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# Decisions for DELAWARE



Sea Grant Looks at  
the Inland Bays

February 1983

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# **DECISIONS FOR DELAWARE**

## **Sea Grant Looks at the Inland Bays**

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## Foreword

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This *Decisions for Delaware*, like past reports in the series, provides legislators and the people they represent with factual information, reasonable interpretations, implications, and alternatives on marine-related topics that have been identified by the Sea Grant Advisory Council as high-priority issues facing the state and the region. Before publication, each report is reviewed extensively to ensure not only that it contains accurate information, but also that it treats these important issues fairly and understandably.

This situation report addresses the need for a comprehensive strategy to ensure the wise use, development, and conservation of the state's Inland Bays. There are many interrelated and conflicting social, economic, and natural resource concerns contributing to the complexity of this issue. This report, though it acknowledges the existence and pervasiveness of the social and economic factors, concentrates on these more fundamental natural resource questions:

- bacterial contamination of shellfish beds
- eutrophication
- dredging effects
- saltwater intrusion
- nitrate contamination

For each of these environmental concerns, the authors discuss the impact on the natural system, the actions taken to date to ameliorate the problem, and the recommendations for future strategies to assist in problem solving.

The *Decisions for Delaware* series is but one facet of the University of Delaware Sea Grant College Program. Managed by the College of Marine Studies, Sea Grant comprises a broad spectrum of application-oriented research, manpower education and training, and advisory service activities designed to stimulate practical marine resource development and use. The University of Delaware Sea Grant College Program is a functioning university-government-private sector partnership, coalescing the necessary intellectual and financial resources to provide an effective, efficient, coordinated, and objective approach to both contemporary and future coastal and marine issues.

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# Overview

In the Inland Bays, an increasing population and unplanned growth are contributing to the degradation of the physical environment. As the demand for drinking water and sewage disposal sites increases and exceeds the **carrying capacity\*** of the area, an environmental crisis may result. It is these issues with which this *Decisions for Delaware* deals. However, none of the five issues detailed in this report is new. For some time, they have been identified as problems that require solutions. This is shown by the previous reports and documents, and the expertise drawn upon to illustrate particular points in this report. This *Decisions for Delaware* is possible because of the efforts of individuals and agencies that have documented and identified issues affecting the Inland Bays.

The goal of this report is to focus attention on several of these issues in a way that assists the public in understanding the complexity of the problems. An examination of the environmental problems in their physical and biological context is necessary, but not sufficient. There is also a need to understand the economic and social impacts before developing an adequate strategy to manage the Inland Bays. Considerable work aimed at documenting some of the economic and social impacts facing the Inland Bays has been undertaken by the Inland Bays Study Group, made up of Department of Natural Resources and Environmental Control (DNREC) agencies and the public. Established in July 1981, its charge is to discuss and ultimately solve the environmental problems that the Inland Bays area is experiencing. To date this group has commissioned the Greeley Technical Group to conduct an economic analysis to estimate the costs of providing environmentally acceptable and economically feasible sewer and water services in selected areas of the Inland Bays region (Greeley Technical Group, 1982; Inland Bays Study Group, 1982).

This *Decisions for Delaware* has not required compilation of new data or field studies. Instead, efforts were directed at documenting selected issues as clearly as possible. This report is designed to help the interested reader understand the natural systems of which the Inland Bays are a part. Such an effort is but the beginning toward fostering solutions to the problems affecting the Inland Bays. A key factor in the eventual development of any comprehensive resource management strategy for the Inland Bays will depend on broad-based public support and knowledge of the issues.

## Present Situation

Currently there is growing concern about how the Inland Bays and their resources are being used. In the past few years, the area has become increasingly attractive to developers and recreationists. For example, in 1938, less than 1% of Rehoboth Bay shoreline and less than 10% of Indian River Bay shoreline were developed. By 1969, 25% of Rehoboth Bay and 44% of Indian River Bay shorelines were developed. Between 1960 and 1970, Sussex County had a net population increase of 9.8%, most of this occurring in the coastal areas (Delaware Office of Management, Budget and Planning, 1978.) From 1970 to 1980, the net population increased by over 40%. This rapid growth is expected to continue. By the year 2000, the year-round population is projected to increase by 30%; the seasonal population by 42%; and the occasional visitor population by 39% (Greeley Technical Group, 1982). This population increase will create greater demands on the **potable water supply** and wastewater disposal facilities, and generate increased traffic congestion.

Concern has been expressed over the perceived deterioration of environmental

quality occurring in the Inland Bays systems. Since 1962, there has been a steady increase in shellfish bed closures due to bacterial contamination. Activities continue to contribute to **eutrophication** of bay waters. Requests for new **dredging** projects continue to be processed individually without comprehensive examination of the long-term costs and benefits of such projects. The incidence of **salt-water intrusion** in the drinking water supply of residential areas surrounding the bays continues to be a problem as documented by the Delaware Geological Survey in 1972 and the University of Delaware Water Resources Center in 1977. In addition, work by Daiber (1969), Robertson (1977), and Ritter and Chirside (1982) has shown an increase in incidences of **nitrate** contamination of the **groundwater** in the Inland Bays area. These issues are discussed in the next chapter.

To date, development of the Inland Bays area has been characterized by incremental decision-making guided by a project-by-project approval process. There is no overall plan or coordinated strategy to ensure the wise use, development, and management of the Inland Bays area. Often project permit decisions are influenced by short-term economic considerations and political pressures that are inconsistent with sound environmental planning and management principles.

## Recommended Action

In part, the issues discussed in this report persist because there is no agreed upon strategy for the management and development of the bays that would ensure present and future benefits to the citizens of Delaware. Educating the public of the complexity of the issues and nature of the problems faced in the Inland Bays

\* Terms in bold face are defined in the glossary.



*Development around the Inland Bays has occurred without the guidance of an accepted management and development plan for the bays.*

area is but a start. Resolution of these five problems will require the implementation of a plan with enforcement mechanisms. To reach this goal, two simultaneous approaches are recommended.

1. The DNREC should be required to comment and provide testimony at all Sussex County planning and zoning hearings (see 9 Delaware Code Chapters 68 and 69) on projects that involve development on a) parcels in excess of five acres; and on b) parcels of five acres or less that involve activities having a **significant environmental impact**. (Significant environmental impact is any change in the environment caused by a human activity or factor. Such activities can include, but are not limited to, dredging, filling, or construction of industrial, commercial, or high-density residential development requiring special waste treatment facilities.) This testimony should represent the department's position with respect to any such projects and become part of the public record.

2. The Governor by executive order should mandate the establishment of a bipartisan task force.\*\* This task force would be charged with the responsibility to recommend the goals, objectives, implementation mechanisms, and enforcement strategy for a comprehensive management and development plan for the Inland Bays area. The product of this group's efforts would be an evaluation of the adequacy of existing laws, regulations, and enforcement mechanisms, and a proposal for changes in existing legislation and for recommended new legislation. Additionally, recommendations should be required that detail how the Inland Bays area should be managed to assure its continued health for the enjoyment and use by future generations. The rationale for

this approach and the proposed task force process is outlined in the next chapter of this report.

\*\*The precedent for the establishment of such a task force to investigate and formulate recommendations on natural resource issues is within the purview of the executive branch of government in Delaware. In 1972, the Peterson administration commissioned a task force on marine and coastal affairs to detail information on the status, trends, and problems relating to the resources of the coastal zone. Again, in 1973, a Governor's Wetlands Action Committee was established to conduct a thorough study of Delaware's coastal wetlands and suggest recommendations for an action program to preserve these lands. During the Tribbitt administration the Delaware Tomorrow Commission was established to comprehensively examine issues, including natural resource use, related to planning for statewide growth. It is in this tradition that the establishment of an Inland Bays task force is recommended.

# Identified Problems

## Introduction

As defined in this document, the Inland Bays of Sussex County, Delaware, include Indian River and Rehoboth Bays (Figure 1). Rehoboth Bay is four miles north to south and three miles east to west. Its surface area is approximately 14.5 square miles. This shallow bay has a maximum depth of seven feet (mean low water) and is bordered mostly by tidal marsh. Its main tributaries are Herring and Love Creeks, the Ditches, the Lewes-Rehoboth Canal, and Balders Pond. The Ditches connect Rehoboth Bay to Indian River Bay.

Indian River Bay is approximately two miles north to south and six miles east to west. Its surface area is approximately 14.8 square miles. This bay is also shallow with an average depth of four feet (mean low water). Indian River Bay is bordered by low bluffs and tidal marshes. Indian River is its main tributary, along with Pepper and White Creeks.

The total drainage area of both bays is 255 square miles. Rehoboth and Indian River Bays are separated from the Atlantic Ocean to the east by a long, narrow bay-mouth barrier.

Because estuaries are semi-enclosed, coastal bodies of water with a free connection to the open sea, saltwater mixes with freshwater from rivers and land drainage, varying the salinity of the water within the system. Delaware's Inland Bays are estuaries and are inhabited by plants and animals (biota) which typify estuaries of the Mid-Atlantic region. Just as the salinity varies in estuaries, so do the biota; some species thrive in the salty, seaward areas of the estuary while others prefer low-salinity areas near tributary streams and rivers.

Organisms live in every part of the estuaries. Fishes and many other small animals and plants live in the water itself, while the bottom sediments of the bays

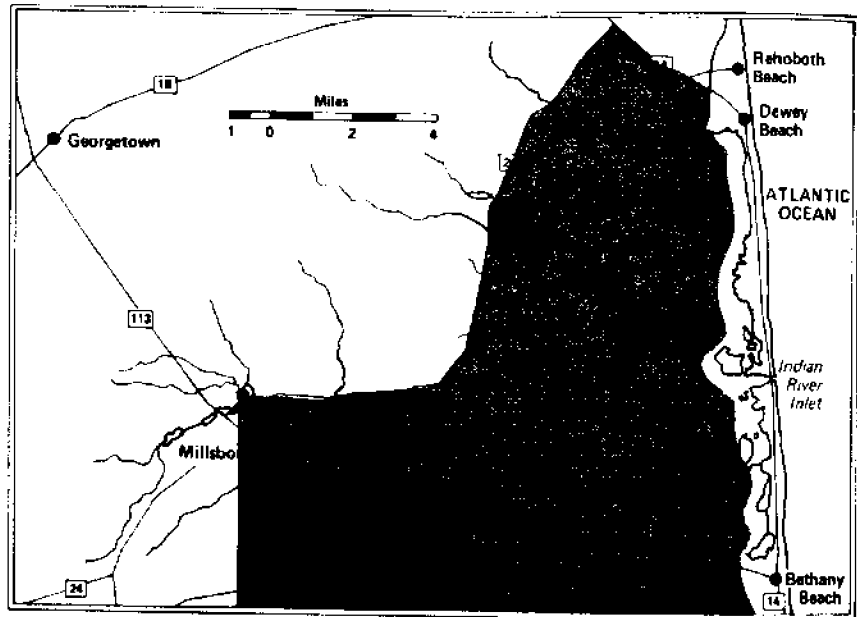


Figure 1. Inland Bays study area, as defined in this report.

are inhabited by shellfish and some grasses. Crabs and some fish live primarily on the bottom at the sediment-water interface. As the bays exchange water with the associated rivers and ocean, numerous species can enter the bays from either of these sources even if only for a temporary visit. The bays are bordered by salt marshes (also called tidal wetlands), farmland, and housing developments.

The Inland Bays are a complex of dynamic, interrelated systems of which people are an integral part. The bay biota are interlinked in food chains in which larger organisms ingest the smaller plants and animals and the decaying matter. Commercially important species (for example, crabs and shellfish) feed, and hence depend, on lesser known or smaller species in the bays. Animals and plants affect, and are affected by, the chemistry of their

habitat. Not only do they need the right nutrients to survive, grow, and reproduce, but also their waste products and their bodies after they die serve to produce new nutrients for other organisms.

Chemicals deposited in the estuary by human activity can affect survival, growth, and reproduction in some cases. Water circulation patterns can affect distribution of dissolved oxygen, nutrients, and the organisms themselves. When circulation changes, so do other parts of the system. Because the parts of the estuarine system are interconnected, no one part of the system can change without affecting the other parts, even if the effect is remote and not obvious. Therefore, any sound approach to management of the bays must consider the entire ecosystem and must consider people as a part of that ecosystem.



Five problems appear to pervade the Inland Bays: bacterial contamination of shellfish beds, bay eutrophication, adverse effects of dredging on the natural system, saltwater intrusion into the drinking water aquifer, and nitrate contamination of the groundwater.

In order for the reader to appreciate the nature of bay water and groundwater quality problems, this chapter will discuss the natural systems, explain the importance of each problem, describe what actions have been taken thus far to deal with the problem, and propose alternative strategies to deal effectively with the problem.

## Bacterial Contamination of Shellfish Beds

### The Natural System

Delaware's Inland Bays are home to a large number of plants and animals, all of which play important roles in the two main food chains of the bays—the grazing food chain and the detritus food chain. These chains differ from one another in the source of food at each base: at the bottom of the grazing food chain are all living plants, while at the base of the detritus chain is nonliving plant and animal matter. Figure 2 shows the many connections between the two chains—the distinction between them is not always clear.

The Inland Bays contain microscopic plants (**phytoplankton**) and animals (**zooplankton**) (Figure 3). There are 92 species of phytoplankton in the bays, and two groups predominate: the **diatoms** in winter and spring and the **dinoflagellates** in summer and fall. Phytoplankton are a vital part of the life of the bays, producing oxygen through **photosynthesis** and providing food for zooplankton and **filter-feeders** (animals, like oysters, that filter water through their gills to trap food).

The zooplankton species are also numerous and, depending on the season, any number of species will predominate—mysid shrimp and polychaete worm larvae are abundant in December, arrowworms in April, and small shrimp and **copepod crustaceans** in July. Zooplankton feed on either phytoplankton or other zooplankton and, in turn, serve as food for many species of fish. They also play an important role in use and reuse of nutrients (principally, forms of nitrogen and phosphorus) in the water column.

Macroalgae of the bays include large, easily visible plants. Macroalgae usually cluster in aggregations unattached to the bottom. Fifty species of macroalgae have been described, but three dominate: two species of red algae and one species of green algae. In Rehoboth Bay, the highest **biomass** (weight of living matter) of macroalgae is found at the mouth of the Lewes-Rehoboth Canal.

Factors that affect the distribution of macroalgae throughout the bays are nutrient load, type of **substrate**, grazing pressure, and competition from other macro-

algae. Macroalgae are a source of **organic matter** for bottom-feeding fish and bottom-dwelling **invertebrates**, and are an important source of oxygen for the bay waters.

At least 60 species of fish occur in the bays, though the actual number varies as fish migrate in and out of the estuary seasonally. Considering the commercial and recreational value of the fish, surprisingly few comprehensive studies have been completed. Studies of White Creek conducted in 1957-58 (Pacheco and Grant, 1965) and in 1973-74 (Campbell, 1975)

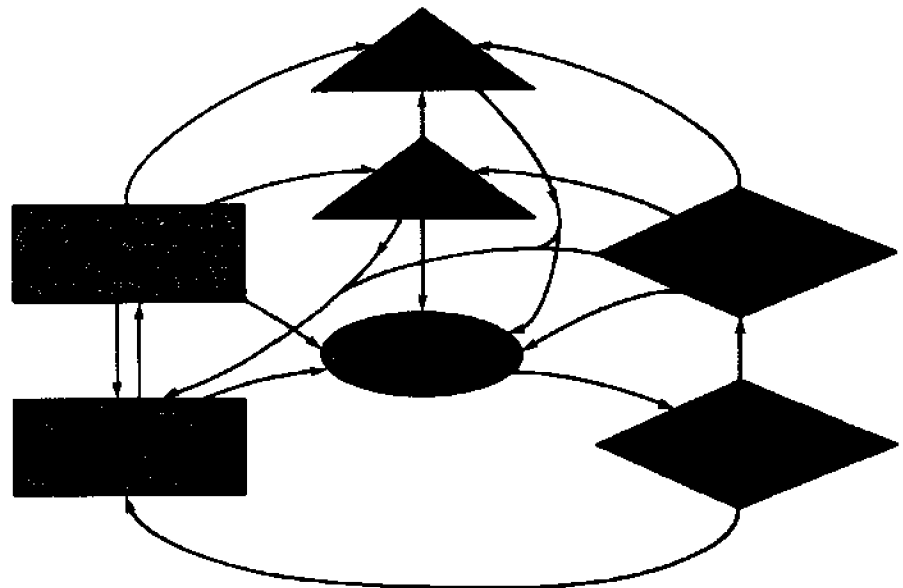


Figure 2. Grazing and detritus food chains, showing how they are interconnected.

