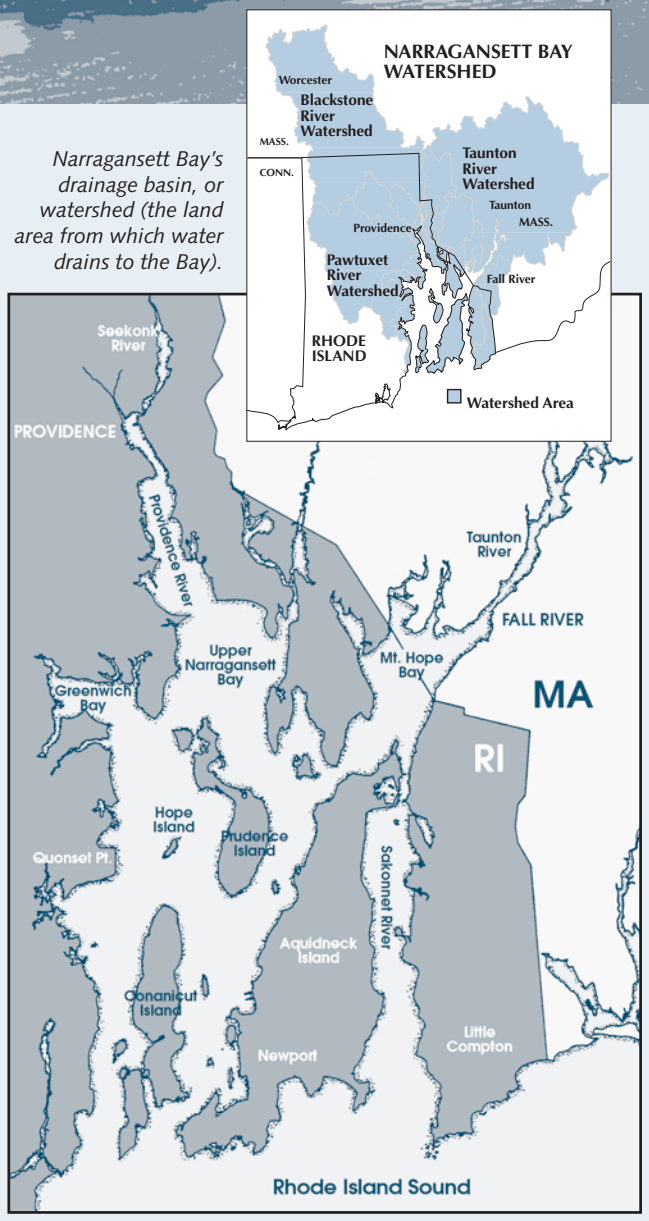
AN OVERVIEW OF

NARRAGANSETT BAY

Narragansett Bay is an estuary–that is, a semi-enclosed inlet of the sea in which seawater is diluted by freshwater. Compared to other estuaries, Narragansett Bay is small-to-medium-sized. Chesapeake Bay, the largest estuary in the United States, covers more than 30 times as much area as Narragansett Bay. Still, Narragansett Bay is big enough to take a good-sized bite out of little Rhode Island. It reaches two-thirds of the way up the state—with the result that no Rhode Islander is more than half an hour's drive from a shoreline—and covers about 10 percent of the state's area.



Narragansett Bay's drainage basin, or watershed (the land area from which water drains to the Bay).

- About 61% of Narragansett Bay's drainage basin—but only 7% of its area—is in Massachusetts.

- The major rivers draining into the Bay are the Blackstone, Taunton, and Pawtuxet.

There are three entrances to Narragansett Bay: the West Passage, the East Passage, and the so-called Sakonnet River, which is really not a river but an arm of the sea. Only the East Passage, with an average depth of 44 feet, is deep enough for large ships.

The Bay's three largest islands are Aquidneck (the Indian name means "longest island"), Conanicut, and Prudence. Some 30 smaller islands, many of them little more than large rocks, also dot the Bay.

