United States
Environmental Protection
Agency

Office Of Water
Gulf Of Mexico Program
Stennis Space Center, MS 39529

EPA 800-B-94-004
*July 1994*

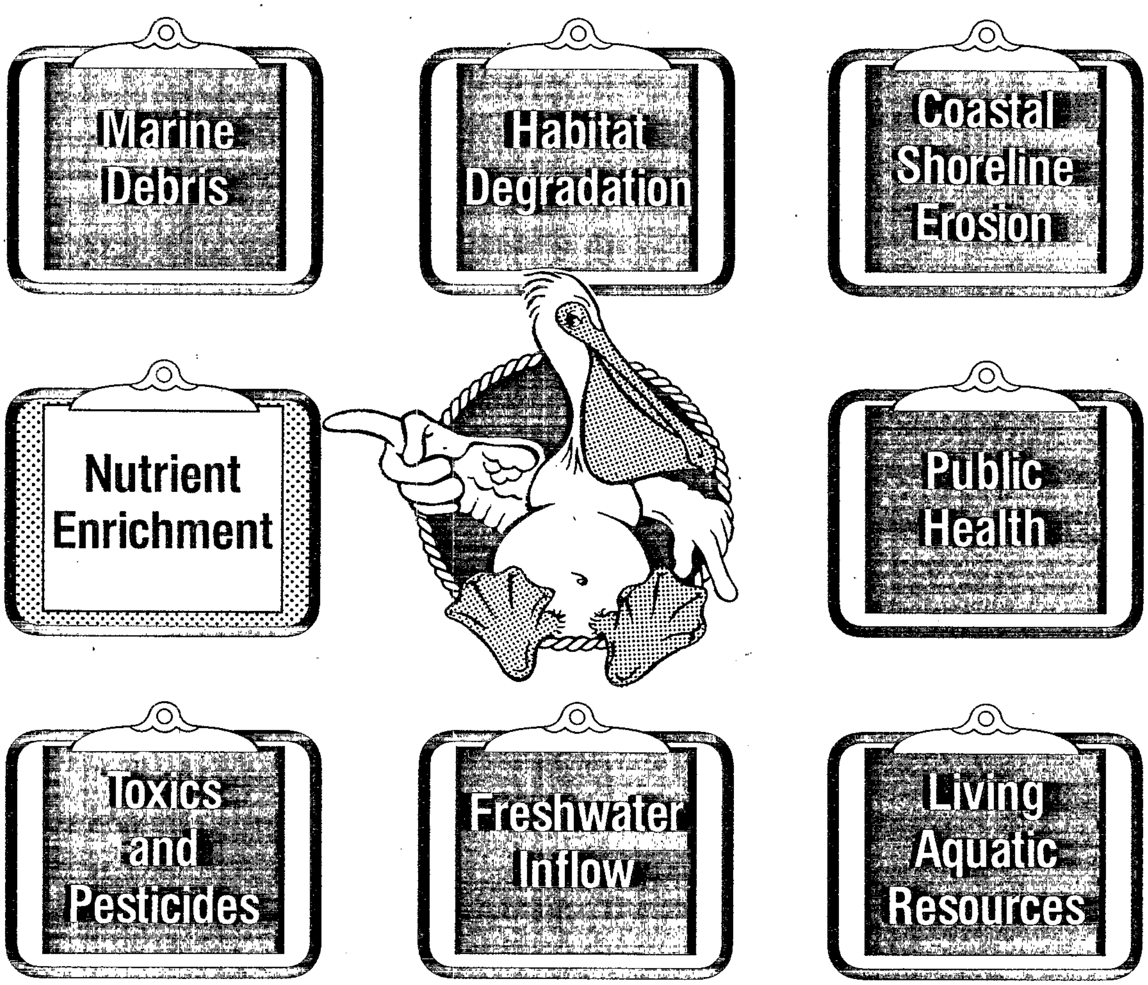
EPA

GULF OF MEXICO PROGRAM

# Nutrient Enrichment Action Agenda For The Gulf Of Mexico

## First Generation—Management Committee Report

## *Framework for Action*



# Nutrient Enrichment Action Agenda for the Gulf of Mexico

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# PREFACE

One of the initial goals for the first five years of the Gulf of Mexico Program was to establish a "framework-for-action" for implementing management options for pollution controls, determining research direction and environmental monitoring protocols, and implementing remedial and restoration measures for environmental losses. As a means of developing this framework-for-action, the Gulf Program established eight committees, composed of experts, to deal with the following environmental issue areas:

- Habitat Degradation
- Marine Debris
- Freshwater Inflow
- Nutrient Enrichment
- Toxic Substances & Pesticides
- Public Health
- Coastal & Shoreline Erosion
- Living Aquatic Resources

Each committee was charged with: 1) characterizing the status of the issue, 2) developing goals and objectives for remedial and restoration activities, and 3) developing descriptions of the projects and tasks to be implemented in order to achieve the stated objectives. This information was incorporated into an "Action Agenda" for each environmental issue area.

This document is the first generation of one of these Action Agendas. Representing the consensus of a large number of subject specialists, this document is considered to be a draft working paper for the Gulf of Mexico Program Management Committee. Since this first generation Action Agenda has not been reviewed and approved by all agencies, it is being made available for informational purposes only.

# EXECUTIVE SUMMARY

The Gulf of Mexico contains ecological and commercial resources matched by few other bodies of water. Yet its blue-green waters disguise the increasing environmental threats that endanger these resources. In recognition of the growing threats, Regions 4 and 6 of the U.S. Environmental Protection Agency (USEPA), which share jurisdiction over the five Gulf Coast States (Alabama, Florida, Louisiana, Mississippi, and Texas), initiated the Gulf of Mexico Program in August 1988. The goal of the Gulf of Mexico Program is to protect, restore, and enhance the coastal and marine waters of the Gulf of Mexico and its coastal natural habitats, to sustain living resources, to protect human health and the food supply, and to ensure the recreational use of Gulf shores, beaches, and waters--in ways consistent with the economic well being of the region.

The Gulf of Mexico Program is a cooperative partnership among federal, state, and local government agencies, as well as with people and groups who use the Gulf. During the early stages of Program development, eight priority environmental problems were identified and the following Issue Committees have been established to address each of these problems: Marine Debris, Public Health, Habitat Degradation, Coastal & Shoreline Erosion, Nutrient Enrichment, Toxic Substances & Pesticides, Freshwater Inflow, and Living Aquatic Resources. There are important linkages among these various Issue Committees and the Gulf of Mexico Program works to coordinate and integrate activities among them.

The Nutrient Enrichment Committee was charged with characterizing nutrient enrichment problems and identifying ways to reduce eutrophication in the Gulf of Mexico. The Issue Committee has been meeting for more than three years--to review information and data collected by citizens and scientists, identify problem areas, discuss actions that can resolve the problems, and evaluate methods for achieving and monitoring results. The culmination of Issue Committee efforts is this Nutrient Enrichment Action Agenda which specifies the initial set of activities needed to control and substantially reduce the deleterious effects of nutrient enrichment in the Gulf of Mexico. This Action Agenda is the first generation of an evolving series of Action Agendas that will be developed to meet the future needs of the Gulf of Mexico.

Chapter 1 of the Nutrient Enrichment Action Agenda provides an overview of Gulf of Mexico resources and the threats now facing those resources. In addition, Chapter 1 describes the structure of the Gulf of Mexico Program, including the Action Agenda development process.

Chapter 2 is a summary of the scientific characterization information compiled by the Nutrient Enrichment Committee.

Chapter 3 describes the federal and state framework currently in place in the Gulf of Mexico to address nutrient enrichment issues and support appropriate management and regulatory actions.

Chapter 4, **The Unfinished Agenda**, contains the goal, objectives and specific activities established by the Gulf of Mexico Program to address nutrient enrichment. The goal is to:

- Protect the waters of the Gulf of Mexico from the deleterious effects of nutrient enrichment, from all contributing sources, and thereby enhance biodiversity, and aesthetic, recreational and economic benefits.

This Action Agenda focuses on protecting the tidal, estuarine, and nearshore waters of the Gulf of Mexico. Freshwater transport from landward sources is addressed as a contributing source.

Nine objectives and fifty-one action items have been developed to support the goal and these are grouped under three types of activity: 1) Characterization & Demonstration, 2) Source Reduction, and 3) Public Education & Outreach (See **Index of Nutrient Enrichment Objectives**). The action items included have been screened by the Gulf of Mexico Program and represent those activities that are currently considered the most significant and most achievable. This is a fairly comprehensive, but not exhaustive, list. This document begins an evolving process of Action Agendas in which action items are designated, implemented, and then reassessed as progress in the Gulf is made. In the future, new nutrient enrichment action items will be developed to meet the changing needs in the Gulf of Mexico.

Action items contained in Chapter 4 are not listed in priority order. Some of the actions are already underway but not yet completed. Others are included because they will guide federal, state, and local government agencies and private sector organizations in allocating resources where they are most needed and in justifying future management strategies. This Action Agenda should prompt specific agencies and groups to become involved.

The Gulf of Mexico Program recently developed ten short-term environmental challenges to restore and maintain the environmental and economic health of the Gulf. Within the next five years (1993-1997), through an integrated effort that complements existing local, state, and federal programs, the Program has pledged efforts to obtain the knowledge and resources to:

- Significantly reduce the rate of loss of coastal wetlands.
- Achieve an increase in Gulf Coast seagrass beds.
- Enhance the sustainability of Gulf commercial and recreational fisheries.
- Protect the human health and food supply by reducing input of nutrients, toxic substances, and pathogens to the Gulf.

- ❑ Increase Gulf shellfish beds available for safe harvesting by ten percent.
- ❑ Ensure that all Gulf beaches are safe for swimming and recreational uses.
- ❑ Reduce by at least ten percent the amount of trash on beaches.
- ❑ Improve and expand coastal habitats that support migratory birds, fish, and other living resources.
- ❑ Expand public education/outreach tailored for each Gulf Coast county or parish.
- ❑ Reduce critical coastal and shoreline erosion.

This Nutrient Enrichment Action Agenda supports these five-year environmental challenges.

For the public, this Gulf of Mexico Action Agenda should serve three purposes. First, it should reflect the public will with regard to addressing nutrient enrichment concerns. Second, it should communicate what actions are needed for eliminating the adverse effects of nutrient enrichment and provide the momentum for initiating these actions. Third, it should provide baseline information from which success can be measured.

This Action Agenda is a living document; therefore, the Gulf of Mexico Nutrient Enrichment Committee intends to periodically revise and update the document.

# Index of Nutrient Enrichment Objectives

## Characterization & Demonstration

**Objective:** Identify programs engaged in managing or regulating nutrient inputs and the ongoing and planned research related to nutrient enrichment for the watersheds draining into the Gulf of Mexico to support effective integration with Gulf initiatives.

**Objective:** Identify the location and quantities of nutrient loadings to Gulf of Mexico watersheds and evaluate the relative contribution of nutrients to the Gulf among these sources to support future targeting of control strategies and the measurement of success.

**Objective:** Identify the impacts and effects of nutrient enrichment on the bays, estuaries, and resources of the Gulf of Mexico to support the future geographic targeting of control strategies.

**Objective:** Identify and determine the relationships of sources of nutrients to resource impacts within the Gulf of Mexico to support optimum Gulfwide control strategies.

**Objective:** Develop demonstration projects on potential Gulfwide priority nonpoint and point sources that have a high probability of success within a reasonable time and have the potential for transferability Gulfwide.

## Source Reduction Strategies

**Objective:** Evaluate the effectiveness of nutrient control technologies for the most significant industrial and municipal point source categories in the Gulf of Mexico.

**Objective:** Implement appropriate Gulfwide or targeted control strategies to reduce significant nutrient loadings from point and nonpoint sources.

**Objective:** Develop alliances with other organizations and associations to address appropriate control strategies for Mississippi River contributions to the Gulf of Mexico nutrient problem.

## Public Education & Outreach

**Objective:** Develop a comprehensive Gulfwide public information and education program to promote involvement in nutrient reduction actions, through appropriate use of products and environmentally sound lifestyles.

