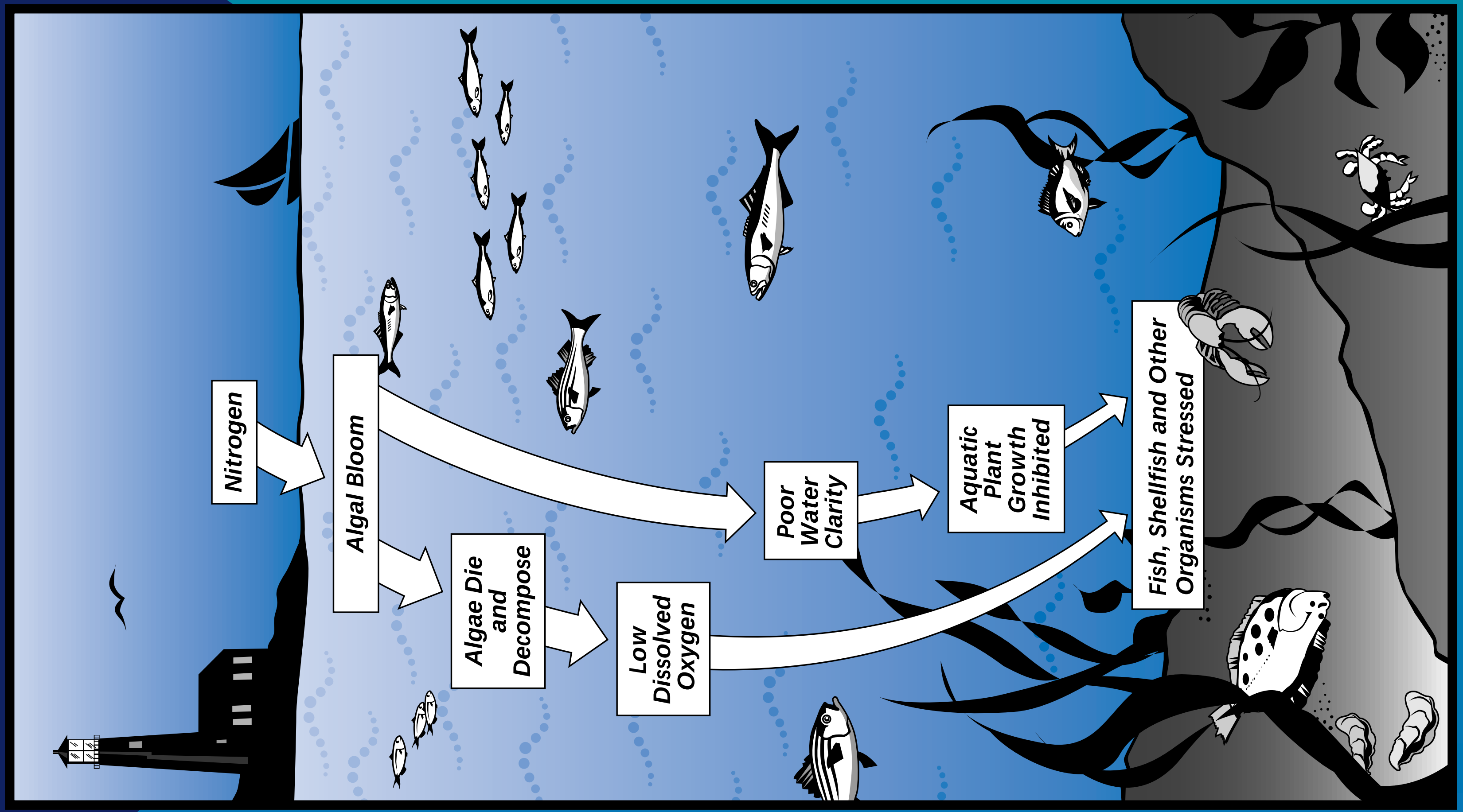
HYPOXIA

Low Dissolved Oxygen

What is Hypoxia?

Hypoxia or low dissolved oxygen has been identified as the most critical issue facing the Sound. Just as we breathe oxygen, the fish and other marine life that live in the Sound require oxygen dissolved in water for them to survive.

Effects of Excess Nitrogen

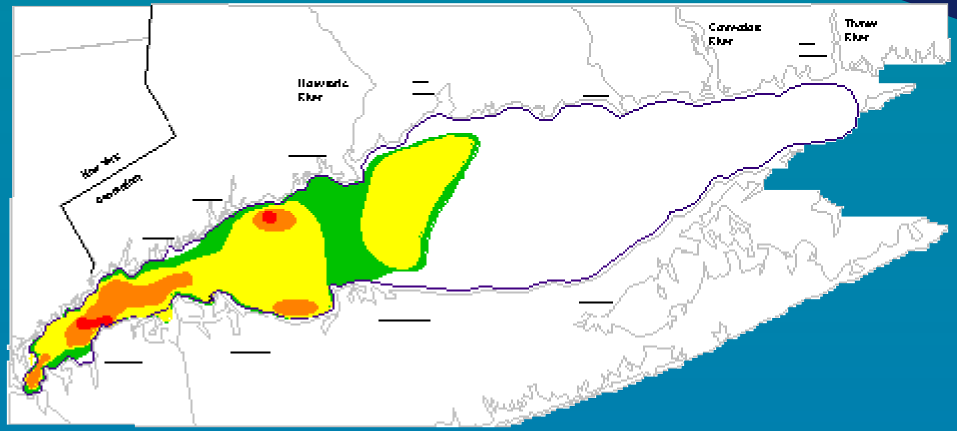


How Does Hypoxia Occur?

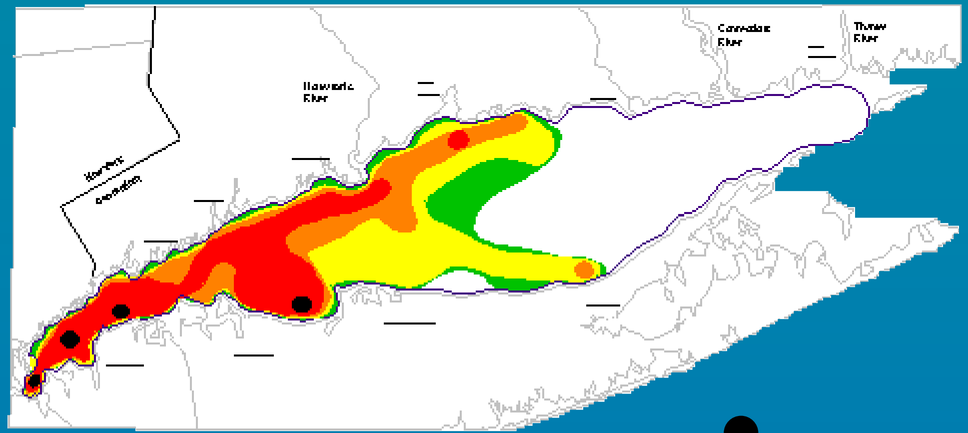
In the summer, warmer air temperatures warm the surface layer of water. Throughout the year, human activities discharge large quantities of excess nitrogen into the Sound, essentially over fertilizing the Sound. Single celled plants, called phytoplankton or algae, grow rapidly when nitrogen is abundant, creating larger and longer blooms than would occur naturally, reducing visibility and resulting in a loss of habitat for submerged aquatic vegetation. As the algae die and sink to the bottom they begin decomposing. The decomposition robs the oxygen from the water, depleting the limited supply in the bottom layer and leaving less oxygen for marine life. The oxygen that is consumed in the bottom layer cannot be replenished by the more oxygenated surface waters because of the pycnocline (density barrier between the cooler bottom water and the warmer surface waters).