As estuaries go, Narragansett Bay is relatively salty: the salinity does not fall below 20 parts per thousand (ppt), except in the Providence River, which represents only a very small portion of the Bay. By contrast, many other estuaries include a wide range of salinities, with large areas in the range of 10 to 15 ppt. (For comparison, seawater has a salinity of 35 ppt.) Like all estuaries, the Bay has a salinity gradient from the head (Upper Bay) to the mouth, with the lowest salinity at the head, where the major rivers flow in.

- The reason for the Bay's high salinity is that the average daily input of freshwater from all sources (rivers, rainfall, and treated sewage) is fairly small, amounting to less than 0.5% of the Bay's total volume.

Life in the Bay

One-celled floating algae called phytoplankton are the basis of the Bay's food chain—or, more accurately, food web. Like land plants, these microscopic plants use photosynthesis to convert carbon dioxide into organic material that ultimately nourishes all other life in the Bay. In spring, summer, and fall, the phytoplankton population can rise ("bloom") and fall rapidly, within a period of weeks. Historically the Bay experienced a major bloom in late winter or early spring nearly every year; but in the past several years this bloom has either not occurred or been reduced. Some scientists hypothesize that this change in the long-term algal bloom pattern may be related to warming of the Bay (the mean surface winter-spring water temperature has risen 1.4 C, or nearly 4 F, over the past 30 years).

- During a bloom, Narragansett Bay's phytoplankton population can double in a single day, and one drop of water may contain up to 4,500 individual cells.

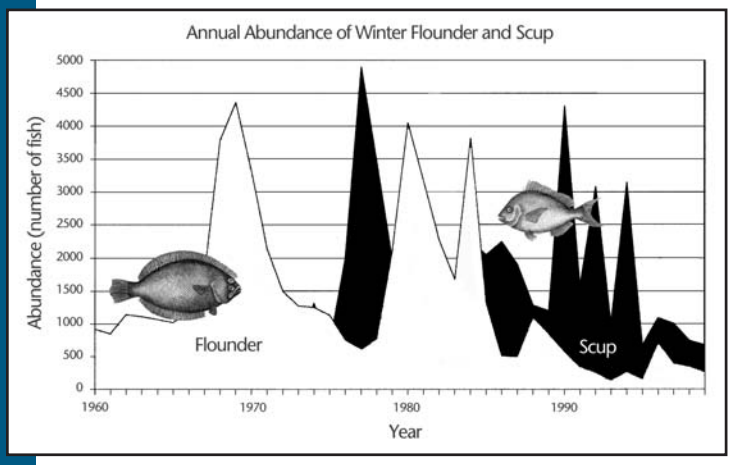
- More than 250 species of phytoplankton have been identified in the Bay.

Narragansett Bay, like any estuary, provides a variety of different habitats for living things. Certain plants and animals are concentrated in particular areas where salinity and other conditions are best suited to their needs. For example, the most productive quahog (hard clam) beds are in the less salty, more nutrient-rich waters of the Upper Bay. On the other hand, lobster and blue mussel prefer the more oceanlike conditions of the Lower Bay.

Fisheries population changes. Two long-term bottom trawl surveys track population fluctuations of Bay fish, squid, and crustaceans. Since 1959, University of Rhode Island (URI) researchers have collected samples from two stations, one in the upper West Passage and one at the mouth of the Bay. The R.I. Department of Environmental Management (RIDEM) has conducted spring and fall surveys since 1979 throughout the Bay and in Rhode Island and Block Island sounds.

These surveys reveal some dramatic changes. For the first three decades of the URI survey, winter flounder was the dominant bottom-dwelling fish species in the Bay. Starting in the late 1980s, a shift occurred: Year-round resident bottom-dwelling fish, especially winter flounder, declined sharply while migratory pelagic species like scup, butterfish, and squid became much more abundant. During the same time period, lobster and crab increased in abundance and quahog populations declined.