# TABLE OF CONTENTS

# LIST OF TABLES

# LIST OF FIGURES

# 1 OVERVIEW OF THE GULF OF MEXICO

## The Gulf of Mexico - A Vast & Valuable Resource

Bounded by a shoreline that reaches northwest from Florida along the shores of Alabama, Mississippi, and Louisiana, and then southwest along Texas and Mexico, the Gulf of Mexico is the ninth largest body of water in the world. The Gulf's U.S. coastline measures approximately 2,609 km (1,631 miles)--longer than the Pacific coastline of California, Oregon, and Washington. The Gulf region covers more than 1.6 million $km^2$ (617,600 $mi^2$) and contains one of the nation's most extensive barrier-island systems, outlets from 33 major river systems, and 207 estuaries (Buff and Turner, 1987). In addition, the Gulf receives the drainage of the Mississippi River, the largest river in North America and one of the major rivers of the world. A cornerstone of the nation's economy, the Gulf's diverse and productive ecosystem provides a variety of valuable resources and services, including transportation, recreation, fish and shellfish, and petroleum and minerals.

Encompassing over two million hectares (five million acres) (about half of the national total), Gulf of Mexico coastal wetlands serve as essential habitat for a large percentage of the U.S.'s migrating waterfowl (USEPA, 1991). Mudflats, salt marshes, mangrove swamps, and barrier island beaches of the Gulf also provide year-round nesting and feeding grounds for abundant numbers of gulls, terns, and other shorebirds. Five species of endangered whales, including four baleen whales and one toothed whale, are found in Gulf waters. These waters also harbor the endangered American crocodile and five species of endangered or threatened sea turtles (loggerhead, green, leatherback, hawksbill, and Kemp's Ridley). The endangered West Indian (or Florida) manatee inhabits waterways and bays along the Florida peninsula.

In addition, a complex network of channels and wetlands within the Gulf shoreline provides habitat for estuarine-dependent commercial and recreational fisheries. The rich waters yielded approximately 771 million kg (1.7 billion pounds) of fish and shellfish in 1991. Worth more than $641 million at dockside, this harvest represented 19 percent of the total annual domestic harvest of commercial fish (USDOC, 1992). The Gulf boasts the largest and most valuable shrimp fishery in the U.S. and also contributed 41 percent of the U.S. total oyster production in 1991 (USDOC, 1992). Other Gulf fisheries include diverse shellfisheries for crabs and spiny lobsters and finfisheries for menhaden, herring, mackerel, tuna, grouper, snapper, drum, and flounder. The entire U.S. Gulf of Mexico fishery yields more finfish, shrimp, and shellfish annually than the South and Mid-Atlantic, Chesapeake, and the Great Lakes regions combined.

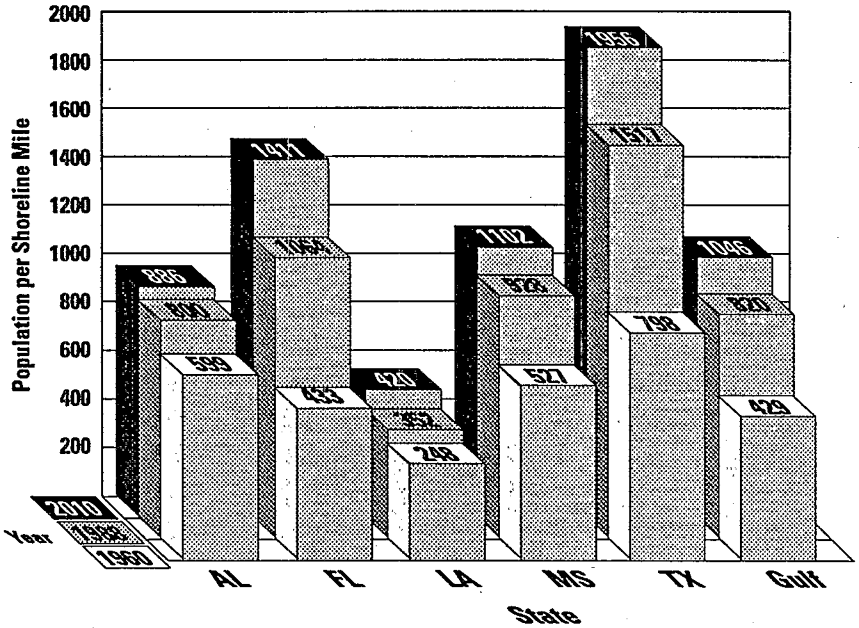
The Gulf's bountiful waters draw millions of sport fishermen and beach users each year. It is estimated that the Gulf supports more than one-third of the nation's marine recreational fishing, hosting four million fishermen in 1985 who caught an estimated 42 million fish (USDOC, 1992). Popular nearshore catches include sea trout (weak fish), cobia, redfish, flounder, grouper, red snapper, mackeral, and tarpon; offshore catches include blue marlin, white marlin, sailfish, swordfish, dolphin, and wahoo. Tourism-related dollars in the Gulf Coast States contribute an estimated $20 billion to the economy each year (USEPA, 1991).

Gulf oil and gas production are equally valuable to the region's economy and are a critical part of the nation's total energy supply. In 1990, more than 1,600 Outer Continental Shelf (OCS) leases were in production, yielding approximately 90 percent of U.S. offshore production. These OCS royalties annually contribute about $3 billion to the Federal Treasury. Thirty-eight percent of all petroleum and 48 percent of all natural gas reserves in the U.S. are estimated to be in the Gulf of Mexico. The industry employs some 30,000 people in the Gulf of Mexico.

Approximately 45 percent of U.S. shipping tonnage passes through Gulf ports, including four of the nation's busiest: Corpus Christi, Houston/Galveston, Tampa, and New Orleans. The second largest marine transport industry in the world is located in the Gulf of Mexico. According to USEPA, vessel trips in and out of American Gulf ports and harbors exceeded an estimated 600,000 trips in 1986. The U.S. Navy is also implementing its Gulf Coast Homeporting Plan, designed to dock at least 25 vessels in Ingelside, TX, Pascagoula, MS, and Mobile, AL.

Millions of people depend on the Gulf of Mexico to earn a living and flock to its shores and waters for entertainment and relaxation. The temperate climate and abundant resources are attracting more and more people. The region currently ranks fourth in total population among the five U.S. coastal regions, accounting for 13 percent of the nation's total coastal population. Although the Gulf region is not as densely settled as others, it is experiencing the second fastest rate of growth; between 1970 and 1980, the population grew by more than 30 percent (USDOC, 1990a). According to the U.S. Department of Commerce, the Gulf's total coastal population is projected to increase by 144 percent between 1960 and 2010, to almost 18 million people. **Figure 1.1** shows the Gulf of Mexico coastal population density or population per shoreline mile projected to the year 2010. Florida's population alone is expected to have skyrocketed by more than 300 percent by the year 2010. The increasing coastal population is of concern with regard to nutrient enrichment because as the population increases, so does the potential for environmental degradation. According to the Chesapeake Bay Nonpoint Source Program (1990), rapid urbanization leads to intensified nonpoint source pollution. Urban and suburban land users contribute much higher nutrient loads, on a per acre basis, than other land users (Chesapeake Bay NPS Program, 1990).

**Figure 1.1** ***Gulf of Mexico Coastal Population per Shoreline Mile***




**(Source: U.S. DOC, 1990a)**

## The Gulf of Mexico - A Resource At Risk

Many of the environmental quality problems affecting Gulf Coast estuaries result from natural processes and human-induced pollution, both within and upstream of the estuarine drainage area. Sources of nutrient enrichment include industrial facilities, wastewater treatment plants, power plants, septic tanks, agriculture, silviculture, atmospheric deposition, animal agriculture, and other waste runoff. The northern Gulf of Mexico is the recipient of the flow of a major river system, the Mississippi and Atchafalaya Rivers, which drains 40 percent of the U.S. and parts of Canada. The inflow from these two rivers dwarfs the input from any other Gulf Coast system, providing 79 percent of Gulf of Mexico freshwater inflow. Long-term water quality changes in the Mississippi River have been documented (Walsh *et al.*, 1981; Turner and Rabalais, 1991a). Mississippi River loadings (Turner and Rabalais, 1991a), and loadings for the entire Gulf Coast (Kircher *et al.*, 1984; Smith and Alexander, 1984; Smith *et al.*, 1987) have risen dramatically over the last three decades.

Recent trends indicate serious long-term environmental damage unless action is initiated today. Signs of increasing degradation throughout the Gulf system include the following (USEPA, 1991):

- Fish kills and toxic "red tides," and "brown tides" were an increasing phenomenon in Gulf waters during the 1980s.
- Alabama, Mississippi, Louisiana, and Texas are among those states that discharge the greatest amount of toxic chemicals into coastal waters.
- Diversions and consumptive use for human activities have resulted in significant changes in the quantity and timing of freshwater inflows to the Gulf of Mexico.
- More than half of the shellfish-producing areas along the Gulf Coast are permanently or conditionally closed. These closure areas are growing as a result of increasing human and domestic animal populations along the Gulf Coast (USDOC, 1991b).
- Louisiana is losing valuable coastal wetlands at the rate of approximately 14-66 $km^2$/year (5-25 $mi^2$/year) (Dunbar, *et al.*, 1992).
- Almost 1,800 kg/mi (2 tons/mi) of marine trash covered Texas beaches in 1988.
- Up to 9,500 $km^2$ (4,000 $mi^2$) of oxygen deficient (hypoxia) bottom waters, known as the "dead zone," have been documented off the Louisiana and Texas coasts (Rabalais, *et al.*, 1991).
- Gulf shorelines are eroding up to 30 m/year (100 ft/year). Few coastal reaches in the Gulf can be characterized as "stable" or "accreting."

# The Gulf of Mexico Program - Goals & Structure

Problems plaguing the Gulf cannot be addressed in a piecemeal fashion. These problems and the resources needed to address them are too great. The Gulf of Mexico Program (GMP) was formed to pioneer a broad, geographic focus in order to address major environmental issues in the Gulf before the damage is irreversible or too costly to correct.

The program is part of a cooperative effort with other agencies and organizations in the five Gulf States, as well as with people and groups who use the Gulf. In addition to the U.S. Environmental Protection Agency (USEPA), other participating federal government agencies include: National Aeronautics and Space Administration (NASA), U.S. Army Corps of Engineers (USACE), U.S. Department of Agriculture (USDA), U.S. Department of Commerce (USDOC), U.S. Department of Defense (USDOD), U.S. Department of Energy (USDOE), U.S. Department of the Interior (USDOI), U.S. Department of Transportation (USDOT), and U.S. Food and Drug Administration (USFDA).

The Gulf of Mexico Program also works in coordination and cooperation with the five National Estuary Programs (NEPs) within the Gulf: Tampa Bay, Sarasota Bay, Galveston Bay, Corpus Christi Bay, and the Barataria-Terrebonne Estuarine Complex. The Gulf of Mexico Program supports and builds on certain activities of these programs, bringing a Gulfwide focus and providing a forum for addressing issues of Gulfwide concern.

