EPA 902-R-98-002

LONG ISLAND SOUND STUDY

Phase III Actions for Hypoxia Management

July 1998

A Partnership to Restore and Protect the Sound

THE LONG ISLAND SOUND STUDY

ESTUARY OF NATIONAL SIGNIFICANCE

The Long Island Sound Study (LISS) is a partnership involving federal, state, interstate, and local agencies, universities, environmental groups, industry, and the public in a program to protect and restore the health of Long Island Sound. The LISS began in 1985 under the sponsorship of the U.S. Environmental Protection Agency (EPA) and the states of New York and Connecticut. At the request of the states of Connecticut and New York, EPA designated Long Island Sound an *Estuary of National Significance* in 1988 and convened a Management Conference. In 1994, the LISS Management Conference issued a Comprehensive Conservation and Management Plan (CCMP) to improve the health of the Long Island Sound, while ensuring compatible human uses. In September 1996, the Governors of New York and Connecticut and the EPA signed a Long Island Sound Agreement, reaffirming their commitment to the restoration effort.

PRIORITY AREAS OF CONCERN

The LISS has identified seven issues meriting special attention: (1) low oxygen conditions (hypoxia), (2) toxic contamination, (3) pathogen contamination, (4) floatable debris, (5) the impact of these water quality problems and habitat degradation and loss on the health of living resources, (6) public involvement and education, and (7) land use.

The LISS has focused its efforts and resources on the most pressing problem, the low oxygen levels affecting substantial areas of western Long Island Sound in late summer, and has identified overenrichment of nitrogen as the primary cause. Management has been proceeding in phases. In 1990, the EPA and the states of New York and Connecticut agreed to cap nitrogen loadings as Phase I. The 1994 CCMP contained commitments to begin to reduce the load of nitrogen to the Sound as Phase II. The EPA and the states of New York and Connecticut also committed to develop Nitrogen Reduction Targets for Long Island Sound to guide Phase III implementation.

PURPOSE OF THIS REPORT

On February 5, 1998, after a year of public review, comment and revision, the Policy Committee for the LISS adopted the Phase III Actions for Hypoxia Management, including nitrogen reduction targets. This report updates the Phase III agreement, succeeding the August 1997 *Proposal for Phase III Actions for Hypoxia Management* (EPA 840-R-97-001). While most of the technical background in the 1997 report remains unchanged, it is repeated here in the interest of completeness. The most significant changes are contained in the strategy and schedule, which were negotiated and revised based on public comments received during the past year. Yet, those changes do not compromise or greatly alter the intent and timing of the original proposal, which enjoyed broad public support throughout the comment period. Questions about the Phase III strategy or the LISS may be directed to the EPA Long Island Sound Office at the following addresses:

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Marine Sciences Research Center
SUNY @ Stony Brook
Stony Brook, NY 11794-5000

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Stamford Government Center
888 Washington Blvd.
Stamford, CT 06904-2152

LONG ISLAND SOUND STUDY

A Partnership to Restore and Protect The Sound

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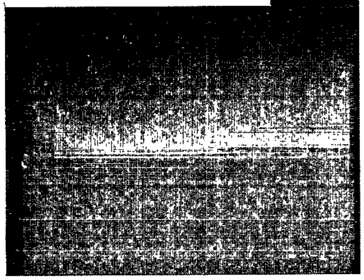
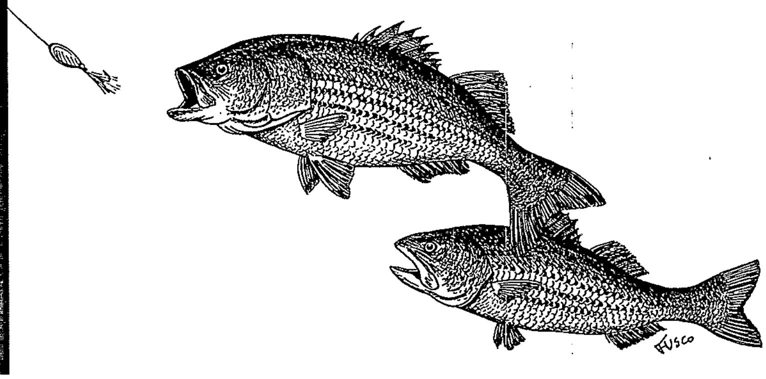


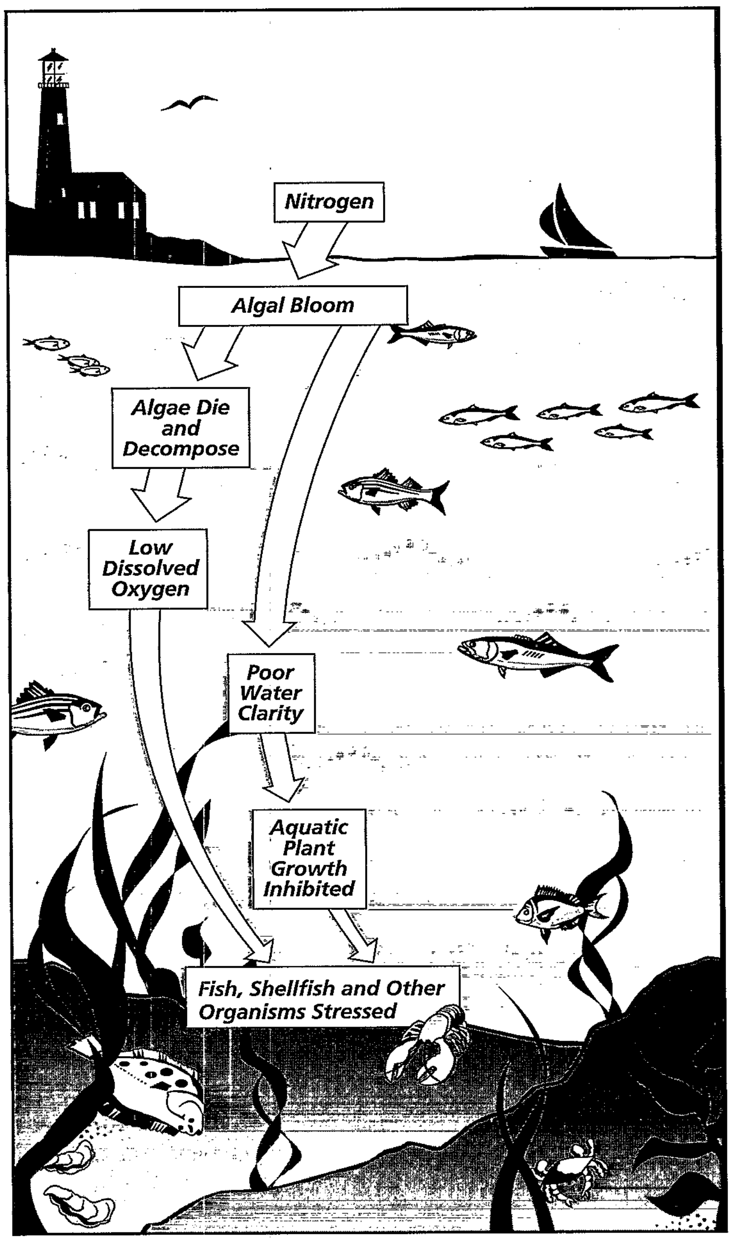


A Matter of Hypoxia

From mid-July through September, Long Island Sound and many of its aquatic inhabitants suffer from a condition called hypoxia—a technical term for low levels of oxygen in the water. During this period, oxygen levels in the bottom waters of Long Island Sound fall well below normal, to levels inadequate to support healthy populations of aquatic life.

But hypoxia is a symptom of a larger problem, the over fertilization of the Sound with nutrients, primarily nitrogen. While nitrogen is a necessary nutrient in a productive ecosystem—a building block for plant and animal tissue—too much nitrogen fuels the excessive growth of planktonic algae. The dense algae blooms cloud the water and shade the bottom. When the algae die and settle to the bottom of the Sound, they are decayed by bacteria, a process that uses up available oxygen. Like people and other air-breathing creatures, aquatic organisms need oxygen to breathe. Oxygen in short supply impairs the feeding, growth, and reproduction of the Sound's aquatic life. In extreme conditions, some organisms may suffocate and die, while others flee the hypoxic zones. The dense blooms also prevent enough light from reaching shallow water bottoms to support the growth of submerged aquatic vegetation, an important habitat for shellfish and juvenile fish. As a result, nitrogen—in excess—impairs the function and health of Long Island Sound (Figure 1).

FIGURE 1 **EFFECTS OF EXCESS NITROGEN**



To address the problem, the Long Island Sound Study (LISS) has been proceeding with a phased approach to nitrogen reduction, allowing the program to move forward in stages as more information is obtained to support more aggressive steps.