Minimum Dissolved Oxygen Concentrations

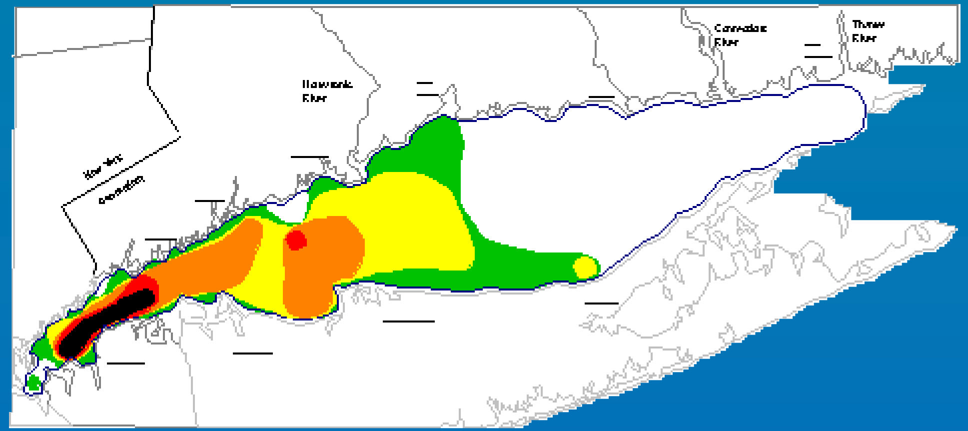
August 10 - 13, 1992



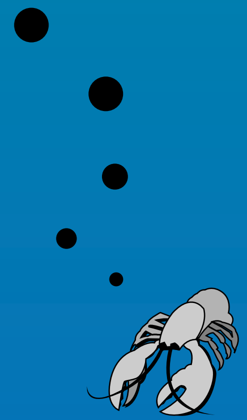
August 1 - 4, 1994



September 3 - 6, 1996



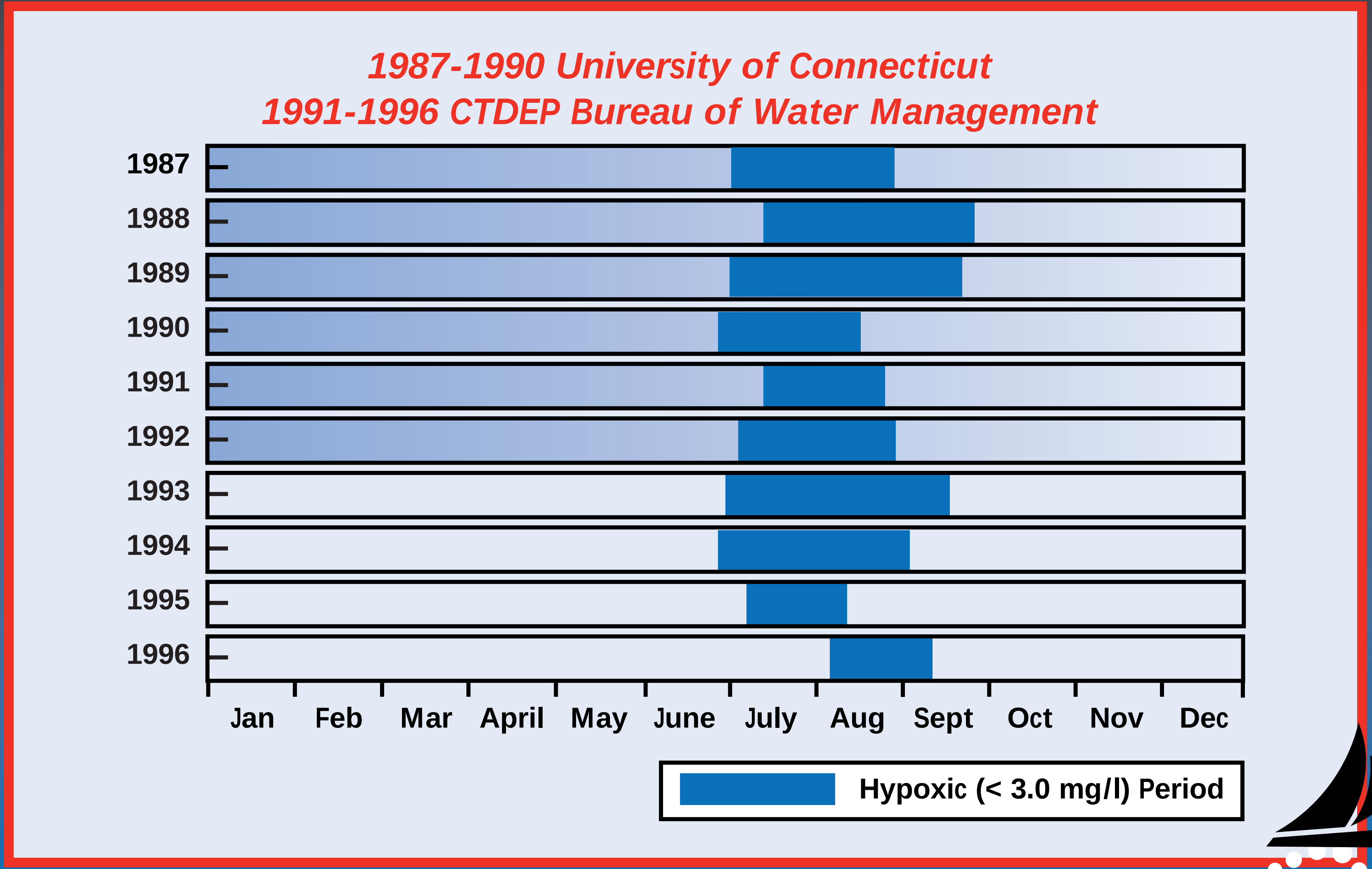
- 0.0 - 1.0 mg/l
- 1.1 - 2.0 mg/l
- 2.1 - 3.0 mg/l
- 3.1 - 4.0 mg/l
- 4.1 - 5.0 mg/l
- 5.1 + mg/l



Hypoxic Events for 1992, 1994, and 1996

Intensive monitoring has continued each year since 1987 to track hypoxia in the Sound. Hypoxia has been observed every summer, as shown on these maps of the maximum extent of low dissolved oxygen conditions from 1992, 1994 and 1996. When hypoxia will begin, how long it will last, and how severe or low the oxygen levels will fall varies from year to year depending on weather conditions.

Duration and Timing of Hypoxia

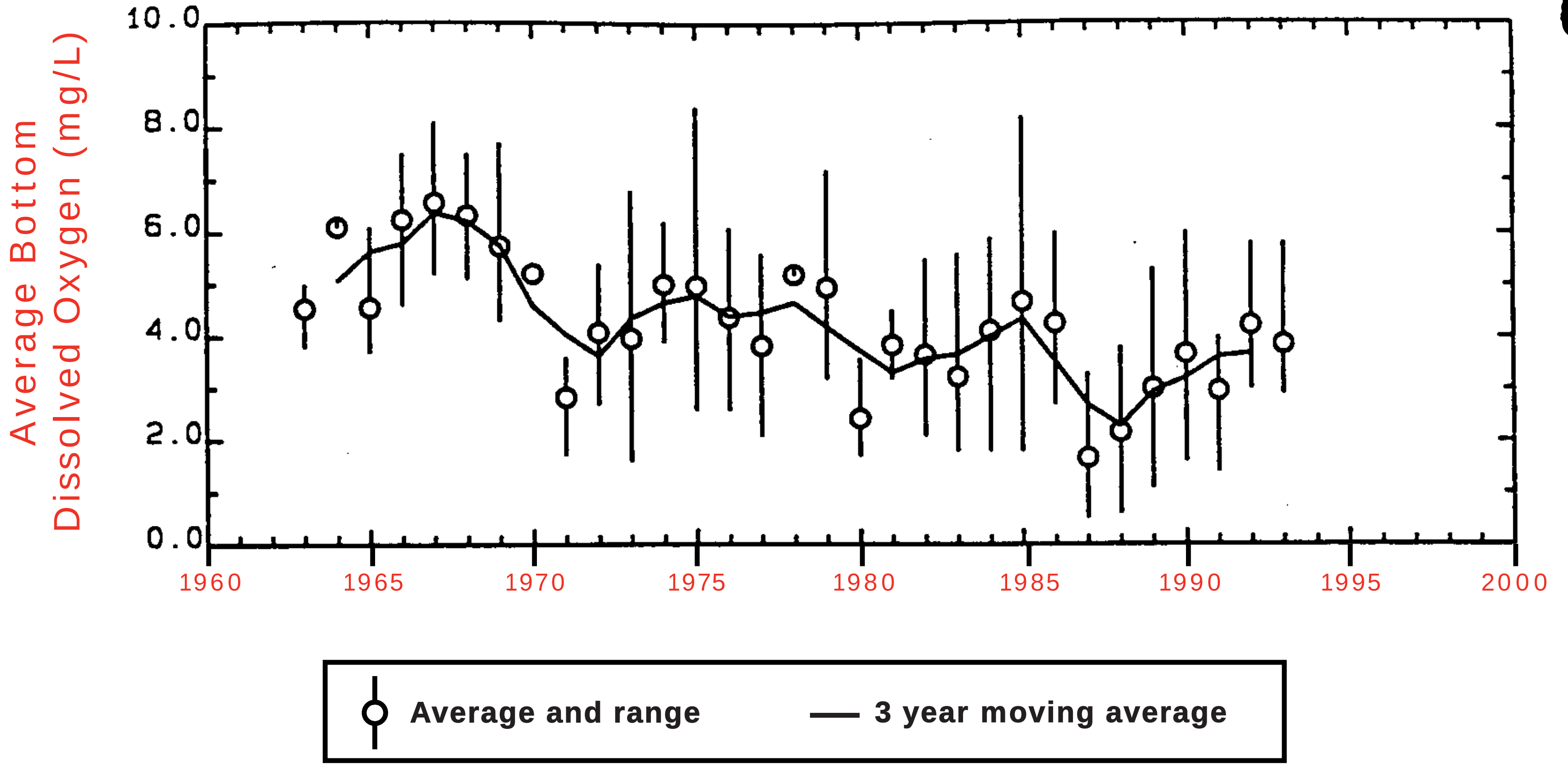


When Does it Occur?

Hypoxia usually occurs sometime from July through September in the deep water of the western and central portions of the Sound and in some shallow embayments. These areas are characterized by high nutrient inputs, marked stratification of the water column, and, in some areas, stagnant conditions. Hypoxia is less common in the eastern Sound but during severe years has reached Mattituck, NY and New Haven, CT. Hypoxia periods vary in duration f rom 1-2 months.

Dissolved Oxygen Trends

Long Island Sound (Hart Island)



How Long has Hypoxia Been Occurring in the Sound?

Hypoxia is not a new occurrence. New York City has been monitoring oxygen levels since 1909 and the data show periods of reduced dissolved oxygen in the East River and western Sound. A study in the 1950's identified mild hypoxic conditions in western portions of the Sound. But it was not until the intensive monitoring by Long Island Sound Study investigators in 1986 that widespread and severe hypoxia was documented. The lowest oxygen readings occurred in 1987 in the area near Hempstead Harbor when anoxic (no free oxygen) conditions were observed.