By building on and enhancing programs already underway, as well as by coordinating new activities, the Gulf of Mexico Program will serve as a catalyst for change. The program's overall goals are to provide:

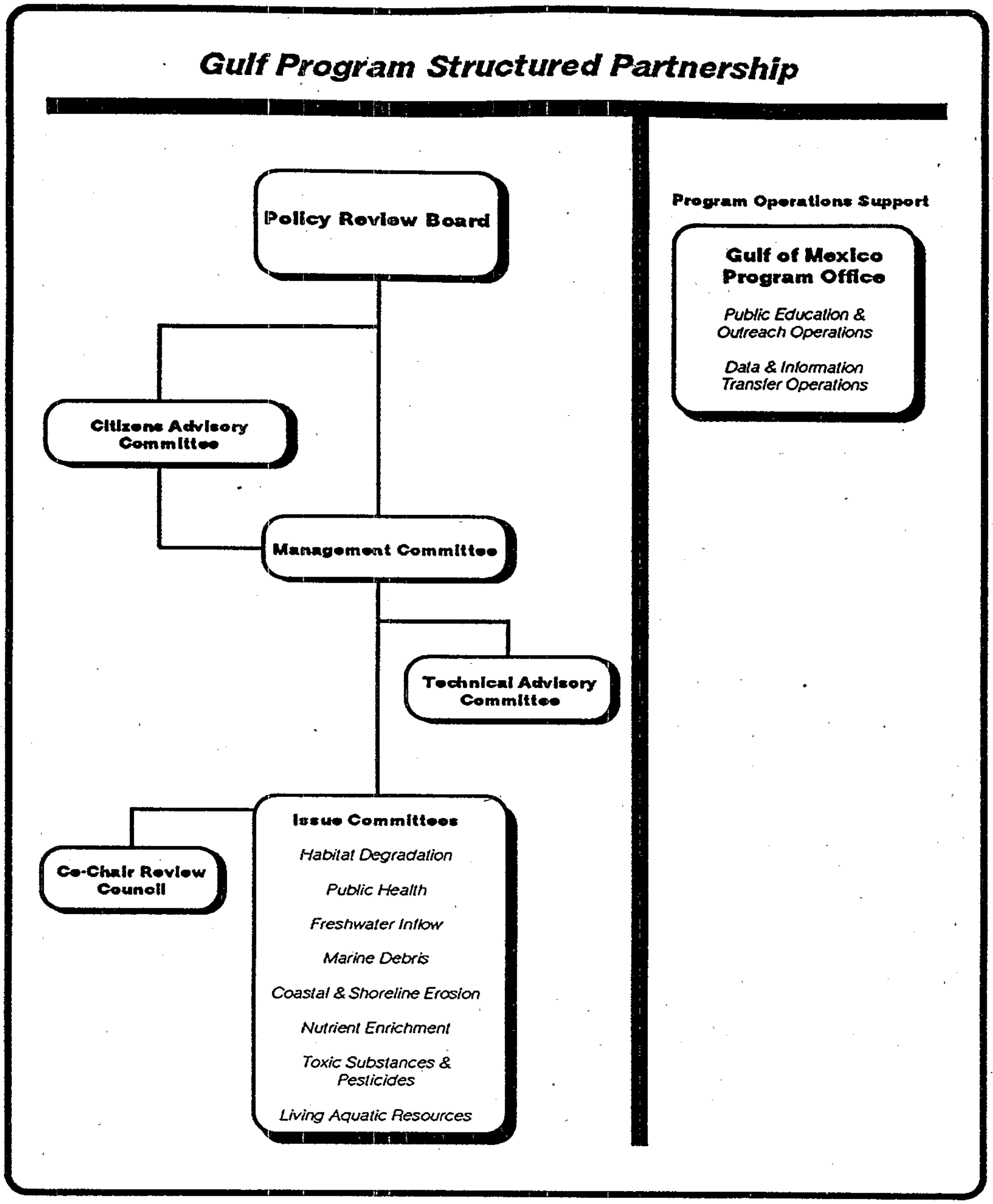
- ❑ A mechanism for addressing complex problems that cross federal, state, and international jurisdictional lines;
- ❑ Better coordination among federal, state, and local programs, thus increasing the effectiveness and efficiency of the long-term effort to manage and protect Gulf resources;
- ❑ A regional perspective to address research needs, which will result in improved transfer of information and methods for supporting effective management decisions; and
- ❑ A forum for affected groups using the Gulf, for public and private educational institutions, and for the general public to participate in the solution process.

The Gulf of Mexico Program is supported by four committees: Policy Review Board (PRB), Management Committee (MC), Citizens Advisory Committee (CAC), and Technical Advisory Committee (TAC) (see **Figure 1.2**). Composed of 20 senior level representatives of state and federal agencies and representatives of the technical and citizens committees, the Policy Review Board guides and reviews overall program activities. The Management Committee guides and manages Gulf of Mexico Program operations and directs the Action Agenda activities of the Issue Committees. The Citizens Advisory Committee is composed of five governor-appointed citizens who represent environmental, fisheries, agricultural, business/industrial, and development/tourism interests in each of the five Gulf Coast States. This committee provides public input and assistance in publicizing the Gulf of Mexico Program's goals and results. Representatives of state and federal agencies, the academic community, and the private and public sectors are members of the Technical Advisory Committee and provide technical support to the Management Committee.

The Gulf of Mexico Program has established the following eight Issue Committees, each co-chaired by one federal and one state representative, to address priority environmental problems:

- ❑ **Habitat Degradation** of such areas as coastal wetlands, seagrass beds, and sand dunes;
- ❑ **Freshwater Inflow** changes resulting from reservoir construction, diversions for municipal, industrial, and agricultural purposes, and modifications to watersheds with concomitant alteration of runoff patterns;
- ❑ **Nutrient Enrichment** resulting from such sources as municipal waste water treatment plants, storm water, industries, and agriculture;
- ❑ **Toxic Substances & Pesticides** contamination originating from industrial and agriculturally based sources;
- ❑ **Coastal & Shoreline Erosion** caused by natural and human-related activities;
- ❑ **Public Health** threats from swimming in and eating seafood products coming from contaminated water;
- ❑ **Marine Debris** from land-based and marine recreational and commercial sources; and
- ❑ **Living Aquatic Resources.**

**Figure 1.2**


Gulf Program Structured Partnership
Policy Review Board
Citizens Advisory Committee
Management Committee
Technical Advisory Committee
Co-Chair Review Council
Issue Committees
Habitat Degradation
Public Health
Freshwater Inflow
Marine Debris
Coastal & Shoreline Erosion
Nutrient Enrichment
Toxic Substances & Pesticides
Living Aquatic Resources
Program Operations Support
Gulf of Mexico Program Office
Public Education & Outreach Operations
Data & Information Transfer Operations

Two cross-cutting technical operating committees support the public education and information and resource management functions of the eight environmental Issue Committees. These are:

- ❑ **Public Education & Outreach Operations**
- ❑ **Data & Information Transfer Operations**

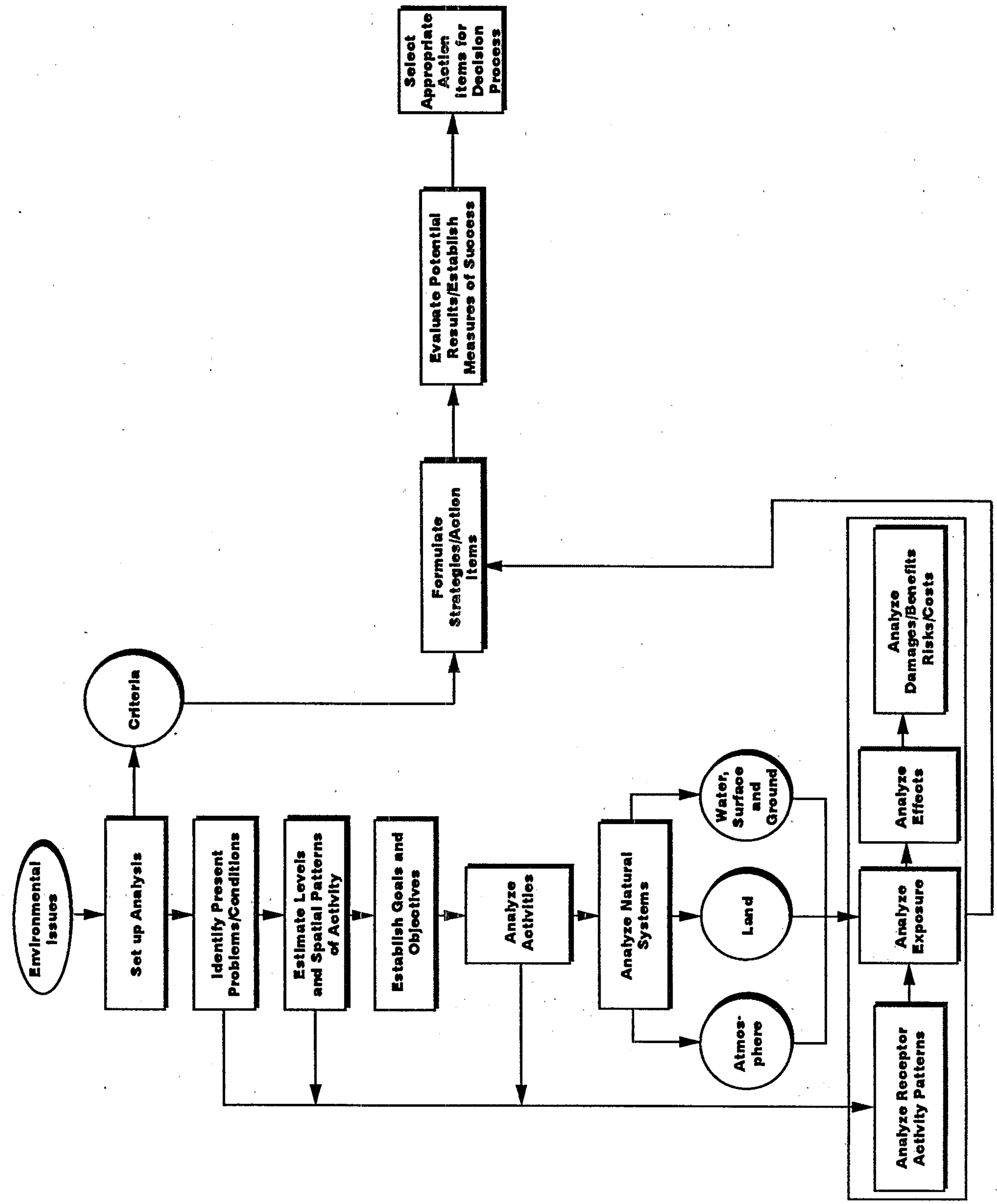
The action planning process used by each Gulf of Mexico Program Issue Committee includes the following key activities:

- ❑ Definition of environmental issues;
- ❑ Characterization of identified problems, including sources, resources, and impacts;
- ❑ Establishment of goals and objectives;
- ❑ Evaluation/assessment of corrective actions and control measures, including cost/benefit analysis;
- ❑ Selection of priority action items;
- ❑ Establishment of measures of success;
- ❑ Implementation of actions; and
- ❑ Evaluation of success and revision of the Action Agenda.

As the Issue Committees progress through each of these activities, ample opportunities are provided for public review and Policy Review Board endorsement is requested at appropriate points. The Gulf of Mexico Program will continuously work to integrate related activities of the eight Issue Committees. Through the consensus of Program participants, a coordinated response will be directed to the successful maintenance and enhancement of resources of the Gulf of Mexico.

The overall analytical framework for the Gulf of Mexico action planning process incorporates the steps provided in **Figure 1.3**. Each technical Issue Committee is generally following this model, although some Issue Committees may be further along than others. Action items provided in Chapter 4 are a combination of characterization/assessment actions where source work is needed and corrective actions where enough is known to recommend such actions.

**Figure 1.3** ***Framework for Analysis of Integrated Environmental Management***



## The Nutrient Enrichment Committee

The Co-Chairs and membership of the Nutrient Enrichment Committee are as follows:

**Co-Chairs:**

| | |
|---|---|
| Mr. Pete Heard | Soil Conservation Service |
| Mr. Dugan Sabins | Louisiana Department of Environmental Quality |

**Members:**

| | |
|---|---|
| Ms. Jan Boydstun | Louisiana Department of Environmental Quality |
| Dr. Fred Bryan | Louisiana State University |
| Mr. Charles Demas | U.S. Geological Survey |
| Dr. Mark Dortch | U.S. Army Corps of Engineers |
| Mr. Mike Dowgiallo | National Oceanic & Atmospheric Administration |
| Mr. Daniel Farrow | National Oceanic & Atmospheric Administration |
| Dr. Robert Fisher | National Council for Air & Stream Improvement |
| Dr. David Flemer | U.S. Environmental Protection Agency |
| Mr. James Fogarty | Citizens Advisory Committee |
| Mr. Tim Forester | Alabama Department of Environmental Management |
| Mr. Johnny French | U.S. Fish & Wildlife Service |
| Mr. Douglas Frugé | U.S. Fish & Wildlife Service |
| Dr. Eddie Funderburg | Louisiana State University |
| Mr. Brian Grantham | Citizens Advisory Committee |
| Dr. Churchill Grimes | National Marine Fisheries Service |
| Mr. Vince Guillory | Louisiana Department of Wildlife & Fisheries |
| Mr. Doug Jacobson | U.S. Environmental Protection Agency--Region 6 |
| Dr. Peter Kuch | U.S. Environmental Protection Agency |
| Mr. Ira Linville | U.S. Environmental Protection Agency--Region 4 |
| Dr. Stephen Lovejoy | Purdue University |
| Mr. Gale Martin | Mississippi Soil & Water Conservation Commission |
| Mr. David Moffitt | Soil Conservation Service |
| Mr. James Moore | Texas Soil & Water Conservation Board |
| Mr. James Patek | Lower Colorado River Authority |
| Dr. Nancy Rabalais | Louisiana Universities Marine Consortium |
| Mr. Dale Rapin | U.S. Forest Service |
| Dr. Alan Shiller | University of Southern Mississippi |
| Dr. Bob Thompson, Jr. | Potash & Phosphate Institute--Midsouth |
| Mr. Lloyd Woosley P.E. | U.S. Geological Survey |
| Dr. Terry Whitledge | The University of Texas at Austin |

The Nutrient Enrichment Committee developed the following long-term goal for addressing nutrient enrichment in the Gulf of Mexico:

- ❑ Protect the waters of the Gulf of Mexico from the deleterious effects of nutrient enrichment, from all contributing sources, and thereby enhance biodiversity, and aesthetic, recreational and economic benefits.