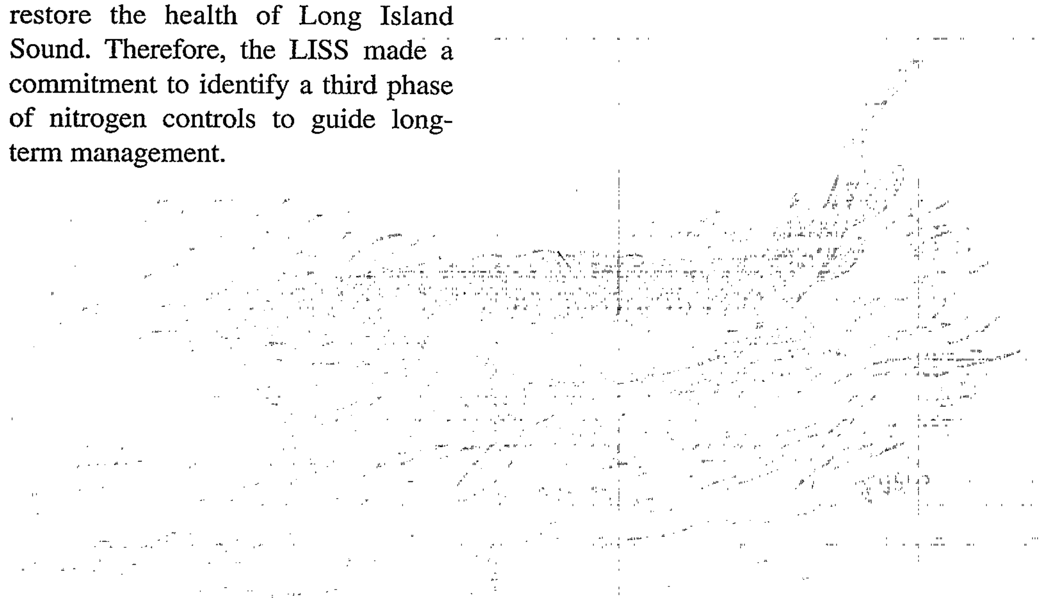
The LISS's first formal action to address the hypoxia problem took place in 1990 with the release of its *Status Report and Interim Actions for Hypoxia Management*. The report announced a freeze on point and nonpoint nitrogen loadings to the Sound in key geographic areas at 1990 levels —a move intended to prevent the hypoxia problem from getting worse. This constitutes what is now known as Phase I of the LISS hypoxia management program.

Phase II, which was adopted in 1994 upon release of the Long Island Sound *Comprehensive Conservation and Management Plan,* initiated actions to begin to improve oxygen levels in the Sound. This phase is being actively implemented in Connecticut and New York and will begin to reverse a 300 year trend of ever-increasing nitrogen loads to the Sound. Phase II reductions, while significant, will not restore the health of Long Island Sound. Therefore, the LISS made a commitment to identify a third phase of nitrogen controls to guide long-term management.

On February 7, 1997, the LISS released a proposal for *Phase III Actions for Hypoxia Management,* including nitrogen reduction targets for 11 "management zones" that comprise the Connecticut and New York portion of the Long Island Sound watershed.

The LISS prepared an earlier version of this report to present the proposal at a series of public meetings that were held in Connecticut and New York. Modifications were made to the proposal in response to public comment and the U.S. Environmental Protection Agency and the states of Connecticut and New York adopted the plan on February 5, 1998, fulfilling a stated commitment of the Long Island Sound *Comprehensive Conservation and Management Plan.*

In addition to identifying the nitrogen reduction targets, this report explains the framework within which the targets were established, discusses the benefits associated with achieving the targets, and recommends specific nitrogen control actions that need to be undertaken to help meet the targets.



UNDERSTANDING HYPOXIA

CONDITIONS

While hypoxia in the Sound is not a new occurrence, a comparison of recent data with that collected since the 1950s suggests that it has become more severe and more common. Monitoring of Long Island Sound conducted since 1986 has recorded hypoxia occurrences each year. Natural variations from year to year in weather and other physical factors have affected the size of the impacted area, the length of time each event has lasted, and how low oxygen concentrations have fallen. Generally, hypoxia occurrences have spanned a period of 40 to 80 days from July through September (Figure 2). In 1989, about 40 percent of the Sound's bottom (more than 500 square miles) experienced unhealthy levels of oxygen during the late summer. As recently as 1994, 25 percent of the Sound was affected.

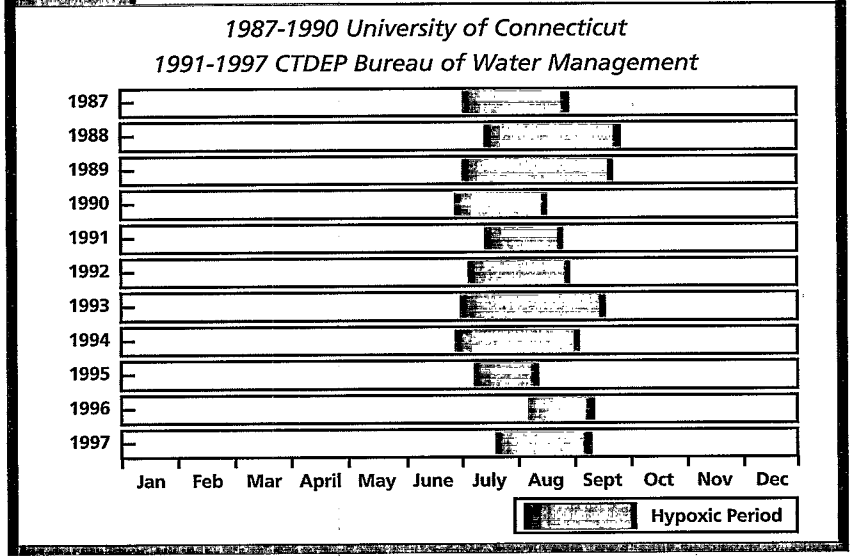
CAUSES

In order to understand the relationship between natural variations in weather and human-induced pollutant loadings, the LISS developed mathematical models of Long Island Sound. The computer modeling effort was designed to answer some fundamental questions:

- What causes low oxygen conditions?
- How much of the problem is caused by natural factors versus human influences?
- What can be done to manage the problem? How effective will different controls be?
- How much will it cost to correct the problem?
- How long will it take to see improvements?

The modeling, combined with field monitoring and laboratory studies, provided a level of detail to support some clear conclusions about hypoxia in the Sound, its causes, and its solutions. In addition, the models allowed the LISS to simulate water quality conditions as they were in the past, as they are today, and as they could be in the future under alternative nitrogen control scenarios.

FIGURE 2 **DURATION AND TIMING OF HYPOXIA**



THE LONG ISLAND SOUND MODELS

The LISS has relied heavily on computer modeling of the Sound to sort out the complex interaction between natural conditions and human influences in causing hypoxia. Two models, a water quality model that approximates the biological and chemical processes of the Sound and a hydrodynamic model that describes physical processes, have been developed. An intensive field program in Long Island Sound to collect data for the computer models was undertaken from April 1988 to September 1989. These data were used to calibrate and verify the models to ensure that they reproduce the important features of the Sound.

The water quality model, called LIS 2.0, provided needed insight into the causes of hypoxia and was the basis for actions to begin to reduce nitrogen discharges to the Sound. However, because it simulates the movement of the Sound's waters in only two dimensions (east-west and surface to bottom) and in a simplified manner, the LIS 2.0 model did not provide the best technical foundation for identifying the total level of reduction in nitrogen loads that should be attained or the most cost-effective means to achieve targeted reductions.

The hydrodynamic model, developed by the National Oceanic and Atmospheric Administration and completed in July, 1993, uses tide and current measurements to simulate the water's circulation in three dimensions (east-west, north-south, surface to bottom). It was coupled to the water quality model, to create LIS 3.0. The LIS 3.0 model provides an advanced tool to relate sources of nitrogen from specific geographic areas to the hypoxia problem in the western Sound. Because the impact of the nitrogen load from different management zones can be determined using LIS 3.0, the LISS can assign priorities for management to ensure that the most the cost-effective options are pursued.

- The most oxygen that can be dissolved in Long Island Sound at summer water temperatures is about 7.5 milligrams per liter (mg/l) of water. This is known as the saturation level.
- Oxygen concentrations greater than 5.0 mg/l provide healthy conditions for aquatic life. Concentrations between 5.0 mg/l and 3.5 mg/l are generally healthy, except for the most sensitive species. When concentrations fall below 3.5 mg/l, conditions become unhealthy. The most severe effects occur if concentrations fall below 2.0 mg/l, even for short periods of time.
- The growth of algal blooms in Long Island Sound is dependent upon the availability of nutrients. These blooms end when the pool of nitrogen available for continued growth is depleted.
- In pre-colonial days, natural, healthy biological activity brought oxygen levels below saturation due to the natural loadings of organic material and nitrogen, but oxygen levels probably fell below 5 mg/l only in limited areas and for short periods of time.
- Under today's higher nutrient and organic material loading conditions, minimum oxygen levels average approximately 1.5 mg/l. These levels are associated with severe hypoxia.
- By substantially reducing nitrogen loadings to the Sound, the minimum oxygen levels in the bottom waters during late summer can be increased to an average of about 3.5 mg/l, thereby significantly reducing the probability and frequency of severe hypoxia and reducing the area affected by hypoxia.
- Increases in nitrogen delivered to the Sound could significantly worsen the hypoxia problem, causing larger areas to have lower oxygen levels for longer periods of time. The probability of events like the summer of 1987, when anoxia (no oxygen) became a reality in the Sound, offshore of Hempstead Harbor, would also increase.

SOURCES

To improve the health of Long Island Sound, the estimated 99,900 tons of nitrogen that enters the ecosystem each year must be reduced. Of that amount, approximately 41,400 tons are from natural sources and not easily reduced by management activity. The remaining 58,500 tons of nitrogen are associated with human activities and have the potential to be reduced through management. (Figure 3).