Reasons for the downward trend in demersal fish species are not well understood, but other factors in addition to overfishing must be at play because declines have persisted in spite of more than a decade of catch restrictions. Factors that may have a role in the declines include the warming of the Bay's waters (most pronounced in winter and spring) and a trend toward increased levels of nutrients and lower dissolved oxygen concentrations during the summer months.



Over the past two decades, Narragansett Bay has experienced a shift from resident cold-water fish species, such as winter flounder, to migratory warm-water species, such as scup. Source: Jeffries (2000).

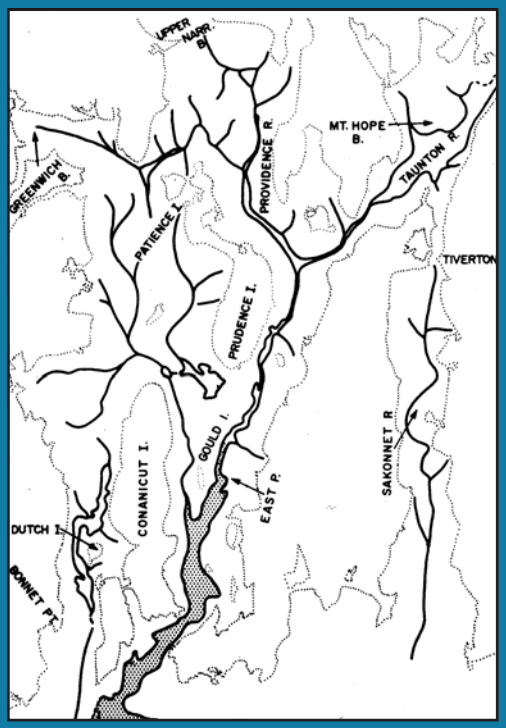
Geological History of Narragansett Bay

25,000 years ago: With the Pleistocene Ice Age in full force, and sea level 300 feet lower than today, Rhode Island lay buried under a sheet of ice 400 feet thick. The glacier extended as far as Block Island. Southward from there, some 70 miles of frozen tundra led finally to the Atlantic coast.

10,000 years ago: Earth was warming. The glacier had receded from Rhode Island, and the ocean was rising but had not yet reached its present level. Prehistoric humans lived in the valleys that today are the passages of Narragansett Bay. They could walk all the way across Rhode Island simply by crossing the small streams that ran through these valleys.

9,000 years ago: As sea level continued to rise, the Atlantic Ocean entered the East Passage of the Bay.

5,000 years ago: Narragansett Bay was filled to almost its present level.



Narragansett Bay 9,000 years ago. Source: McMaster (1984).

Commercial Fisheries

The Bay's commercially important species include the following:

- Demersal (bottom-dwelling) fish: winter flounder, summer flounder, tautog, black sea bass
- Pelagic fish (fish that feed in the water column): bluefish, striped bass, scup, squeteague (weakfish), menhaden, Atlantic herring, and alewife (for use as lobster bait)
- Shellfish: quahog, oyster
- Lobster
- Squid

The demersal fish, as well as quahog and oyster, are Bay residents that are able to live in the Bay year-round and during all stages of their life cycle. Most of the commercially important pelagic fish—as well as squid, which is a pelagic invertebrate—migrate to Narragansett Bay in May or June. Each year, representatives of about 100 different fish species may visit the Bay at one time or another.

Because of Narragansett Bay's small size, and its crucial role both as a feeding area for the young of many species and as a spawning ground, the Bay's resources need to be carefully managed. Restrictions govern fishing methods, size of fish or shellfish that may be kept, amount of catch, and where and when fishing is permitted.

Shellfishing. At the beginning of the last century, the Narragansett Bay oyster—highly prized by gourmets—was the most important commercial species in the Bay. The oyster industry started shortly after the Civil War, peaked in 1910 at 15 million pounds harvested, and continued to flourish through the 1920s. Up to 20,000 acres—about one-fifth of the Bay—were leased for oyster farming (aquaculture) during the industry's heyday. But subsequently the oyster business declined for a variety of reasons. Predators, hurricane damage, poaching, and pollution have all been blamed. The last Narragansett Bay oyster company closed its doors in 1957. Landings remained below 10,000 pounds from the mid-1950s through 1995. A resurgence began in 1996 and peaked the following two years with annual landings in the neighborhood of 200,000 pounds (meat weight). However, after 1998 landings declined, dropping to about 40,000 pounds in 2001. The temporary "boom" was apparently caused by unusually favorable conditions leading to a couple of years of exceptionally good sets; but recently few juveniles have been seen in harvestable waters.