This Action Agenda focuses on protecting the tidal, estuarine, and nearshore waters of the Gulf of Mexico. Freshwater transport from landward sources is addressed as a contributing source.

The Gulf of Mexico Policy Review Board endorsed this goal on November 8, 1990. In developing this Action Agenda, the Nutrient Enrichment Committee has sought input and advice from other technical Issue Committees, as well as from organizations, interest groups, and private concerns outside of the Gulf of Mexico Program. An "Action Agenda Workshop" sponsored by the Committee in Covington, LA, on September 2-4, 1992, to review an early version of the Action Agenda, was attended by approximately 60 persons comprising a mix of Program and non-Program participants. In addition to Gulf of Mexico Program participants, representatives from the following agencies, organizations, and industries attended the workshop: Sarasota Bay National Estuary Program, U.S. Environmental Protection Agency, Soil Conservation Service, Louisiana Department of Natural Resources, Freeport-McMoRan, Inc., Louisiana Universities Marine Consortium, Louisiana State University, Tennessee Valley Authority, Chesapeake Bay Program, Mississippi Bureau of Marine Resources, Mississippi Farm Bureau Federation, U.S. Army Corps of Engineers, Delta Council, YMD Water District, Minnesota Department of Natural Resources, Izaak Walton League, Galveston Bay National Estuary Program, Matagorda County Water Council, and U.S. Fish & Wildlife Service. This meeting generated a significant number of comments that have been addressed in the present document. (See **Appendix D: Participants in Action Agenda Development Process**.)

# 2 NUTRIENT ENRICHMENT IN THE GULF OF MEXICO*

***Much of the information in Chapter 2 is directly quoted from Rabalais (1992) with permission from the author.**

**NOTE: The Nutrient Enrichment Committee recognizes that the material contained in Chapter 2 is not necessarily geared to the general public, and the Committee's intent is to include a more user-friendly section in the next iteration of this Action Agenda.**

Although the Gulf of Mexico is viewed as one of the most healthy and productive coastal environments nationwide, during recent decades it has begun to show signs of stress and deteriorating environmental quality. In the U.S., coastal and marine pollution controls have historically focused on conventional and toxic pollutants, specific point source dischargers (power plants, industrial plants, and municipal wastewater treatment plants), and the ocean dumping of sewage sludge, dredged material, and industrial waste. Other, less identifiable, sources of pollutants enter rivers, estuaries, and coastal areas from urban runoff, agricultural runoff, and runoff from rural communities. Many of these nonpoint sources contribute organic material, nutrients, and chemicals to receiving water bodies and ultimately the Gulf of Mexico.

There is increasing concern in the U.S. and other nations that nutrient enrichment of coastal waters from multiple sources may be having pervasive effects on living resources. Nutrient enrichment is an important environmental concern because of the effects of oxygen depletion on fisheries and their supporting food web, noxious algal blooms that may have toxic effects on marine life or humans consuming tainted seafood, indirect effects such as periphytic and phytoplanktonic shading of submerged aquatic vegetation, changes in the nutritional value of primary producers, and changes in energy flow pathways.

## Definitions

The words **nutrient enrichment, nutrient over-enrichment,** and **eutrophication,** are often used interchangeably but often without similarly intended meanings. For the purposes of this Action Agenda, the "over-" prefix will be dropped from the word enrichment, since enrich already means "to increase the proportion of a valuable or desirable ingredient."

There has been considerable discussion and general lack of agreement on the definition of "eutrophication." In many instances it is used interchangeably with "nutrient enrichment." The definition of **eutrophication** that will be used in this Action Agenda is "a natural or artificial addition of nutrients to bodies of water and the *effects* of added nutrients" (NAS, 1969).

The word **increase** often connotes change in a positive direction. However, nutrient increases are often detrimental. An adequate supply of essential nutrients is required to support food webs, and intentional nutrient additions have been shown to increase fish stocks in some experimental systems. However, aquatic systems are limited in their assimilative capacities and the effects of eutrophication are known to be deleterious.

The term **hypoxic** describes conditions or responses produced by stressful levels of oxygen deficiency. Based on laboratory and/or field observations on oxygen stress responses in invertebrate and fish faunas, the general consensus on the definition of hypoxic corresponds to dissolved oxygen levels lower than 2 mg/L [=1.4 ml/L (at standard temperature and pressure)] (Tyson and Pearson, 1991).

## Role of Nutrients & Other Constituents Within Ecosystems

All living organisms have specific requirements for growth and reproduction. Nitrogen and phosphorus are two nutrients required in relatively high concentrations by all living organisms. When nitrogen and phosphorus become depleted, growth may be limited; however, when they are in excess, growth increases until some other resource becomes limiting (Dudley, 1992). Marine and coastal waters are considered to be nitrogen-limited and freshwater systems are phosphorus-limited. Both nitrogen and phosphorus are important in estuaries, depending on the season, total nutrient loadings, and various physical and chemical conditions.

Accelerated eutrophication occurs when excessive loads of nitrogen and phosphorus are supplied. The ecological effects of accelerated eutrophication include algal blooms, decreased light availability, changes in community structure, and decreased biological diversity (Dudley, 1992). Silicate availability, an indirect consequence of phosphorus loading, may strongly influence the occurrence of the deleterious effects of eutrophication.

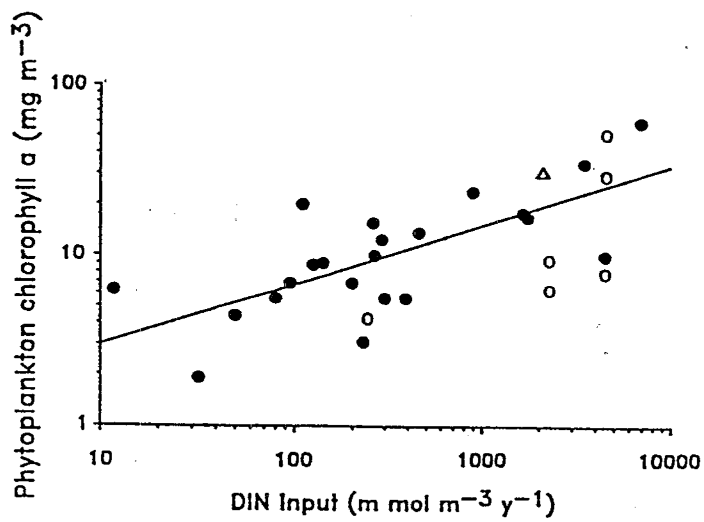
Other chemical constituents such as carbon, trace metals, dissolved organic compounds (*e.g.*, amino acids) and chelators may also affect specific systems under certain conditions. In addition, physical features (*e.g.*, light, temperature, physical mixing, and vertical stratification) control primary production with the associated negative consequences of hypoxia/anoxia, algal blooms, and shifts in the food web to less desirable species. In some situations, predators may exert some influence on nutrient supplies.

## Effects of Nutrient Enrichment

The potential and observed consequences of nutrient enrichment in coastal habitats are often documented in bold newsprint that announces a major fish kill, dead zone, red tide, catastrophic decline of seagrass beds, or reduced fishery landings. Few such reports, however, have specifically linked increases in nutrient supplies to these problems. Many anthropogenic factors, such as overfishing and dredging and filling, as well as climatic factors and long-term global changes, can contribute to a reduction in coastal water quality and changes in natural resources.

Experimentally or empirically derived relationships between changes in nutrients and biological and/or chemical effects (see **Figure 2.1**) provide the basis for determining how nutrient enrichment affects estuarine and coastal systems (see **Table 2.1**). **Figure 2.1** illustrates the resultant increase in chlorophyll *a* when dissolved inorganic nitrogen is present in increased quantities. Other relationships are not as straightforward, and complex interactions obscure direct lines of evidence. Nutrient enrichment may be further categorized into the following major groupings: altered trophic structure, oxygen depletion, and habitat alteration.

**Figure 2.1** ***Relationship of Mean Dissolved Inorganic Nitrogen (DIN) Loading to Different Estuaries & Mean Annual Chlorophyll in Water***




***Black Circles:*** ***Data from many different estuaries (compiled by S. Nixon and M. Pilson)***

***White Circles:*** ***Data from Waquoit Bay LMER***

**(Source: LMER Coordinating Committee, 1992)**

**Table 2.1** ***Effects of Nutrient Enrichment***

| | |
|---|---|
| **Direct Effects** | • Increases in nutrient concentrations (particularly N and P)<br>• Changes in loads & seasonal delivery<br>• Changes in nutrient ratios (*e.g.*, stoichiometric ratios of 20 Si:16 N:1 P) |
| **Biological Responses** | • Increased phytoplankton production<br>• Increased biomass & abundance<br>• Changes in species composition |
| **Indirect Effects** | • Noxious algal blooms<br>• Turbidity increases and shading effects<br>• Changes in submerged aquatic vegetation<br>• Changes in secondary production<br>• Altered energy flow pathways<br>• Altered habitats<br>• Fish kills<br>• Increases in extent, duration & severity of oxygen-depletion events |

**(Source: Rabalais, 1992)**

## Altered Trophic Structure

Many factors interact to influence changes in primary producer and consumer populations, including the supply, relative availability and timing of nutrient inputs, and various physical characteristics of the estuary or coastal water body such as temperature, turbidity, currents, and water column stratification.

Increased phytoplankton production and biomass are the likely result in an otherwise nitrogen-limited coastal food web (Harris, 1986; Valiela, 1984). Although there are no phytoplankton indicator species of incipient or advanced states of coastal eutrophication presently identifiable, a significant shift in phytoplankton community structure at the phylogenetic level is occurring globally in response to coastal nutrient enrichment (Smayda, 1989, 1990, 1991; Richardson, 1989; Cherfas, 1990; Cadeé, 1990a,b,c). Smayda (1991) further notes that this phylogenetic shift has been towards increased abundance and seasonal dominance of species that may be noxious, harmful, or toxic in increased concentrations; and that their sinking and decomposition in the water column or seabed may contribute to increased hypoxic/anoxic episodes.

Diatoms, tiny planktonic algae, are thought to provide the primary energy source for traditional food webs that support top predators. The abundance of coastal diatoms is influenced by silicon supplies, whose Si:N atomic ratio is about 1:1 (Redfield Ratio). Diatoms out-compete other algae in a stable and illuminated water column of favorable silicate concentration. Anthropogenic enrichment of N and P, leading to long-term increases in these nutrient loadings, has also led to long-term declines in the Si:N (Turner and Rabalais, 1991a) and Si:P ratios. When nitrogen increases and silicate decreases, flagellates may increase in abundance (Officer and Ryther, 1980). The decline in the Si:P and Si:N ratios has particularly favored non-diatom blooms and is a key factor associated with the global epidemic of novel toxic and harmful phytoplankton blooms and phylogenetic shifts in phytoplankton biomass predominance in coastal seas (Smayda 1989, 1990, 1991); similar shifts may be occurring in the waters adjacent to the Mississippi River (Dortch and Whitledge, 1992). In particular, noxious blooms of flagellates are becoming increasingly common in coastal systems. There is evidence for an ongoing global increase in the frequency, number of occurrences, and dynamics of toxic and harmful phytoplankton blooms (Dundas *et al.*, 1989; Richardson, 1989; Cherfas, 1990; Cadee, 1990a,b,c).