In some cases, human activities outside of the area can affect the amount of nitrogen entering Long Island Sound. For example, 10,700 tons of nitrogen per year enter the Sound through its boundaries — the East River in the west and The Race in the east. The tributaries flowing into Connecticut bring 2,300 tons of nitrogen per year from activities north of the state line. Deposition of nitrogen from the atmosphere from rain and dryfall is another significant source, contributing 6,500 tons of nitrogen per year, 3,700 tons of which fall directly onto the Sound and 2,800 tons onto the watershed. Of the 39,000 tons of nitrogen per year resulting from human activity in the Sound's drainage basin, point source discharges, primarily sewage treatment plants, contribute 37,000 tons of nitrogen and nonpoint source discharges, such as agricultural and stormwater runoff, contribute 2,000 tons of nitrogen. These loading estimates have been revised based on updated information since the 1994 *Comprehensive Conservation and Management Plan* was published.

FIGURE 3 **SOURCES OF NITROGEN**

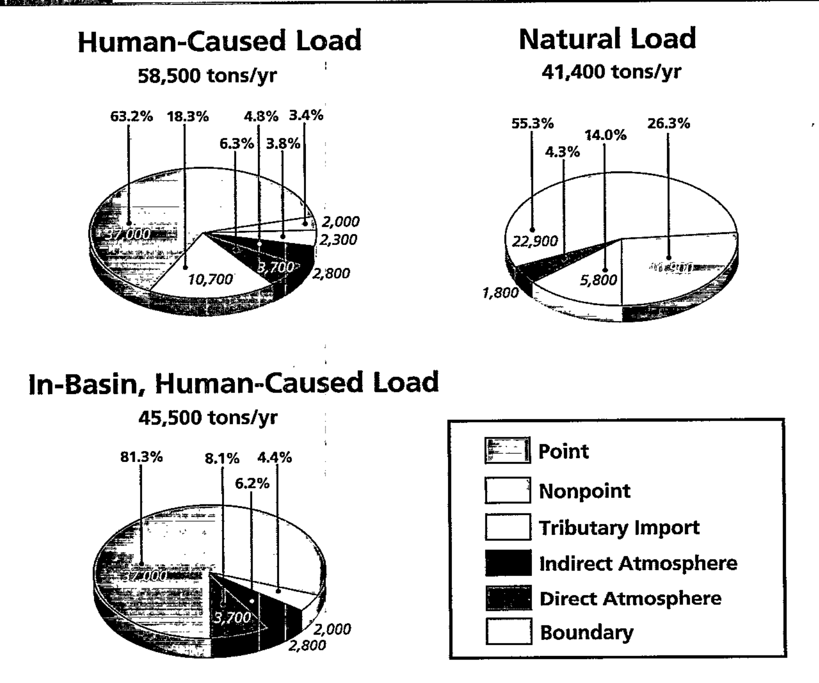
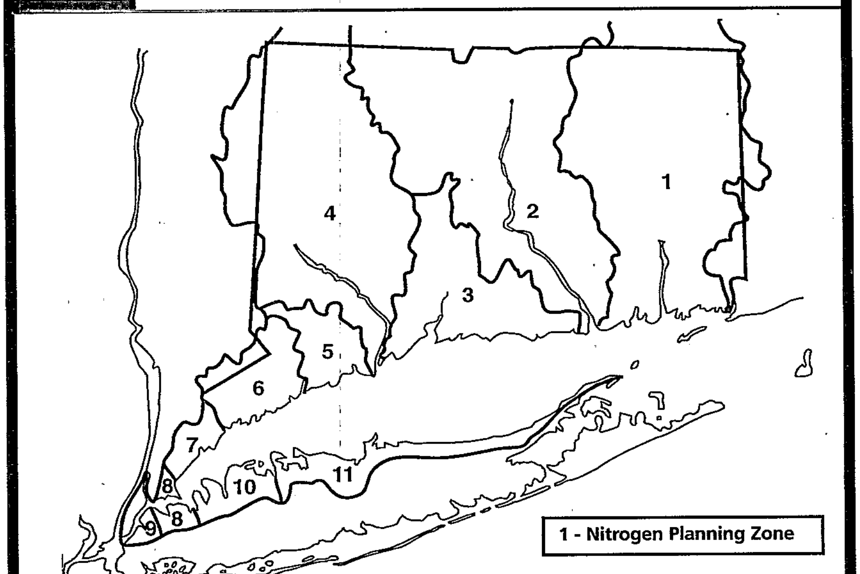


FIGURE 4 **MANAGEMENT ZONES**



BIOLOGICAL NUTRIENT REMOVAL

Conventional primary and secondary sewage treatment plants remove only small amounts of nitrogen and phosphorus from the wastewater. Biological nutrient removal (BNR) removes much greater amounts of nitrogen and phosphorus using natural breakdown processes. Relatively minor modifications (retrofitting) can be made to the equipment or operation of the sewage treatment plant to achieve nutrient removal, but only if the plant has excess capacity. Full BNR often requires reconstruction of the treatment plant at a high cost.

In BNR, biological organisms are used to remove the nitrogen from the wastewater. The basic principal is to have alternating anaerobic (no or little oxygen) and aerobic (oxygenated) zones or tanks within the treatment process. In the aerobic zones, nitrification occurs while in the anaerobic zones, denitrification occurs.

Nitrification is a process in which bacteria convert ammonia and organic nitrogen to nitrate. In sewage treatment plants, ammonia and organic nitrogen come from human wastes and dead plant and animal matter. The nitrifying bacteria are cultured for use at the plants to convert ammonia to nitrite and nitrate. Nitrification occurs naturally in ecosystems such as streams and salt marshes and plays an important role in the cycling of nitrogen through the earth's environment. In sewage treatment plants and in nature, nitrification requires the presence of nitrifying bacteria and high concentrations of dissolved oxygen, also referred to as "oxic" or "aerobic" conditions.

In the denitrification process, another type of bacteria extract oxygen from nitrates, causing harmless nitrogen gas to be released into the atmosphere. Like nitrification, denitrification also occurs naturally in salt marshes and other ecosystems but under low oxygen conditions, or "anoxic" conditions, in the presence of denitrifying bacteria, nitrates, and organic carbon.

The two processes are linked through the recycling of the wastewater in the anoxic and oxic zones of the tanks. Typically, bacteria and nitrates generated in the nitrification stage are cycled along with sewage from the secondary settling tanks to the anoxic denitrification zone to fuel the denitrification process just described.

Eleven watershed management zones, based on natural drainage basin and political boundaries, have been established to foster identification of nitrogen sources and comprehensive watershed planning (Figure 4).

REDUCTIONS

Since 1990, activities have been underway in New York and Connecticut to manage nitrogen from sources within the New York and Connecticut portions of the drainage basin, starting with adoption of the Phase I "freeze" on loadings. The sewage treatment plants under the freeze are identified in Figure 5. In 1992, as a consequence of ending ocean disposal of sewage sludge from New York City, and the resulting need to treat some of the sludge at New York City sewage treatment plants discharging to the East River, the nitrogen load increased by 4,500 tons per year.

For Phase II, the LISS made a commitment in 1994 to reduce nitrogen discharges to the Sound from peak loadings by approximately 7,550 tons per year. This phase consists of incorporating a variety of low-cost nitrogen removal technologies at selected sewage treatment plants, which are identified in Figure 6. The states have moved aggressively to implement nitrogen control activities, using innovative strategies and seeking the cooperation of local governments.

In Connecticut, the goal was to achieve a reduction of 850 tons per year in nitrogen loads. The state of Connecticut has awarded more than $15 million through its State Clean Water Fund to 11 southwestern sewage treatment plants to test and demonstrate the efficiency of upgrades for nitrogen treatment. In addition, the first plant in the state designed to denitrify has been constructed in Seymour. As of December 1997, the load of nitrogen from plants in the Phase II agreement has been reduced by almost 900 tons per year, exceeding the Phase II goal.

The state of New York revised the permits issued to sewage treatment plants, with the consent of local authorities, to establish nitrogen limits at 1990 levels. The permits include an aggregate load for facilities within Management Zones 7-11 (New York