During the 20th century, the Bay's quahog harvest went through two cycles of abundance and decline. Commercial landings peaked at 5 million pounds of meats in 1955—the last year that power dredging was permitted—then fell to a low of 840,000 pounds in 1974. By 1983 landings had climbed again to 4.3 million pounds, only to drop back down to 880,000 pounds in 1998. In 1999 and 2000 landings were around 1.3 million pounds. Recent low harvests are primarily due to three factors: pollution-related closures, lower quahog populations, and fewer quahoggers.

The Bay presently supports shellfish aquaculture on a very small scale, with 30 acres under lease. In 2000 the wholesale value of farmed shellfish (primarily oysters) was $300,000.

Lobstering. For the state of Rhode Island as a whole, the lobster is the most economically important species. In the 1990s, Rhode Island landings held fairly stable at about 6 to 7 million pounds per year, with a value at the dock of around $20 million. While there are no firm data regarding where these lobsters were taken, probably no more than 10 to 20 percent of the catch came from Narragansett Bay.

Finfishing. The great majority of Rhode Island's commercial catch of finfish and squid comes from outside the Bay, in Rhode Island Sound and the Atlantic Ocean, up to 100 miles offshore. Currently, about a dozen small commercial trawlers fish in the Bay, primarily for summer flounder, scup, squid, lobster, and butterfish. At present, fishing for winter flounder is prohibited inside the Bay.

Shipping

Maritime commerce, based on the infamous rum-slaves-sugar "triangle trade" and centered in Newport, was Rhode Island's first major commercial enterprise. By the early 19th century, manufacturing along the Bay's major rivers had replaced shipping as the basis for Rhode Island's economy. To accommodate the manufacturers, the shipping industry followed them up the Bay to Providence and Fall River, Mass.

Today, Narragansett Bay has three public ports: Providence, Quonset Point-Davisville, and Fall River. Several dredged channels allow large vessels to reach these ports. The longest and deepest channel runs 17 miles from the southeast side of Prudence Island up to the Port of Providence, the most active of the three ports. This channel is authorized to be maintained at 40 feet deep, but because of the difficulty of finding acceptable sites for disposal of contaminated dredge spoils it has not been dredged since 1976. Currently the channel is as shallow as 30 feet in some places, making it impassable for deep-draft vessels. However, the U.S. Army Corps of Engineers recently completed an environmental impact study, and a permit to dredge the ship channel back to a depth of 40 feet has been issued.

- The total cargo brought into Rhode Island ports exceeds 8 million tons annually.

- In 1999, 84% by weight of the total cargo delivered to Narragansett Bay ports consisted of petroleum products (gasoline, heating oil, diesel, kerosene, and natural gas).

- Most commercial vessels using the Bay are barges, tugs, and tow vessels.

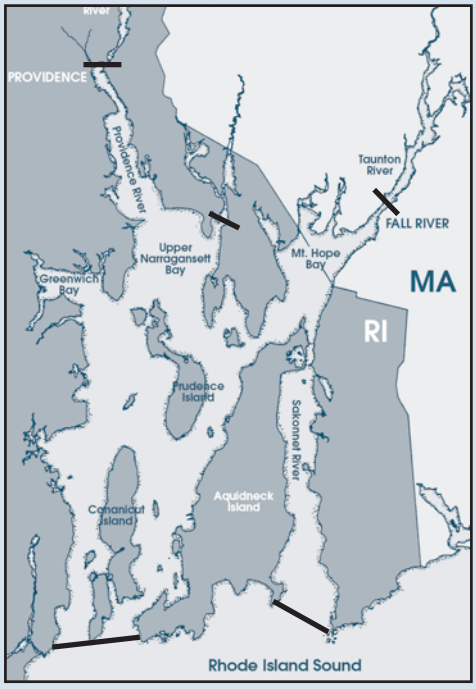
The heavy commerce in petroleum products puts the Bay at risk for oil spills. The largest have been the June 1989 *World Prodigy* spill, which released 392,724 gallons at the Bay's entrance, and the January 1996 *North Cape* spill, which released 828,469 gallons off Point Judith in South Kingstown.