In the northern Gulf of Mexico, riverine input of Si:N from the Mississippi River has decreased from 4:1 to approximately 1:1 over the last three decades (Turner and Rabalais, 1991b). These changes may have a major impact on Si availability, phytoplankton species availability, carbon flux and hypoxia (Turner and Rabalais, 1991b; Dortch and Whitledge, 1992).

Phylogenetic shifts within phytoplankton communities may alter the food supply available to herbivorous organisms. Evidence suggests that smaller, "less desirable" flagellate-and cyanobacterial-dominated communities are less acceptable as food for grazers. Zooplankton, the main consumers of whole diatoms and a staple of juvenile fish, are thus affected by these nutrient changes in a cascading series of interactions. Alternatively, changes in type and distribution of higher trophic-level herbivores and predators may have a cascading effect down the food web to primary producers.

A change in the timing of the spring bloom that supports fish entering estuaries to feed during critical recruitment periods may also be an important consequence of eutrophication. Altered trophic structure associated with nutrient enrichment could potentially influence predation and feeding success. Changes in the nutrient loading and timing could affect recruitment success through a mis-match of larval recruitment and food supply, as well as an altered food chain. Starvation, not predation, may be the major source of larval mortality and a potential determinant of recruitment levels. Also, starvation and malnourishment can mediate predation, *i.e.*, weakened larvae are more susceptible to predators (Hunter, 1981).

Early blooms with a greater sedimentation to the benthos could positively affect demersal fishes, but late blooms positively affect pelagic fisheries through the zooplankton food chain. Zooplankton graze on diatoms extensively, so that changes in nutrient loading and the ratio of nutrients could affect the balance and timing of the demersal and pelagic food webs.

### Oxygen Depletion

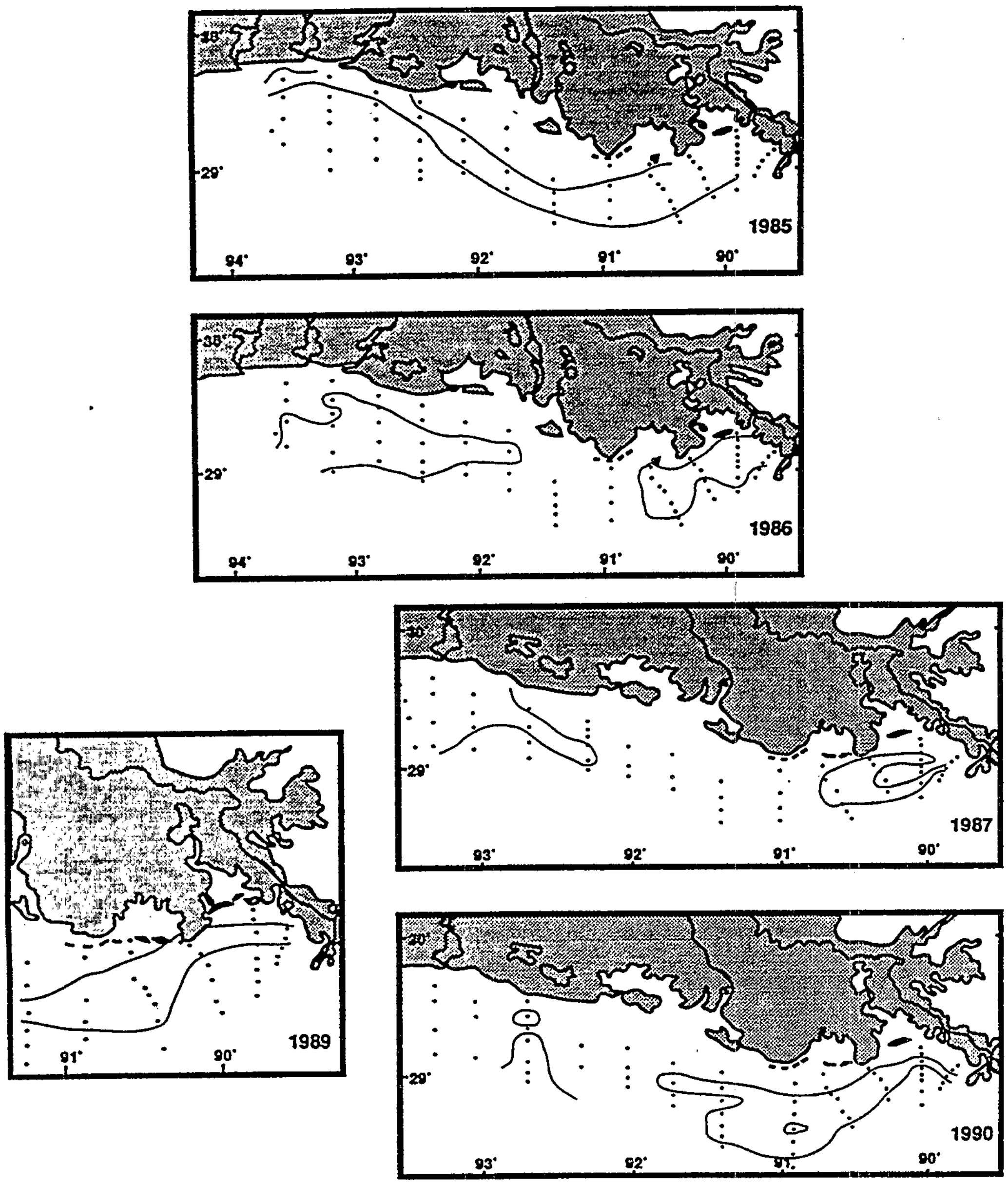
Oxygen-depleted waters are often caused by nutrient enrichment. Where eutrophication occurs, oxygen depletion often follows presumably as a consequence of the increase in organic loading that is stimulated by increased nutrients. Excessive organic material in surface waters may sink to the bottom, either directly, as grazed material, or through advection. Decomposition of these materials may lead to oxygen depletion, especially in stratified water columns where the rate of depletion of oxygen is greater than the reaeration of the water column from surface oxygen production or diffusion.

Low dissolved oxygen concentrations, however, are not caused exclusively by nutrient enrichment. Many physical features of the estuary and water column contribute to the formation of hypoxic water masses. Where increased nutrients contribute to organic loading and subsequent decomposition of material and depletion of oxygen, these features are usually coupled with the physical phenomenon of a stratified water column. This density stratification, controlled by temperature or salinity differences, prevents the reaeration of the bottom waters at a rate sufficient to offset the depletion of oxygen during respiration. Salinity affects the density of water, which affects oxygen depletion. Strength of stratification is sensitive to freshwater inflows and climatic conditions forcing tidal waters into estuaries. In many deep channels, this density stratification may occur and oxygen may be depleted without increased organic inputs. However, the oxygen demand in the bottom waters of deeper channels, especially near industrialized and urbanized areas, may be related to chemical oxygen demand or organic loading from sewage outfalls. Other deep channels or topographically lower features may be consistently hypoxic in the bottom waters just because of the physical structure and lack of mixing of the water column.

In areas with submerged aquatic vegetation, low oxygen levels will be present in the early morning hours following extensive respiration of the vegetation during the dark cycle. In other instances, the movement of naturally stagnant swamp waters into other bodies of water following a flushing event may contribute temporarily to a low oxygen condition.

Widespread and catastrophic depletion of dissolved oxygen has been observed in coastal areas worldwide (Swanson and Sindermann, 1979; Falkowski *et al.*, 1983; Swanson and Parker, 1988; Renaud, 1986a; Pokryfki and Randall, 1987; Rabalais *et al.*, 1991; Stachowitsch, 1984; Faganeli *et al.*, 1985; Justic´ *et al.*, 1987; Tolmazin, 1985; Rosenberg, 1986, 1990; Westernhagan *et al.*, 1986). Oxygen-depleted waters have also been identified in numerous estuaries of the U.S. (Whitledge, 1985). The largest, most severe and most persistent zone of hypoxia in U.S. coastal waters [9,500 $km^2$ (4,000 $mi^2$)] is found in the northern Gulf of Mexico on the continental shelf off Louisiana. This hypoxic zone occurs at the terminus of the Mississippi River and amidst the nation's richest and most extensive fishing grounds (see **Figure 2.2**).

**Figure 2.2** ***Distribution of Hypoxic Bottom Waters on the Louisiana Continental Shelf in Mid-Summer for the Years Indicated***
***(hypoxic areas are <2 mg/L dissolved oxygen)***




***Note: Figures differ in station coverage and scale, longitude provides relative distance.***

**(Source: Rabalais, 1992)**

For a National Oceanic & Atmospheric Administration Nationwide Review Project (Rabalais *et al.*, 1985; Whitledge, 1985; Windsor, 1985), a dissolved oxygen concentration of greater than 4 mg/L was determined the minimum level acceptable for coastal waters. In that review, estuaries or coastal areas were categorized as having marginal and/or deteriorating water quality with respect to this level of dissolved oxygen concentration. Within the 36 estuaries categorized by Rabalais *et al.* (1985) for Alabama, Mississippi, Louisiana, and Texas, 12 were categorized with severe or regularly occurring hypoxia in part or all of the estuary. Windsor (1985) listed seven of 19 estuaries as having potential problems or deteriorating water quality. For both studies, a little over half (56 percent) of the estuaries were categorized as having adequate data for evaluation.

Contrary to the earlier findings (Rabalais *et al.*, 1985; Windsor, 1985), levels of 2-3 mg/L may be a more biologically realistic level in the warmer waters of the Gulf of Mexico. Values below 2 mg/L affect populations of demersal fishes and macroinvertebrates as noted in field studies. Dissolved oxygen concentrations of 2 mg/L equate to an oxygen saturation level of 25-27 percent in northern Gulf of Mexico waters. Values below this are associated with reduced benthic macroinfauna, and values below 0.5 mg/L (or seven percent oxygen saturation) are associated with severely reduced numbers of benthic infauna.

Oxygen concentrations of surface waters may also be a key to the eutrophication status of a water body. Nutrient enrichment, which stimulates phytoplankton growth, may result in the supersaturation of oxygen in surface waters. Values of oxygen saturation greater than 100 percent are commonly found in Louisiana coastal waters when high chlorophyll *a* biomass is coincident. The presence of an oxygen minimum zone with depth, particularly above a pycnocline (zone of maximum density resulting from temperature and salinity), may also indicate high respiration rates in the water column. These conditions are prevalent on the Louisiana shelf.

## Habitat Alteration & Impacts on Living Resources

Excessive nutrient loading can cause accelerated eutrophication; the resultant increase in planktonic biomass decreases the distance that light can penetrate through the water column. Reduced light penetration has been shown to inhibit photosynthesis in deeper waters of some eutrophic estuaries (Pennock, 1985; Pennock and Sharp, 1987) and to affect photosynthetic microorganisms, as well as submerged aquatic vegetation (Short, 1987, 1991; Johansson and Lewis, 1992).

Excessive nutrient loading in an estuary can have detrimental effects on a seagrass system in three ways: 1) change to a plankton-dominated ecosystem, 2) change to a macroalgal-dominated ecosystem, and 3) change to a system with excessive amounts of epiphytic algal growth (Short, 1991). All three possible changes have been observed in the field and have been directly associated with documented seagrass declines (Short, 1987, 1991). The loss of seagrass beds following decreased water clarity is often observed (Cambridge and McComb, 1984; Cambridge *et al.*, 1986; Johansson and Lewis, 1992). Certain coastal fisheries species seem to require a physical structure to escape from predators while young. Where the area of estuarine macrophytes declines or improves, fisheries harvest is observed to respond proportionally (Turner and Boesch, 1987).

Long-term changes in the turbidity of the water column are also related to nutrient enrichment, with coincident long-term declines in the oxygen concentration of the water column and negative impacts on habitat and living resources. Other long-term changes in the turbidity of the water column in coastal systems may be related to the reduction of the suspended sediment load of a major freshwater source. This appears to be the case in the waters adjacent to the Mississippi River, where a long-term change in the turbidity of the water column is perhaps related to increased water clarity as a result of the reduction of the suspended sediment load and/or changes in phytoplankton community composition (Meade and Parker, 1985; Turner and Boesch, 1987). Increased water clarity adjacent to the Mississippi River Delta may have implications for increased phytoplankton production and biomass in a system where turbidity is a factor limiting phytoplankton growth at various levels of light intensity. Turbidity may result from dredging operations.