Impacts of Nutrient Enrichment

Hypoxia

- "Avoidance" of Hypoxic Areas by Fish
- Death or Stress of Remaining Organisms
- Reduced Growth and Reproduction
- Seasonal Degradation of Habitat

Impacts of Nutrient Enrichment - Hypoxia

Hypoxia affects the health of the living resources in the Sound and represents a loss of valuable habitat. Hypoxia reduces the abundance of fish and shellfish by reducing growth and reproduction, and at low enough concentrations causes mortality. Hypoxia also reduces commercial and recreational harvest of fish and shellfish.

Impacts of Nutrient Enrichment

Habitat and Human Use

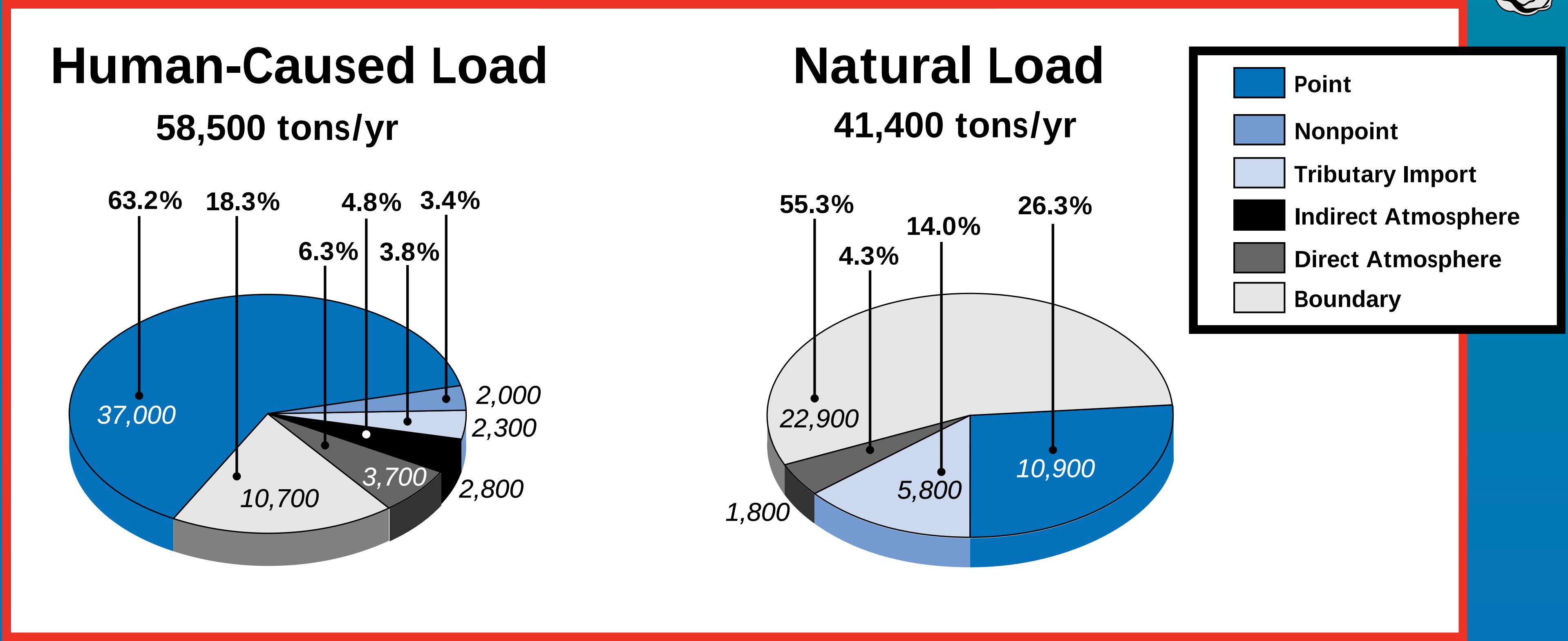
- Fishing
- Algal Blooms
  - Water clarity
  - Submerged aquatic vegetation
- Beachgoing
- Birdwatching and Sightseeing
- Diving

Impacts of Nutrient Enrichment - Habitat and Human Uses

Nutrient enrichment also impacts habitat functions and human use of the Sound. Anglers catch less fish in areas with low oxygen levels. The algal blooms decrease water clarity and decrease sunlight necessary for bottom rooted plants. Summer visitors to the beach, divers and snorkelers are discouraged from enjoying the Sound by these algal blooms. Birds and wildlife may not be directly affected by low oxygen levels however, the small fish, shellfish and crustaceans they feed on are, resulting in less species for birders to see. Field and laboratory studies demonstrate that most severe effects occur when dissolved oxygen falls below 3.5 mg/l , but mild effects occur when dissolved oxygen concentrations fall below 5 mg/l. The severity of effects depends on how low the dissolved oxygen concentrations get and the duration and spatial extent of hypoxia, as well as water temperature and the distribution and behavior patterns of species.

Sources of Nitrogen

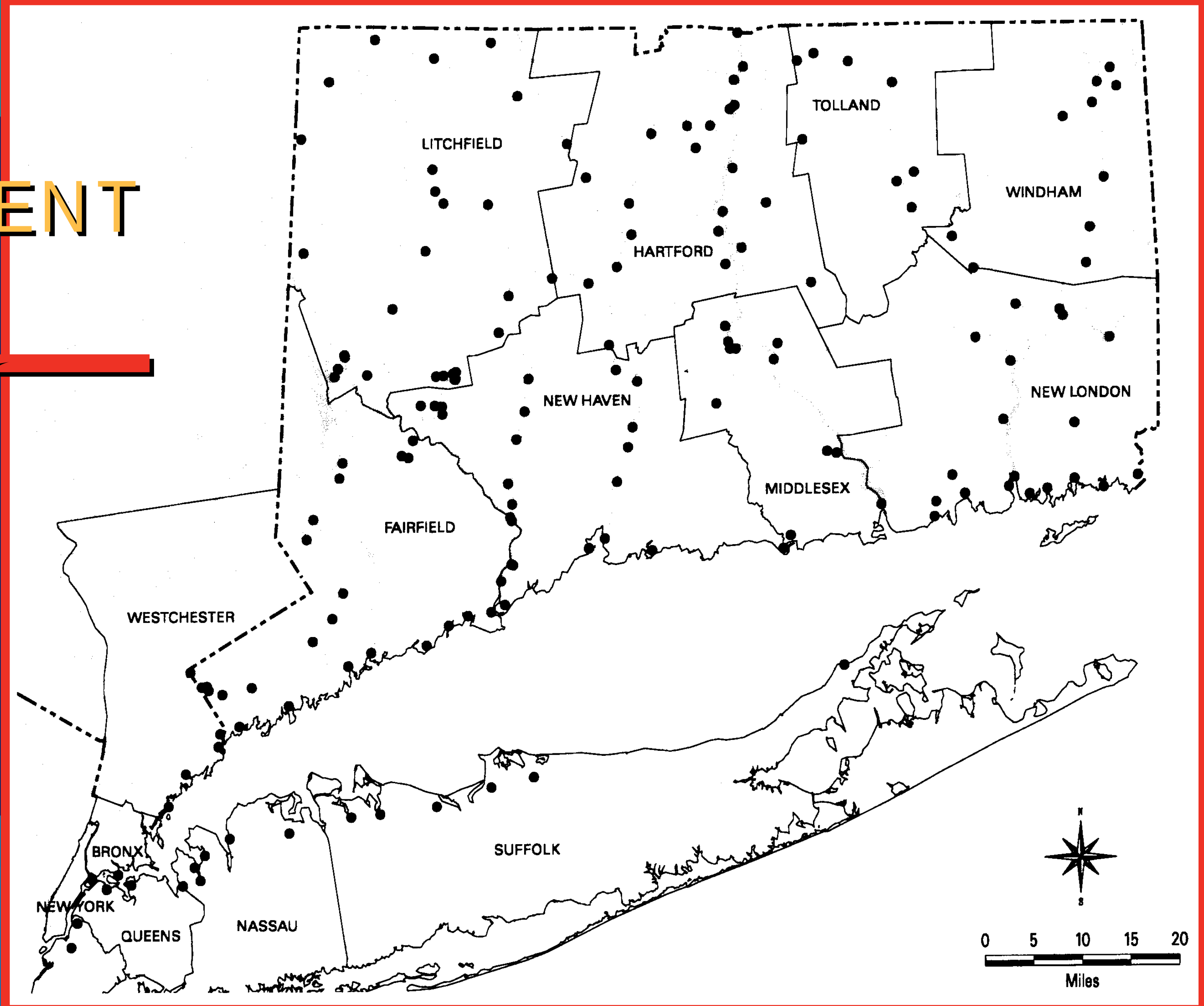
Human and Natural Sources



What are the Sources of Nitrogen?

Today about 100,000 tons of nitrogen are estimated to reach the Sound each year. Just over 40,000 tons are estimated to originate from natural sources. Human activities account for nearly 60,000 tons of the annual nitrogen load. Nitrogen is a constituent of all living tissues. Nitrogen enters Long Island Sound from natural sources including precipitation, dustfall, and runoff from the land. Nitrogen is incorporated into plant life, and is passed through the food chain into fish and shellfish. Bacteria break down organic matter, recycling the nitrogen.