Physical Characteristics of Narragansett Bay

Measurements for area, volume, depth, and shoreline are based on the Bay area bounded by the **black bars,** shown on the map at right.

- **Length:** 25 miles (40 kilometers)
- **Width:** about 10 miles (16 kilometers)
- **Surface area:** 132 square miles (342 square kilometers), not including Taunton River.[1]
- **Volume:** 706 billion gallons (2.7 billion cubic meters) at mid-tide
- **Average depth:** 26 feet (7.8 meters)
- **Deepest point:** 184 feet (56 meters) in East Passage off Castle Hill
- **Shoreline:** 256 miles (412 kilometers), including island shorelines
- **Drainage basin (watershed):** 1,853 square miles (4,801 square kilometers)
- **Average salinity:** 29 to 31 ppt
- **Daily freshwater input, all sources:** 2.4 billion gallons (9.1 million cubic meters)
- **Temperature range, mid-Bay:** from 32 F (0 C) in winter to 73F (23 C) in summer
- **Flushing time:** 10 to 40 days; mean = 26 days
- **Tides:** 3 to 4 feet (0.9 to 1.2 meters) every 12.5 hours; tide takes about 20 minutes to move up the Bay from Newport to Providence
- **Prevailing winds:** from the southwest in summer; northwest in winter

[1]Area is 143 square miles (370 square kilometers) when lower portion of Taunton River is included (Ries, 1990).



Note: Various estimates for these characteristics have been published. Disagreement is due to differences in (1) choice of boundaries for Narragansett Bay and (2) techniques used to obtain the measurements.

Sources: Pilson (1985); Chinman and Nixon (1985).

Recreation and Tourism

Visitors and residents alike treasure Narragansett Bay's waters, beaches, and parks for fishing, boating, swimming, diving, sunbathing, picnicking, and other recreational activities. The total annual economic value of all Bay-related recreational activities is estimated at $2 billion.

Recreational fishing. Recreational fishing on the Bay, whether from a boat, a dock, a bridge, or the shore, is very popular.

- According to federal survey statistics, about 300,000 anglers—of whom 60% were nonresidents—participated in recreational saltwater fishing in Rhode Island waters in 2000, landing an estimated 3.8 million pounds of fish.

These statistics are for the state as a whole. No separate data exist for the Bay, but RIDEM's "best guess" is that one-third to one-half of recreational fishing takes place inside the Bay, and most of the rest occurs in state waters—that is, within 3 miles of shore.

The state's total commercial landings for finfish—close to 82 million pounds in 2000—dwarf the recreational landings, but about 95% of this catch is taken in federal waters. For Rhode Island state waters, the recreational catch is about the same as the commercial catch; and inside the Bay the recreational catch is greater, though specific numbers are not available. For bluefish, striped bass, and tautog, all of which are mainly caught in the Bay or in nearshore waters, total recreational landings exceeded total commercial landings in 2000.

Boating. The Bay is considered one of the best sailing locations in the world. Its safe, sheltered waters, with few shoal areas, are rarely too rough for small boats during the summer months, and sailors can generally count on an afternoon sea breeze of 12 to 15 knots.

- In 2000, 36,522 boats were registered in Rhode Island (up from an average of about 33,000 for the years 1995–1999).

- 91% of all boating facilities (marinas, boatyards, and yacht clubs) in Rhode Island are on the Bay.