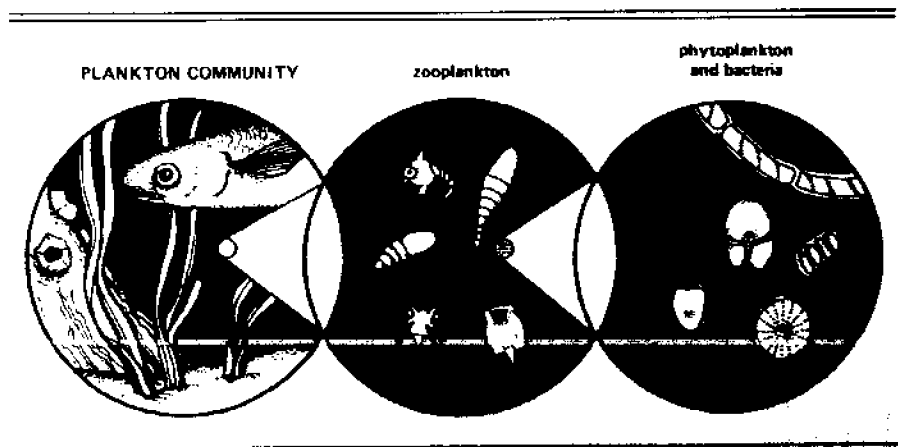


Figure 3. Some zooplankton species found in the Inland Bays (adapted from Chesapeake Bay: Introduction to the Ecosystem, USEPA, 1982).



The salt marshes of Indian River and Rehoboth Bays are typical examples of Delaware's vulnerable wetlands.

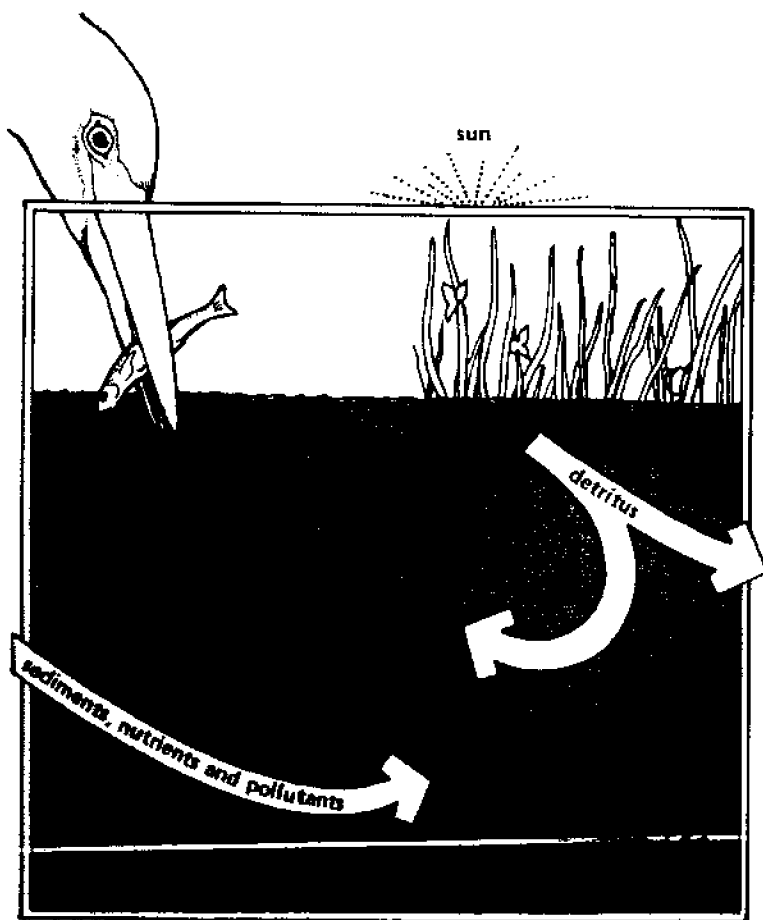


Figure 4. Cross-section of the bay and salt marsh, showing intense feeding by birds and fish, and exchange of nutrients, sediments, and detritus with surrounding estuarine environments (adapted from Chesapeake Bay: Introduction to the Ecosystem, USEPA, 1982).

showed little change in the numbers of species caught in White Creek over this time period. The dominant species (ranked most to least dominant) were Atlantic silverside, common mummichog, spot, bay anchovy, striped mummichog, menhaden, sheepshead minnow, waxen silverside, and mullet.\* In another study, where dredged lagoons were compared to natural areas, the two dominant species were the common mummichog and Atlantic silverside (Daiber, 1972). However, the dredged areas had decreased numbers of mummichogs, presumably because even these fish cannot tolerate low dissolved oxygen levels measured there. Although saltwater fish that need low-salinity water or freshwater to spawn are found in the Inland Bays, they do not spawn there. This is probably because the bays are too shallow and freshwater input is low.

The tidal salt marshes of Indian River and Rehoboth Bays are typical of all the wetlands in this area (Figure 4). In the lowest intertidal zone, cordgrass in the tall form is present. The upper marsh consists of short cordgrass, saltmarsh hay, and spike grass. The shrub zone, found at yet higher elevation, consists of marsh elder and sea myrtle. Farther landward is the forest over which the marsh encroaches as the sea level rises.

The salt marshes of the Inland Bays are a natural wildlife habitat for many species of waterfowl and diving birds, including ducks, grebes, ospreys, hawks, and gulls. The marshes are a frequent resting place for migratory birds, which often feed on the small fish in the water or on the crabs, clams, and worms found in the nearby muds. Marshes are inhabited by mammals such as muskrats and several species of small rodents. Salt marshes are considered to be shoreline buffers that reduce the impact of storm tides and waves, areas that absorb floodwaters, sources of nutrients for the bay and coastal ecosystems, and natural filters for absorption of pollutants.

Although catching blue crabs is a popular pastime in the Inland Bays region, very little is known about the crab population. The population of blue crabs in the bays undergoes considerable change in abundance from year to year and overall the

\* A 1969 study (Derickson and Price, 1973) of fish in White Creek, in which it was found that the number of fish species had decreased since the 1957-58 study, is not directly comparable to the 1957-58 and 1973-74 studies because sampling times differed.

population is active and reproducing. Fewer blue crabs have been found in dredged areas than in tidal creeks and open bay waters. In the winter, the population of blue crabs in Island Creek, the site of the Indian River Power Plant thermal effluent discharge, increases relative to the number of crabs in the entire study area. Not enough is known to determine effects of thermal effluent on the reproductive cycle of the blue crab. Although blue crabs mate in low-salinity water, they spawn in high-salinity water. Evidence suggests that blue crabs that have mated in heated water may spawn their planktonic larvae earlier in the spring than other blue crab populations in the Delaware Bay estuary (Epifanio, 1983). Whether the heated waters affect the blue crab fishery is not known.

Several commercially important shellfish species in the Inland Bays are hard clams, oysters, razor clams, soft clams, and scallops. In the 1950s the oyster populations in bays of the Mid-Atlantic region were devastated by the protozoan parasite, *Minchinia nelsoni*, known as MSX. No estimates of oysters in the Inland Bays have been made since. Only the hard clams have been studied comprehensively. In 1968, Indian River Bay contained 116,894 bushels of hard clams per 5,170 acres, while Rehoboth Bay contained 103,827 bushels per 4,599 acres. Taken together, this is equivalent to 22.6 bushels per acre (Humphries and Daiber, 1968). This same density was found in areas approved for clamming. In 1980, more of Indian River Bay was closed to shellfishing, including the recently closed mouth of Indian River. Shellfish area closures are based primarily on the levels of disease-causing microorganisms (pathogens) present. Any new closures, then, indicate a potential water quality problem in the area.

### The Problem

One of the most obvious manifestations of water quality problems in the Inland Bays is the necessity to close these areas to shellfishing (Figure 5). Prior to World War II, all waters of these bays were open to shellfishing. Today, extensive areas are off limits due to excessive levels of coliform bacteria found in shellfish intestine. Shellfish accumulate bacteria and viruses in their intestine and, if consumed, could cause diseases, such as viral hepatitis.

Three conditions are required for an area to be open for shellfish harvesting: (1) the area must be sufficiently removed from sources of fecal contamination so

not to be dangerous to the public health; (2) the area must be free from even small quantities of fresh sewage; and (3) bacteriological sampling does not normally show unacceptable levels of indicator bacteria total or fecal coliforms. In order to protect the public, the Delaware Division of Public Health is responsible for regularly analyzing bay water samples for the presence of coliform bacteria. To determine if shellfish are suitable for human consumption, a total coliform bacteria count is used as an indicator of the presence of disease-causing organisms in the water. If the median total coliform level exceeds 70 MPN (most probable number) colonies per 100 milliliters (ml) of bay water or if more than 10% of the samples exceed 330 MPN colonies/100 ml, the area is likely to be closed to shellfish harvesting (DNREC Order Number 79-W-12/25/79). Closure or conditional closure is based primarily on the median of the last 15 samples collected in the area.

The total coliform bacteria count has been useful because coliform bacteria colonies are easy to identify and the test provides a quantitative result on which standards can be based. Drinking water and recreational water quality standards also use a type of coliform bacteria count. Recently, however, several health experts have questioned the value and reliability of the total coliform bacteria count standard (James and Evison, 1979). The original purpose of the test was not to indicate water quality, but to determine the level of pathogens in sewage treatment plant effluent. However, lacking a consensus on alternative shellfish harvesting water quality criteria, the total coliform bacteria count test is used widely throughout the United States, including Delaware.

In addition to the Delaware Division of Public Health, the Delaware Division of Fish and Wildlife is responsible for the management and protection of the shellfish resource. Together, these agencies regulate shellfish harvesting.

### Actions to Date

The increase in the number of areas closed to shellfish harvesting indicates declining water quality because more bacteria are entering the bays than ever before. The Department of Natural Resources and Environmental Control (DNREC) has tried to remedy this problem by requiring sewage treatment plants, which release effluent into the bays, to upgrade their facilities.

The aim of wastewater (sewage) treatment is to remove physical and chemical

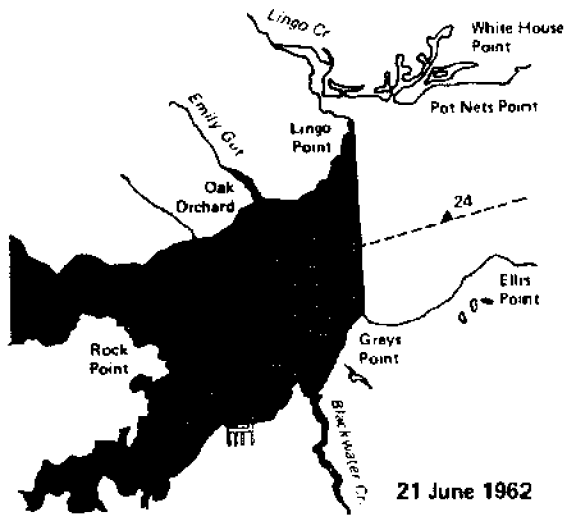
components of wastewater that render the water toxic, aesthetically unpleasing, or otherwise unsuitable for its intended use. Sewage treatment is concerned with removing solids, toxic substances, pathogenic organisms, and breaking down organic wastes from households and other facilities.

Treatment can consist of mechanical processes alone or a combination of mechanical, biological, and chemical processes. The three types of central treatment are the following:

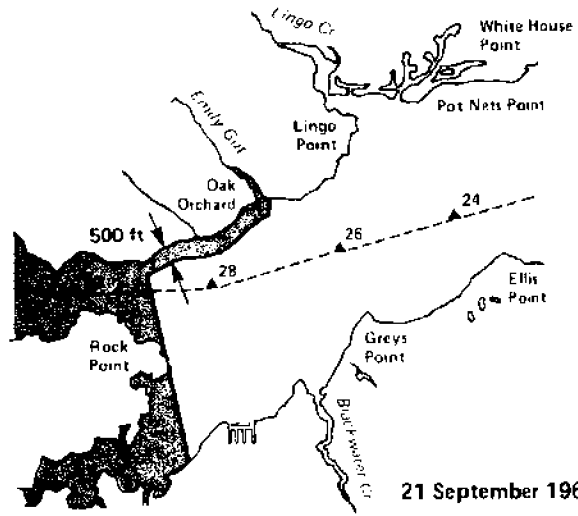
- Primary treatment physically removes solids through sedimentation, but does not deal with organic substances, toxic substances, or pathogenic organisms. It removes approximately 50% of the solids and reduces the dissolved oxygen demand by 50%. In Delaware, chlorination is used to reduce the number of pathogens. Excessive chlorination should be avoided because chlorine and chlorine compounds can have sublethal effects on estuarine organisms (Brungs, 1973).
- Secondary treatment, in combination with sedimentation, biologically breaks down organic material with 85% removal efficiency. This treatment also uses chlorination to reduce pathogens.
- Tertiary treatment chemically removes phosphorus and nitrogen compounds and through filtration eliminates additional organics and suspended solids. Tertiary treatment is the most effective method for wastewater treatment (95% removal rate), but it is very expensive and often undesirable for small, rural communities. The South Coastal Regional Wastewater Facility in Sussex County employs filtration and chlorination, but does not remove nutrients.

In addition to producing clean (or cleaner) water, sewage treatment processes create large amounts of sludge material. Depending on the original effluent and the nature of treatment, sludge may contain toxic (poisonous) or pathogenic substances and must be disposed of with care. Sludge can exist as a liquid, a semi-solid sludge cake, or ash. If all toxins are removed, it can be used as fertilizer, an irrigant, or landfill.

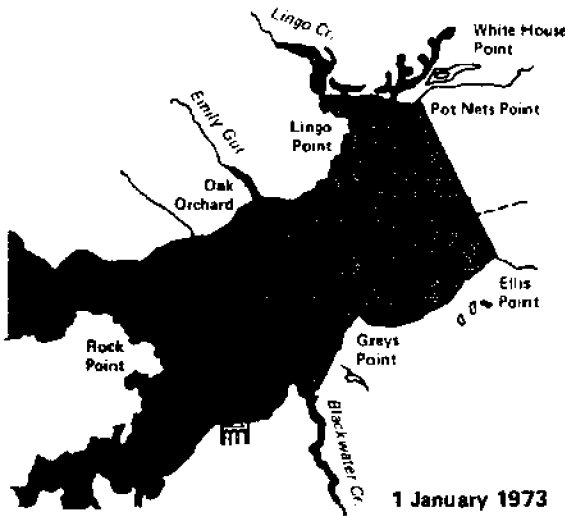
Sanitary collection systems consist of pipes connected to homes and other facilities for transport of sewage only. Storm sewer systems transport run-off from roads and other paved areas and from land. Heavy rain or rapid snow-melt can quickly overwhelm the capacity of sewer systems and result in flooding.