SEWAGE TREATMENT PLANTS



Human Sources - Map of Sewage Treatment Plants

But, human activity has greatly increased the amount of nitrogen delivered to the Sound causing changes in the system. The single largest category of sources of nitrogen most responsible for the increase are sewage treatment plants that discharge both directly into the Sound and into the tributaries leading to the Sound; nonpoint source runoff and atmospheric deposition from upwind combustion processes also contribute nitrogen. Sewage treatment plants are called point sources of pollution because their effluent comes from a single point - a discharge pipe. The Clean Water Act requires municipal waste water to achieve what is called a secondary level of treatment. Secondary treatment removes biodegradable organic materials, suspended solids, and kills disease causing pathogens. Significant amounts of toxic materials are removed, however, only a small amount of nitrogen is removed. Worse still, sewage treatment plants convert nitrogen from human and other organic waste into ammonia and nitrate that is readily usable by plant life. It's the same fertilizer applied to lawns and

Nonpoint Source Pollution

Pollutants From Diffuse Sources Throughout A Watershed

- **Urban Stormwater Runoff**
- **Septic Systems**
- **Boats/Marinas**
- **Agricultural Runoff**

Nonpoint Source Pollution

Nitrogen is also carried by rain directly from the atmosphere and stormwater runoff after being picked up from agricultural, residential and urban lands. Car exhaust emits nitrogen oxides as part of the combustion process, and septic systems leach nitrogen. Nitrogen may also come from other human activities such as over fertilization of lawns and crops, or homeowners who may apply the right amount of fertilizer but at the wrong time. These diffuse sources are referred to as nonpoint sources because they are not discharged from a single source that can be easily identified and managed (or controlled). Approximately 18% of human nitrogen contributions comes from nonpoint sources and atmospheric deposition. Although stormwater is often discharged from sewer pipes and can be regulated as a point source, throughout this discussion, it is considered a nonpoint source because of its diffuse origin prior to being channeled into a storm sewer system.

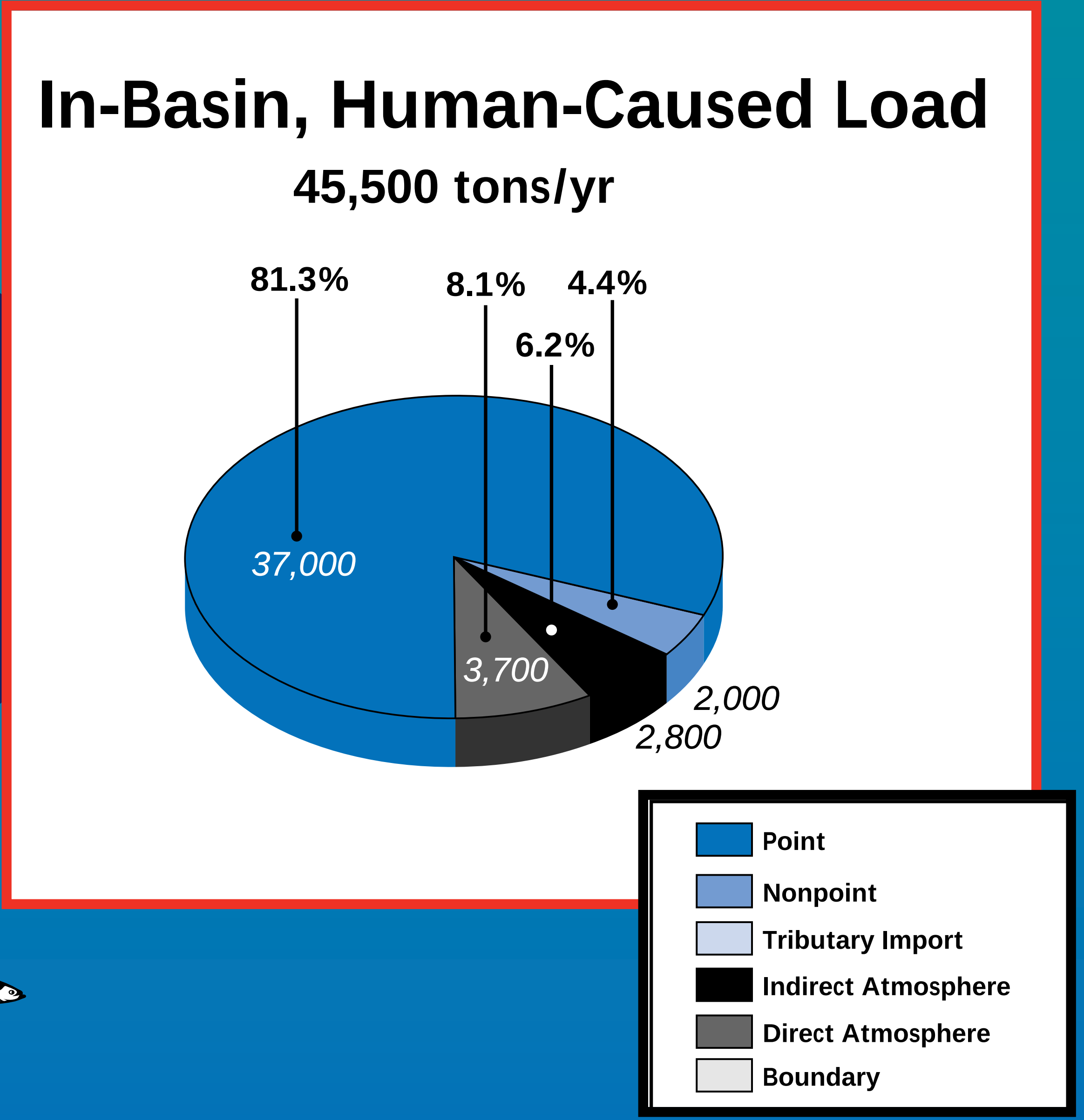
Delivery Routes

- **Rivers**
- **Stormwater Runoff**
- **Groundwater**
- **Atmospheric Deposition**

Delivery Routes

Key delivery routes of nitrogen from nonpoint sources to the Sound include rivers, direct stormwater runoff from coastal lands, groundwater transport, and atmospheric deposition directly on the Sound's surface and onto the Sound's watershed. Nitrogen also enters the Sound from the Atlantic Ocean and from the East River. 70% of this nitrogen is from natural sources, while 30% is generated from point, nonpoint and atmospheric deposition throughout the east coast region. The delivery of nitrogen to Long Island Sound from sources outside the Sounds geographic boundaries presents a far reaching management challenge; however, it does contribute to hypoxia. Overall the boundary contributes roughly 20% of the nitrogen delivered to the Sound.

Sources of Nitrogen



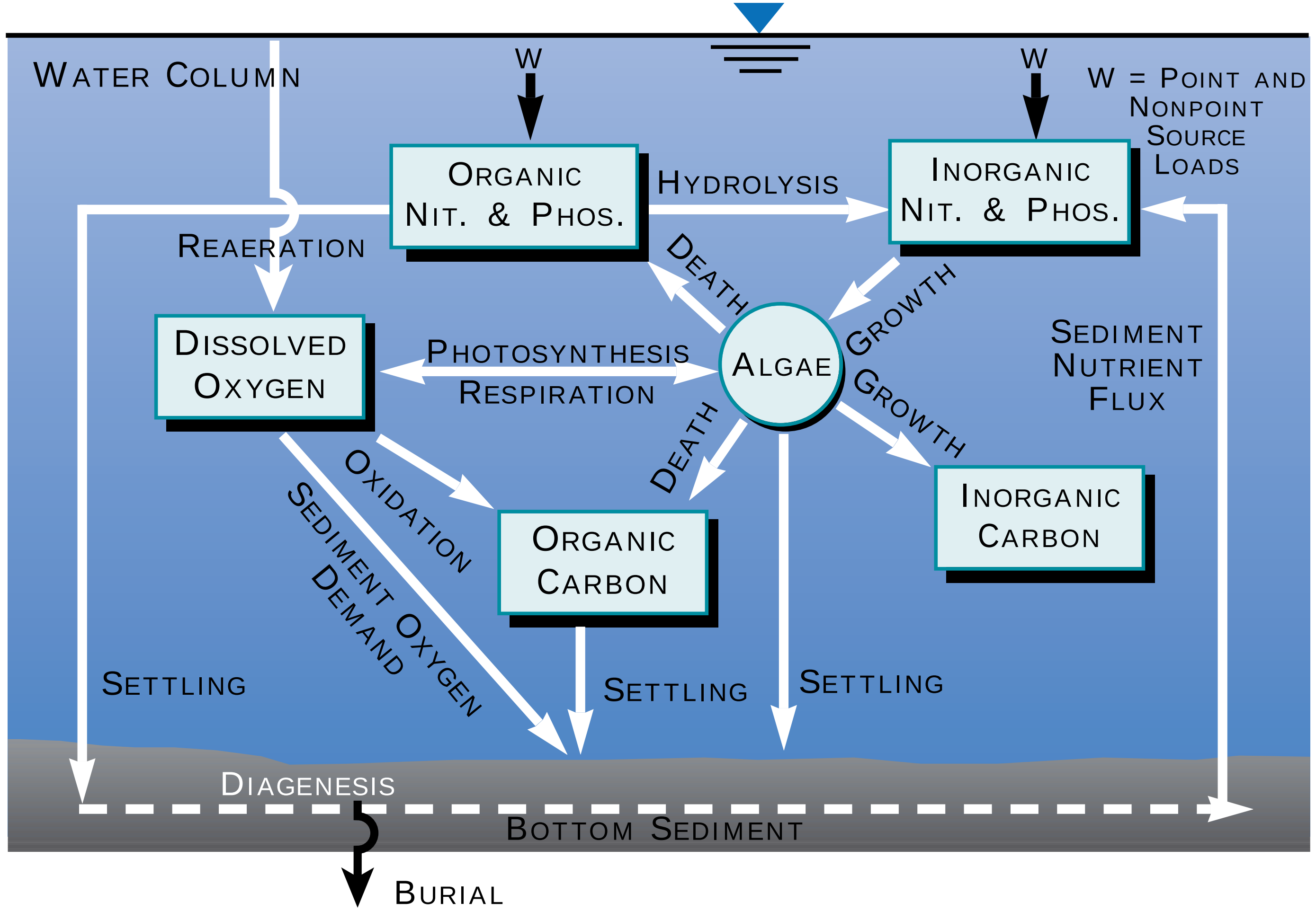
In-basin, Human Load

Because the boundary load is not readily traceable to its origin, we are focusing our management attention on sources nearer to the Sound, those originating in Connecticut and New York. These 45,500 tons per year, broadly categorized as in-basin, human sources come from point and nonpoint sources which can be more directly managed by Long Island Sound Study. Of the 45,500 tons per year, 37,000 tons come from point sources and an estimated 8,500 tons come from nonpoint sources, including atmospheric deposition on land and the Sound.