Diving and swimming. Recreational scuba divers are drawn to the Bay by the warm water temperature, the diversity of marine life, and an estimated 100 shipwreck sites. Near shore, the water can reach a surface temperature of 74 F—ideal for swimmers at town and state beaches along the Bay and island shores. Of the Bay's parks and beaches, Colt State Park is the most visited, followed by Scarborough Beach and Goddard State Park.

Tourism. Situated at the center of the Washington, D.C.-Boston "megalopolis," Rhode Island attracts many visitors. The tourism industry is the state's second-largest employer, surpassed only by the health services sector.

- In 2000, an estimated 15.7 million people visited Rhode Island for business or leisure. About 5.1 million of them stayed overnight.

- In 2000, tourism brought an estimated $3.2 billion to the state, of which approximately $800 million could be attributed to Bay-related activities.

Pollution

Field's Point treatment facility, Providence, R.I.

In 1793, the opening of America's first water-powered textile mill on the Blackstone River in Rhode Island marked the beginning of the Industrial Revolution in the United States. This event also gave Narragansett Bay a head start over the nation's other estuaries in serving as a receptacle for industrial waste. By 1860, Rhode Island was the nation's most heavily industrialized state. Jewelry factories, textile mills, and other industries freely discharged toxic chemicals into the Bay and its tributaries, and there were reported cases of people fainting from the stench of decomposing human sewage in the Providence River.

The Bay has come a long way since those days. In particular, state regulations based on the federal Clean Water Act, originally passed in 1972, have led to major reductions in industrial discharges. Still, problems remain. The most significant are bacterial contamination, excess nutrients (especially nitrogen), and low dissolved oxygen. In general, pollution levels are highest in the more urbanized and industrialized Upper Bay and lowest at the Bay's southern end.

Bacteria. Antiquated "combined sewage" systems in Providence and other towns channel stormdrain runoff into the same pipes that carry domestic sewage to wastewater treatment plants. Here the wastewater undergoes a treatment process that is very effective at removing solids and a number of contaminants and killing bacteria, although it is less effective against viruses. This combined sewage system works well in dry weather, but during heavy rainfalls (i.e., more than a half inch in 24 hours) the pipes cannot handle the volume, so a mixture of stormwater and untreated (raw) sewage overflows into "relief pipes" and is carried into the Bay.

Combined sewer overflows (CSOs) are the major source of bacteria and viruses to Narragansett Bay. Bacteria from failing septic systems can also be a significant source in areas where large numbers of older septic systems occur along the shores of shallow, poorly flushed embayments such as Wickford Harbor or parts of Greenwich Bay.

- There are 33 wastewater treatment plants in the Narragansett Bay watershed (including Massachusetts).

- Over 100 CSOs in the Providence River region and the city of Fall River discharge a mixture of untreated sewage and stormwater into the Upper Bay during heavy rain events.

Shellfish harvesting is prohibited in the most polluted waters because shellfish taken from these waters can carry bacteria and viruses, including those that cause gastroenteritis and hepatitis. Nearly 20 percent of the Bay's area, including the Providence River, a portion of Mount Hope Bay, and a number of small areas in the immediate vicinity of sewage treatment plants or marinas, is permanently closed to shellfishing, and an additional 11 percent of the Bay consists of "conditionally approved" areas that are closed after heavy rains.

Nutrients and hypoxia. Dissolved oxygen levels are an important indicator of the overall health of any water body. Hypoxia (low oxygen) impairs the feeding, growth, and reproduction of fish, shellfish, and other organisms. The primary cause of hypoxia in estuaries is overenrichment with nutrients, especially nitrogen compounds, which act as fertilizer and can lead to excessive growth of algae. These algae soon die and are decomposed by bacteria, a process that consumes oxygen. In Narragansett Bay, wastewater treatment plants are the major source of excess nutrients.