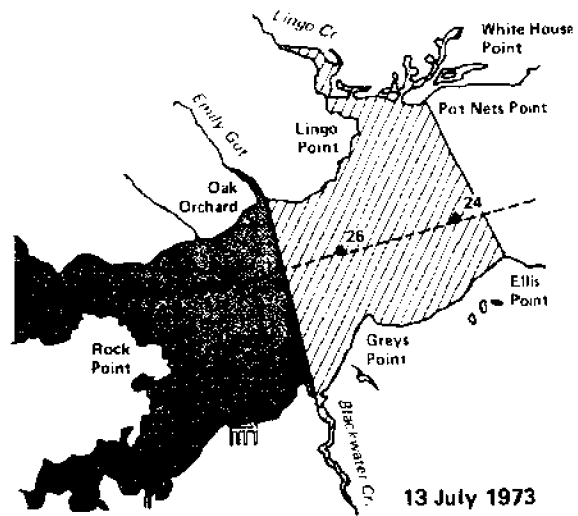
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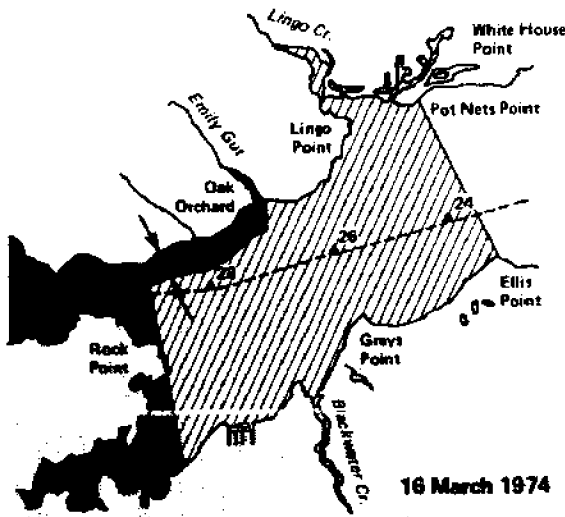
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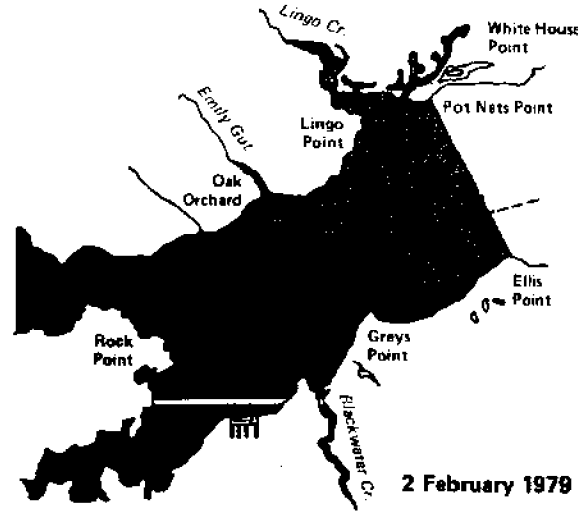
1 January 1973



13 July 1973



16 March 1974



2 February 1978

■ Closed

▨ Conditional

□ Open

Despite improvements in sewage treatment practices and the enforcement of effluent standards, the amount of area closed to shellfishing has increased over the last two decades. The Delaware Coastal Management Program funded a study to model the distribution of coliform bacteria in the Inland Bays. The study results suggest that **nonpoint sources**, which include agricultural run-off, precipitation, on-site septic systems, and salt marshes, contribute significantly more bacteria than do **point sources**, such as sewage treatment plants (Jensen et al., 1981).

### Proposed Strategy

At this time, Delaware does not have a strategy for addressing the above-mentioned possible sources of bacteria. To determine the source of bacteria into the bays, the state should consider supporting a scientific investigation of the sources and strategies that might be useful in mitigating the problem. Such an investigation would include identification of the bacterial sources and sinks in the bays, daily and seasonal measurement of bacterial concentrations in shellfish intestine and bay water, definition of existing problem areas, and identification of potential problems in the future.

Shellfish are an important economic and recreational resource. The state must decide how it wants to ensure the future well being and use of the resource.

*Figure 5. Historical changes in shellfish bed closures in Indian River Bay, showing that the area between Lingo Point and Pot Nets Point, open in 1962, was closed in 1979 (adapted from "Executive Summary: Analysis of Coliform Bacteria Problems in Indian River Bay, Delaware," Espey, Huston and Associates, Inc., 1981).*

## Eutrophication

### Introduction

Nutrients, such as phosphorus, nitrogen, and carbon, are essential to the growth of algae and other aquatic plants in all estuaries. Nutrient sources include raw and treated sewage, various organic and inorganic industrial, municipal, and recreational wastes, sediments from land erosion, and runoff of fertilizers. However, when the amount of nutrients in the estuary is too great called **nutrient enrichment**—plant growth is uncontrolled. When nutrient enrichment occurs, the estuary becomes unhealthy and less attractive aesthetically.

The health of an ecosystem is defined as "that state in which the components and processes remain well within specified limits of system integrity, selected to ensure that there is not diminution in the capacity of the system to render its basic service to society throughout the indefinite future" (Darnell and Soniat, 1980). This section will discuss nutrient enrichment of the Inland Bays and the subsequent impacts on the health of the bay ecosystems.

### The Natural System

Eutrophication is the process of nutrient enrichment of water bodies either naturally through maturation or artificially by human activities. Eutrophication has produced significant biological changes in many lakes and estuaries (Smith, 1974). Increases in nutrient loads stimulate a dense growth of planktonic algae, dominated by blue-green forms, and rooted aquatic plants in shallow water. These increases disturb normal food chains. The **herbivores**, principally grazing zooplankton, are unable to consume the bulk of the algae as they normally do. Abnormal quantities of unconsumed algae, as well as larger plants, die and sink to the bottom. Due to oxygen depletion, the oxygen-using decomposers on the bottom are unable to reduce this organic matter to **inorganic matter**, and so they perish. They are replaced by organisms that do not need oxygen and that only incompletely decompose the organic matter. As partially decomposed sediments build up the bottom, **sulfate-reducing bacteria** release **hydrogen sulfide** that can poison bottom waters. These chemical and environmental changes cause major shifts in the plant and animal life of the affected aquatic ecosystem.

The oxygen concentration in the waters of the Inland Bays is a function of several processes. The amount of dissolved oxygen that the waters of the Inland Bays can hold decreases as salt content and water temperature increase. Even if there were no life in the bays, the dissolved oxygen concentration would follow a seasonal pattern as the salinity and temperature of the water passed through an annual cycle.

Oxygen gas physically enters bay water from the atmosphere by **diffusion** across the air-water boundary and through bubbles caused by breaking waves. The rate of transfer is dependent upon temperature, sea state and wind velocity, and amount of oxygen already dissolved in the water. Oxygen also enters bay water through some biological processes, notably through photosynthesis by phytoplankton and submerged rooted vegetation, in the presence of sunlight. Due to higher summer temperatures, biological activity increases and dissolved oxygen can become quite low. Nutrient enrichment accelerates this process of oxygen depletion. Oxygen dissolved in the bay waters is removed by **respiration** of animals in the water (and sediments) and, at night when they are respiring but not photosynthesizing, by phytoplankton and rooted vegetation. Dissolved oxygen can also be removed from the water by oxygen-consuming chemical reactions, occurring primarily in the sediments. Thus, the dissolved oxygen concentration measured in the Inland Bays is the net result of the interaction of these physical, biological, and chemical processes.

The principal result of nutrient enrichment that concerns managers is the increased oxygen demand created by the decay of organic material, the growth of which is stimulated by the presence of nutrients. Therefore, the criteria for establishing the current health of the Inland Bays system are related to the potential oxygen demand.

### The Problem

Because eutrophication results in low-oxygen conditions, levels of dissolved oxygen are considered an indicator of eutrophication. A major result of numerous human activities in and around the Inland Bays is the reduction of the amount of dissolved oxygen in the water. Most organisms need oxygen to survive, grow, and reproduce. And while they might be able to survive low oxygen levels, their growth and reproduction

Table 1. Chesapeake Bay Study classification of high-salinity (> 0.5 ‰) estuarine waters (from Tippie et al., 1983)

Class	Total nitrogen (mg/l)	Total phosphorus (mg/l)	Potential dissolved oxygen demand (mg)
1	0-0.30	0-0.042	6
2	0.31-0.60	0.043-0.084	12
3	0.61-0.80	0.085-0.112	16
4	0.81-1.00	0.113-0.140	20
5	1.01-1.75	0.141-0.245	35
6	> 1.76+	0.246+	36+

Table 2. Comparison of Inland Bays nitrogen and phosphorus loads from different sources (adapted from Ritter and Scheffler, 1977)

Watershed	Source	Nitrogen (kg/year) (%)		Phosphorus (kg/year) (%)	
		kg/year	(%)	kg/year	(%)
Indian River	Point	164,700	(16)	57,200	(64)
	Nonpoint	680,900	(68)	19,400	(22)
	Septic tank	26,900	(3)	12,200	(14)
	Wetlands	129,600	(13)		
Rehoboth Bay	Point	32,700	(8)	18,300	(50)
	Nonpoint	259,000	(61)	7,400	(20)
	Septic tank	23,800	(5)	10,800	(30)
	Wetlands	110,000	(26)		

Table 3. Oxygen tolerance of principal Chesapeake and Inland Bays species (adapted from USEPA Chesapeake Bay Program Draft Final Report, Tippie et al., 1983)

Species	Oxygen (ml/l)	
	Death occurs	Stress behavior occurs
American oyster	0.7	1.7
Atlantic silverside	0.6	1.1
Blue crab	0.5	1.8
American menhaden	0.4	1.0
Spot	0.4	0.9-2.7
Mummichog	0.04	0.9

might be affected. Many toxicants act more effectively with a reduction of oxygen. For example, fish are more vulnerable to the effects of toxic substances in low-oxygen environments because fish must increase their gill irrigation rates, which in turn causes increased absorption rates of toxicants.

As more nutrients enter the bay waters, the potential oxygen demand by chemical reactions greatly increases as shown in Table 1 (Tippie et al., 1983). Researchers investigating nitrogen loading in estuaries throughout the United States have found that nonpoint sources, including agriculture and on-site waste disposal systems, account for as much as 60% of the nitrogen load (USEPA, 1982; Novotny and Chesters, 1981; Clark, 1977). Locally, Ritter and Scheffler (1977) found that nonpoint sources, not including septic tanks and salt marshes, contribute 68% of the nitrogen load into Indian River Bay and 61% of the nitrogen load into Rehoboth Bay (Table 2).

Relating nutrients, organic material, and potential oxygen demand to determine eutrophic conditions is a traditional concept that the USEPA Chesapeake Bay Study (Tippie et al., 1983) has extended to a classification scheme for the Chesapeake Bay and its tributaries. This scheme assigns classes 1 through 6 to characterize segments of the Chesapeake Bay relative to nutrient enrichment. Class 1 is pristine, with no nutrient enrichment; class 6 is very highly enriched. When Indian River and Rehoboth Bays are classified by total nitrogen concentration, and ranked according to the Chesapeake Bay Program classification scheme (Figures 6a and 6b), most of Indian River Bay is highly to very highly enriched (class 6), while most of Rehoboth Bay is moderately enriched (class 4).

The total nitrogen classification scheme developed for the Chesapeake Bay appears to be qualitatively transferable to the Inland Bays because the classification system predicts that problems can exist in waters with high total nitrogen concentrations. Researchers have found that

*in Indian River and Indian River Bay... the levels of percent saturation of dissolved oxygen had a trend to be low west of the DP&L [Delmarva Power and Light] power station. There have been several fish kills in this area since 1976. The percent saturation of [dissolved oxygen] (D.O.) is lower than 1973 levels west of the power plant... [and]... (Rehoboth) Bay has had*

only minor problems with its percent saturation of dissolved oxygen; and generally, there has not been a serious problem with a lack of D.O. ... (State Water Inventory Technical Appendix, 1980).

Dissolved oxygen is of great importance because it directly affects aquatic life. The State of Delaware standard for the dissolved oxygen content of its tidal waters says that the dissolved oxygen levels shall not be less than a daily average of 6 milligrams per liter (mg/l) nor go below 5 mg/l at any time (DNREC, 1979).

These standards are conservative, in that they are conditional limits well short of the critical limits of tolerance of important bay organisms. Thornton (1975) has measured the dissolved oxygen concentrations necessary to kill 50% of test batches of juvenile and adult fishes in Indian River Bay at specified temperature and salinity conditions. Thornton's data

and other research work are summarized in Table 3. Given the variability obtained in these experiments, the potential sensitivity of eggs and larvae to all of the important organisms in the bays, and the desire to set a standard well above the level necessary to kill the organisms in the bays, the state has acted prudently in establishing its dissolved oxygen standard.

Dissolved oxygen concentration can be used to measure whether the components and processes are within the specified limits, and, therefore, whether the bays are healthy. The definition of health specified "a state in which the components and processes remain well within specified limits of system integrity." On a yearly basis, lowest dissolved oxygen concentrations should occur during the summer when water temperature is highest (reducing solubility), winds are lowest (reducing mixing), and respiration by bay organisms is greatest (because the animals living in the bay increase their metabolism

as temperature increases). To maintain a healthy bay, all of these processes that tend to reduce the dissolved oxygen concentrations need to be balanced by the photosynthetic production of oxygen and reaeration from the atmosphere.