Understanding Hypoxia

Water Quality Model Framework

Water Column-Bottom Sediment Interactions for Nutrients, Carbon, and Dissolved Oxygen



Understanding Hypoxia

The physical, chemical and biological factors involved in hypoxia are extremely complex. To understand hypoxia and to identify management actions that are cost effective, the Long Island Sound Study constructed mathematical models to predict how Long Island Study would respond to different management options. Preliminary results showed that by substantially reducing nitrogen loadings to the Sound, the probability, frequency, and intensity of hypoxia can be reduced.

Progress to Date

Phased Program of Hypoxia Management

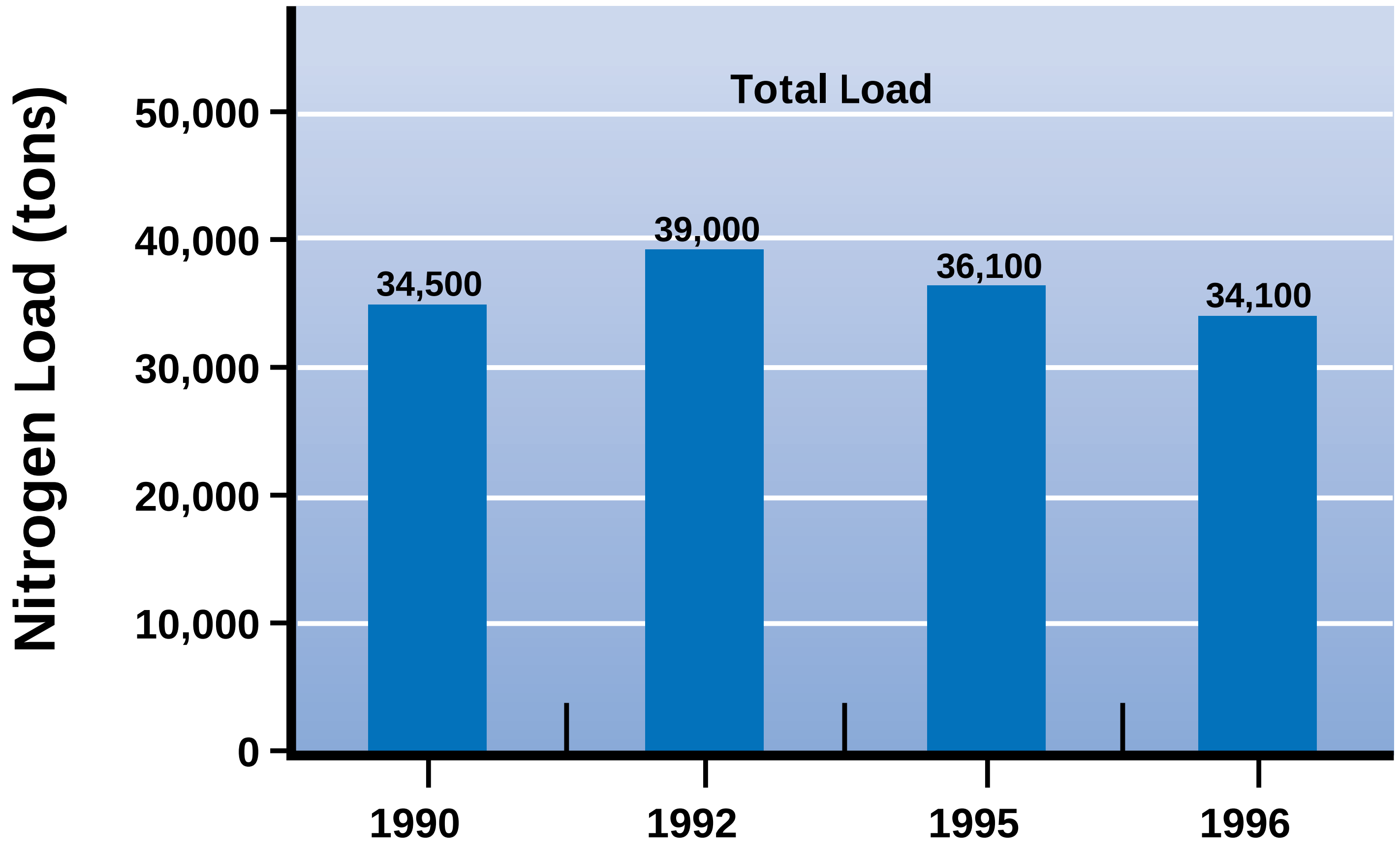
- **Phase I (1990): Freeze**
- **Phase II (1994): Low-Cost Reductions**
- **Phase III (1997): Nitrogen Reduction Targets to Guide Long-Term Effort**

Progress to Date

The goal of the Long Island Sound Study is to eliminate the adverse impacts of hypoxia resulting from human activities. Since achievement of this goal will require large investments of money and a long term commitment, the Long Island Sound Study has established a phased approach, using what is known now to support early phases and committing to take additional steps as our understanding improves. Phase I, announced in 1990, froze nitrogen loadings to the Sound in critical areas at 1990 levels to prevent hypoxia from worsening. Phase II, detailed in the Long Island Sound Study 1994 Management Plan, involves implementation of low-cost retrofits to sewage treatment plants, beginning the process of improving conditions. The Long Island Sound Study Comprehensive Conservation and Management Plan identifies a range of reductions that would be needed to minimize adverse impacts. Therefore, the Long Island Sound Study made a commitment to identify a third phase of nitrogen controls.