FIGURE 5 SEWAGE TREATMENT PLANTS SUBJECT TO PHASE I FREEZE

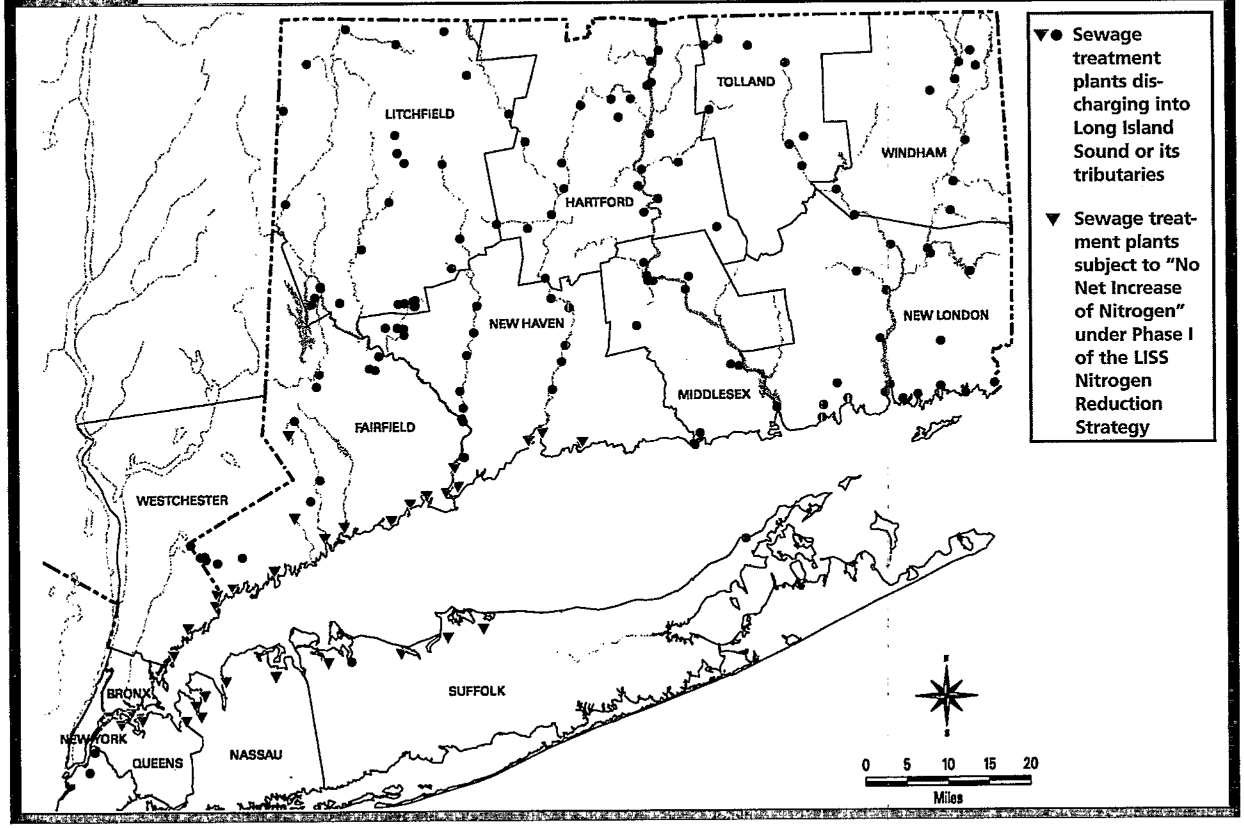
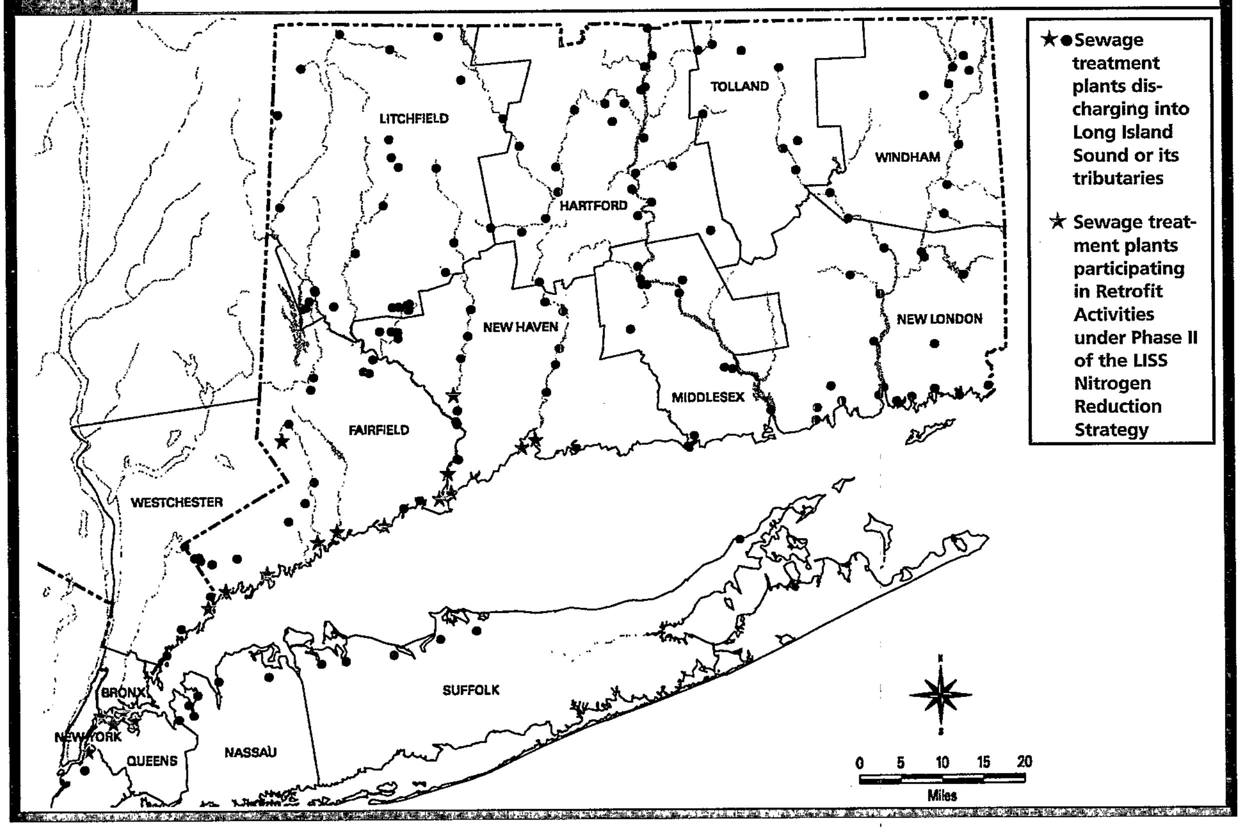


FIGURE 6 SEWAGE TREATMENT PLANTS SUBJECT TO PHASE II REDUCTIONS

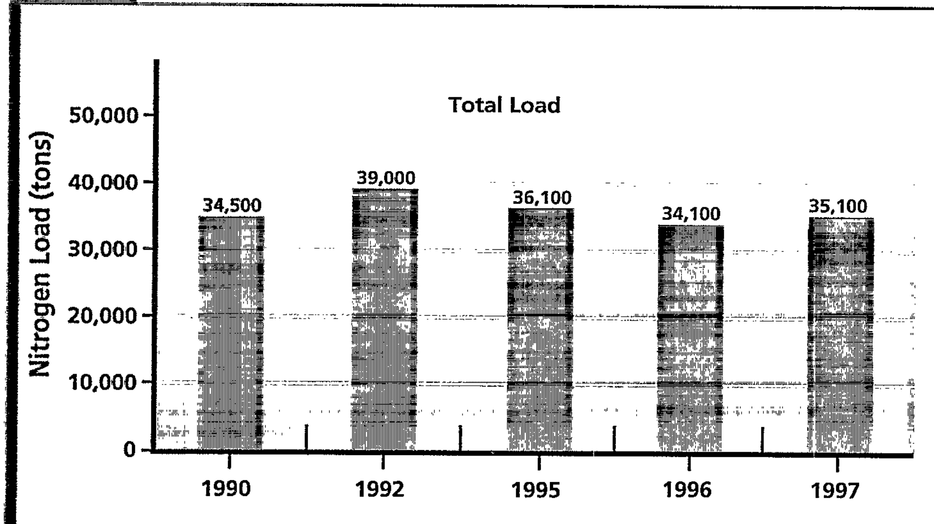


City, Westchester County, and Long Island). The New York goal was to reduce nitrogen loadings by 6,700 tons per year from peak loadings from actions to be completed by 2006. The goal of these actions was to compensate for the increased load due to sludge treatment and reduce loadings back below 1990 levels. As of 1997, one sewage treatment plant in Westchester County and four in New York City have implemented nitrogen removal technologies. New York City is required to implement additional nitrogen removal technologies at the upper East River sewage treatment plants. As of December 1997, the load of nitrogen from sewage treatment plants in New York had decreased by 3,000 tons per year from peak loadings. In addition, New York City has entered into a consent order to provide nitrogen removal at the reconstructed Newtown Creek facility, scheduled for completion in 2007.

In addition, both states have:

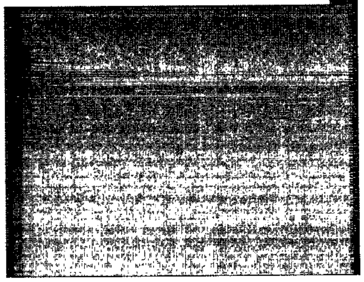
- Developed materials and conducted training for treatment plant personnel on nitrogen removal technologies and procedures.
- Required sewage treatment plants to identify in their plans how they will remove nitrogen, if required to do so.
- Required nutrient monitoring at sewage treatment plants to improve understanding of nitrogen sources and treatment plant capability.
- Increased the share of nonpoint source pollution control funds targeted to projects that reduce nitrogen loads to the Sound.
- Formulated Coastal Nonpoint Pollution Control Programs to address coastal nonpoint sources of nitrogen.
- Undertaken demonstration projects that address a variety of nonpoint source control issues and technologies (e.g., urban runoff treatment by artificial pond/wetland systems, parking lot runoff treatment, septic system technologies to treat and remove nitrogen, controlling runoff from agricultural land and from marinas).

FIGURE 7 CHANGES IN HUMAN-CAUSED NITROGEN LOADS



As of December 31, 1997, nitrogen loadings to the Sound from point and nonpoint sources within the New York and Connecticut portions of the watershed have been reduced as a result of these activities by 3,900 tons per year from peak loadings (Figure 7). The small increase in the 1997 load compared to 1996 was due to reconstruction activities in Connecticut that temporarily disrupted nitrogen removal and an increase from the upper East River facilities in New York.