Lowest dissolved oxygen concentrations occur at about dawn, while highest values are found near mid-day. This cycle, which Campbell (1975) has demonstrated occurs in White Creek (a tributary to Indian River Bay), is important to consider when evaluating the health of the bays based on dissolved oxygen concentration. In part, the time of day when the sample is taken determines whether the water body is regarded as healthy or unhealthy. At dawn in the summer, Thornton (1975) found all dissolved oxygen values below 4.2 mg/l, with occasional values below 3 mg/l in White Creek. By 4 p.m., the dissolved oxygen was above 10 mg/l at all stations. Clearly, all of the waters sampled at dawn along the entire length of White

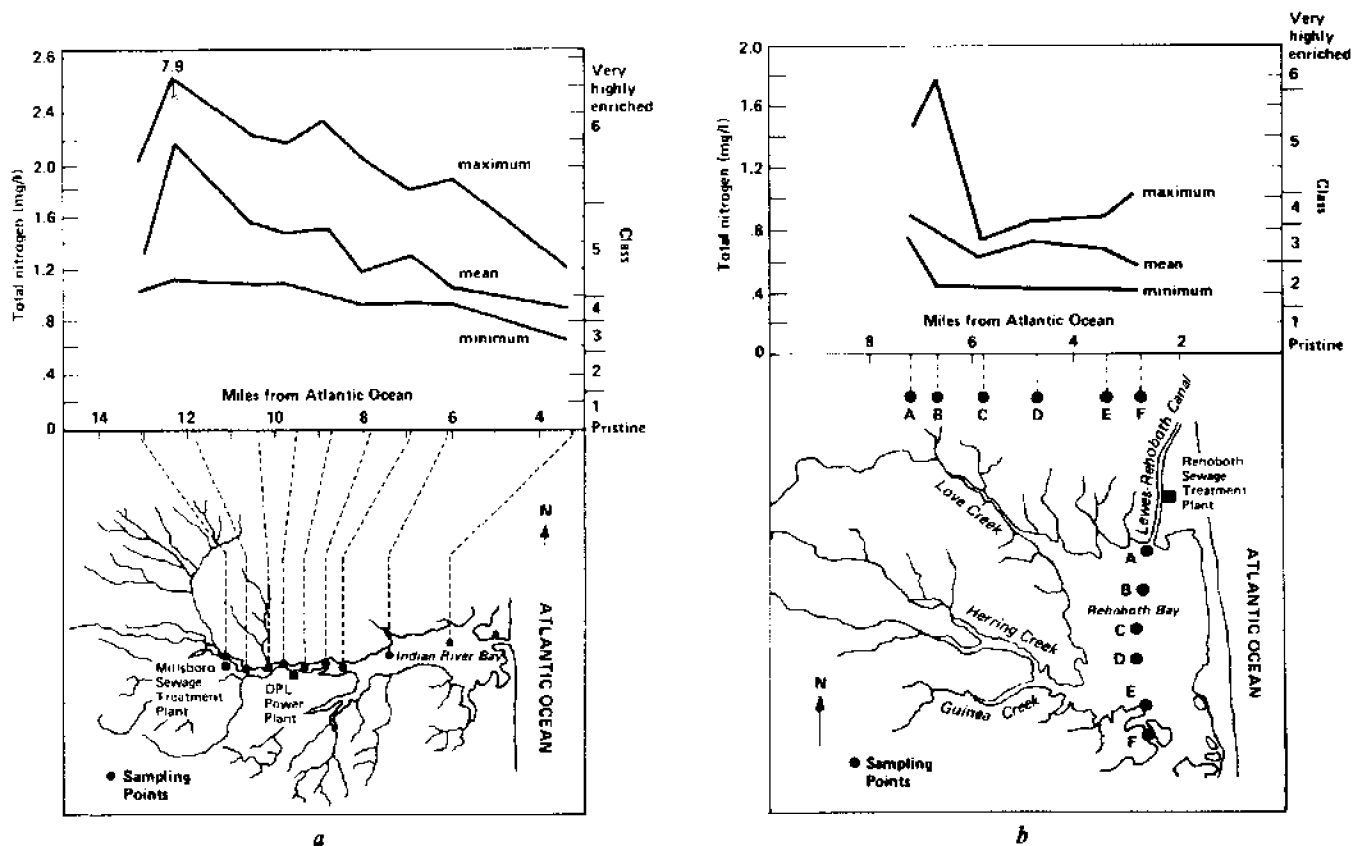


Figure 6. Total nitrogen concentrations for Indian River and Rehoboth Bays, October 1978 through September 1979, based on classification scheme from USEPA Chesapeake Bay Study. (Data from Delaware DNREC, 1980).

Creek violated the state standards for dissolved oxygen.

The day-night fluctuations in dissolved oxygen concentration are natural because of the presence or absence of sunlight that stimulates the growth of phytoplankton and, therefore, oxygen-yielding photosynthesis. However, the degree of fluctuation can be influenced dramatically by the addition of nutrients. If phytoplankton growth is stimulated, more oxygen will be produced during the daylight and more oxygen will be needed for respiration at night. Thus, daytime dissolved oxygen concentration will be even higher and nighttime even lower. If the nighttime reductions become too great, then mobile organisms may avoid such waters. The DNREC monitors the concentration of dissolved oxygen in the Inland Bays, presumably acquiring data during daylight. Based on the discussion in this section on eutrophication, an increase in daytime dissolved oxygen concentration from one year to the next might indicate degrading water quality. Yet the DNREC annual assessment for 1974 concluded otherwise:

*The profiles presented on the following pages indicate an increase in dissolved oxygen in the last four years in Indian River Bay with a decrease in dissolved oxygen in Rehoboth Bay. . . (Water) quality in Indian River Bay appears to be better than that in Rehoboth Bay. . . (Delaware Division of Environmental Control, 1975).*

Although nighttime dissolved oxygen data from the studies by Thornton and Campbell are available, few nighttime dissolved oxygen studies other than Daiber (1972, 1974) have been conducted for the Inland Bays. However, an analysis of the DNREC daytime dissolved oxygen data suggests a plausible conclusion opposite to that reached by the DNREC. Given the dissolved oxygen standard of 5 mg/l (minimum), it is suggested that the time to sample for dissolved oxygen is not during the day, when dissolved oxygen is likely to be higher than the 24-hour minimum, but at dawn, especially during the summer.

While the Thornton data show that dissolved oxygen values at dawn approach concentrations that provoke avoidance by some fish and approach lethal concentrations for others, there are no data indicating that massive or persistent mortalities have occurred. Based on the very limited nighttime dissolved oxygen data that are available, it is not reasonable to assert that a crisis is imminent. Instead, it is suggested that summer nighttime dissolved oxygen

concentrations are approaching dangerously low levels, that the year-to-year daytime dissolved oxygen levels in Indian River Bay are experiencing wider fluctuations, and that both of these observations are consistent with the high total nitrogen concentration of Indian River Bay.

#### Actions to Date

The DNREC conducts an excellent water quality monitoring program of the Inland Bays and has conservative regulations for dissolved oxygen in tidal waters. The Delaware Coastal Management Program has supported studies that have identified the major sources of nitrogen and phosphorus to the bays, developed a water quality model for the bays, and identified best management practices that could be implemented to reduce pollutants entering the bays.

#### Proposed Strategy

It is possible that the state water quality reports on the bays might have misinterpreted high daytime dissolved oxygen concentrations as an indicator of good health, when it is at least as likely that such high daytime values might indicate degrading water quality. While it is lamentable that there is no Sussex County Comprehensive Plan from which to project future growth and demands on the Inland Bays region, the state, through its wastewater discharge permit process, can regulate and limit nitrogen and phos-

phorus additions to the Inland Bays by estimating their assimilative capacity and developing a wastewater management allocation plan.

Therefore, it is strongly suggested that a prudent course of action would involve the following: (1) monitoring dissolved oxygen at dawn during the summer of 1983 over wide areas of Indian River and Rehoboth Bays and their tributaries; (2) monitoring dissolved oxygen hourly for 24 hours at selected key locations; (3) reviewing existing water quality data, models, and management scenarios to reduce ambient nitrogen and phosphorus concentrations in Indian River Bay; and (4) developing a wastewater management allocation plan for nitrogen and phosphorus so that individual wastewater discharge applications would be viewed as part of the whole process.

Eutrophication is a process that does not result from one individual cause, but rather represents the end product of numerous human activities. Activities in the bays that might enhance eutrophication are sewage disposal, organic effluents, dredging, oils from boat discharges, and heated thermal effluents from power plants. Because so many activities can contribute to eutrophication, their impacts must be considered as a whole, not just one-by-one. All of these activities are occurring simultaneously so that while one alone might not be detrimental to the health of the bays, the sum of all human activities might be.



*Nutrients are essential for maintaining a healthy bay ecosystem, but if nutrient levels are too high, eutrophication can occur.*



## Dredging Effects

The demand for maintaining existing channels and creating new channels for recreation and navigation in the Inland Bays has increased. Dredging can affect marine resources in several ways. Dredging operations stir bottom sediments, which increases turbidity, thus limiting photosynthesis. Dredging of new channels also can alter natural water circulation patterns that inadvertently introduce new conditions on the shoreline and impact certain marine species. Because dredging affects the overall productivity of estuarine systems, it is expressly addressed in the state's Wetland Act of 1973 (see 7 Delaware Code 6602).

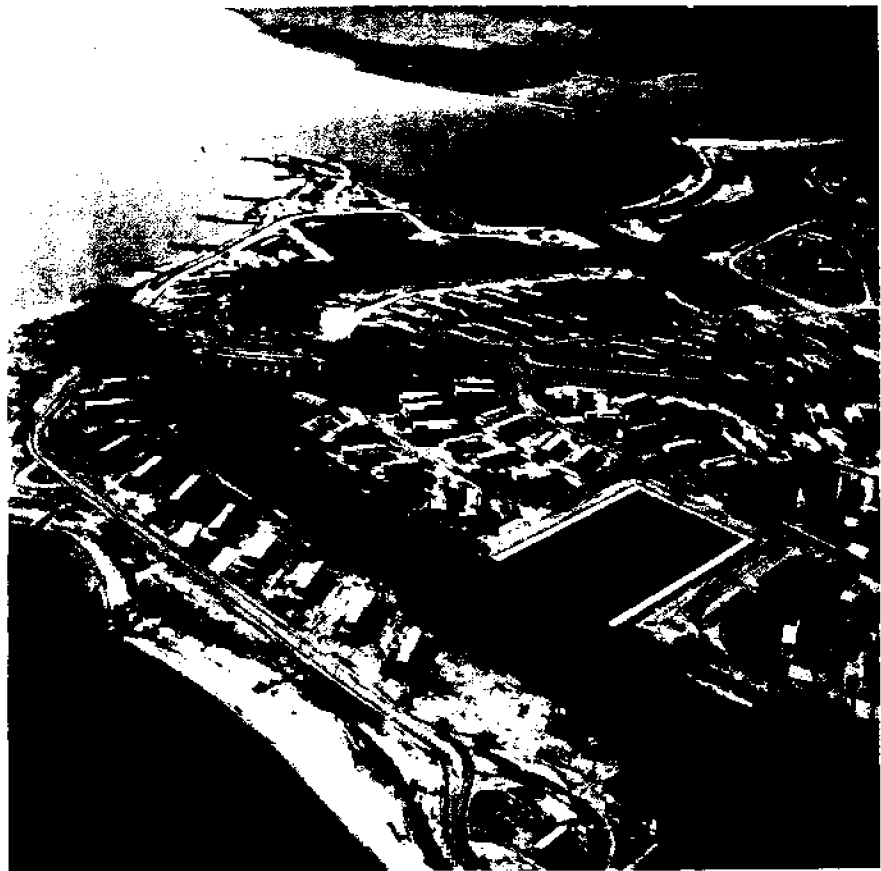
At the secondary level, there is growing concern that the type and location of dredging projects within the Inland Bays area are major determinants in the pattern of adjacent land uses following a project's completion. It appears that the availability of navigable channels, or lack thereof, often directly encourages or discourages adjacent upland development. A survey of dredging permit project applications reveals that certain dredging projects have resulted in deep-water access, making development possible in areas where it might not have occurred otherwise.

### The Natural System

The environmental effects of dredging can be limited if careful methods are used. To minimize adverse effects, it is first necessary to understand the natural systems. This section briefly describes the relationships between the sediments and **benthic species** that inhabit the Inland Bays.

The sediments of the Inland Bays contain at least 150 bottom-dwelling (benthic) species, which live and feed in different ways. They are primarily burrowers and **tube-builders** that are filter-feeders, **carnivores**, or **deposit-feeders**. Deposit-feeders feed on the sediments they inhabit by extracting nutrient from the associated detritus and microorganisms. In general, more species are present in the summer than in other seasons and more occur in Indian River Bay than in Rehoboth Bay. The dominant species are polychaete worms, **bivalves**, and **amphipod crustaceans**.

Benthic species serve a number of purposes in the estuary. They are food for bottom-feeding fish. Through their



*Man-made lagoons and other dredging activities in the Inland Bays can alter natural water circulation.*

burrowing and tube-dwelling activities they rework the sediments, constantly turning over the top 10 to 15 centimeters, and hence, oxygenate the sediments. Deposit-feeders help break down plant detritus which accumulates from benthic algae, the salt marsh grasses, and terrestrial plant litter. Some benthic species accumulate **heavy metals** in their tissues and thus reduce the availability of the metals to the rest of the marine ecosystem. However, if they are eaten by fish and crabs, any accumulated material might be transferred up the food chain. Benthic species also affect the flux of nutrients and organic compounds out of the sediments and into the water column. Organic matter tends to be ten times more concentrated in the sediments than in the water column above (Sherk, 1972). In addition, some scientists consider benthic species better indicators of **stressed habitats** than are fish and crabs, because benthic species are relatively immobile.

Creating **lagoons** to enhance shoreside development has a direct impact on the bays' benthic communities. Lagoons are confined coastal water bodies with

restricted inlets to the sea that generate little freshwater inflow (Clark, 1977). Because they are confined, the circulation of the lagoons is sluggish. Therefore, these dredged bodies of water are particularly vulnerable to environmental disturbances such as **pollution**, defined by Houston (1979) as the presence of matter or energy whose nature, location, or quantity produces an undesirable environmental effect. Consequently, lagoons bordered by residential developments are highly susceptible to degradation if not designed properly to deal with the secondary effects of water eutrophication caused by septic system **leachates** and **enriched land runoff**.

### The Problem

The main result of dredging the bottom sediments is an increase in the amount of sediment suspended in the water. This, in turn, can impair light penetration into the water column and subsequently limit photosynthetic activity in the water column. Resuspension of sediments causes an increase in available

nutrients, organic matter, hydrocarbons, and heavy metals that adsorb readily onto sediments while they are in place. Because of their great surface area, fine-grained sediments, which often are found in areas that need maintenance dredging, contain high levels of organic matter and heavy metals. The oxygen demand of resuspended sediments is eight times that of the same material when it was on the bottom (Sherk, 1972).

Dredging can present other problems, such as where to dump the spoils. Overboard deposition of spoils can cause a 50-fold increase in total phosphorus and a 100-fold increase in total nitrogen, hence a rapid increase of nutrients to the ecosystem. Heavy loads of suspended sediments can adversely affect the gills of fish and tissues of filter-feeders (clams, oysters, bottom-dwellers, zooplankton). Of the estuarine species studied in the laboratory, the Atlantic silverside had the lowest tolerance to suspended sediments (Sherk, 1972). Organisms also have a limited ability to tolerate heavy metals and hydrocarbons. This ability depends on many factors, such as dosage of metals or hydrocarbons, water temperature, pH, and dissolved oxygen levels, or presence of other compounds. The level of organic materials present also can affect the ability of a benthic invertebrate to tolerate

heavy metals. Finally, even though an organism survives the impact of a pollutant, the sublethal effects must be considered most frequently, reproductive output and growth decrease.

On-land disposal can cause contamination of the subsurface drinking water supply from saltwater and toxic materials that leach out every time rain falls onto a spoil pile. Coastal Sussex is particularly vulnerable to this threat because the soils are sandy and the drinking water supply is near the surface.

These problems associated with dredging are particularly acute in the development of artificial lagoons. In the Inland Bays area these lagoons have been created to satisfy the demand for boating access from new housing or trailer park development. To create a lagoon, a canal is dredged from the landward end ("dead end") of the lagoon toward the water. Once excavation of the area has been completed, the strip of land separating the lagoon from open water is destroyed, allowing the water to flow into the lagoon (Daiber et al., 1976).

Since 1970, several studies have investigated the effects dead-end lagoons have on the marine environment and biota. The studies conducted on the Inland Bays have demonstrated that the subsequent inadequate circulation and flushing of the lagoon result in stratification of the water column, especially in regard to its oxygen content, temperature, and salinity (Daiber et al., 1976).

Oxygen demand in the water and sediments often leads to depletion of oxygen in the bottom water, particularly in summer. Bacteria use oxygen to break down the organic material of dead microorganisms. Without replenishment of oxygen, anoxic (lacking oxygen) conditions can result in massive die-offs of organisms present in the lagoon. The surrounding housing developments can contribute leachate from septic tanks and run-off from streets and yards (Clark, 1977). This nutrient enrichment can promote algal blooms and anoxic conditions in the water, thereby compounding the problem.

The physical shape of dead-end lagoons is principally responsible for the circulatory problems that result in anoxic conditions. Water cannot circulate freely because there is only one opening. Thus, the critical natural flushing essential for a healthy environment is reduced or absent. In addition to the single opening, a sill is present, which prevents the free exchange of bottom water between the lagoon and the bay (Daiber et al., 1976).