Changes in Nitrogen Loads

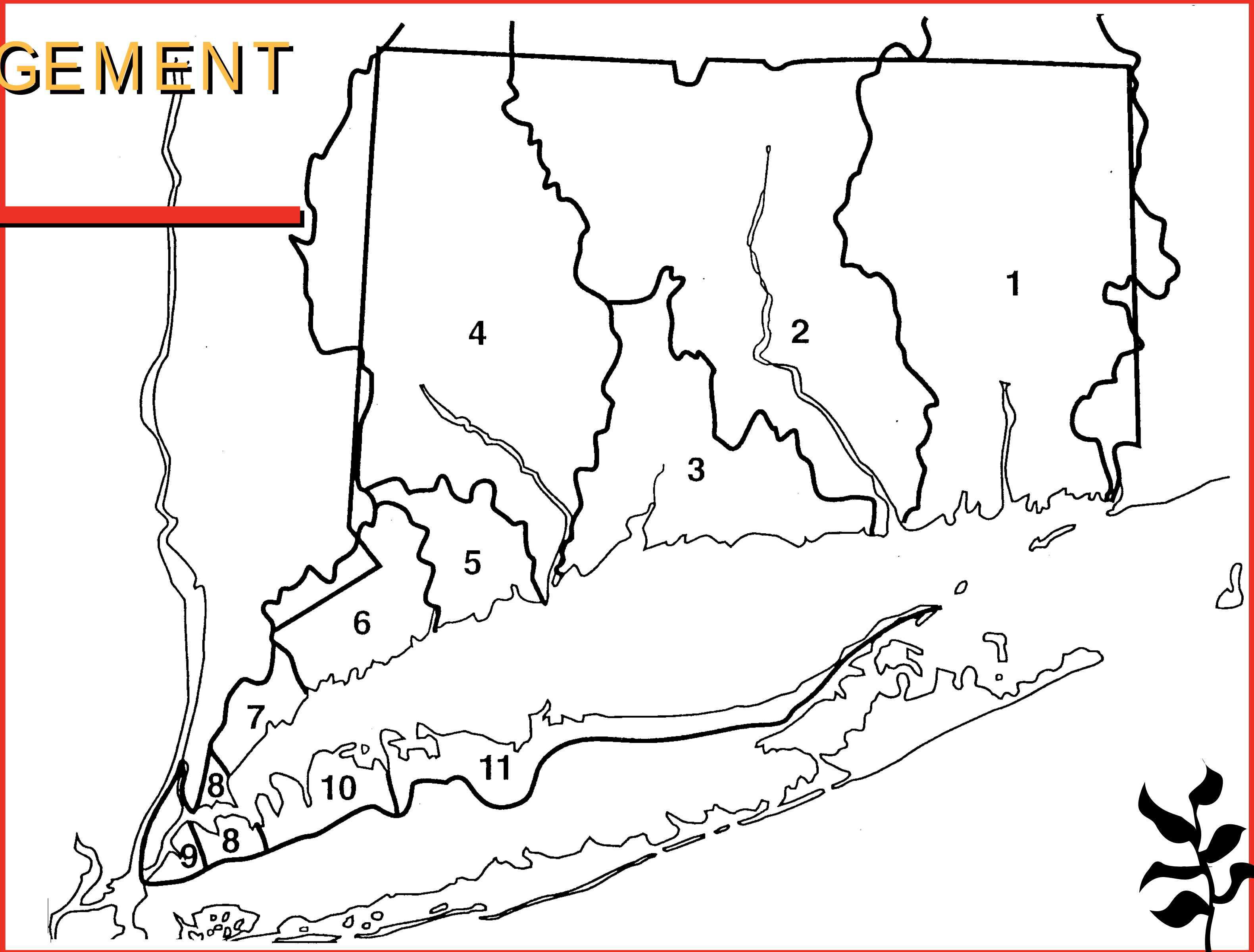
As of 12/31/96



Progress to Date

Beyond maintaining the Phase I freeze the Long Island Sound Study investigated inexpensive means to reduce nitrogen loads beyond the 1990 baseline as the means for implementing Phase II reductions. Retrofitting sewage treatment plants proved to be such a viable option that relatively inexpensive reductions have already resulted in a considerable net reduction in loading of nitrogen to the Sound. For about $15 million in Clean Water Fund grants, and low interest loans to municipalities, coupled with utility energy grants, Connecticut was able to reduce nitrogen loads by 1,000 tons per year from Southwest Connecticut coastal towns from New Haven to Greenwich by 1996. In New York, one sewage treatment plant in Westchester and four in New York City have implemented nitrogen removal and additional removal is expected at East River plants later this year. Phase II reductions of 4,900 tons/year, while significant, will not restore the health of Long Island Sound.

MANAGEMENT ZONES



Management Zone Map

The Long Island Sound Study agreed to propose nitrogen reduction targets for each of the twelve management zones.

Management Issues

- **Attainment of Water Quality Standards**
- **High Cost**
- **Equity**

Management Issues

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 in all areas of the Sound, nor would all adverse impacts be prevented. The range of management options available for making progress lies between Phase II actions (inexpensive reductions) and the level of reduction achievable from applying technology limits to point and nonpoint sources.

Developing Nitrogen Reduction Targets

Framework

- **Identify Conditions That Will Minimize Adverse Impacts**
- **Identify Reductions From In-Basin Sources to Make Cost-Effective Progress**
- **Consider Other Sources and Alternatives**

The Framework for Developing Nitrogen Reduction

To help establish priorities for action, the Long Island Sound Study has identified oxygen conditions that will minimize adverse impacts on living resources in the Sound. Long Island Sound Study managers then looked at a range of nitrogen reduction options to sources within the New York and Connecticut portion of the watershed that could cost-effectively achieve these conditions. More distant sources or alternatives to nitrogen removal will be considered to further improve conditions.

Oxygen Benchmarks

- **Bottom Waters**
  - **Fully protective**
    - **$\geq$5 mg/l over 24 hours**
  - **Protective for most species**
    - **$\geq$3.5 mg/l over 24 hours**
    - **$\geq$2.0 at any time**

Dissolved Oxygen Benchmarks

Research efforts have provided information on how low oxygen conditions affect living resources in the Sound. Unhealthy conditions occur whenever oxygen levels fall below 2.0 mg/l at any time. Oxygen concentrations below 3.5 mg/l is considered protective for most species and above 5 mg/l is considered fully protective.

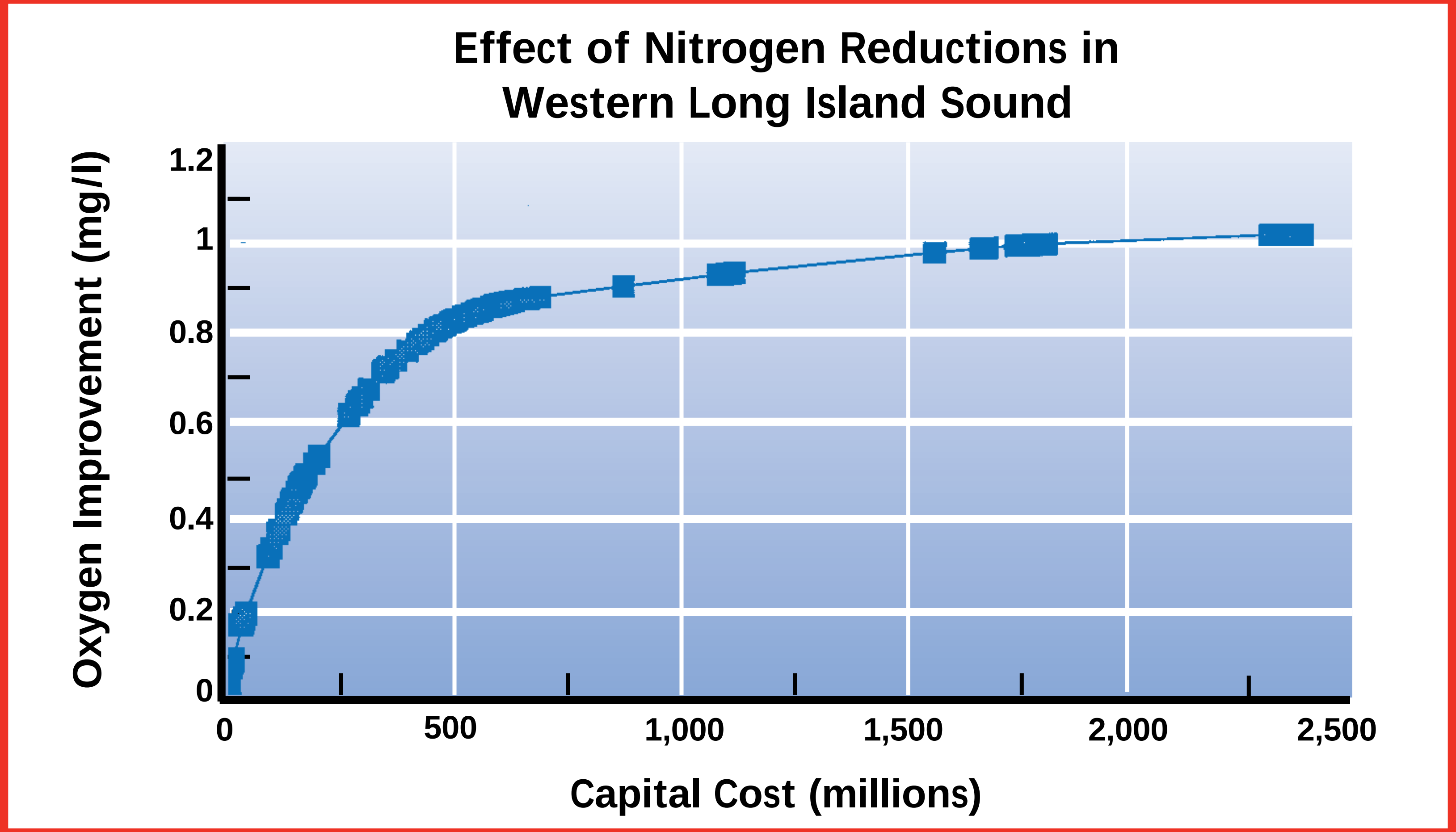
Cost-Sensitive Progress

- Cost-Effective Reductions at STPs
- Aggressive Nonpoint Reductions
- Aggressive Controls on Industrial Facilities

Cost-Sensitive Progress

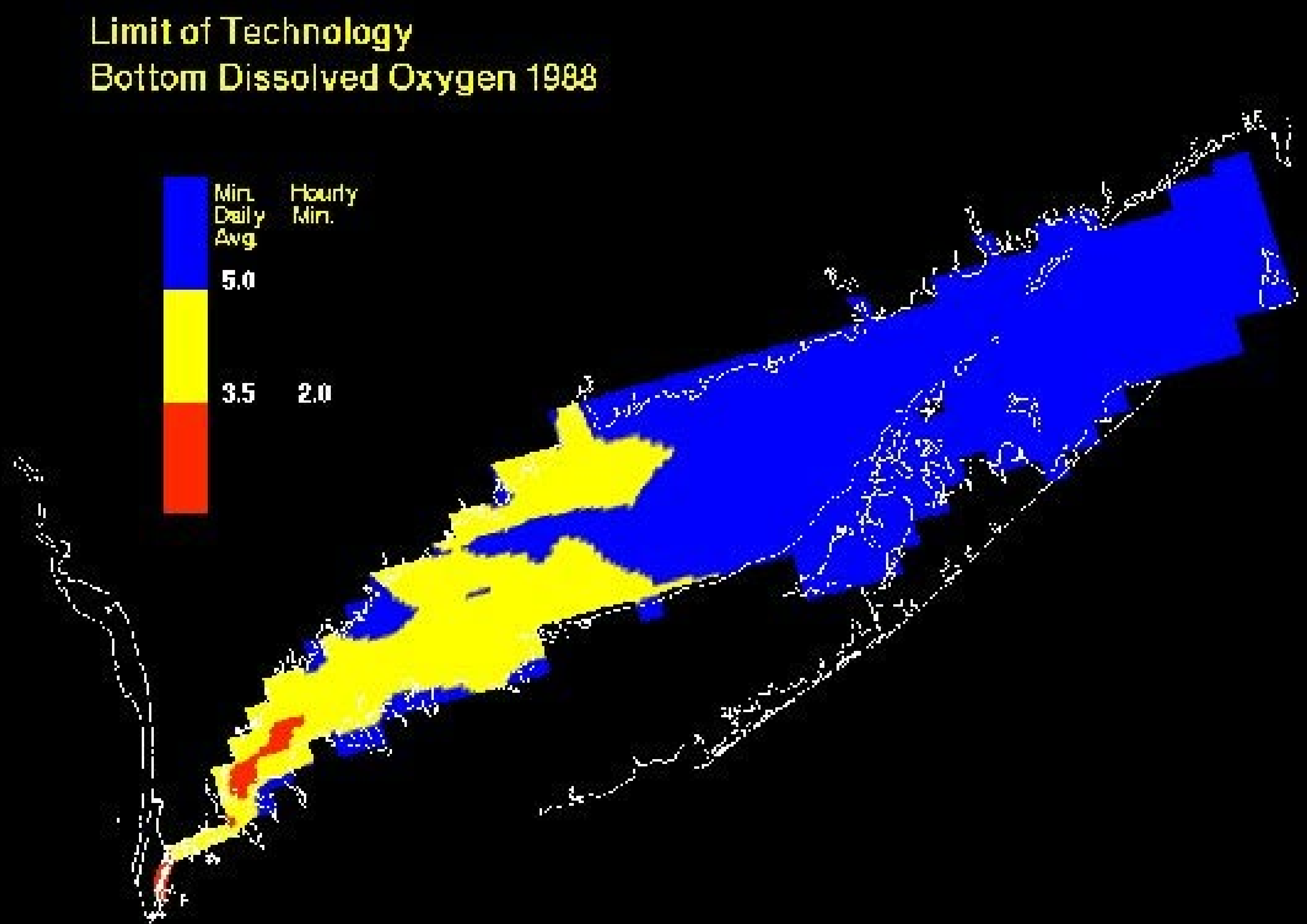
The Long Island Sound Study recommends a level of nitrogen reduction for Phase III that maximizes progress in improving dissolved oxygen conditions through cost-effective reductions at sewage treatment plant, reductions from an aggressive level of control at industrial point sources, and reductions from an aggressive nonpoint source control effort. These Phase III reductions will greatly reduce the time and area of exposure to unhealthy dissolved oxygen conditions.