Light attenuation may also occur by absorption, which takes place naturally in certain streams by humic substances (*i.e.*, substances leached from decaying plants and trees). Although this process is natural, and although the light attenuation process is a natural phenomenon, primary productivity in these colored waters may be less than would be the case if the waters were not colored. Similar but not identical chemicals are leached from wood chips and pulp in conventional pulping and bleaching processes, and paper mill effluents may attenuate light in receiving waters due to light absorption. The effect of paper mill effluents on primary production due to light attenuation is site- and process-specific.

There are numerous examples of the impacts of low oxygen conditions on reduced benthic fauna, in terms of fewer species, lower abundance, or both (Rosenberg, 1977; Gaston, 1985; Gaston *et al.*, 1985; Rosenberg and Loo, 1988; Stachowitsch, 1984, 1986; Westernhagen *et al.*, 1986; Harper *et al.*, 1991; Boesch and Rabalais, 1991). The degree of effect depends on the level of organic enrichment and/or concentration of dissolved oxygen in the overlying waters and whether hydrogen sulfide is generated from the sediments during anoxic events (Boesch and Rabalais, 1991; Harper *et al.*, 1991; Rabalais *et al.*, unpublished data). Reduction in the benthic fauna is a habitat alteration that may have an indirect impact on other parts of the food web (*e.g.*, reduction in adequate food supplies for other species, such as demersal fish and shrimp).

The potentially enormous consequences of oxygen depletion to living resources in the northern Gulf of Mexico are a regional and national concern. The area impacted by the duration of hypoxia on the Louisiana shelf is important because, in 1991, the entire Gulf's commercial fisheries landings accounted for 19 percent of the U.S. total commercial landing (USDOC, 1992), and approximately $641 million. Certain life stages of penaeid shrimp may be affected by hypoxic bottom waters, and critical periods in the life history of both brown and white shrimp occur during May through September when hypoxia is present. The decline in the shrimp catch of Louisiana may be related to hypoxic events, particularly those recorded from May 1983 to May 1984 and in 1982 (Renaud, 1986b). Trawl samples indicate that the demersal catch is reduced to virtually zero when the bottom water dissolved oxygen levels fall below 2 mg/L. The processes involved--direct mortalities, avoidance by bottom-dwelling shrimp and finfish, altered migration, susceptibility to predation--are not known. Although dead or decaying fish have been pulled up in trawls where hypoxia occurs, the trawls are usually empty in areas with reduced bottom water oxygen.

As a result of oxygen depletion, the area of suitable habitat may be reduced and the individuals become more susceptible to predation. Also, hypoxic bottom water may act as a physical barrier to juvenile shrimp emigration offshore and to postlarval migration into estuaries. Experimental work of Renaud (1986a) indicates that white shrimp (*Penaeus setiferus*) detected and significantly avoided water containing ≤1.5 ppm dissolved oxygen, and brown shrimp (*Penaeus aztecus*) were more sensitive and avoided water of dissolved oxygen concentrations ≤2.0 ppm. In addition, the stress incurred by fish, such as experiencing low oxygen tensions or starvation following oxygen depletion, is believed to be a contributing factor to the development of disease in fish (Nielsen and Mellargaard, 1989).

Less motile invertebrates are stressed by low oxygen conditions and either adapt behaviorally or are killed. Dead and decaying invertebrates have been observed on seabeds where oxygen levels are severely reduced (Stachowitsch, 1984; Faganeli *et al.*, 1985). Behavior modifications include movement to the sediment surface, extending body parts above the sediment surface, or finding topographically higher locations, all of which expose the typically infaunal organisms to increased predation pressure.

Habitat suitability is the result of several interacting conditions, including oxygen. Low oxygen levels in the water column, typically below 2 mg/L, are generally not satisfactory for fish habitat. Because nutrient enrichment and eutrophication frequently lead to low oxygen levels, an indirect effect of eutrophication may be the contraction of suitable habitat necessary for reproduction and growth of fish.

An uncommon, but potentially very important, impact of nutrient enrichment on living resources is the influence of altered trophic structure on larval fish recruitment processes. Recruitment is the process through which new individuals are spawned and survive to enter the population or fishery. Recruitment, along with growth and natural fishing mortality, determine fishery yields. Recent studies conducted in the vicinity of the Mississippi River discharge plume indicate that physical and biological interactions (*e.g.*, altered trophic structure resulting from nutrient enrichment) have the potential to influence recruitment success (Govoni *et al.*, 1989).

## How Much (of What) Is Too Much?

**Nitrogen, Phosphorus, Silicate & Dissolved Oxygen.** Using the classification of concentrations in **Table 2.2** (U.S. DOC, 1990b), an estuary with low concentrations of nutrients is characterized by maximum diversity of aquatic life whereas an estuary with high nutrient concentrations is characterized by high chlorophyll levels, low species diversity, and occasional algal blooms.

**Table 2.2** ***N, P, Si & DO Units & Concentrations****

| | **Unit** | **Definition** | **Concentration** |
|---|---|---|---|
| ***Nitrogen*** | Total Kjeldahl Nitrogen (TKN) (mg/L, µM/L, or µg-at/L) | Total $NH_3$ -N + organic N (dissolved or particulate) | < 0.1 mg/L = **low**<br>0.1 - 1.0 mg/L = **medium**<br>> 1.0 mg/L = **high** |
| | Dissolved Inorganic Nitrogen (DIN) (mg/L, µM/L, or µg-at/L) | nitrate + nitrite (may also include ammonia) | |
| | Total Nitrogen (mg/L, µM/L, or µg-at/L) | TKN + nitrate + nitrite | |
| ***Phosphorus*** | Total Phosphorus (TP) (mg/L or µg-at/L) | dissolved or particulate fraction or both | < 0.01 mg/L = **low**<br>0.01 - 0.1 mg/L = **medium**<br>> 0.1 mg/L = **high** |
| ***Silicate*** | Si<br>units similar to DIN or TP (mg/L, µM/L or µg-at/L) | | Indirectly related to P loadings--may strongly influence eutrophication |
| ***Dissolved Oxygen*** | DO (mg/L) | Bottom water dissolved concentrations(standard measurement technique to determine general health of a water body) | <2 mg/L = **hypoxic**<br><0.1 mg/L = **anoxic** |

***Note: 1) Dissolved inorganic solids, which are a concern in freshwater systems, as a general indicator of water quality and of the suitability of water for various uses, are not a concern in estuarine or coastal systems. Dissolved inorganic solids are normal components of sea water (sodium, potassium, calcium, magnesium, carbonate, bicarbonate, chloride, and sulfate ions).**

**2) Mole (M) is the gram-molecular weight of a substance. It is the amount of the substance having a weight equal to the molecular weight of the substance in grams. A micromole (µM) is 1 one-millionth of a mole.**

**3) Microgram (µg) atomic weight of a chemical element is the amount of the element with the weight equal to its atomic weight measured in micrograms. For example, the atomic weight of nitrogen is 14, thus 14 µg of nitrogen is 1 microgram atom. A solution containing 14 µg of nitrogen in 1 liter of water would produce a concentration of 1 µg atom of nitrogen/liter.**

**Phytoplankton.** Phytoplankton, such as algae, are microscopic plants that live in water. Phytoplankton is measured in several ways, either as the rate of primary production, biomass (concentration of chlorophyll), or number of individuals. Phytoplankton growth requires nitrogen and phosphorus in the approximate atomic proportion of 16:1, the Redfield Ratio (Redfield, 1934, 1958). The National Oceanic & Atmospheric Administration/U.S. Environmental Protection Agency Team on Near Coastal Waters (USDOC, 1990b) suggested that N:P ratios between 10:1 to 20:1 were the range for which a potentially limiting nutrient could not be determined with any assurance without site-specific information. Where N:P ratios fall between 10:1 and 20:1, the potentially limiting nutrient may be highly dependent upon the species of phytoplankton present. Outside of this range, there may be insufficient nitrogen to balance all of the available phosphorus, or vice versa. Silica is also an important nutrient for phytoplankton growth and is likely to limit diatom growth when adequate supplies of the other nutrients are present. Silica is required by diatoms in proportions of Si:N:P=20:16:1 (Redfield, 1958).

With time, changes in single or multiple nutrients and the relative proportion of these nutrients are important indicators of nutrient enrichment. These changes are important to understand, if only because nitrogen is commonly thought to be limiting phytoplankton growth in coastal and oceanic waters (*e.g.*, Harris, 1986; Valiela, 1984). However, not all coastal systems are nitrogen-limited (Turner *et al.*, 1990), nor is changing nutrient loading the only factor influencing phytoplankton growth (Skreslet, 1986). Marine phytoplankton may also respond differently to nutrient additions that are introduced gradually or suddenly, with changing flushing rates or salinity, and with cell density (Sakshaug *et al.*, 1983; Sommer, 1985; Suttle and Harrison, 1986; Turpin and Harrison, 1990). In many cases, determination of the limiting nutrient in a system is difficult because there is no single, generally accepted method for determination.

## Sources of Nutrient Enrichment--Anthropogenic Factors

As human activities have increased within the drainage area of the Gulf of Mexico, nutrient loads within the rivers draining into the Gulf have increased. This has resulted in eutrophication of some of the estuaries and near coastal waters of the Gulf. Human population growth; increased numbers of animals in concentrated feeding operations; application of fertilizers on cropland, parks, and lawns; along with manufacturing, mining, construction, increased use of fossil fuels for energy; and other associated activities have each contributed to the increase in nutrients. The implications of these nutrient contributions to rivers, estuarine systems, and coastal waters are a matter for concern. Long-term changes in coastal systems have been documented worldwide where major rivers deliver nutrient enriched waters to coastal seas. (Nehring, 1984; Fransz and Verhagen, 1985; Rosenberg, 1985; Lancelot *et al.*, 1987; Anderson and Rydberg, 1988; Wulff and Rahn, 1988; Turner and Rabalais, 1991b).

**Table 2.3** ***Major Sources of Nutrient Enrichment Problems in the Gulf of Mexico***

**POINT SOURCES:**

**Industrial Point Sources**
(including food processing facilities and fertilizer manufacturing plants)

**Municipal Wastewater Treatment Plants**

**NONPOINT SOURCES:**

**Agricultural Nonpoint Sources**
- Crop Production
  - --Rainfed
  - --Irrigation
- Livestock Production (including dairies, aquacultural operations, poultry feeding operations, swine feeding operations, and other concentrated feeding operations)
- Silviculture

**Urban and Suburban Nonpoint Sources**
(including storm run-off, individual septic tanks, and golf courses)

**Atmospheric Deposition**

**OTHER SOURCES OF NUTRIENTS:**

**Transport from Offshore Waters**

**Sanitary Discharges from Boats & Ships**

## Point Sources

**Industrial Point Sources.** The Gulf of Mexico region has 3,700 permitted point sources of pollution--more than any other region in the U.S. (USDOC, 1990b). Over half of the 3,700 permits are to industrial facilities. A federal government-sponsored study found that 347 major permits are to industrial facilities that discharge wastes through pipelines directly into the waters of the Gulf and its surrounding estuaries (Weber *et al.*, 1992). These were distributed among the Gulf States as follows: Texas (192), Louisiana (79), Mississippi (30), Alabama (29), and the Gulf Coast of Florida (17). The majority of these permitted dischargers are petroleum refineries and petrochemical plants, although there are many forest product and fish processing permits as well. Galveston Bay, TX, has the greatest concentration of permitted point sources, followed by Mississippi Sound (USDOC, 1991a).

In addition to these direct point source dischargers, there are many other permitted sources that discharge their treated wastes into streams and rivers that ultimately flow into the Gulf. After draining more than 40 percent of the land area of the contiguous U.S., the Mississippi River flows into the Gulf transporting large amounts of contaminants from other parts of the country (Weber *et al.*, 1992).