## Actions to Date

Currently three groups routinely conduct dredging operations in the Inland Bays area. These are the U.S. Army Corps of Engineers, the Department of Natural Resources and Environmental Control's (DNREC's) Division of Soil and Water Conservation, and the private sector. The U.S. Army Corps of Engineers is responsible for maintenance dredging of the majority of navigable channels in the area. The Division of Soil and Water Conservation is equipped with a dredge to handle small creeks, inlets, and some beach replenishment projects (Falk, 1980). Private sector dredging has included those projects that have created lagoon development communities and contract work for silt removal by private marina operators.

All of these groups are required to obtain the necessary state and federal permits prior to conducting dredging activities in the Inland Bays. State regulatory officials encourage applicants who want to dredge in wetlands or subaqueous lands to notify them when first beginning the project to discuss the projects and possible alternatives. State officials are now working closely with prospective applicants to ensure that projects comply with state regulations and limit environmental damage (Falk, 1980).

Prior to the issuance of federal permits for work in navigable waters, the permit application must be reviewed and approved by the U.S. Fish and Wildlife Service, the National Marine Fisheries Service, and the U.S. Environmental Protection Agency. Each of these federal agencies reviews the application, inspects the site if necessary, and forwards its comments to the U.S. Army Corps of Engineers. (The U.S. Army Corps of Engineers regulates activities in waterways under the Rivers and Harbors Act of 1899 (33 U.S.C. 408) and adjacent wetlands and inland waters under the provisions of Section 404 of the Federal Water Pollution Control Act of 1972 (33 U.S.C. 1344).) It is incumbent upon the permit applicant to resolve any objections with the appropriate agencies prior to issuance of a permit. Since 1981, the DNREC and the U.S. Army Corps of Engineers have been jointly processing permit applications, thereby facilitating the permit process and reducing the time to issue a permit.

Many have expressed concern that dredging projects undertaken by the state need to be formally prioritized and comprehensively examined to determine the long-term costs and benefits of the environmental and economic impacts of these



*Dredging of bottom sediments in the Inland Bays has been necessary to satisfy increased demands for access to recreational boating areas.*

projects. Currently, dredging projects are determined annually. The process is legislative in that constituents or the Division of Soil and Water Conservation petition their representatives to submit a resolution before the General Assembly to appropriate state funds for dredging projects. Since 1970, the state has dredged or scheduled dredging in the Inland Bays area in Love Creek, White Creek, Guinea Creek, Herring Creek, Lee Joseph Creek (Cozy Cove), Cedar Creek, Jefferson Creek, Blackwater Creek, and Pepper Creek.

### Proposed Strategy

The dredging of lagoons and creeks in the Inland Bays area is an activity that can cause significant environmental impacts if not carefully planned. This was recognized in 1976 during the development of recommendations for the state's Coastal Management Program (CMP). A report funded by the CMP, an *Atlas of Delaware's Wetlands and Estuarine Resources*, made recommendations and suggested policies that need to be considered prior to initiating such projects. Of nine specific recommendations regarding the development of lagoons, only five have been adopted by the DNREC. They stated the following:

- Projects that benefit the public at large, rather than a small private interest, should be given priority.
- Dredging should be done only in areas where it does not threaten wetlands. *[Adopted]*
- All dredging should be preceded by ecological feasibility studies in conjunction with economic assessments and engineering studies.
- Integrity of natural waterways should be maintained.
- Dredging should be restricted to November through mid-March to avoid interference with migrations and spawning seasons of finfish. *[Adopted]*
- Lagoon construction should be designed to facilitate water circulation; that is, no dead-end lagoons should be permitted. *[Adopted]*
- If dead-end lagoons are constructed, they should be no longer than twice their width *[Adopted]*
- Dredging should not be carried out below the natural water depths of the locality (that is, no sills). *[Adopted]*
- Residences should be placed on adjoining uplands. Proper community planning, including density of housing, sewer systems, soil characteristics, and

land drainage, should be accounted for. *[Adopted in part]*

With respect to the development of criteria to assess the need for and primary and secondary environmental and economic consequences of proposed state dredging projects, the situation is not clear. According to the Director of the Division of Soil and Water Conservation, efforts to establish an interagency group to evaluate and recommend criteria to assess the merits of such projects are underway (Ireland, 1982).

Any dredging policy adopted should consider the following items:

- All dredging should be scheduled to minimize disruption to fish and bird breeding, migrations, marine habitats, and water circulation.
- An analysis of bottom sediments should be made prior to dredging to determine if toxins are present and to determine which bottom areas are most productive biologically.
- Disposal of dredge sediments should be used, when practical, for beach nourishment or should be disposed of into the longshore current system.
- An inventory should be conducted to locate spoil sites that are environmentally acceptable. Disposal should not alter the bays natural sediment transport processes (Swisher, 1982).
- Dredging should be conducted in areas that will benefit the general public as established in a suitable cost-benefit analysis.

These items are necessary components for any criteria established to assess dredging projects conducted by the state. In addition, a policy statement should be developed that specifies the types of projects and under what conditions such projects qualify as state-funded activity.

## Saltwater Intrusion

Although the quantity of groundwater in eastern Sussex County adequately meets demands, the quality is sometimes a problem. The presence of chloride indicates saltwater intrusion, a severe threat where the water table is low. As the major source of water for domestic, agricultural, and industrial use, groundwater quality is critical. What follows is a discussion of the natural processes, the problem, what has been done, and the proposed strategy to deal with this problem.

### The Natural System

Sussex County rests on the Atlantic Coastal Plain. This plain consists of a wedge of sedimentary material, thicker along its southeastern edge, atop a basement of igneous and metamorphic rocks. In Delaware, this sedimentary wedge consists of unconsolidated sand, gravel, and clay formations that dip gently toward the southeast. The combined thickness of these sediments ranges from 4200 to 7800 feet.

Sediments of the Atlantic Coastal Plain contain significant amounts of freshwater. This groundwater, known as an aquifer, is stored in sediments in two ways: it is found relatively near the surface as part of the water table, and it is stored in artesian layers at various depths below the land surface.

The water table is that horizon in the ground below which the soil is completely saturated with water. The source of this water is rain, and the recharge area of an aquifer is the land above it, from which rain and other precipitation drain. Because it depends on local precipitation for recharge, the surface of a water table aquifer, that is, the water table, will move up and down as the amount of local precipitation changes. Because of its proximity to the land surface, an aquifer can be tapped easily to supply water to households and other facilities. Unfortunately, it also can become easily contaminated.

About 90% of the water pumped for domestic, agricultural, and industrial use in Sussex County comes from the water table aquifer (Sundstrom et al., 1976). This system is recharged through the natural water cycle process. The hydrologic (water) cycle is powered by solar energy (Figure 7). Water vapor enters the atmosphere through evaporation from water bodies and the soil and through transpiration from the leaves of plants. This water vapor condenses in the cooler

upper atmosphere and forms clouds. When water droplets are too heavy to stay in the atmosphere, they leave the atmosphere in the form of precipitation.

Some of the water falling on land flows over the surface to streams and other bodies of water; some percolates into the ground where it can also flow underground to a water body; and some is absorbed by plants and ingested by animals. Through the process of respiration, animals lose water to get rid of their body wastes. And when all living things die, water is lost through the process of decomposition (Houston, 1979).

The water table aquifer extends throughout Sussex County and, due to the abundance of precipitation in the area, is nearly always "brim full." The Sussex County water table aquifer holds about 3 cubic miles of water. Consequently, the amount of water removed for human use constitutes only a small percentage of the aquifer's reserves. In 1969, the amount of water removed for human use in Sussex County was approximately 18 million gallons per day (MGD), compared with a recharge of 490 MGD.

Sussex County uses the groundwater supply for both its agricultural and municipal needs. In 1957, the agricultural community used 0.4 MGD. By 1974, however,

this demand had increased to 5.7 MGD, an increase greater than 1000%. At the same time, municipal withdrawal of groundwater had increased from 3.7 MGD in 1957 to 6.5 MGD in 1974. Experts believe that the aquifer, which supplies 90% of coastal Sussex County's water demands, could support pumping as high as 100 MGD without suffering ill effects provided that development is properly planned and the pumping properly distributed (Sundstrom et al., 1976). Proper planning would have to address the existing problem of saltwater intrusion in developments that are seaward of the 10-foot contour.

### The Problem

While the quantity of groundwater in eastern Sussex County is considered adequate to meet present and future demands, there have been, and continue to be, problems with the quality of this water. At several locations in coastal Sussex County, the chloride content of water pumped for human consumption has registered well in excess of the maximum standard of 250 mg/l, as established by the U.S. Department of Public Health and the U.S. Environmental Protection Agency. This problem is generally the result of excessive

pumping, which causes a local drop in the water table. The subsequently diminished pressure head within the aquifer allows a wedge of saltwater, which underlies the freshwater aquifer, to migrate landward (Figure 8). If the saltwater wedge migrates far enough, it may intersect and, thus, contaminate the well.

The threat of saltwater intrusion is most severe along the coast of southern Delaware, where the water table is less than 10 feet above mean sea level and the vertical distance to the saltwater horizon is small. In such areas, pressure exerted by the aquifer on the underlying saltwater wedge is slight enough that carelessly-monitored pumping can result in landward migration, or intrusion, of the wedge and subsequent contamination of even shallow wells.

The amount of chloride present is often used as an indicator of saltwater intrusion. This is because chloride usually is associated with sodium as part of the common salt compound sodium chloride found in saltwater. However, because sodium can come from a variety of other sources, its presence does not necessarily indicate the presence of saltwater. Although the ingestion of chloride is not a significant threat to human health, the ingestion of sodium can be. Sodium is abundant in natural waters through the process of geological leaching of surface and underground salts, from human activities such as salting the roads in winter and septic tanks systems, and from saltwater intrusion into freshwater aquifers (Safe Drinking Water Committee, 1977).

Researchers have determined that sodium taken in excess of human need can induce an increase in blood pressure levels and eventually can induce hypertension in susceptible persons. Medical studies indicate that adults can maintain normal body functions on a sodium intake of less than 2000 mg/day. Sodium requirements for growing infants and children are estimated at less than 200 mg/day. Many Americans, however, consume more than ten times the necessary sodium intake (Safe Drinking Water Committee, 1977). In addition to human health impacts, salt adversely affects agriculture. Many important crops in Delaware have low salt tolerance and could be damaged if irrigation water is too salty. Because the agricultural community depends on the groundwater for its irrigation supply, and because the presence of salt can affect human health, it is essential that the groundwater supply be protected from saltwater intrusion. This is a critical problem because as little as 2% mixing of saltwater can

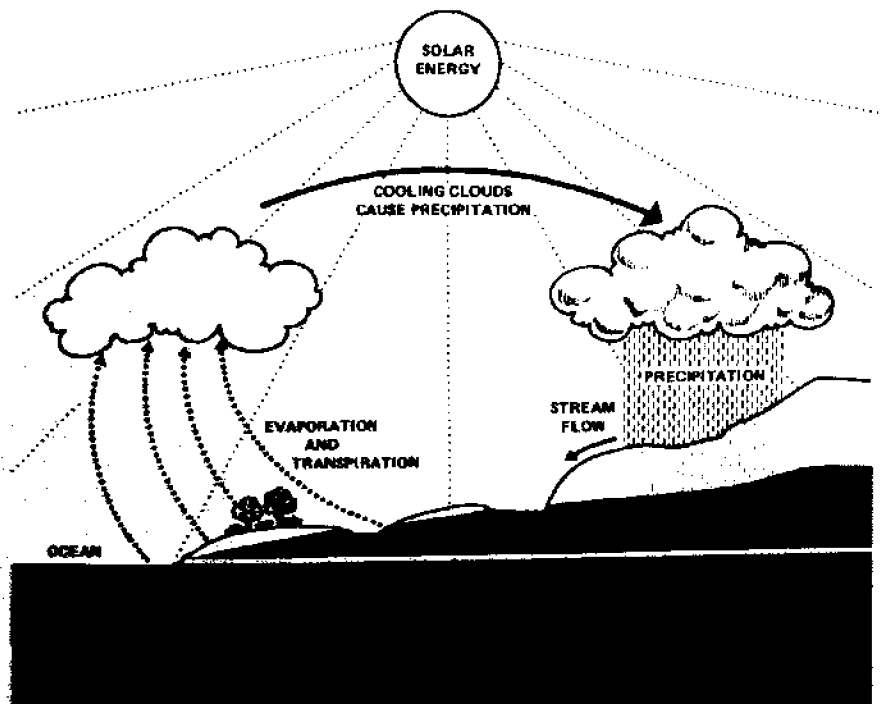


Figure 7. Hydrologic cycle (from *Americans and the World of Water*, University of Delaware Sea Grant College Program, 1977).

render freshwater unfit for irrigation and unpotable, that is, unfit for human consumption (Clark, 1977).

To protect public health from contaminated water supplies, the U.S. Congress enacted the Safe Drinking Water Act of 1974. This law authorized the U.S. Environmental Protection Agency to devise standards for drinking water. The State of Delaware adopted the national standard of 250 mg/l of chloride as the maximum allowable limit for drinking water. The Delaware Division of Public Health (DPH) is responsible for sampling community drinking water wells to determine if chloride and other contaminants are present. Measurements in the Inland Bays are typically above the 250 mg/l standard. In regular sampling by the DPH during the summer of 1982, wells in the Rehoboth Bay area were found to contain excessive levels of chloride as high as 667 mg/l (DPH files, 1982). Long Neck has been identified as having saltwater intrusion problems (Ritter and Chirnside, 1982).

The threat of saltwater intrusion in Sussex County is greatest in the summer because the resident population increases dramatically, thereby increasing the demand for water, and because agricultural demands increase. Therefore, it is reasonable to conclude that saltwater intrusion is occurring because the other causes of salt contamination would not explain the tremendous increase in chloride concentrations.

#### Actions to Date

Unfortunately, the areas most susceptible to saltwater intrusion include those most prone to recreational and residential development. Communities where well contamination has been a problem include Long Neck between Indian River and Rehoboth Bays, Dewey Beach, and South Bethany. Both the towns of Lewes and Rehoboth have had to relocate their well fields above the 10-foot contour because of existing or potential problems. Other communities have been able to mitigate the problem by regulating pumping rates.

The Department of Natural Resources and Environmental Control (DNREC) Water Resources Section is responsible for water supply management, enforcement of surface water quality standards, well water permits, and groundwater management. The DPH enforces drinking water standards. Until recently, saltwater intrusion episodes have been considered on a case-by-case basis by the DNREC, but with no specific criteria. Recognizing

the lack of a comprehensive approach to water resources protection and allocation by the state government of Delaware, Governor Pierre du Pont IV issued Executive Order Number 97 on 20 February 1981, which created the Comprehensive Water Resources Management Committee, which

*shall provide guidance to DNREC and serve as a forum for resolution of water resources management issues, development of goals and objectives, exchange of information, coordination of work programs, and recommendations on methods and approaches to facilitate management of Delaware's water resources. . . (Executive Order Number 97, 1981).*

The committee has been subdivided into five subcommittees: Water Allocation, Groundwater Quality, Water Shortage, Agency Roles, and Data Management. The committee has no authority to develop or adopt policies, but advises the resource managers and users.

The Subcommittee on Agency Roles (SAR) reported in its Draft Summary Report that specific "policy and guidelines should be written to establish criteria for the placement of wells" (SAR, March 1982). The subcommittee went on to recommend that such criteria should specify (1) the volume of water to be withdrawn, (2) well spacing, (3) the use of nearby wells, (4) the effect on further land uses, and (5) the depth of the proposed well. Such a policy would require the involvement of Sussex County government in cooperation with the DNREC.