Oxygen Improvement vs Capital Cost of STP Upgrades



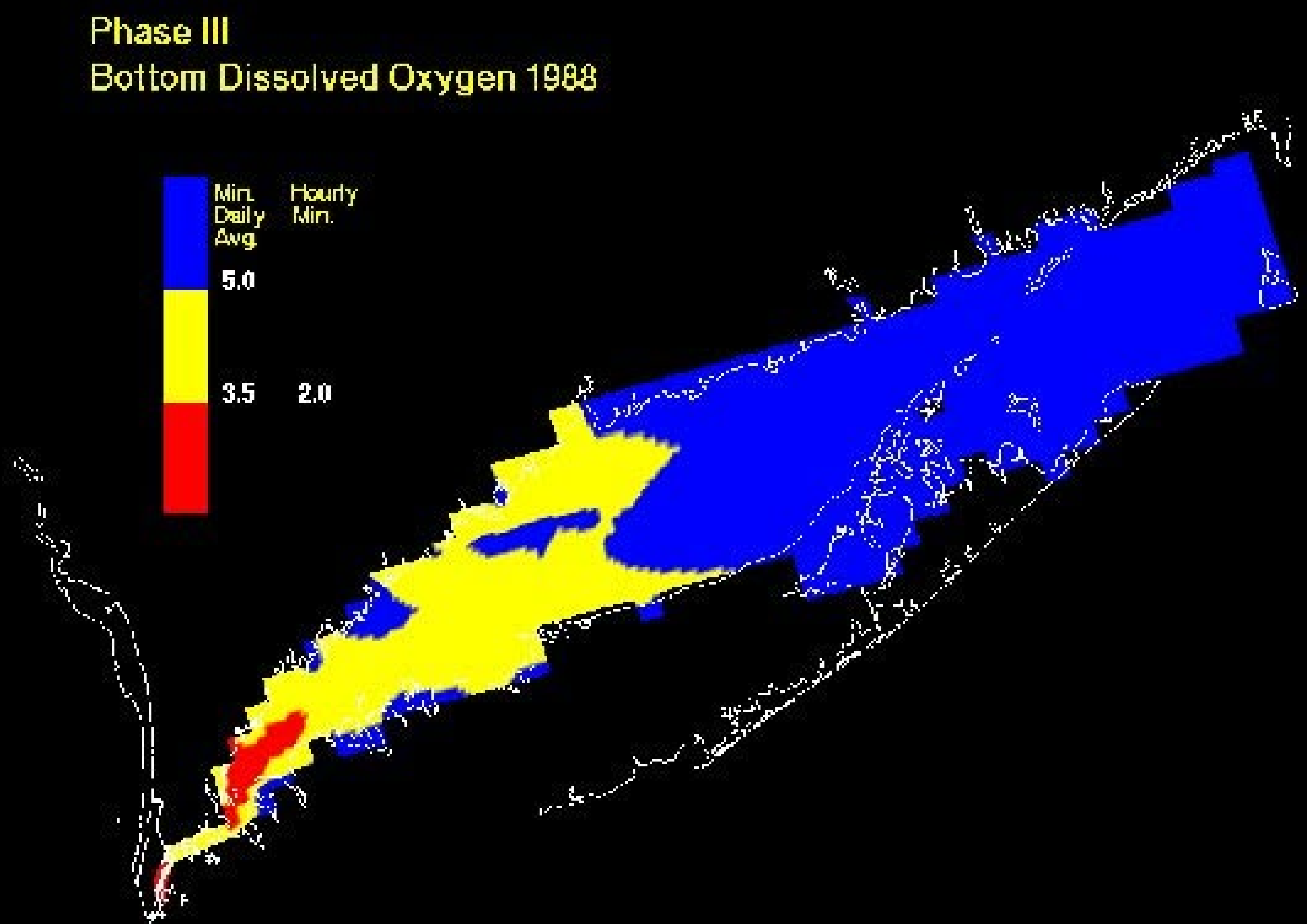
Conclusions - the Cost Curve Graph

Under current technologies, there is a point at which more stringent nitrogen removal requirements result in diminished dissolved oxygen improvements relative to the increased cost of management, particularly for sewage treatment plants. About 80% of the potential benefit from nitrogen reduction occurs from the first 25% of the potential cost.



Base Case, Phase III, Limit of Technology, and Pastoral Model Scenarios

Using information on cost effective levels of nitrogen removal from point and nonpoint sources, the Long Island Sound Study developed a nitrogen reduction target of 58.5 %. The water quality model was used to evaluate the water quality improvements of implementing this reduction compared to base, or current, conditions. Model scenarios were also performed to evaluate the water quality benefits of requiring the current limits of technology to point and nonpoint sources and the natural, or pastoral, conditions of Long Island Sound before development of the watershed. Unhealthy conditions are in red, generally healthy conditions are in yellow, and healthy conditions are in blue.



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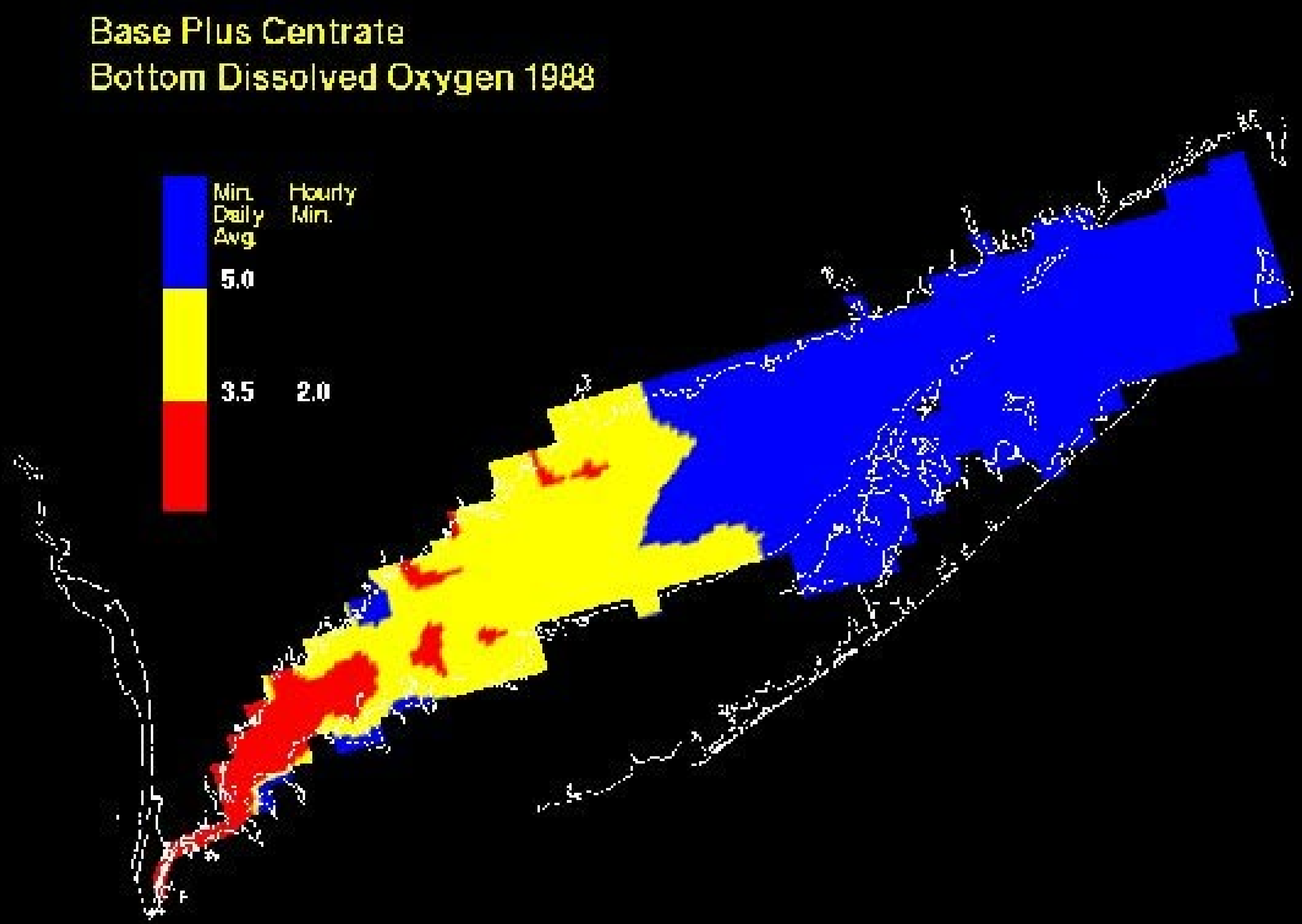