**Municipal Wastewater Treatment Plants.** The coastal regions of the Gulf of Mexico have experienced rapid population growth in recent years along with its associated burdens. The most significant burdens are changes in land use patterns as more land becomes urbanized (or suburbanized), and the increased need for the treatment and discharge of sewage. There are 1,293 permitted municipally-owned waste water treatment plants in Gulf of Mexico estuarine drainage areas (USDOC, 1990b). Most municipal wastewater treatment plants provide secondary treatment and discharge treated waste, including nutrients, into receiving waters. The 113 municipalities immediately surrounding the Gulf release more than a billion gallons a day of treated sewage effluent into Gulf waters (Weber *et al.*, 1992). Waste treatment loads in Florida are expected to increase by more than three hundred percent by the year 2000; similar trends can be expected elsewhere (USDOC, 1990b).

**Accidental Spills.** Accidental spills and discharges that exceed permit limitations continue to present risks to human health and the environment. The major source of pollutants entering the Mississippi River in Louisiana, other than permitted industrial and municipal discharges, is accidental spills. During the period from October 1989 through September 1991, the Louisiana Department of Environmental Quality, Water Quality Management Division investigated 1,524 spills statewide. Ambient monitoring for priority organic pollutants in the Mississippi River has revealed that, most of the time, few, if any, pollutants are detected, and when detected, they are usually associated with short-term spill events (LADEQ, 1992).

### *Nonpoint Sources*

Nonpoint sources have been identified as the main factor contributing to a large and recurring area of oxygen-depleted waters off the Louisiana coast. There is evidence of oxygen-depleted waters in other parts of the Gulf as well. Nonpoint sources have also been identified as the primary pollution factor in many estuaries nationwide that are too polluted to support fishing, swimming, and the propagation of marine life. (Weber *et al.*, 1992).

**Agricultural Nonpoint Sources.** Fertilizer use on agricultural land is a source of nutrients. Agricultural activity accounts for 31 percent of the land use in the Gulf of Mexico region (USDOC, 1990b); however, agricultural land use is probably declining in some areas due to increased urbanization. With this land use comes the application of fertilizers and pesticides.

The use of fertilizer by agricultural operations has increased dramatically in the U.S. since the 1940s (see **Figure 2.3**), along with more intense cropping systems, concentration of livestock operations, changes in land ownership and leasing patterns, and greater implementation of drainage and tillage practices. These changes in farming operations have created a higher potential for nutrient contribution to the bays and estuaries. The application of fertilizer to agricultural lands in the Gulf of Mexico estuarine drainage areas is substantial depending on the type of agriculture. In 1989, the greatest applications per acre within Gulf of Mexico watersheds were around the Galveston Bay, Matagorda Bay, and Lower Laguna Madre estuaries.

Nutrient runoff from fertilizers is a significant nutrient source (greater than 25 percent of the total inputs of either phosphorus or nitrogen) in South Ten Thousand Islands, North Ten Thousand Islands, Charlotte Harbor, Suwannee River, Lower Laguna Madre, Apalachee Bay, Choctawhatchee Bay, Pensacola Bay, Perdido Bay, Matagorda Bay, San Antonio Bay, Aransas Bay, and Corpus Christi Bay (USDOC, 1990b). This runoff includes fertilizer, which has been picked up by runoff water or eroding sediment and transported off-site, runoff from excess applications of fertilizer due to improper management, as well as direct discharges and runoff from fertilizer manufacturing facilities.

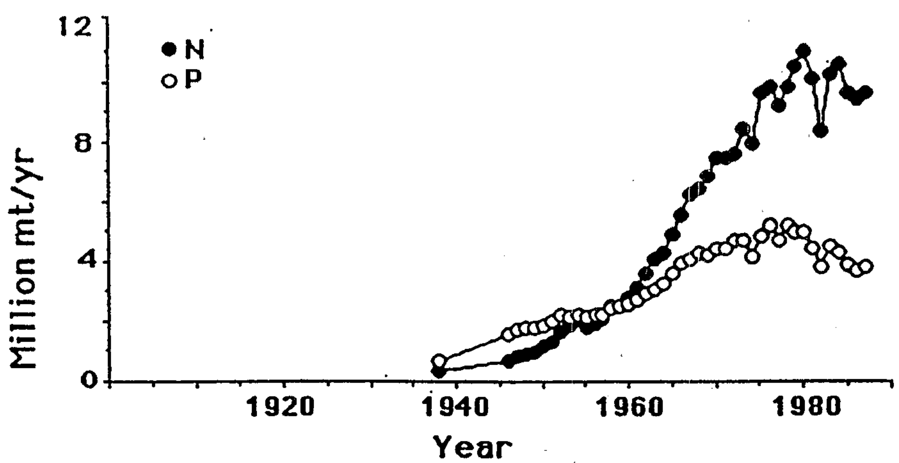
Widespread changes in nutrient loading to coastal zones has also changed the annual and seasonal variability of nutrient concentration. Fertilizer is usually applied in the spring, just before or during the planting period. A spring rise in nitrate concentration is now evident in the lower Mississippi River at St. Francisville and New Orleans, Louisiana, and a previous seasonal signal in silicate concentration is no longer evident (Turner and Rabalais, 1991b). Increased nutrient enrichment during the spring may be attributed to the following: 1) increased fertilizer applications reach the Gulf of Mexico via smaller, shorter rivers that flow directly into the Gulf; 2) runoff is greatest in the spring and is therefore more likely to carry additional nutrients; and 3) during the lag time between winter and spring, nutrient levels in the water are higher because plants are growing slower and are consuming fewer nutrients.

Animal waste runoff may be another potential nutrient source related to agricultural activities. In some cases, feed lots are considered point sources since they generate large quantities of waste that should be treated in mass. By leaching into ground water or running off into surface water, animal manure can contaminate drinking water with nitrates and cause eutrophication of ponds, lakes, and estuaries. Excessive eutrophication and releases of ammonia from urine may have adverse effects on fish. In addition, bacteria from animal manure has resulted in the closure of shellfish beds (USEPA, 1992).

Other agricultural sources of nutrients may be the improper handling or storage of manure or the application of manure to land at rates that exceed crop uptake, resulting in excessive manure supplies. Also, although farmers may apply manure to cropland at agronomic rates, water resource degradation still may occur because the rate of nutrient release in manure is not synchronized with the rate of nutrient uptake in the crop (USEPA, 1992).

Additional nutrients are released through decomposition of vegetation, soil erosion in general, and mineralization.

**Figure 2.3** ***Nitrogen (as N) and Phosphorus (as $P_2O_5$ Equivalent) Fertilizer Use This Century in the U.S. Up To 1987 - 1988***




**(Source: Turner and Rabalais, 1991b)**

**Silvicultural Nonpoint Sources.** Approximately 50 percent of the land area in the five Gulf States is classified as timberland, covering a wide range of types. Fourteen percent of the timberland area are pine plantations, 23 percent are natural pine stands, 17 percent are mixed pine/hardwood stands, 22 percent are bottom land hardwood stands, and 24 percent are upland hardwood stands. Combined timber products are the highest valued agricultural crop in the Gulf States with the total value exceeding $2 billion. During the past ten years, 3-5 percent of the total timberland acreage was disturbed to some degree by timber management, natural occurrences, or activities associated with community development or agriculture. Various studies have allocated 3-9 percent of total nonpoint pollution to forest land management activities on a broad watershed basis. However, increases in runoff and sediment can be significant on an individual stream reach or tributary watershed. Silvicultural best management practices have been proven to be effective in preventing nonpoint pollution in the form of excess sediment and nutrients when adequately utilized. Each of the Gulf States has a voluntary silvicultural nonpoint pollution program in place. State forestry agencies manage the programs and monitor compliance and effectiveness.

**Urban & Suburban Nonpoint Sources.** Septic tanks and other forms of on-site sewage disposal systems (OSDS) are commonly used by residences in Gulf rural areas. Septic tanks in coastal areas and estuarine watersheds may represent a major source of nutrients in coastal waters. Such systems are relatively inefficient at degrading human wastes unless several conditions are maintained, including unsaturated soil conditions, minimal densities, and routine pumping of solids from the tank. Typically, these systems do very little to prevent nitrogen from entering ground water; a nitrogen removal rate of 20 percent is typical in conventional systems. Effluent leaving a typical septic system is estimated to have a total nitrogen concentration of 40-60 mg/L, primarily in the form of ammonia and organic nitrogen. These forms are readily converted to nitrates in the drainage field, and could result in groundwater contamination.

Other urban and suburban nonpoint sources of nutrients include storm water runoff from sites such as industries, golf courses, and residential lawns. A recent report indicates that runoff from residential use of commercial fertilizers and pesticides in Houston may be impacting the Galveston Bay watershed (Newel *et al.*, 1992).

**Atmospheric Deposition.** Atmospheric deposition results when nitrogen and sulfur compounds or other substances, such as heavy metals and toxic organic compounds, are transformed by complex chemical processes and deposited on the earth away from the original sources. The transformed chemicals return to the earth in either a wet or dry form. The wet forms can fall to the earth in the form of rain, snow, or fog; the dry forms may exist as gases or particulates. Once these transformed substances reach the earth, they can pollute surface waters, including rivers, lakes, and estuaries.

The worldwide rise in the concentration of nitrogen in rainfall and snowfall is symptomatic of the extent of human activities on the environment. The importance of atmospheric inputs of essential nutrients has only recently been understood, but is clearly important and changing (Morris, 1991). Atmospheric sources of ammonium ($NH_4^+$) may also be generated from livestock wastes (concentrated production) (Morris, 1991). Emissions from power plants and industrial boilers, as well as urban air pollution, may be sources of increased nitrogen in surface waters.

### Other Sources of Nutrients

Another potential source of nonpoint source pollution in tributaries and near-coastal waters is transport from waters far offshore. This problem may involve the transport of phosphorus into estuaries with subsequent adsorption into fine sediment (suspended and in-place) and subsequent use by plants. Estuaries along the east coast have been adversely affected by phosphate that has been transported from the continental shelf, a major and uncontrollable source. Consequently, the benefits of a strategy to control phosphorus may be diminished. Several phosphorus control measures should be evaluated to determine the relative magnitude of phosphorus loads from the land versus loads from the sea. Mass balances may determine whether observed phosphorus concentrations can be accounted for or not.

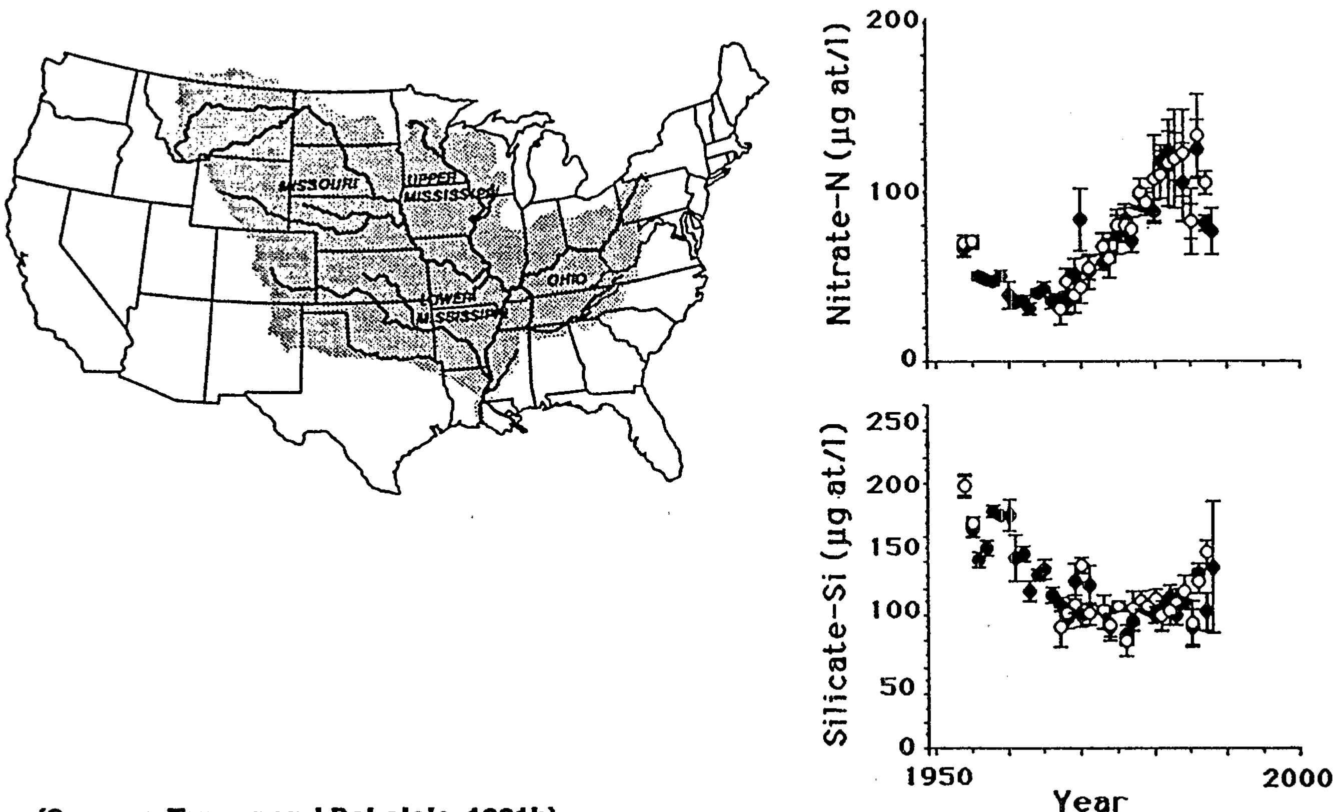
Erosion of soils will mobilize the organic carbon and nutrients found in those soils. While some of this material may be refractory (*i.e.*, unreactive), there is nonetheless the potential to cause further oxygen depletion in areas where human activities accelerate this erosion. This oxygen depletion occurs through the bacterial respiration of the organic matter, as well as through the stimulation of productivity by the associated nutrients. **Table 2.5** shows that soil loss from croplands can be substantial. However, erosion is likely to be of special concern for marshy areas, which typically have a high organic content. Coastal Louisiana, which is experiencing a high loss of wetlands, may be particularly affected by this issue. No detailed examination of this potential problem has been performed.