Phase III Framework



While steps taken in Phases I and II will help to reduce the extent of hypoxia, additional nitrogen reduction is needed to restore the health of Long Island Sound. Phase III sets the course by setting specific nitrogen reduction targets for each of the 11 management zones around the Sound. An array of environmental and economic considerations were taken into account throughout the process. This chapter describes the process—step by step.

Oxygen Benchmarks

The water quality standard for oxygen in Long Island Sound is 6 mg/l in Connecticut and 5 mg/l in New York. Modeling indicates that even if maximum nitrogen reduction technologies were implemented, the water quality standards for oxygen would not be achieved throughout the summer in all areas of the Sound. To help establish priorities for action, the LISS has identified oxygen conditions that will minimize adverse impacts on living resources of the Sound.

Two major research efforts have provided much of the information on how low oxygen conditions affect living resources in the Sound. The first of these was a study conducted by the EPA's Office of Research and Development. Species of fish and crustaceans (e.g., crab, shrimp, lobster) known to reside in the bottom waters of Long Island Sound were exposed to low levels of oxygen in the laboratory. The effect of different concentration of oxygen on growth and survival was measured. Life stages known to be sensitive to low oxygen levels, such as the eggs and juveniles, were emphasized in the tests. In the second study, the Connecticut Department of Environmental Protection (CTDEP) collected bottom-dwelling fish and invertebrates and compared the quantity of organisms and number of species with the levels of oxygen in the water.

Both studies corroborated that severe effects occurred whenever levels of oxygen fell below 2.0 mg/l. The field surveys noted large reductions in the number and types of aquatic life present. The lab experiments recorded reductions in growth and increases in mortality. In both studies, effects became significant when oxygen levels fell below 3.5 mg/l, though some effects occurred at levels between 3.5-5.0 mg/l.

As a result, the LISS has determined that unhealthy conditions occur whenever oxygen levels fall below 2.0 mg/l at anytime or remain below 3.5 mg/l over a 24-hour period. Most adverse impacts can be prevented if oxygen levels exceed these conditions, and they have been used as benchmarks to assess the relative benefits of alternative management strategies for improving the health of Long Island Sound.

COST-EFFECTIVENESS

How do we maximize progress in improving water quality within the framework of existing technology and financial capability? The answer lies somewhere between where we are now (Phase II) and what is achievable if all currently available technologies were employed. LISS managers looked at a range of nitrogen reduction options for the three major sources of nitrogen in the watershed, sewage treatment plants, industrial facilities, and nonpoint source runoff, to answer that question

- **SEWAGE TREATMENT PLANTS:** As nitrogen removal requirements become more stringent, the cost of controls tends to increase. To identify a cost-effective level of treatment, LISS managers arrayed the possible nitrogen reduction options for all 70 sewage treatment plants in the 11 management zones and calculated the average oxygen improvement in the Sound per dollar spent. Improvements at sewage treatment plants that had better than average cost-effectiveness at improving oxygen conditions in the Sound were identified. These actions, in total, could achieve a 62 percent reduction in loads, or 122,044 pounds/day.

- **INDUSTRIAL FACILITIES:** A limited number of industrial facilities directly contribute nitrogen to the Sound; all are located in Connecticut and contribute an estimated 6,717 pounds per day of nitrogen to the Sound. Because information on the cost of reducing nitrogen from industrial sources was not readily available, these facilities were not included in the cost analyses used for sewage treatment plants. Instead, the cost-effective level of treatment identified for sewage treatment plants, 62 percent, was applied to the industrial sources, resulting in a 4,165 pounds per day reduction for industrial facilities. This represents an aggressive but cost-effective level of nitrogen control for these sources.

OXYGEN IMPROVEMENT VERSUS COST FOR SEWAGE TREATMENT PLANTS

To find out how critical areas of the Sound would respond to specific management options, data on oxygen improvement versus cost were plotted on curves for three key areas in the Sound: western Narrows, offshore of New Haven, and offshore of Stony Brook. Figure 8 on page 12 shows the curve for the western Narrows. Each point on the curve represents a specific nitrogen reduction approach at a specific plant at an associated cost. The point at which the curve begins to level out represents the "knee" of each curve, the area where we begin to experience much less oxygen improvement for that region per dollar spent. This point separates those options that yield better than average cost-effectiveness from those with below average cost-effectiveness. This analysis was repeated for two other hot spots in the Sound. Actions with better than average cost-effectiveness in improving oxygen conditions in any one of the three locations were identified and the cost of the actions tallied. Based on the curves for the three response regions, environmental improvement can be maximized and costs minimized with nitrogen reductions of 62 percent reduction from sewage treatment plants (122,044 pounds/day) at a cost of around the $650 million.

ESTIMATING POTENTIAL REDUCTIONS IN NONPOINT SOURCE RUNOFF

Current information on land cover in the watershed and the cost and effectiveness of best management practices (BMPs) to control nitrogen from that land cover was assessed. To determine a loading reduction level, BMP effectiveness was multiplied by the percent of land on which the BMPs are applied. For example, estimates suggest that BMPs reduce nitrogen runoff, on average, by 20 percent. If BMPs were applied to over 50 percent of the land, the level of nitrogen reduction would be 10 percent from the total nitrogen load from urban and agricultural sources. A maximum level of management (100% coverage) would be unrealistic. Thus, a 50 percent BMP application scenario, reflective of an aggressive nonpoint source program, was used to calculate the Soundwide nonpoint source reduction target. This resulted in a 10 percent reduction in nonpoint source nitrogen runoff.

- **NONPOINT SOURCES:** Decisions on controls of nonpoint source runoff must be made in the broader context of watershed management, since control measures will also help reduce suspended solids, toxic contaminants, pathogens, and floatable debris. The LISS recommends that aggressive controls of nonpoint source pollution be implemented for both existing and new development, through both habitat protection and restoration activities, and structural and nonstructural best management practices. This effort could result in a 10 percent reduction in the nonpoint source load from sources within the New York and Connecticut portions of the watershed, or 2,604 pounds per day.

Adding the potential nitrogen reductions from cost-effective controls on sewage treatment plants, industrial sources, and nonpoint runoff sources results in a total reduction of 128,813 pounds per day (23,500 tons per year). The next step is to allocate responsibility for achieving these reductions among the 11 management zones fairly.

ALLOCATING RESPONSIBILITY

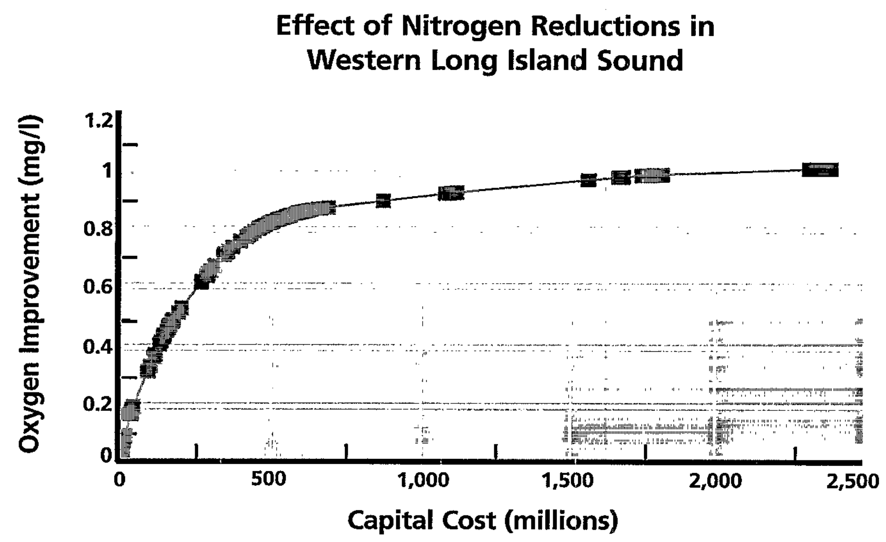
The cost curve analysis provided an option for allocating nitrogen reductions among the sewage treatment plants. Sewage treatment plant upgrades with greater than average cost-effectiveness would be implemented while upgrades with below average cost-effectiveness would not be implemented. However, the LISS decided that relying on the cost curve analysis alone would not be a fair or even feasible approach and would not provide the best solution to allocating nitrogen reduction.

There are several reasons for this conclusion. Most importantly, the cost estimates were general and not uniform in their development. More accurate cost estimates must await detailed facilities planning based upon a clear definition of the nitrogen discharge limits that will have to be met. In addition, local concerns and considerations such as the need to purchase land for expansion and to distinguish between costs for nitrogen removal versus ongoing maintenance, expansions for growth, and secondary upgrade needs (which were not included in the cost estimates) were not addressed evenly in the cost analysis.

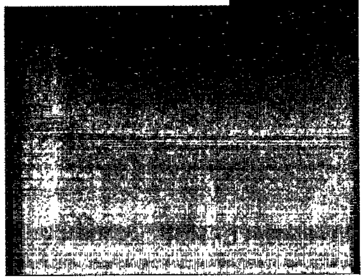
Cost considerations aside, it is necessary for all sewage treatment plants to share the burden of nitrogen removal. All sewage treatment plants contribute nitrogen to Long Island Sound, albeit with different effect. All jurisdictions will benefit from improved water quality. Therefore, it is reasonable to expect all contributors to the problem to contribute to the solution.