For most of the 20th century, effluent from wastewater treatment plants carried particulate organic matter into Narragansett Bay. In the Bay, this organic material was decomposed by bacteria, leading to lowered dissolved oxygen levels. In the early 1980s, improvements to the treatment process brought about a marked reduction in the amount of organic material in treatment plant effluent. However, the improvements only partially solved the problem of nutrient input (or "loading") because wastewater treatment plant effluents still contained high levels of dissolved nutrients.

- RIDEM estimates that sewage treatment plant inputs account for about 66% of the total nitrogen loading to the Providence River.

CSOs and urban runoff (the stormwater that washes from roads, parking lots, and other impervious surfaces) are additional sources of nutrients to the Bay, as are individual septic systems.

- 30% to 40% of Rhode Island's population uses septic systems.

- Individual septic systems account for approximately half of the nitrogen entering Greenwich Bay. Most of the rest comes from the East Greenwich wastewater treatment facility.

Runoff from roads and parking lots is a source of nutrients and other pollutants.

Toxic pollution. Over the past two decades, toxic metal loadings to Narragansett Bay have decreased substantially for two reasons: stricter requirements for effluent pretreatment by industries and improvements to wastewater treatment plants. In addition, concentrations of lead have been declining ever since leaded gasoline was phased out beginning in the 1970s. Pretreatment by industrial dischargers has led to decreases in the levels of cadmium, chromium, copper, mercury, nickel, silver, lead, and zinc coming into the Field's Point treatment plant, the largest treatment facility discharging to the Bay.

■ Since 1981, the Field's Point wastewater treatment facility has documented a 94.4% reduction in total metals concentrations and a 95.6% reduction in cyanide concentration in the treated wastewater going into the Bay.

In terms of significant impacts to Bay life and human health, contamination of Bay sediments and waters with metals and other toxic compounds now ranks behind the problems of bacterial pollution, nutrient overenrichment, and hypoxia. Nevertheless, in portions of the Upper Bay, concentrations of some metals and other toxic pollutants still exceed standards set to protect aquatic life. Some of these pollutants come from urban runoff. Cars and other vehicles, for example, are a source of copper, lead, cadmium, and chromium, as well as hydrocarbons such as motor oil. Moreover, high levels of toxic metals from historic inputs still lie buried in deeper sediments. These contaminants can be resuspended by dredging or severe storms.