#### Proposed Strategy

In addition to the previously mentioned approaches to protecting the aquifer from saltwater intrusion, various researchers have proposed the following (Clark, 1977):

- **Artificial recharge** can augment the natural recharge of the aquifer by spreading water on the surface (if the aquifer is unconfined) or through injection into the wells (if the aquifer is confined).
- Construction of **interceptor wells** adjacent and parallel to the coast might prevent saltwater from migrating landward.

These techniques require modifications imposed on the natural water system. Instead of modifying the system (which according to scientists has the capacity to provide freshwater to Sussex County if not overpumped), it might be more practical to work within the system. That is, impose and rigorously enforce water withdrawal limits and well-siting criteria for both agricultural and domestic users.

All regulations must be equitably designed and enforced so that one user group does not have to bear the entire regulatory burden. This requires reasonable water allocation, particularly during high summer demand, for all user groups: farmers, residents, commercial interests, and seasonal visitors.

The State of Delaware and Sussex County must cooperate in creating reasonable and effective public policy in order to optimally manage the valuable water resource and protect public health.

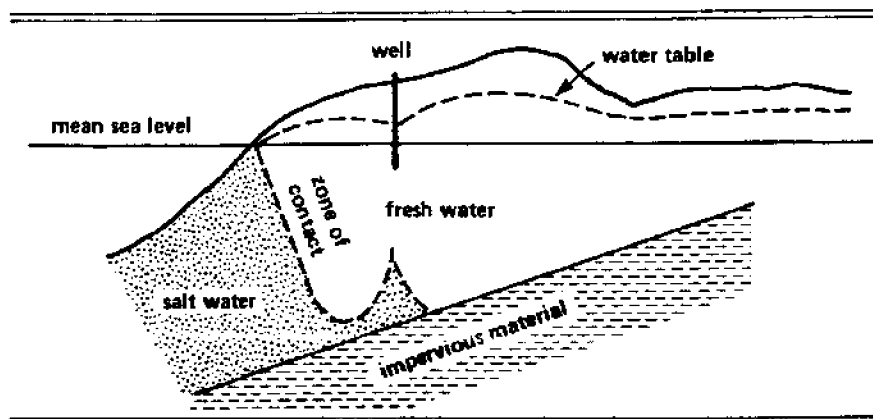


Figure 8. Effects of pumping water from wells in unconfined aquifers exposed to saltwater (adapted from "Hydrology, geology, and mineral resources of the coastal zone of Delaware," Delaware Coastal Zone Management Program Technical Report 3, 1976).

## Nitrate Contamination of Groundwater

Nitrogen is essential to life, but in groundwater it can be a contaminant. Notable sources of nitrate contamination of groundwater in Sussex County include septic tank systems and leaching from agricultural sources. Understanding how these sources release nitrate contaminants enables a better understanding of how to solve the problem. The proposed strategy to deal with nitrate contamination goes beyond the actions taken to date.

### The Natural System

Nitrogen, essential to all living things, comprises 79% of the atmosphere and is found in proteins, vitamins, hormones, fertilizers, enzymes, and animal and human waste products. Nitrogen must be converted to other forms, however, before it can be used by plants and animals. The nitrogen cycle is a complex cycle that illustrates the many forms in which nitrogen appears (Figure 9).

To be used by green plants, nitrogen in the atmosphere is converted into useable forms (*fixation*) such as nitrates and **ammonium**. Plants absorb these compounds and eventually convert them into protein. Animals then ingest the plants, using the nitrogen compounds to build protein and other essential substances. Once an organism dies, decomposition of the tissue breaks down the proteins and

changes them back into ammonium and nitrate compounds. The final step of the cycle converts these compounds into **nitrite** or atmospheric substances.

Other nitrogen present in the natural system comes from internal combustion of fuels, fertilizers, animal and human wastes, and urban and rural run-off of nitrates into streams, rivers, and estuaries. When nitrate, which is the most stable nitrogen compound, is used as a fertilizer, some of it is absorbed by the plant system. Much of it, however, leaches out of the soil and can be carried into the groundwater or washed into the marine environment. Just as nitrate is effectively absorbed by plants, it is also easily absorbed into the marine environment.

Ritter and Chirnside (1982) identified nitrate contamination of groundwater in Sussex County as the most significant groundwater pollution problem. Nitrate is introduced into the groundwater from septic tank systems and leaching from agricultural sources, including poultry manure and fertilizer applications (see Table 2). Each of these sources will be discussed below.

**Septic Tank Systems.** Most residents of the Inland Bays have individual septic tank systems on their lots. A septic system consists of a tank, which is connected to household plumbing by a pipe, and a leach field, which is connected to the tank by another pipe (Figure 10). Wastewater from the household enters the tank, where it resides for approximately two days. During this time, heavy solid

materials settle to the bottom and light oily residues float to the surface. Some biological treatment and digestion occur at this time. The remaining liquid (which may still contain some solids) is pumped or drained from the tank into the leach field, which consists of a perforated pipe system embedded in porous, permeable material. Wastewater trickles out of the holes in the pipe down through the bedding material and into the soil. Bacteria in the bedding material and soil break down the organic compounds in the water. If designed properly and located on suitable soils, septic systems can treat household wastes efficiently, with the exception of heavy metals, organic toxins, viruses and other pathogens.

Septic systems can add nitrate to groundwater when the water table is near the land surface. Where the soil is impermeable, downward drainage of effluent is impeded and pools of liquid may accumulate at the surface. If the soil is too permeable, effluent may drain quickly and reach the groundwater before it has been adequately treated by the soil. In addition, where the density of septic systems is too great and the soil is permeable, local precipitation may be insufficient to dilute wastes accumulating in groundwater. Over time, wastes in groundwater may build up to intolerable levels. Contamination of the area's groundwater renders the aquifer that supplies the drinking water unuseable for decades (Subcommittee on Groundwater Quality, 1982).

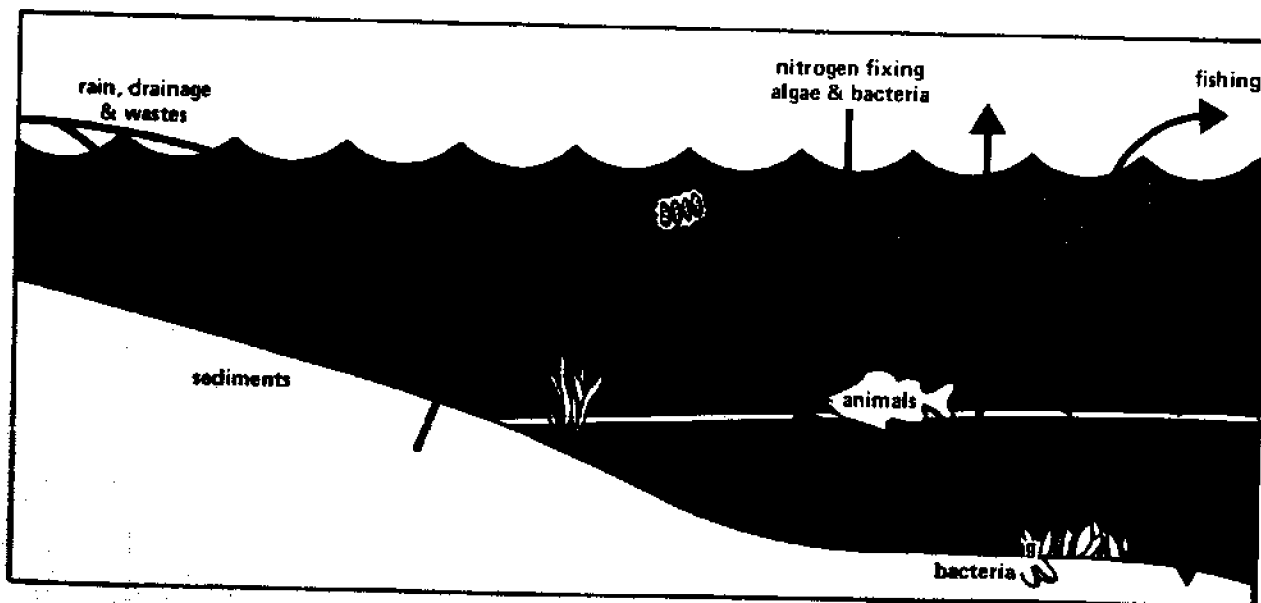


Figure 9. Nitrogen cycle (adapted from Chesapeake Bay: Introduction to the Ecosystem, USEPA, 1982).

**Agricultural Sources.** Agricultural lands account for approximately 42% of land use in Sussex County. This includes cropland and confined animal operations; corn, soybean, and poultry farm production are the predominant activities (Smith, 1982). While total farm acreage has remained essentially constant since 1955 (Figure 11), the quantity of nitrogen added as fertilizer (almost exclusively in the form of water soluble nitrogen compounds) has tripled (Hargert and Berry, 1980). According to the North Coastal Land Use Plan, agricultural land use has been projected to increase by between 29 to 35% for the 25-year period 1975 to 2000 (Weston, 1979). Because agricultural land use is expected to increase, it is reasonable to assume that fertilizer use will also increase.

To continue the high yields of Delaware crops, nitrogen fertilizer is applied heavily. Much is utilized by the crops, some remains in the soil, and some inevitably ends up in the water table. Poultry operations continue to increase, resulting in a need to dispose of large quantities of manure. Sometimes manure is spread on the fields and at other times it is stockpiled.

Nitrogen in fertilizers and manure is lost from the soil to the water by **percolation** of water through the soil and through leaching of soluble nutrients. In Sussex County, surface run-off of nitrogen is not a significant problem because of the gradual slope of the land.

### The Problem

The most significant human health impact is the problem of **methemoglobinemia**, also called infant cyanosis. When nitrate is present in groundwater, it is ingested by humans. In the human intestine, bacteria convert nitrate to nitrite. Nitrite enters the blood stream and reduces the blood's ability to carry oxygen, essential for the well-being of all living tissue. Without an adequate supply of oxygen, brain damage, anoxia, and death may ensue. The principal health threat is to infants, because of their small size and high respiration rate, and pregnant women. The bluish appearance of an infant who has been ingesting nitrate-rich water indicates the induction of cyanosis.

Scientists have found that cyanosis incidents occur when water contains more than 10 mg nitrate (as nitrogen) per liter. This 10 mg/l limit is the adopted standard of maximum concentration for drinking water in Delaware. To safeguard drinking water, the Delaware Division of Public Health (DPH) is responsible for testing

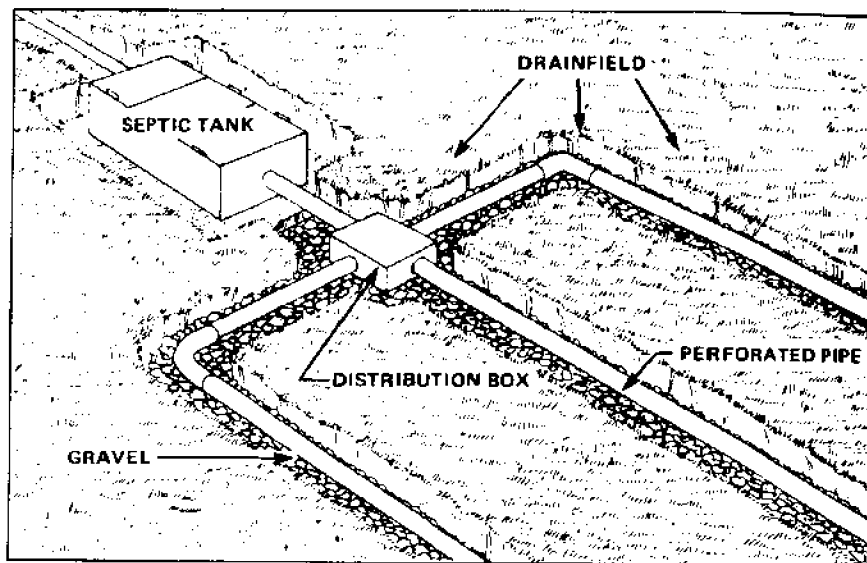


Figure 10. On-site septic disposal system, with trenches partially uncovered to show distribution pipes (adapted from "Home Septic Systems, Proper Care and Maintenance," University of Delaware Cooperative Extension Service Bulletin 126, 1982).

public drinking water supplies for nitrate contamination (and other contaminants). If a well is found to contain nitrate concentrations in excess of the standard, the owner of a public or community well is put on notice until the problem is eliminated. In 1981, wells in East Millsboro, Dagsboro, Cedar Neck, and Millville were identified by several studies as containing excess nitrate levels (DPH files, 1982; Ritter and Chirside, 1982). The Subcommittee on Groundwater Quality (SGWQ) of the State Comprehensive Water Resources Management Committee stated in its 1982 report that 41% of the 118 agricultural wells tested in coastal Sussex County had nitrate levels in excess of the 10 mg/l standard (SGWQ, 1982).

Once nitrate enters the potable water supply, it is reasonable to assume that the groundwater is threatened because 90% of Inland Bays' water demand is satisfied using the aquifer. Once the groundwater is contaminated, the aquifer is unfit for human consumption, and alternative sources of water must be used to meet the demand. This would impose additional costs on the consumer despite the availability of a water supply that was at one time potable.

### Actions to Date

The Department of Natural Resources and Environmental Control (DNREC) has focused its attempts at abating nitrate pollution through the recent septic system

permitting revisions. Before a septic system can be installed, a percolation test is required, which is intended to ensure that septic effluent filters below the surface and does not pool at the surface. The soils of Delaware's Inland Bays tend to be very sandy and permit percolation rather easily. In fact, a study has reported that "the standard percolation test is not a suitable means of determining the suitability of a site for disposal of septic-tank effluent." The researcher went on to say the following:

*Such a method was devised to determine whether a certain soil was suitable for filtering disease-causing organisms from the effluent, but the test is not suitable for evaluating a site when: (1) the soils are very permeable; (2) the water table is low; (3) nitrogen compounds in the form of nitrate are present; and (4) the amount of septic tank effluent on the land is so great that nitrates cannot be diluted by downward percolating groundwater (Miller, 1972).*

The DNREC has recognized the limited application of percolation tests in Sussex County and will be issuing new regulations that rely on the Soil Conservation Service's (SCS) soil rating system in March or April of 1983. The SCS's rating system will continue to be used to screen permits for individual lots. For all lots where the