For those reasons, LISS has assigned each management zone equal responsibility to reduce its share of the nitrogen load. To achieve a similar level of oxygen improvement from reductions allocated to each zone by the same percentage, the load reduction target was adjusted slightly to 23,800 tons per year from the original 23,500 tons per year. The total human-derived load coming from sewage treatment plants, industrial point sources, and nonpoint sources, including atmospheric depositions within the watershed, is 40,650 tons per year. Therefore, the Soundwide nitrogen target is a 58.5 percent reduction in the human-derived load from point and nonpoint sources in the watershed.

FIGURE 8 **OXYGEN IMPROVEMENT VS CAPITAL COST OF SEWAGE TREATMENT PLANT UPGRADES**



Phase III Actions



Phase III actions will minimize adverse impacts of hypoxia caused by human activities in a cost-effective manner, while ensuring that new information is gathered to refine and improve management over the long term. Using the framework described in the previous chapter, the LISS set a 58.5 percent reduction target for the enriched load of nitrogen from sources within the New York and Connecticut portions of the watershed. The specific Phase III Actions for Hypoxia Management are provided as an appendix to this report.

Strategies

Attaining the nitrogen reduction targets will require aggressive control of point sources, such as sewage treatment plants and industrial sources, and nonpoint sources, such as on-site sewage systems and runoff from roads, parking lots, and construction sites. To achieve the reduction targets, the states, working with local governments, will select the mix of point and nonpoint source controls to be implemented in each management zone. Recognizing that each watershed is different, the plan provides the states and municipalities considerable flexibility in determining how nitrogen reduction actions are carried out within each zone.

By August 2000, the states will take the following actions:

- Develop watershed plans for each management zone that will set the course for achieving the targets as scheduled.
- Consistent with those plans, incorporate limits on the amount of nitrogen that can be discharged from sewage treatment plants and industrial sources into discharge permits.
- Conduct comprehensive nonpoint source management and habitat restoration activities.

Because the total nitrogen load entering the Sound from human sources is dominated by point source discharges, the plan emphasizes technologies that can be applied to sewage treatment facilities and industrial discharges.

In order to achieve significant reductions in the nonpoint source nitrogen load, home owners, farmers, businesses, municipalities, and the states will need to reduce current inputs of nitrogen to the watershed and restore and preserve the nitrogen removal capabilities of existing natural systems. These reductions can be achieved using a number of approaches—resource-based land use decisions at the local level, watershed-wide use of appropriate structural and nonstructural best management practices (e.g., stormwater detention ponds, artificial wetlands, streetsweeping, cleaning catch basins), habitat protection and restoration, and pollution prevention management practices. All approaches will require a concerted education and outreach effort.

TIMING

The planning, financing, and construction of upgrades to sewage treatment plants necessary to achieve the 58.5 percent reduction target will require sustained effort and commitment over a long period of time. Therefore, the LISS recommends phasing-in the necessary reductions over 15 years:

- 40 percent in 5 years,
- 75 percent in 10 years, and
- 100 percent in 15 years.

COST

The *Comprehensive Conservation and Management Plan* identified that the cost of achieving maximum nitrogen removal from all point sources would range from $6 to $8 billion ($5.1 to $6.4 billion in New York state and from $900 million to $1.7 billion in Connecticut). Because of the successful demonstration of full scale nitrogen removal technologies at sewage treatment plants undertaken as part of Phase II, the estimated costs of capital improvements at sewage treatment plants have decreased. The estimated cost of achieving maximum nitrogen removal levels at the 70 treatment plants in New York and Connecticut is now about $2.5 billion

Because of the cost-effective approach described in the previous chapter, the LISS nitrogen reduction strategy would not require all treatment plants to meet limit-of-technology reductions. As a result, the incremental capital cost of achieving the Phase III point source controls was estimated to be $300 million for New York state and $350 million for Connecticut. These cost estimates have been questioned and will be revised as more detailed facility planning and design is performed. However, they show clearly that the potential cost of achieving our goals can be much less than originally estimated.

Nonpoint source controls will be implemented as part of broader watershed and habitat protection efforts. The cost of controlling nonpoint sources is more difficult to estimate than the cost of point source controls. Rather than one type of technology applied to a similar source, a variety of strategies can be applied to control a variety of nonpoint sources of nitrogen. As a result, the costs of achieving nonpoint nitrogen reductions will be addressed in the zone-by-zone plans developed by the states.

FINANCING

As recommended in the *Comprehensive Conservation and Management Plan*, the main source of funding for these wastewater treatment facility improvements will be the State Revolving Fund programs. The EPA, through the federal Clean Water Act, provides financing to support State Revolving Fund loan programs.

Connecticut uses the capitalization grant from EPA to leverage with state bond funds to provide grants and low interest loans, at 2 percent interest over 20 years, to finance improvements at municipal facilities. Connecticut provides about $50 million per year in state bonding to supplement the $15 million per year provided under the Clean Water Act. At this capitalization rate, Connecticut should be able to meet municipal financing needs to implement Phase III nitrogen reductions. During fiscal year 1997, CTDEP awarded $250 million from their Clean Water Fund to finance projects of benefit to Long Island Sound, including major sewage treatment plant upgrades in Norwalk and Waterbury.

New York state established its State Revolving Fund in the custody of the Environmental Facilities Corporation. This public corporation benefits local governments in New York state by offering below-market interest rate loans to municipalities to finance wastewater improvements. Currently, the interest rate is set at up to one-half of the market rate to be repaid in 20 years. Lower rates of interest, including zero interest loans, are available for communities that can demonstrate an inability to pay the standard subsidized rate. Another major source of funding in New York state is the $1.75 billion Clean Water/Clean Air Bond Act approved by voters in November 1996. The Bond Act targeted $200 million for Long Island Sound that will be available for sewage treatment upgrades, habitat restoration, nonpoint source control, and pollution prevention.

The possible funding sources for nonpoint source controls reflect the diversity of both the sources and the control options. Grant funding through federal and state water quality management, natural resources management, and coastal zone management programs is available for nonpoint source activities. The State Revolving Fund loan program is also available to fund stormwater management and habitat restoration projects but has not been used to a great extent for these types of activities due to the magnitude of existing point source funding needs in Connecticut and New York.

EFFLUENT TRADING

To provide further flexibility and incentives for maximizing the timeliness and cost-effectiveness of nitrogen reduction actions, the LISS is investigating the feasibility of allowing effluent trading. Trading, if employed as part of the nitrogen reduction effort, may be an innovative way to use market forces to more efficiently meet water quality goals. The LISS is developing a trading proposal and will convene a public forum for federal, state, and local water quality officials, together with public and private interests, to evaluate its potential.

ENFORCEMENT

The provisions of the federal Clean Water Act provide a vehicle for ensuring that nitrogen reduction targets are legally enforceable. Section 303(d) of the Act requires the identification of a Total Maximum Daily Load for pollutants that will result in the attainment of water quality standards. Once a Total Maximum Daily Load has been established, the act calls for reductions to be allocated to sources so that the load target is met.

New York and Connecticut and EPA will use their authorities to provide an enforceable foundation for achieving the nitrogen reduction targets. By August, 1998 the states will propose a Total Maximum Daily Load designed to meet state oxygen standards. The current Long Island Sound standards were developed with limited data on how low oxygen levels affect aquatic life in Long Island Sound. EPA is currently developing regional marine oxygen criteria that will provide a more scientifically valid basis for the development of oxygen standards. Based on this information, the states may, in the future, modify their oxygen standards.

While LISS managers predict significant improvement in water quality as the nitrogen reduction targets are implemented, the attainment of current water quality standards at all times and in all areas is not expected. For this reason, the

LISS will continue to assess what other kinds of actions will be needed to bring the Sound into full compliance with water quality standards.

These actions may include control of nitrogen and carbon sources outside of the Long Island Sound basin (e.g., tributary import from point and nonpoint sources north of Connecticut, atmospheric deposition, boundary import from point and nonpoint sources affecting New York Harbor and The Race). Alternatives to nitrogen reduction, such as aeration, will need to be considered as a possible means to achieve water quality standards in remaining areas.

EVALUATING PROGRESS

The LISS will track, monitor, and report on progress in meeting the nitrogen reduction targets annually. In addition, a formal review of the goals and objectives of the program will be performed every 5 years, coinciding with the progress checkpoints for nitrogen reduction. The review will consider:

- Progress and cost of implementation, including a reevaluation of the knee-of-the-curve analysis used to establish the Phase III nitrogen reduction targets,
- Improvements in technology, including the results of quality controlled pilot projects,
- The regional dissolved oxygen criteria to be published for comment,
- Water quality standards,
- Refined information on the ecosystem response to nitrogen reductions,
- The results of peer reviewed modeling, and
- Research on the impacts of hypoxia to living resources and their habitats.

Each of these factors will be considered in a balanced manner in the reevaluation process. As a result of the review, the LISS may recommend improvements that could result in changes in how the overall program will be implemented.

Benefits of the Phase III Nitrogen Reduction Targets

Ecosystem Health

Phase III will yield significant ecological and environmental benefits. The maximum area of the Sound that is unhealthy for marine life will be reduced by an estimated 75 percent (Figures 9 and 10). The period during which unhealthy conditions exist in the Sound is predicted to be reduced by 85 percent, from more than 50 days to 6.5 days.

By limiting the area and duration of unhealthy conditions, overall biological effects will be greatly reduced Soundwide.

In the western Narrows:

- Death rates of larvae of marine life sensitive to hypoxia will be reduced by 67 percent;
- Adverse impacts on fish abundance will be reduced by 97 percent;
- Adverse impacts on scup (porgy) abundance will be reduced by 61 percent and on winter flounder abundance by 99 percent. Effects on lobster abundance will be eliminated.