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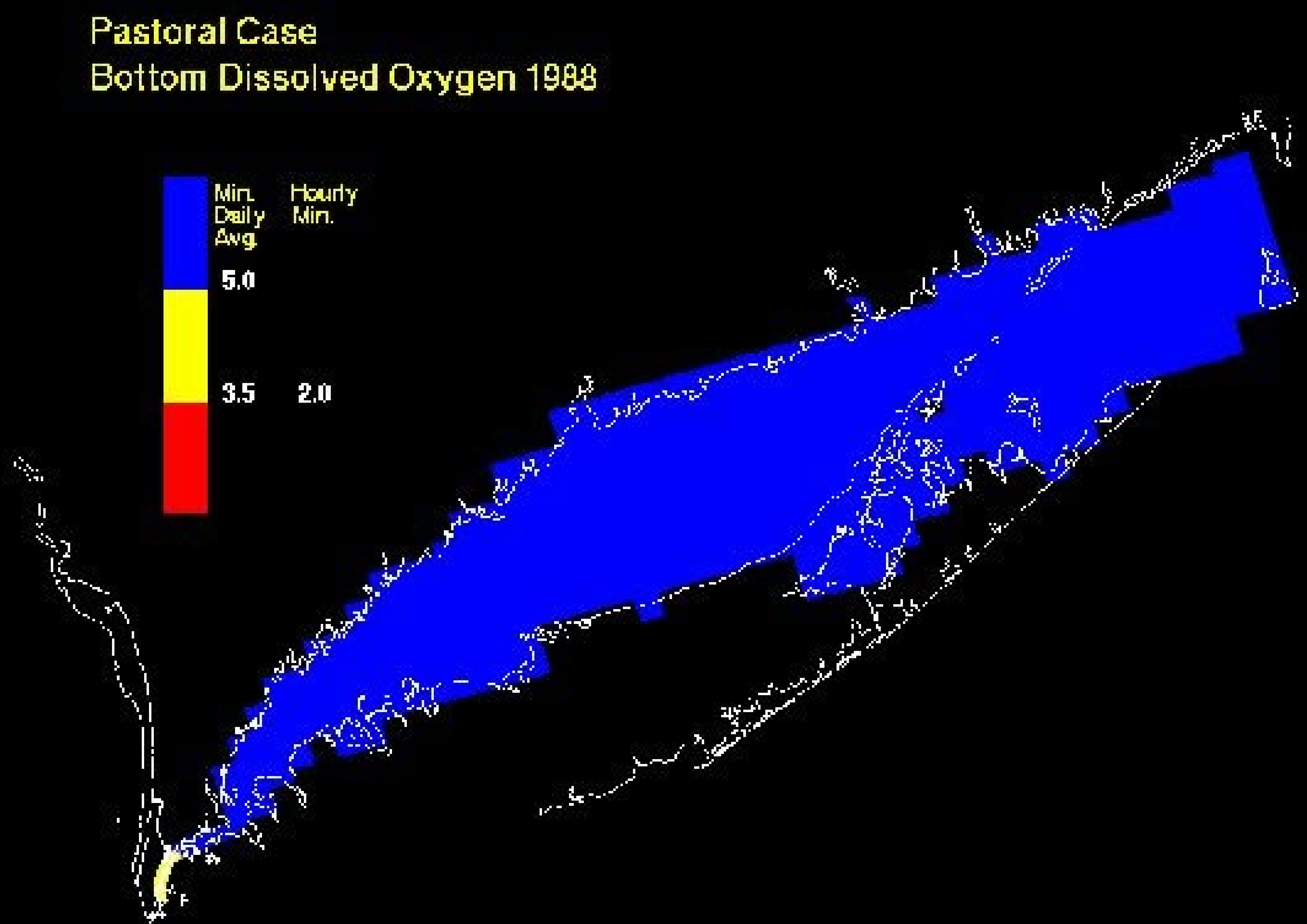

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Phase III Proposal

- 58.5% Reduction
- Allocate to Each Management Zone
- States to Develop Enforceable, Flexible Program
- Investigate Nitrogen Trading Program

Proposed Phase III Reductions

The 58.5 % reduction will be applied to each of the 11 management zones. Reductions from each zone will ensure that each area contributes to improvements in dissolved oxygen conditions in a fair and equitable manner.

Phase III Proposal

- **Phased, Enforceable Schedule**
  - **40% of target within 5 years**
  - **75% of target within 10 years**
  - **100% of target within 15 years**
- **Reevaluate Targets Every 5 Years**
  - **Progress and cost**
  - **Dissolved Oxygen criteria**
  - **Ecosystem response**

Phase III Proposal

The Long Island Sound Study recommends that the nitrogen reduction targets be met within 15 years after adoption of the targets, with 40% of the targets achieved in 5 years and 75% achieved in ten years. This schedule reflects both the need for steady, measurable progress and the fact that full achievement of the reduction targets will require major capital investments. Within two years of adoption of the targets the states will develop zone-by-zone plans to achieve the 5, 10 and 15 year reduction targets. A formal reevaluation of the nitrogen reduction targets will be made every five years that considers progress and cost of implementation, improvements in technology, refined information on ecosystem response to nitrogen reductions, and research on the impacts of hypoxia to living resources.

BENEFITS

- **75% Reduction in Area**
  - **120,000 Acres to 33,000**
- **85% Reduction in Duration**
  - **50 days to 6.5**
- **Reductions in Biological Effects**

	HART ISLAND	NEW HAVEN	STONY BROOK
FISH ABUNDANCE	97%	100%	100%
LARVAL MORTALITY	67%	65%	84%

Benefits

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%. The period during which unhealthy conditions exist in the Sound is predicted to be reduced by 85%, from more than 50 days to 6.5 days. Not only will oxygen levels improve and increasing habitat that is healthy for aquatic life but people who live around and use the sound will benefit also, more fish and shellfish, improved water clarity.

Costs

- **Incremental Capital Cost for STPs**
  - **$300M NY, $350M CT**
  - **More detailed planning and design needed**
- **Significant Nonpoint Source Control Costs**

Costs

The cost of managing nitrogen from point and nonpoint sources will be significant. The estimated cost of upgrading all sewage treatment plants to provide state-of-the art treatment was $6 billion. Advances in technology have now resulted in these estimates to decrease to $2.5 billion. However, not all 70 plants will be required to implement the new technology to achieve the proposed Phase III reductions and therefore the actual estimated cost is $300 million for New York and $350 million for Connecticut. The cost of nonpoint source controls will vary widely depending on the management practice implemented and land use on which it is applied.

Implementation

- **Adopt Targets**
- **Develop Total Maximum Daily Load**
  - **Permit modifications by August 1999**
    - **Nitrogen limits to achieve 40% of targets in 5 years**
    - **Limits for 75% and 100% of targets in future permit cycles**
  - **Commit to nonpoint controls by August 1999**

Implementation

Within two years after adoption of the nitrogen reduction target by the Long Island Sound Study, New York and Connecticut will propose permits that will require that plans be developed and implemented to achieve the nitrogen reduction target within 15 years. The permits will also include the nitrogen limits associated with achieving 40% of the nitrogen reduction target in five years. The nitrogen reduction target to be achieved after ten and 15 years would be incorporated in future permit revisions. The Long Island Sound Study will commit to evaluate the nitrogen reduction target every five years based on new information before proceeding with the new permit revisions.

Total Maximum Daily Load

Assimilative Capacity of System to Achieve Water Quality Standards

- Nitrogen reduction target
- Reductions in nitrogen sources outside of the watershed
- Treatment alternatives

Total Maximum Daily Load

While the proposed Phase III reductions will greatly improve the habitat quality of Long Island Sound, they will not fully achieve the current dissolved oxygen standards. Since the ultimate goal of management must be the attainment of water quality standards, New York and Connecticut will develop a phased Total Maximum Daily Load (TMDL) that identifies other actions necessary to achieve the standard. New dissolved oxygen criteria are being developed that will provide a more scientifically defensible basis for identifying conditions necessary to protect the health of the Sound. Therefore, a phased Total Maximum Daily Load could be based on the current state standards or on a new, consistent standard adopted by both states. Proceeding with a Phased Total Maximum Daily Load would be dependent on defensibly demonstrating what is necessary, beyond the nitrogen reduction targets, to achieve standards.