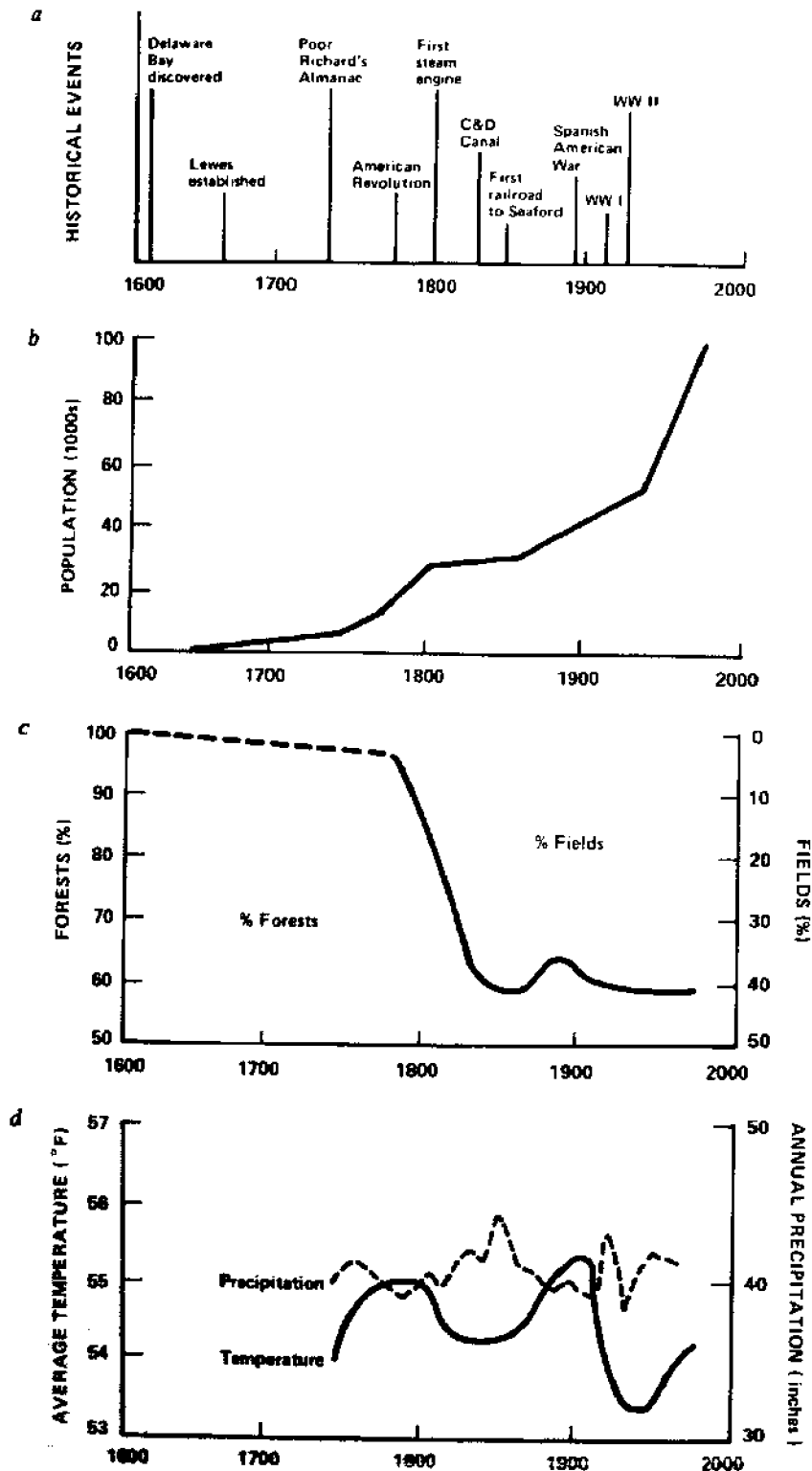


Figure 11. Historical perspective of important events and changes that have impacted the Inland Bays. a. National and regional events. b. Sussex County population (from U.S. Department of Commerce Census Bureau). c. Sussex County land use, primarily reflecting the clearing of land for agricultural purposes (from U.S. Department of Agriculture). d. Regional mean temperature and precipitation (U.S. Department of Commerce NOAA Weather Service, Philadelphia). The curves are useful for estimating warm-cool and wet-dry trends over time, but do not represent Sussex County values.

survey indicates a permeability problem, high water table, or a wide range of soil types, DNREC personnel may conduct on-site investigations and take samples to ensure the accuracy of the test data and to prevent the falsification of information (Delaware Division of Environmental Control, 1982).

There exists some question, however, as to the effectiveness of this new approach in the Inland Bays. The Subcommittee on Groundwater Quality Report stated that

*the soil survey's rating system of limitations for septic systems... (indicates only) the likelihood to cause a septic system to malfunction. The likelihood of groundwater pollution is only marginally considered. A highly permeable soil is assigned a rating of "slight" although it presents the worst threat to groundwater quality (SGWQ, November 1982).*

The SGWQ recommended that the DNREC regulations be revised to require that appropriate septic system density be adopted to protect existing and future uses of groundwater. This density would be on the order of one to two acres per system, as opposed to the existing 1250 gallons/acre/day standard for sewage discharge to the ground. The low-density development recommendation is based on the assimilative capacity of the aquifer. More scientific research is needed to determine the appropriate septic system densities in the Inland Bays (SGWQ, 1982).

Beside the attention given to septic systems, the state has not sufficiently addressed the other primary contributor of nitrate to the aquifer and the bays: that is, agricultural practices.

#### Proposed Strategy

At this time, the State of Delaware has been encouraging the agricultural community to voluntarily adopt recommended Best Management Practices (BMPs), aimed at balancing soil and water protection with the needs of everyday agricultural production. More attention must be given to creating and implementing BMPs aimed at groundwater protection.

The State of Delaware is responsible to its citizens for the protection of public health. To effectively deal with nitrate pollution of the groundwater and the waters of the Inland Bays, it is essential that it works with the agricultural community to limit nonpoint sources of nitrate. One method available to the state



for controlling nitrate inputs into the groundwater supply is to implement a program to control nonpoint sources through the use of BMPs.

Several researchers (Ritter and Chirnside, 1982; USEPA, 1978; SGWQ, 1982; among others) have identified many BMPs for controlling groundwater pollution from agricultural sources, including the following:

- Apply only what manure or fertilizer will be removed by the crop.
- Test manure and fertilizer nutrient levels for accurate indicators.
- Institute soil-testing programs on a comprehensive level.
- Calibrate manure spreaders for correct rate of application.
- Use slow-release nitrogen fertilizers.
- Correct soil pH by liming.

These researchers have emphasized the critical need to control agricultural sources of nitrate pollution and to initiate BMPs at the state level. The state, therefore, must provide farmers with BMP guidelines. Education outreach programs are available through the University of Delaware's College of Agricultural Sciences Cooperative Extension Service. In addition, Cooperative Extension can play a major role in the research and development of alternative technologies for the implementation of BMP techniques.

Ideally, the agricultural community and the state would continue to cooperate in voluntarily implementing BMPs for groundwater protection. Otherwise, the state might consider formulating policy to regulate control of nonpoint sources of nitrate through BMPs. Such a policy might include the following components:

- performance indicators to analyze the desirability and effectiveness of the policy;
- control mechanisms, if necessary, through legislative and regulatory initiatives;
- enforcement mechanisms to ensure compliance in critical situations when the groundwater supply is threatened; and
- institutional responsibility with penalties for noncompliance with the guidelines aimed at preventing groundwater pollution.

At present, the state has focused its effort on controlling nonpoint sources of nitrate pollution from septic tank systems. But because more than 60% of the problem appears to result from nonpoint sources other than septic tank systems, the state needs to address these—in particular, agricultural sources—to effectively protect the valuable and vulnerable potable groundwater supply.

## Drawing Conclusions

One can conclude from the earlier sections that there are both realized and potential impacts from human activity on Delaware's Inland Bays. For the most part, all of these activities are occurring simultaneously, and therefore, have a simultaneous impact on the bay ecosystem. The bays are a complex of dynamic interrelated systems, and impacts on one part of the system affect other parts. The connections are not always obvious to the untrained, and even trained, eye. However, it is the connections between the cycles such as food chain cycles, nutrient cycles, and water circulation cycles that drive the system as a whole.

The previous discussion on identified problems illustrates that responsibility for the slow degradation of the environmental quality of the Inland Bays is not easily placed. Individuals living in the Inland Bays region are as responsible as developers and industry. People choose to live and work in this area because of the attraction of the bays themselves and the relatively inexpensive housing. Most have little understanding of the overall impact that human activities have on the bays. If present trends and problems persist, the overall Inland Bays situation will eventually develop into a crisis.

Rowe et al. (1978) have stated that it takes a threat of a crisis before individuals or groups will move to action. That is what they caution against in their book:

*Under such a collective state of mind, we tend to treat the systems by piecemeal efforts woven into a nightmare of entangling legislation rather than to develop a comprehensive program to address the overall problem. Second, given such an atmosphere, it becomes all too apparent to many that someone must be responsible for our problems. Consequently, the witch hunt begins in search of the "bad guys," as though a good hanging would solve everything.*

This scenario should not be allowed to happen. It would be counter-productive, and the only loser would be the Inland Bays. What is needed is to understand why certain approaches have not worked and how the current system might be structured to accommodate a comprehensive and collaborative planning and management approach—an approach where state and local govern-



*Increasing residential development around the Inland Bays will place additional demands on the groundwater supply.*

ments jointly prepare and implement local and regional land use plans. (For a detailed discussion of this process, see Sorenson, 1978.)

Policies have been developed and implemented to try to cope with these environmental problems. As we have seen from previous cases, several piecemeal policy options have been tried. The state has developed and is revising performance standards for on-site septic systems. These standards are workable, but not necessarily optimum. Once the standards are set, there is no incentive for the private sector to advance the technology. Often systems are designed and sites altered to comply with the letter of the law and not necessarily its intent—pollution abatement.

Land use controls are being used to control some development and limit environmental degradation. These controls are similar to zoning and involve very difficult equity questions. For example, in the Inland Bays region there are 30,000 lots that have been approved and which are automatically eligible for building permits. These county approvals have been granted without considering the social and environmental impact that could

result if all the lots were built out. Currently, the only means to assess environmental suitability of such development is through the DNREC's authority to issue and deny septic tank and well permits, required for all development. Consequently, there is no comprehensive plan that articulates a specific subdivision policy, but only what appears to be an arbitrary, after-the-fact septic tank and well permitting policy enforced by the state.

These strategies typify the piecemeal approach\* toward environmental management rather than a comprehensive approach that stresses an overall problem-solving strategy. What is needed is a comprehensive strategy to manage the social, economic, and environmental components that comprise the Inland Bays region to achieve certain desirable characteristics. The way to initiate such a process is to understand the natural environment and how it interacts with human activities. Understanding the relationships among natural systems and human activities can provide the basis for comprehensive management.

But before such management can proceed, one must appreciate the need for

a basic understanding and forge a consensus on what are the desirable characteristics that should be maintained in the Inland Bays region. The next chapter sets the stage, develops the justification, and suggests a process to achieve understanding and consensus.

\* Piecemeal approach and incremental decision-making as used here are synonymous concepts. William E. Odum in a recent article titled "Environmental Degradation and the Tyranny of Small Decisions" (1982), describes the situation this way: "A series of small, apparently independent decisions are made, often by individuals or small groups of individuals." As an illustration, he notes "Consider, for example, the loss of coastal wetlands on the east coast of the United States between 1950 and 1970. No one purposely planned to destroy almost 50% of the existing marshland along the coasts of Connecticut and Massachusetts. . . . However, through hundreds of little decisions and the conversion of hundreds of small tracts of marshland, a major decision in favor of extensive wetlands conversion was made without ever addressing the issue directly."

# Towards Management

## Introduction

In the preceding pages, the Inland Bays are portrayed as unique and complex natural resource systems. The point has been made that these natural systems sometimes respond to stress in predictable fashion and at other times fall victim to unfathomable environmental consequences. What has been illustrated is that the condition of the Inland Bays is directly affected by man's activities on and around these bodies of water. These linkages have been discussed in some detail, both in this document and throughout the scientific literature, which is cited. It is increasingly being demonstrated that because of the interrelationships that exist in marine and coastal systems an impact in one area has a rippling effect on the system as a whole.

A similar effect occurs with respect to the governmental decision-making related to the Inland Bays. Not only have the bays become an attractive area for second-home development, but also the amount of recreational activities they support has increased tremendously in the past few years. The approval of this type of development is characterized by incremental decision-making that is guided by granting project-by-project approvals. Currently, no overall plan or coordinated policies and strategies exist to ensure that these incremental decisions promote the wise use, development, and management of the Inland Bays. As a result, projects are often influenced by economic considerations and political pressures that are inconsistent with sound estuarine resource planning and management principles.

Without such policies and strategies, both the public and private sectors are failing to address these critical questions: How are the bays and their resources being used? How should they be used? These are most important considerations

given that the Inland Bays are a resource with greater-than-local appeal and, if not managed properly, are prone to slow deterioration.

It is the purpose of this chapter to outline a process that would initiate the consideration of wise management and development of the Inland Bays. The authors recognize that the resource management of the Inland Bays is as much a political problem as it is a technical one. This report documents the complexity of the ecological systems and, likewise, acknowledges the complexity of the economic systems involved. In some instances the case was made that too little is known about the ecological systems of the Inland Bays. However, although more study is needed, this fact is not an excuse for inaction.

This document tries to give the reader insight into the Inland Bays as a natural environment. This is the basis for gaining an understanding and appreciation of the impacts that unplanned development might have on the natural systems. It is important to understand that no problem such as the slow degradation of the Inland Bays will be confronted until someone realizes the significance of the resource and what threatens it. This is prerequisite to any proposed program that seeks to wisely manage and develop the Inland Bays for our immediate enjoyment and that of future generations.

House Joint Resolution No. 27 before the 131st General Assembly sought to identify the Inland Bays as a problem area demanding immediate attention. This resolution would have designated certain areas within the Inland Bays as a critical region subject to Department of Natural Resources and Environmental Control (DNREC) review. This resolution passed the House but was never brought to

a vote in the Senate. Many credit county government and development interests for its lack of passage. This seems plausible if one tries to understand that even though the Inland Bays are a resource that have greater-than-local significance, the land area around the bays are controlled by local and county governments which are under heavy pressure to garner the property tax revenues that intensive development might bring.

The intent of the resolution was to focus attention and establish a mechanism whereby the ecological impacts of development would be formally reviewed by the DNREC prior to the county or local jurisdictions granting zoning, subdivision, conditional use, site plan, or other development approval for projects or plans within specific areas (HJR 27, 1982). The areas subject to review include parcels in excess of five acres, and parcels five acres or less that involve activities having a significant environmental impact upon the area. The DNREC's review would have been based on existing "statutes, rules, regulations, and policies governing Department actions, as well as the project's impact on the overall environmental quality of the area." Further it noted that "special conditions may be imposed on individual projects to make them compatible with the overall management strategy of the area."

To date there has been no articulated management strategy adopted by the DNREC or the county government.\* For this approach to succeed there will have

\*The North Coastal Land Use Plan (Weston, 1979) was created to encourage development toward areas where utilities do or soon will exist; guide future development and intense land uses away from sensitive environmental

to be a concomitant development and implementation of a resource management program with enforcement provisions.

Passage of HJR 27 would have set in motion a process of state review of local and county projects. However, this would have proceeded without the adoption of a specific management plan, development criteria, or policies for the management of the Inland Bays other than those that already existed within the DNREC. It is questionable whether, without a specific plan and performance standards, this approach could have adequately accommodated state and local interests in the management of the Inland Bays. Though never passed, the resolution did increase public interest in the bays and for the first time called for an examination of the impact of development on the overall environmental quality of the bays.

Presently no mechanism exists to evaluate the environmental effect or cumulative impact of development projects on the Inland Bays. To ameliorate this situation, two strategies are proposed simultaneously:

1. The DNREC should be required to comment and provide testimony at all Sussex County planning and zoning hearings\*\* on projects that involve development on a) parcels in excess of five acres;\*\*\* or on b) parcels of five

acres; promote "Nodal Development Centers" in relatively undeveloped areas and expansion of existing communities instead of scattered development; protect natural areas and valued land and water resources not capable of supporting development; and discourage land use that over-extends the capacity of utilities and on-going regional service improvement programs by coordinating development with that of public utilities. The North Coastal Land Use Plan has not been adopted. Since the plan was proposed in 1979, however, some assumptions on which the plan was based are no longer current.

\*\* Participation by the state during County Planning and Zoning Hearings as provided for already in 9 Delaware Code 68, 69.

\*\*\* This five-acre minimum requirement was included in HJR 27 and was based upon the DNREC's experience with assessing environmental impacts of previous projects in the Inland Bays region. It was felt that projects five acres or more would serve as a reasonable unit for an environmental assessment and separate individual permit requests from those involving the development of discrete subdivisions, although projects less than five acres that might have significant environmental impact are also included. This standard is a benchmark and should be subject to further evaluation based on its practicality and potential for efficient implementation.

acres or less that involve activities having a significant environmental impact.