In the waters off of New Haven, Connecticut:

- Mortality of sensitive larvae will be reduced by 65 percent;
- Adverse impacts on fish abundance will be eliminated.

In the waters off of Stony Brook, New York:

- Larval mortality will be reduced by an estimated 84 percent;
- Adverse impacts on fish abundance will be eliminated.

While the model analysis was intended to analyze the open waters of the Sound, improvements are expected in harbors, embayments, and near shore waters as well. These waterways are flushed with water from the Sound as a result of tidal action. As the quality of water from the Sound improves, we can expect improvement in the harbors, embayments, and near shore waters as well. Improved visibility of waters will also expand the amount of shallow water area conducive to the growth of submerged aquatic vegetation, an important habitat that has diminished in range from historical levels.

Human Use Benefits

Research commissioned in 1990 by the LISS estimated that more than $5 billion are generated annually in the regional economy from boating, commercial and sport fishing, swimming, and beachgoing. Actions that result in improved oxygen levels in the Sound, besides increasing habitat that is healthy for aquatic life, will also benefit people who live around and use the Sound. Other expected benefits from improved water quality resulting from nitrogen reduction in the Sound would include:

- **BOATERS:** By reducing nitrogen loadings to the Sound, algal blooms will be reduced or prevented. By reducing or preventing algal blooms, the clarity and aesthetics of the water will be improved, increasing enjoyment for boaters.
- **SWIMMERS:** Swimmers will notice better water clarity, as a result of less severe algal growth. Less nitrogen will also bring growth of seaweed back into balance.
- **ANGLERS:** Because finfish actively avoid unhealthy waters with low oxygen levels, the Phase III nitrogen reductions will benefit anglers by increasing the area of the Sound in which fish are likely to be found.
- **SCUBA DIVERS AND SNORKELERS:** Scuba divers and snorkelers will benefit from improved visibility underwater as a result of reduced algal blooms, as well as the presence of more abundant and healthier marine life.
- **BIRDWATCHERS AND SIGHTSEERS:** Although birds and wildlife that use the shore area are not directly affected by oxygen levels, many of them feed on marine life, such as small fish, shellfish (e.g., mussels), and crustaceans (e.g., crabs). By improving the health of the waters of the Sound, birds and wildlife will have a greater supply of food, and will be more likely to use the shoreline areas. Therefore, birdwatchers and sightseers will benefit from Phase III nitrogen reductions because shorebirds, waterfowl, and wildlife will be more abundant along the shoreline.
- **COMMERCIAL FISHING AND SHELLFISHING:** The healthier the condition of the Sound, the more fish and shellfish will prosper, which means that more of them will be available for harvest by people. The value of commercial fishing in Long Island Sound during 1990 was more than $148 million.
- **TOURISM:** Visiting the beach, fishing and diving charters, sightseeing trips, and other leisure pastimes contribute to the local economy, both directly to the tourism industry and to other businesses that support the tourist trade (e.g., restaurants, gas stations, sporting goods stores).
- **REAL ESTATE:** Studies have shown that the value of properties used for recreation (e.g., seasonal cottages) drop in value in response to decreasing water quality. It is likely that improved water quality in the Sound will increase property values along the shore.

FIGURE 9 **EXISTING OXYGEN CONDITIONS**

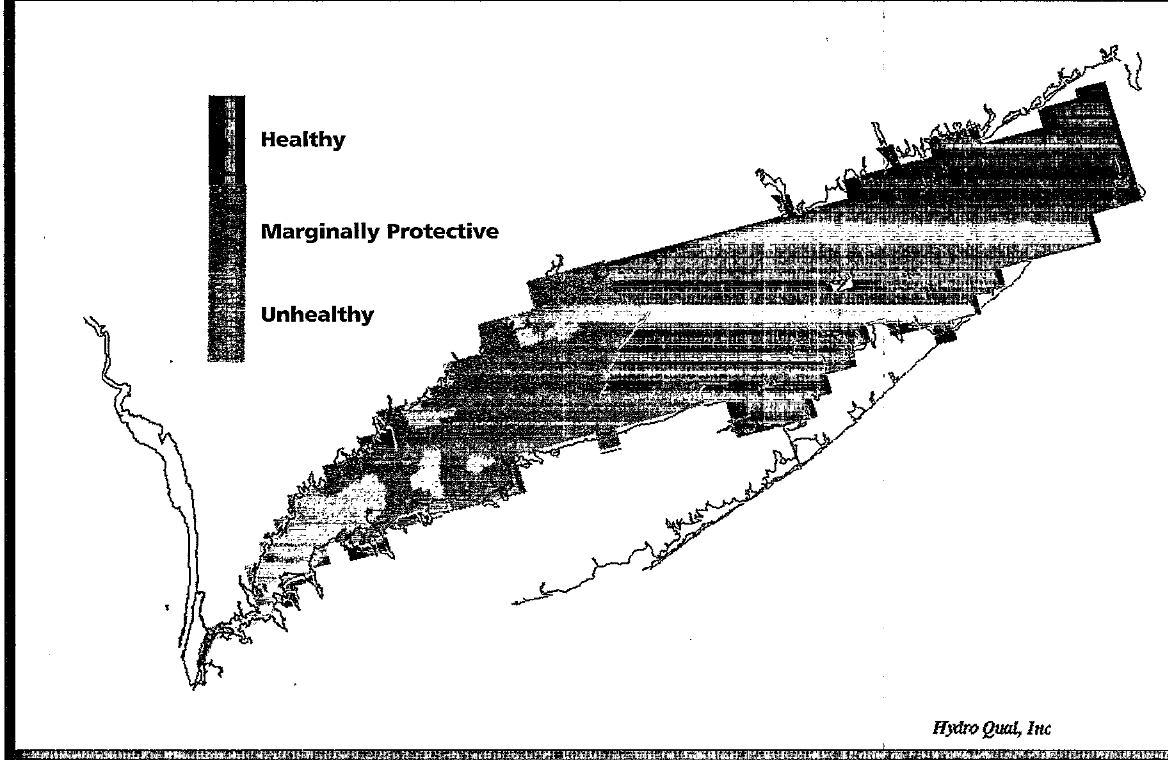
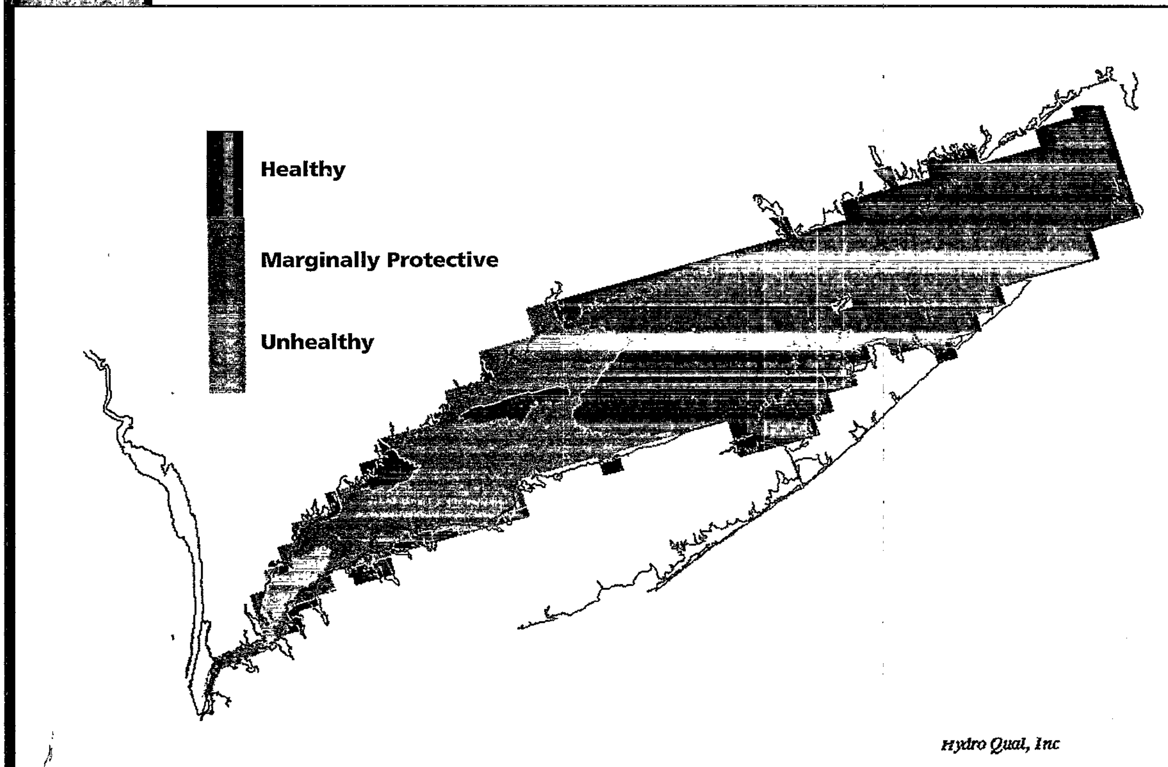


FIGURE 10 **PROJECTED PHASE III OXYGEN CONDITIONS**



Suggested Reading

The following list represents selected reports available from the Long Island Sound Office that provide additional information.

1. Altobello, M.A. 1992. The Economic Importance of Long Island Sound's Water Quality Dependent Activities. University of Connecticut.

