achieve improvements in water quality.

The responsibility for protecting the Bay's water quality is shared by the Department of Environmental Management and the Narragansett Bay Commission and by each of the 100 municipal governments within the Bay's watershed. Municipalities have the legal authority to regulate land use through zoning and subdivision ordinances. The location and density of homes, roads, and businesses within the watershed's cities and towns can result in either an improvement or a degradation of water quality of the Bay, depending upon the extent to which water quality was taken into consideration when developing town and city ordinances. Furthermore, individual decisions relating to the use of fertilizers, pesticides, and the proper disposal of used motor oil are also crucial to water quality in Narragansett Bay. State and municipal governments have worked together to make "oil igloos" available in many Rhode Island municipalities as an alternative to the illegal dumping of waste motor oil into storm drains.

The personal environmental ethic of people who live and work in the Narragansett Bay watershed is crucial to the improvement of water quality. Such a stewardship ethic results in environmentally-sound personal practices and also creates the widespread expectation and insistence that all levels of government institute and enforce laws and regulations that are protective of Narragansett Bay.

Employing a **watershed** perspective is a powerful tool for improving the water quality and other natural attributes of Narragansett Bay. Resources and expertise can be maximized for an entire ecosystem by recognizing and utilizing the benefits of collaboration between Rhode Island and Massachusetts, the dozens of communities, and nonprofit and private stakeholders. Although such a comprehensive approach may make the problem seem daunting, this orientation to environmental challenges creates new opportunities since it involves more people in the problem-solving process and results in integrated solutions. As a result of the watershed approach, more people, communities, businesses, and organizations assume responsibility for protecting the water quality of Narragansett Bay.

Sources of Indicator Charts, Tables, and Graphs

Figure 1 —
R. I. Clean Water Finance Agency, the Narragansett Bay Commission, and the Department of Environmental Management, personal communications, 1997.

Figure 2 —
Alan Desbonnet and Virginia Lee, Historical Trends - Water Quality and Fisheries - Narragansett Bay, Coastal Resources Center, University of Rhode Island, 1991.

Figure 3 —
S. Bricker Urso and S. W. Nixon, The Impact of Human Activities on the Prudence Island Estuarine Sanctuary as Shown by Historical Changes in Heavy Metal Inputs and Vegetation, URI Graduate School of Oceanography, final report to the Narragansett Bay Estuarine Sanctuary Scientific Committee, 1984.

Figure 4 —
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Figure 5 —
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Figure 6 —
Charles T. Roman, Pathogens in Narragansett Bay, inputs and improvement options, Narragansett Bay Project, 1989 (Alan Desbonnet and Virginia Lee, Historical Trends - Water Quality and Fisheries - Narragansett Bay, Coastal Resources Center, University of Rhode Island, 1991).

Figure 7 —
R. I. Department of Environmental Management, Office of Water Resources, The State of the State's Waters - Rhode Island, July 1997.

Figure 8 —
R. I. Department of Environmental Management, Office of Water Resources, The State of the State's Waters - Rhode Island, July 1997.

Figure 9 —
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Figure 10 —
S. W. Nixon, S. L. Granger, and B. L. Nowicki, An Assessment of the Annual Mass Balance of Carbon, Nitrogen, and Phosphorus in Narragansett Bay, in the journal Biogeochemistry 31:15-61, 1995.

Figure 11 —
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Related Internet Web Pages

Department of Environmental Management - -http://www.state.ri.us/dem

Narragansett Bay Estuary Program - - http://home.earthlink.net/~narrabay/nbep.html

Narragansett Bay Commission - - http://narrabay.com/

Greenwich Bay Project - - http://seagrant.gso.uri.edu/G Bay/

New England Water Pollution Control Commission - - http://www.neiwpcc.org/.

Save the Bay - - www.savethebay.org

Reader's Comments
on the
State of the Environment Report
Narragansett Bay Water Quality: Status and Trends

What are your general impressions of this report (text, graphics, layout, other)?

Would you have preferred more or less detail? On which specific aspects of water quality?

Do you have suggestions for natural resource topics of future reports?

Other Comments:

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