2. The Governor, by an executive order, should mandate the establishment of a bipartisan task force. This task force would be charged with recommending the goals, objectives, implementation mechanisms, and enforcement strategy for a comprehensive management and development plan for the Inland Bays area.

The first strategy would formally establish the DNREC's position with respect to the potential environmental impacts of development projects and make the information available at Sussex County planning and zoning meetings. Introduced as testimony before the biweekly Sussex County Planning and Zoning Commission hearings, it becomes public record. This would provide an environmental perspective for county decision-makers to consider and would clarify the DNREC's position to the public and developers. This procedure would reinforce the existing Development Advisory Service process that is a voluntary DNREC program. It is hoped that this action would facilitate accountable and representative decision-making on projects that could immediately impact the environmental quality of the Inland Bays area.

This approach would be linked closely to the second strategy, the creation of a task force (Figure 12). Both strategies need to be implemented simultaneously to initiate a collaborative and comprehensive process to deal with the issues facing the Inland Bays. Together, these strategies recognize the need to focus immediate attention on the issues now facing the Inland Bays, and establish a process to examine the long-term considerations that need to be addressed to adequately manage the Inland Bays in the future.

#### Task Force Rationale

There are two questions that need to be answered regarding the formation of such a task force. First, why is there a need for such a group? Second, what should this task force hope to accomplish?

The need for a gubernatorial task force is predicated on the growing public concern for how the bays and their resources are being used and how they should be used, given that these resources are limited and prone to deterioration. Certain problems exist in connection with the development of these bays relating to the maintenance of water quality, the protection

of critical habitat, the lack of a dredge policy, the need for the development of a comprehensive management plan, the need to understand the causes of erosion in the bays, the determination of a plan for the management of the bays, and other matters. Many of these issues have been previously identified and documented. Several recent issue listings have been compiled by the Inland Bays Study Group (1982) and the Inland Bays Workshop (Manus and Scotto, July 1982). These bays constitute one of the greatest physical and biological assets of the state, both for tourism and recreational development. Consequently, it is imperative that a task force be established to study the problems facing the Inland Bays and make its report and recommendations available to the Governor and to the 132nd General Assembly for both public and legislative consideration.

#### Task Force Mandate

The charge to this group would be to document the issues facing the bays and suggest safeguards that need to be implemented to assure that the conservation and development of the Inland Bays be undertaken to serve the best interests of the citizens of Delaware. Specifically this charge would require the following:

- a. Review the existing laws and regulations applicable to the management of the Inland Bays.
- b. Examine the conflicts between local, county, and state government with respect to the management of the Inland Bays.
- c. Assemble and summarize the available information describing the natural environment and social and economic characteristics of the Inland Bays.
- d. Compile and analyze all available information describing the existing plans for the Inland Bays.
- e. Make a preliminary assessment of the Inland Bays environmental carrying capacity, which includes the identification of areas with special limitations for growth or particular suitability for accommodating growth.
- f. Document the available population and economic growth projections to estimate demands for increased services in and around the Inland Bays.
- g. Determine the need for the development of a comprehensive plan for the Inland Bays, the goals and objectives such a plan should consider, and

recommend at what level(s) of government authority should be vested to implement the plan.

#### Task Force Composition

It is recommended that the Inland Bays Task Force be structured to include the following representation:

- 2 members of the Delaware House of Representatives to be designated by the Speaker of the House, one from each political party
- 2 members of the Delaware State Senate to be designated by the President Pro Tempore of the Senate, one from each political party
- 1 Sussex County Administrator, or his designee
- 2 members of the Sussex County Council, one from each political party
- 1 member of the Sussex County Planning and Zoning Commission
- 1 Secretary of the Delaware Department of Natural Resources and Environmental Control, or his designee
- 2 public members appointed by the Governor

Further it is recommended that a staff be appointed to work with the task force. This working group would serve as resource people for the task force. These members should be selected on the basis of their familiarity with the issues facing the Inland Bays, their ability to identify available information and data, and their ability to analyze the information rapidly and to clearly communicate the findings. These individuals could be drawn from the ranks of local, county, or state government; institutions of higher learning; or the private sector. Their number should be restricted to nine. These individuals would serve at the pleasure of the task force and assist in the researching and writing of the report. This approach should help augment capabilities of the task force members and discourage the hiring of an outside consultant, while encouraging the members themselves to become conversant with the issues.

#### Task Force Mission

In addition to researching and documenting the topics previously noted, the task force is to solicit public input. This will require public hearings to take testimony from interested citizens who can contribute knowledge and insight into the problems of the Inland Bays. Meetings should be held in the Inland Bays region and at other convenient locations to

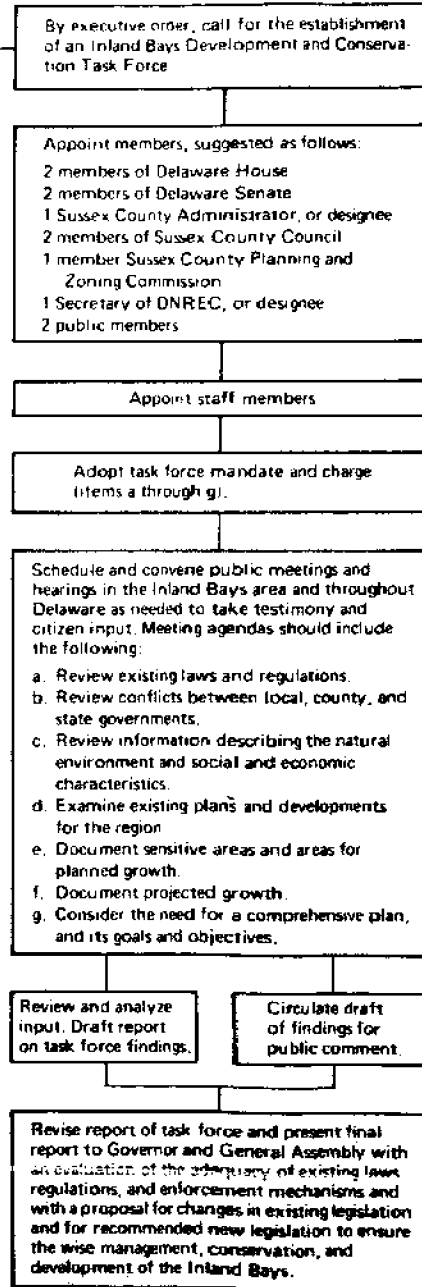
reach all affected citizens. This input along with the analysis and work of the task force should be presented in a report at the start of the Second Session of the 132nd General Assembly. The report should provide an evaluation of the adequacy of existing laws, regulations,

and enforcement mechanisms, and a proposal for changes in existing legislation and for recommended new legislation. Additionally, it should detail how the Inland Bays area should be managed to assure its continued health for the enjoyment and use by future generations.

#### STRATEGY 1: A Continuing Process



#### STRATEGY 2: A 9-Month Process



Month 1

Months 2-5

Months 6-8

Month 9

Figure 12. Concurrent strategies and task force process.

# Glossary

*Adapted in part from the "Glossary of Environmental Terms" in Understanding the Game of the Environment (Houston, 1979).*

- absorption:** the process of taking inorganic salts, in solution, into root hairs from soil water by osmosis
- algal blooms:** a dense concentration of phytoplankton which occurs in response to optimum growth conditions
- ammonium:** a substance consisting of nitrogen and hydrogen, used by plants to make proteins
- amphipod crustacean:** a small shrimp-like animal found in aquatic environments, ranging from 5 cm to 28 cm in length
- anoxic conditions:** an environment with dangerously low oxygen concentrations
- aquifer:** an underground bed or layer of earth, gravel, or porous stone that contains water
- artesian layers:** subsurface areas where rock layers store water under pressure; water can be forced to the surface by natural pressure
- artificial recharge:** water from external sources added to the natural recharge system
- atmosphere:** the gaseous envelope of air that surrounds the earth and is held to it by the force of gravity
- benthic species:** species that inhabit the bottom region of a water body
- biomass:** the total weight (mass) of living matter in a particular area
- biota:** all species of plants and animals that occur within a certain area
- bivalves:** a group of aquatic animals that have their bodies protected by two outer shells
- carnivores:** organisms that eat animals
- carrying capacity:** the limit to the amount of life that can be supported by any given area; the reasonable limits of resource use by humans
- chloride:** a reactive form of the element chlorine that is part of the common table salt compound, sodium chloride
- chlorination:** the addition of chloride to sewage effluent, which results in a reduction in the level of pathogens present
- coliform bacteria:** any of a number of bacteria common to the intestines of humans and animals, and whose presence in wastewater is an indicator of pollution and potentially dangerous contamination
- copepod crustaceans:** small zooplankton ranging in size from a few to several millimeters
- decomposition:** a process whereby bacteria and fungi chemically break down organic matter
- deposit-feeders:** animals that engulf masses of sediments and process them through the digestive tract in order to extract nutrient
- detritus:** excrement and other waste products of all types of organisms, including their remains after death
- diatoms:** any of numerous microscopic, one-celled aquatic algae that have shells composed mostly of silica
- diffusion:** the transfer of substances along a gradient from regions of high concentration to regions of lower concentration
- dinoflagellates:** any of numerous microscopic aquatic algae that are able to propel themselves by the use of their tail-like flagella
- dissolved oxygen demand:** the amount of dissolved oxygen required to drive chemical reactions occurring in a water body
- dredging:** a method for deepening coastal waters by scraping and removing solids from the bottom; the resulting mud is deposited elsewhere in a process called filling
- ecosystem:** the complete system of a given area including the interaction of the living community with its physical environment
- enriched land run-off:** nutrient-rich waters derived from the land that flow into streams and ultimately into the ocean
- estuary:** a confined coastal water body with free access to the ocean in which saltwater is measurably diluted by freshwater entering the water body
- eutrophication:** nutrient overenrichment of water that leads to excessive plant growth
- evaporation:** the process whereby liquid water is changed into water vapor
- filter-feeders:** organisms that filter water in order to extract nutrient
- fixation:** the process of making a substance stable by decreasing or destroying volatility
- groundwater:** the supply of freshwater under the earth's surface trapped in an aquifer
- heavy metals:** metallic elements, such as lead, mercury, chromium, cadmium, and arsenic, that have high molecular weights and that, even in low concentrations, can be toxic to animal and plant life
- herbivores:** organisms that feed on plants
- hydrocarbons:** a vast family of compounds containing carbon and hydrogen, found especially in fossil fuels
- hydrogen sulfide:** a gas composed of hydrogen and sulfur that has a noxious odor characteristic of rotten eggs; it is released during the natural decomposition of organic matter and is the natural accompaniment of advanced stages of eutrophication

**hydrologic cycle:** the water cycle

**igneous rocks:** rocks that have been formed from the solidification of molten magma

**inorganic matter:** matter derived from sources other than plants or animals

**interceptor wells:** wells drilled adjacent and parallel to the coast that cut into the aquifer to prevent saltwater migration into freshwater aquifers

**invertebrates:** organisms that do not have a backbone

**lagoon:** a relatively shallow estuary with very restricted exchange with the sea and no significant freshwater inflow

**leachates:** substances that have been washed into a lower layer of soil or that have been dissolved and carried away by water

**longshore current:** a current, created by waves, that moves parallel to and against the shore, particularly in shallow water, and which is most noticeable in the surf or breaker zone

**metabolism:** the sum of all chemical processes occurring in living tissue

**metamorphic rock:** rock that has undergone a pronounced change, effected by pressure, heat, and water, that results in a more compact and more highly crystalline condition

**methemoglobinemia:** a cyanotic condition in humans that results from deficient oxygenation of the blood, causing a bluish or purplish discoloration of the skin

**microorganism:** minute plant or animal organisms such as plankton not visible to the unaided eye

**nitrate:** the most stable compound that is composed of nitrogen and oxygen; can be a contaminant in drinking water supplies

**nitrite:** a compound composed of nitrogen and oxygen that is less stable than nitrate; bacteria in the human intestine convert nitrate into nitrite, which is then absorbed into the bloodstream, causing oxygen deficiencies in infants and pregnant women

**nitrogen:** a very abundant element that comprises 79% of the earth's atmosphere

**nonpoint sources:** sources, such as agriculture, on-site waste disposal systems, and precipitation, that contribute chronically to pollution of the environment through incremental additions of pollutants

**nutrient enrichment:** the addition of nutrients, such as nitrogen, phosphorus, and carbon, into a water body that greatly increases the potential for plant growth

**nutrients:** substances that are essential for the growth of all organisms

**organic matter:** matter derived from living or dead organisms

**pathogens:** disease-causing organisms

**percolation:** downward flow or infiltration of water through the pores or spaces of rock or soil

**pH:** a measure of the alkalinity or acidity of any substance based on a scale of 0 to 14; 7 represents a neutral state (water), 0 represents the most acidic, and 14 the most alkaline

**phosphorus:** an essential nutrient

**photosynthesis:** the process by which chlorophyll-bearing (green) plants combine carbon dioxide and water in the presence of light energy to form carbohydrates; it is the conversion of light energy to potential chemical energy of food, releasing oxygen in the process

**phytoplankton:** the plant plankton that produce large amounts of oxygen

**point sources:** sources, such as wastewater treatment plant

effluent, that contribute pollutants to the environment in well-defined releases

**pollutant:** any introduced matter or energy that makes a resource unfit for a specific purpose

**pollution:** the presence of matter or energy whose nature, location, or quantity produces undesirable environmental effects

**potable water:** water suitable for human consumption or cooking purposes

**precipitation:** water from the atmosphere that falls to the ground as rain, snow, sleet, or hail

**protozoan parasite:** a single-celled, microscopic animal that obtains its food at the expense of the animal on which it lives

**respiration:** aerobic oxidation (using oxygen) of food or organic substances by organisms; respiration releases useable energy, carbon dioxide, and water

**salinity:** the degree of salt in water

**saltwater intrusion:** the migration of the saltwater wedge landward that underlies the freshwater aquifer, to the point where the aquifer becomes contaminated by saltwater

**sediment:** soil particles (sand, clay, silt, and minerals) washed from land into water systems as a consequence of natural or human activities

**sediment-water interface:** the common boundary of sediment and water

**sedimentary rock:** rock formed over time by the deposition and consolidation of mineral sediments or of fragments of older rocks

**sedimentation:** in wastewater treatment, the settling out of solids by gravity

**significant environmental impact:** any change in the environment caused by human activity or factors; such activities include dredging, filling, or construction of industrial, commercial, or high-density residential development requiring special waste treatment facilities

**sill:** a ledge that prevents the free exchange of bottom water between a lagoon and a bay

**spoils:** dirt or rock that has been removed by dredging of the bottom of waterways

**stressed habitat:** an environment that is subjected to demands in excess of its natural carrying capacity

**subaqueous lands:** lands that are under the surface of water

**sublethal effects:** processes or activities that diminish the health of an organism or its environment

**substrate:** the base or surface upon which an organism lives

**sulfate-reducing bacteria:** bacteria that convert sulfate compounds into less-oxidized forms, such as hydrogen sulfide gas

**thermal effluent:** outflow of heated waters from power plants, which is hotter than the water into which it is released

**toxic substance:** material that is poisonous or harmful to plant or animal life

**toxicant:** a substance that kills or injures organisms or that alters its environment through chemical or physical action

**transpiration:** evaporation of water from the leaves of plants

**tube-builders:** organisms that construct tubes in the substrate in which they live

**water column:** the area of water above the bottom substrate

**water table:** the upper groundwater level

**wetlands:** areas that are regularly wet or flooded and where the water table stands at or above the land surface for at least part of the year

**zooplankton:** planktonic animals that supply food for fish

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