2. CTDEP. 1995. A study of Marine Recreational Fisheries in Connecticut. Federal Aid to Sport Fish Restoration. F54R Final Report.

3. Howell, P., D. Simpson. 1994. Abundance of Marine Resources in Relation to Dissolved Oxygen in Long Island Sound. Estuaries. 17:394-402.

4. HydroQual. 1991. Water Quality Modeling Analysis of Hypoxia in Long Island Sound. Prepared for the Management Committee of the Long Island Sound Study and the New England Interstate Water Pollution Control Commission. Job #NENG0012.

5. HydroQual. 1996. Water Quality Modeling Analysis of Hypoxia in Long Island Sound Using LIS 3.0. Prepared for the Management Committee of the Long Island Sound Study and the New England Interstate Water Pollution Control Commission. Job #NENG0035.

6. HydroQual. 1997. Evaluation of Nutrient Management Scenarios Using LIS 3.0. Prepared for the Management Committee of the Long Island Sound Study and the New England Interstate Water Pollution Control Commission. Job #NENG0035.

7. Long Island Sound Study. 1990. Status Report and Interim Actions for Hypoxia Management. 40 pp. U.S. Environmental Protection Agency.

8. Long Island Sound Study. 1994. Comprehensive Conservation and Management Plan. 168 pp. U.S. Environmental Protection Agency, LIS Office, Stamford Connecticut.

9. Long Island Sound Study. 1997. Framework for Developing the Proposed Phase III Nitrogen Reduction Targets. 19 pp. U.S. Environmental Protection Agency, LIS Office, Stamford Connecticut.

10. Miller, D.C., S.L. Poucher, L. Coiro, S. Rego, W. Munns. 1995. Effects of hypoxia on Growth and Aurvival of Crustaceans and Fishes of Long Island Sound. In: *Proceedings of the Long Island Sound Research Conference: Is the Sound Getting Better or Worse? New York Sea Grant Institute.* NYSGI-W-94-001

11. Parker, C.A., and J.E. Reilly. 1991. Oxygen Depletion in Long Island Sound: A Historical Perspective. Estuaries. Volume 14, No. 3.

12. U.S. EPA. 1996. Draft Framework for Watershed-Based Trading. U.S. Environmental Protection Agency, Office of Water. Washington, DC

APPENDIX

PHASE III ACTIONS FOR HYPOXIA MANAGEMENT ADOPTED BY THE LISS POLICY COMMITTEE

February 5, 1998

PHASE III NITROGEN REDUCTION TARGETS

Based upon currently available estimates of treatment performance and costs of nitrogen reduction technologies, a "knee-of-the-curve[1]" analysis was performed to determine appropriate levels of nitrogen reduction to alleviate hypoxia in the Sound. As a result of this analysis, USEPA, NYSDEC, and CTDEP recommend:

1. A 58.5 percent[2] reduction in the total enriched load[1] of nitrogen to Long Island Sound from point and nonpoint sources within the New York and Connecticut portion of the watershed within 15 years[3].

2. Each of the eleven watershed-based management zones established by the LISS be allocated a 58.5 percent reduction.

3. To administer and enforce the nitrogen reduction targets consistent with the Clean Water Act, the LISS will develop a Total Maximum Daily Load/Wasteload Allocation/Load Allocation necessary to meet standards for dissolved oxygen in Long Island Sound.

   A. CTDEP and NYSDEC will work with EPA to develop, by July 1998, a TMDL necessary to meet the dissolved oxygen standards. NYSDEC and CTDEP will propose the TMDL in August 1998 and submit the TMDL, as appropriate, to EPA by December 1998 for approval. EPA will develop the TMDL if it is disapproved, as required by the CWA.

   - The TMDL will include point and nonpoint source controls in the New York and Connecticut portion of the watershed to meet the 58.5 percent reduction target.
   - The TMDL will also include future actions and schedules beyond the 15-year Phase III plan for achieving water quality standards, such as the control of carbon and nitrogen from outside of the LISS management area, including point and nonpoint sources north of Connecticut in New England, atmospheric deposition, point and nonpoint sources affecting import from New York Harbor and The Race, and other alternatives, such as aeration and load relocation.
   - The TMDL will include a provision for periodic review every five years and revision as appropriate.

   B. CTDEP and NYSDEC will develop zone-by-zone plans (WLA/LA) by August 1999 to achieve the nitrogen reduction target, highlighting a mix of quantifiable

1. As defined in the January 1997 LISS's *Framework for Developing the Proposed Phase III Nitrogen Reduction Targets.*
2. From pre-nitrogen management conditions, defined as the 1990 baseline plus centrate from the cessation of ocean dumping.
3. From August 1999, the date by which the states will develop zone-by-aone plans to achieve the target.

point and nonpoint source controls to be implemented in each management zone.

C. CTDEP and NYSDEC will propose modifications to NPDES permits for point source discharges by August 2000.

- incorporating nitrogen loading limits to achieve the point source component of the five-year load reduction target, and
- requiring that plans and implementation schedules be developed to achieve the point source component of the nitrogen reduction targets within 15 years.

D. August 2000, CTDEP and NYSDEC will commit to the quantifiable actions necessary to achieve the nonpoint source reduction component of the five-year load reduction target.

E. Any new permits issued within this interim period must specifically address A-C, above.

F. The states will report on progress on the nitrogen reduction targets as part of the annual Management Conference reporting requirements.

4. 15-year, phased, enforceable schedule, commencing after completion of zone by zone plans, be established to assure steady progress in achieving the nitrogen reduction targets

- 40 percent progress toward the 58.5 percent target reduction within five years
- 75 percent progress toward the 58.5 percent target reduction within ten years
- 100 percent progress toward the 58.5 percent target reduction within 15 years

5. Five years after adoption of the nitrogen reduction targets and every five years thereafter, the LISS will formally evaluate the nitrogen reduction targets, considering the:

- progress and cost of implementation, including a reevaluation of the knee-of-the-curve analysis used to establish the Phase III nitrogen reduction targets,
- improvements in technology, including the results of quality controlled pilot projects,
- the regional dissolved oxygen criteria to be published for comment,
- water quality standards,
- refined information on the ecosystem response to nitrogen reductions,
- the results of peer reviewed modeling, and
- research on the impacts of hypoxia to living resources and their habitats.

Each of these factors will be considered in a balanced manner in the reevaluation process.

A. During each five year period, the LISS, through the advice of the TAC and CAC, will encourage continued monitoring, modeling, and research necessary to provide critical information to support the reevaluation of the nitrogen reduction targets.

B. EPA will complete a report on deriving regional protection limits for dissolved oxygen.

C. The states will review and revise their water quality standard for dissolved oxygen.

D. The LISS will reevaluate the nitrogen reduction targets. The states will confirm point source loading limits for ten and 15 years in future permit revisions and commit to the actions necessary to achieve the necessary ten and 15 year nonpoint source nitrogen reductions.

E. The states will review and revise, as appropriate, the TMDL and submit it to EPA for approval.

6. By June 1998, the LISS will investigate the feasibility, cost, benefits, and drawbacks of establishing a program to allow nitrogen trading within and among zones in administering the Phase III reductions, beyond the current bubble concept already in use in New York. However, under no circumstances can trading occur if the 1990 aggregate cap has not been met within a management zone.

TIMELINE

February 1998 Policy Committee adopts the Phase III Nitrogen Reduction Targets.

June 1998 LISS to report on the feasibility, cost, benefits, and drawbacks of establishing a program to allow nitrogen trading within and among zones in administering the Phase III reductions, beyond the current bubble concept already in use in New York.

July 1998 States and EPA develop TMDL necessary to meet Nitrogen Reduction Targets.

August 1998 States propose the TMDL.

December 1998 States submit TMDL to EPA for approval.

August 1999 CTDEP and NYSDEC will develop zone-by-zone plans (WLA/LA) to achieve the nitrogen reduction target, highlighting a mix of quantifiable point and non-point source controls to be implemented in each management zone. Fifteen year implementation schedule begins.

August 2000 CTDEP and NYSDEC will propose modifications to NPDES permits for point source discharges, incorporating nitrogen loading limits to achieve the point source component of the five-year load reduction target, and requiring that plans and implementation schedules be developed to achieve the point source component of the nitrogen reduction targets within 15 years.

CTDEP and NYSDEC will commit to the quantifiable actions necessary to achieve the nonpoint source reduction component of the five-year load reduction target.

February 2003 LISS formally evaluates the nitrogen reduction targets considering the progress and cost of implementation, including a reevaluation of the knee-of-the-curve analysis used to establish the Phase III nitrogen reduction targets, improvements in technology, including the results of quality controlled pilot projects, the regional dissolved oxygen criteria to be published for comment, water quality standards, refined information on the ecosystem response to nitrogen reductions, the results of peer reviewed modeling, and research on the impacts of hypoxia to living resources and their habitats.

August 2003 CTDEP and NYSDEC review and revise the TMDL, as appropriate.

August 2004 CTDEP and NYSDEC will propose modifications to NPDES permits for point source discharges incorporating nitrogen loading limits to achieve the point source component of the 10-year load reduction target.

February 2008 LISS formally performs second reevaluation of the nitrogen reduction targets.

August 2008 CTDEP and NYSDEC review and revise the TMDL, as appropriate.

August 2009 CTDEP and NYSDEC will propose modifications to NPDES permits for point source discharges incorporating nitrogen loading limits to achieve the point source component of the 15-year load reduction target.

August 2014 Nitrogen Reduction Targets achieved.