Future Directions

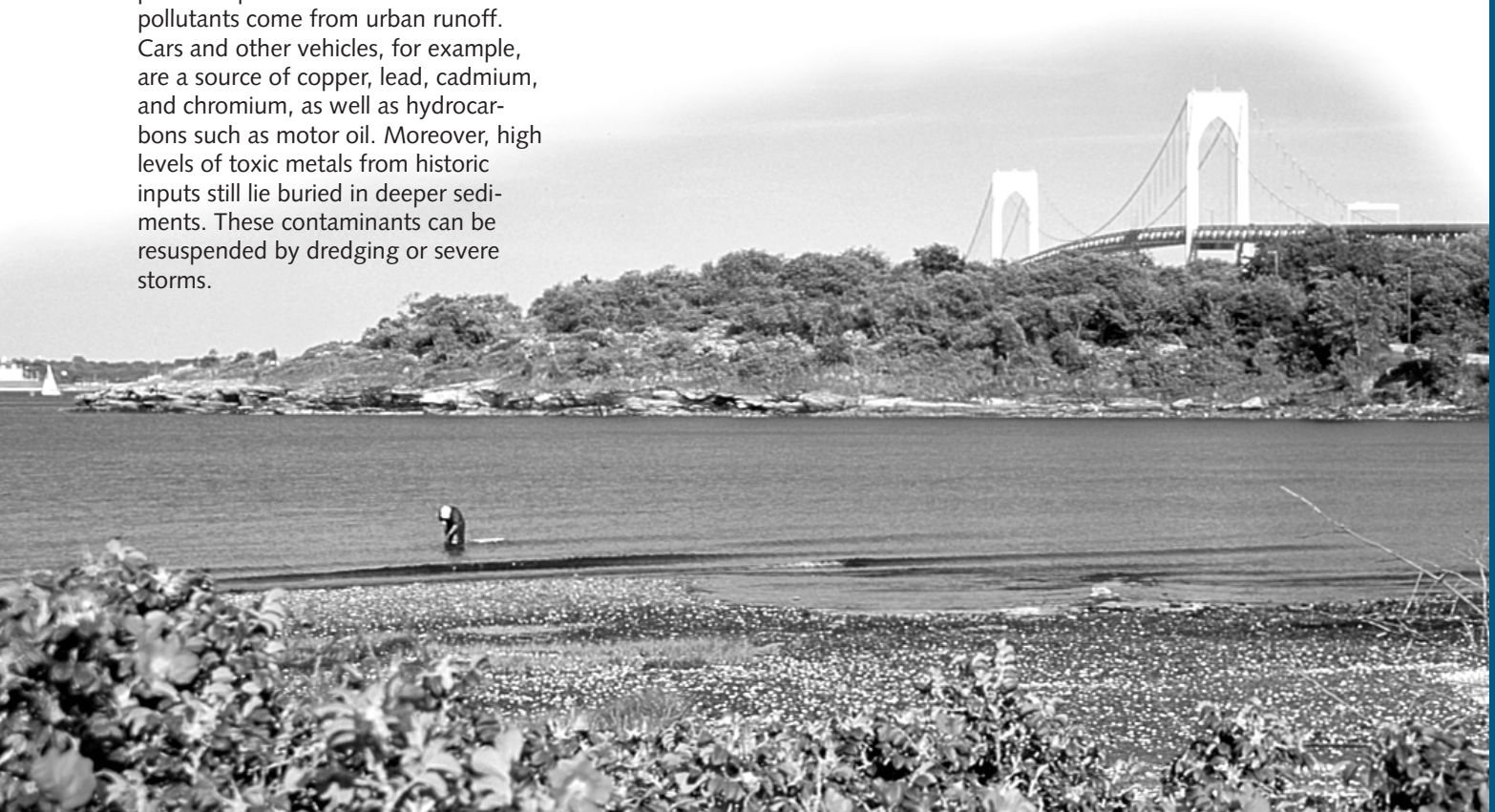
Several projects are under way to tackle major problems still facing Narragansett Bay. In 2002, work began on an ambitious effort to correct the CSO problem by constructing an enormous underground tunnel system. During heavy rains, when the volume of stormwater and untreated sewage in the combined sewage system becomes too large for treatment plants to handle, the excess flow will be diverted into the tunnels. After the storm is over, the wastewater will be pumped to treatment facilities. It is hoped that the resulting reduction in bacteria coming into the Upper Bay will reduce or eliminate the need for conditional shellfish bed closures. The new system will also reduce inputs of nutrients and toxics, both of which are currently carried to the Bay via CSOs.

To further reduce nutrient loading to the Bay, RIDEM is providing financial and technical assistance to communities for treatment plant retrofits or upgrades that will reduce the levels of dissolved nitrogen compounds in effluents. The process involves using organisms naturally present in sewage to transform the nitrogen in organic compounds into nitrogen gas, which is released into the atmosphere.

Meanwhile, one source of bacteria to the Bay has already been eliminated. In 1998, the U.S. Environmental Protection Agency designated all of Rhode Island's marine waters as a "no-discharge" area, meaning that boat sewage is not allowed to be discharged into Bay waters. In addition, a new program has been launched in which state revolving loan funds are being used to provide low-interest loans for replacing failed and substandard septic systems.

Finally, as discussed in the "Shipping" section, the problem of maintaining the ship channels at the desired depth is also nearing resolution, with work on an approved dredging project scheduled to begin late in 2002.

Through the combined effects of all these projects and initiatives, the next few years hold the promise of bringing real solutions to some of the Bay's longstanding pollution problems.



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Rhode Island Department of Environmental Management (RIDEM): *www.state.ri.us/dem*

Rhode Island Sea Grant: *seagrant.gso.uri.edu*

Save The Bay: *www.savebay.org*

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Written by Eleanor Ely
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