An additional nonpoint source of nutrients in the Gulf may be sanitary discharges from boats and ships.

## Mississippi River as a Conduit for Upstream Sources of Nutrients

Nutrient inputs and concentrations within an estuarine body or coastal area originate from sources outside the system and from within the system. The relative proportion of nutrients will likely vary down the stem of an estuary. An example of water quality changes in the U.S. is represented by the nitrate and silicate concentrations in the Mississippi River, which drains 40 percent of the U.S. and is the dominant freshwater inflow source into the Gulf of Mexico. The average annual nitrate-nitrogen concentration doubled after 1950, and the silicate concentration was reduced by half (see **Figure 2.4**) (Turner and Rabalais, 1991b). The average annual nitrate concentration is affected by a broad range of human activities within the watershed. The annual silicate concentration in the river has been reduced, presumably because phosphorus stimulates diatom growth and diatoms sink to lake and reservoir sediments, thus storing silica that would otherwise go into the water column and downstream (Turner and Rabalais, 1991b).

**Figure 2.4** ***Generalized Diagram of the Drainage Basin of the Mississippi River and the Changes in Nitrate & Silicate in the Lower Mississippi River***




**(Source: Turner and Rabalais, 1991b)**

For an average day in 1989, it is estimated that more than 171,914 kg (189.5 tons) of phosphorus and more than 849,441 kg (936.3 tons) of nitrogen (TKN) were discharged into the Gulf of Mexico from the surface waters of the U.S. (Lovejoy, 1992). Based on a 1989 National Oceanic & Atmospheric Administration/U.S. Environmental Protection Agency report, approximately 72 percent of the total loadings of nitrogen and 74 percent of the total loadings of phosphorus come from the Mississippi River system alone (including the Atchafalaya River), originating far upstream from the Gulf of Mexico (USDOC, 1989).

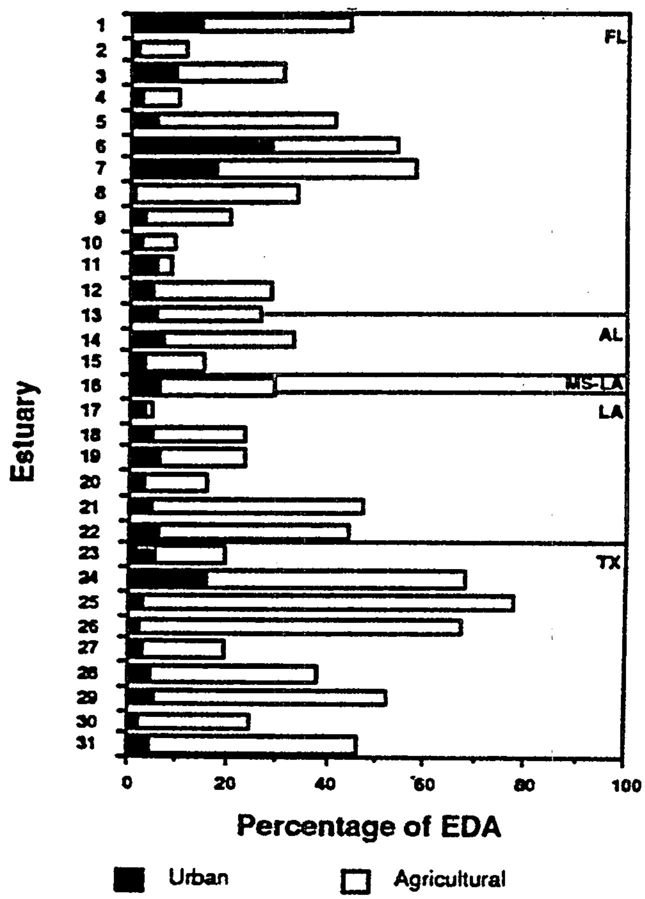
Increased loadings of nutrients from outside the system can lead to increased primary production (Nixon *et al.*, 1986; Oviatt *et al.*, 1986a,b; Malone, 1987) The quantification of these relationships and paths of nutrient uptake and regeneration are not, however, adequately known. Several studies suggest that recycled nutrients account for a greater percentage of the ambient nutrient concentration than the "new" load entering the system each year (Boynton *et al.*, 1982; Kemp *et al.*, 1982; Fisher and Doyle, 1987). Although recycled nutrients from within the system are essentially unmanageable, an understanding of their contributions is necessary to understand the effects of all sources of nutrient inputs.

From the Lovejoy analysis (Purdue University), it is clear that the regions of the Ohio River basin and the Upper Mississippi River basin are the major sources of both nitrogen and phosphorus during much of the year. In both of these regions, nonurban nonpoint sources provide by far the largest sources of nutrient pollution to the waterways. Therefore, policies directed toward decreasing nutrient runoff from nonurban lands in these upstream regions would have the biggest impact on programs to reduce nutrient pollution in the Gulf of Mexico.

## Selected Characteristics of Gulf of Mexico Estuaries

The Gulf of Mexico ranks first among U.S. regions in total square miles of estuarine drainage area (EDA) and in total water surface area. Within the Gulf of Mexico region, the estuaries vary substantially with respect to size, relative size of fluvial drainage area, amount of freshwater inflow, hydrologic characteristics, variability in freshwater inflow, precipitation patterns, tidal cycles, and land use patterns. **Figure 2.5, Table 2.4,** and **Table 2.5** provide information on physical and hydrologic features, economic activities, and demographics for major estuaries within the Gulf of Mexico. More specific analyses of nitrogen and phosphorus loadings are provided in **Table 2.6** and **Table 2.7**; however, please note that these tables are based on 1987 data.

**Figure 2.5** ***Urban & Agricultural Land Use in Gulf of Mexico Estuaries***




**(Source: Modified from USDOC, 1990b)**

## Table 2.4 *Selected Characteristics of Gulf of Mexico Estuaries*

SELECTED CHARACTERISTICS OF GULF OF MEXICO ESTUARIES

| | | PHYSICAL AND HYDROLOGIC FEATURES | | | | | | | ECONOMIC ACTIVITIES | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Land Use (% of EDA) | | Point Sources of Pollution | |
| Map ID# | Estuary | Estuarine Drainage Area (100 sq.mi.) | Total Drainage Area (100 sq.mi.) | Water Surface Area (sq.mi.) | Average Depth (ft.) | Avg. Daily Freshwater Inflow (100 cfs) | Volume (billion cu ft.) | Population Density 1980 (per sq.mi.) | Urban | Agriculture | Industrial | MWTP |
| | GULF OF MEXICO | | | | | | | | | | | |
| 1 | Florida Bay | 11 | 11 | 538 | 8 | N/D | 110 | 17 | 14 | 30 | 0 | 3 |
| 2 | So. Ten Thousand Islands | 13 | 13 | 77 | 7 | N/D | 14 | 29 | 2 | 9 | 0 | 0 |
| 3 | No. Ten Thousand Islands | 9 | 21 | 192 | 6 | N/D | 31 | 3 | 9 | 22 | 0 | 3 |
| 4 | Rookery Bay | 2 | 2 | 14 | 5 | N/D | 2 | 31 | 2 | 8 | 0 | 1 |
| 5 | Charlotte Harbor | 50 | 50 | 311 | 8 | 48 | 73 | 105 | 5 | 36 | 56 | 22 |
| 5a | Caloosahatchee River | 14 | 14 | 26 | 5 | 19 | 3 | 127 | 4 | 29 | 10 | 6 |
| 6 | Sarasota Bay | 3 | 3 | 44 | 6 | 4 | 8 | 923 | 28 | 26 | 6 | 11 |
| 7 | Tampa Bay | 26 | 26 | 346 | 13 | 24 | 123 | 476 | 17 | 40 | 69 | 29 |
| 8 | Suwannee River | 19 | 102 | 42 | 5 | 112 | 6 | 24 | 1 | 33 | 3 | 3 |
| 9 | Apalachee Bay | 37 | 46 | 159 | 10 | 53 | 45 | 64 | 3 | 17 | 21 | 5 |
| 10 | Apalachicola Bay | 30 | 205 | 214 | 9 | 291 | 54 | 15 | 2 | 7 | 3 | 4 |
| 11 | St. Andrew Bay | 11 | 11 | 94 | 12 | 45 | 31 | 65 | 5 | 3 | 12 | 7 |
| 12 | Choctawhatchee Bay | 23 | 54 | 129 | 14 | 85 | 51 | 42 | 4 | 24 | 3 | 8 |
| 13 | Pensacola Bay | 35 | 70 | 143 | 13 | 116 | 51 | 72 | 5 | 21 | 6 | 6 |
| 14 | Perdido Bay | 12 | 12 | 50 | 7 | 22 | 10 | 121 | 7 | 26 | 6 | 12 |
| 15 | Mobile Bay | 49 | 446 | 409 | 10 | 793 | 113 | 85 | 3 | 12 | 101 | 41 |
| 16 | Mississippi Sound | 121 | 269 | 1,850 | 11 | 436 | 568 | 125 | 6 | 23 | 197 | 173 |
| 16a | Lake Borgne | 79 | 148 | 282 | 9 | 251 | 74 | 134 | 9 | 26 | 1 | 119 |
| 16b | Lake Pontchartrain | 55 | 55 | 710 | 11 | 107 | 220 | 122 | 7 | 27 | 1 | 116 |
| 17 | Breton/Chandeleur Sounds | 25 | 25 | 2,086 | 8 | 103 | 420 | 384 | 3 | 1 | 1 | 9 |
| 18 | Mississippi River | 19 | 11,317 | 600 | 26 | 4,644 | 386 | 326 | 4 | 19 | 11 | 16 |
| 19 | Barataria Bay | 22 | 22 | 646 | 5 | 55 | 90 | 203 | 6 | 17 | 1 | 21 |
| 20 | Terrebonne/Timbalier Bays | 16 | 16 | 680 | 6 | 46 | 110 | 67 | 3 | 13 | 0 | 30 |
| 21 | Atchafalaya/Vermillion Bays | 72 | 1,006 | 703 | 7 | 2,238 | 137 | 76 | 3 | 34 | 7 | 71 |
| 22 | Calcasieu Lake | 11 | 43 | 99 | 9 | 63 | 26 | 117 | 6 | 38 | 1 | 8 |
| 23 | Sabine Lake | 48 | 209 | 94 | 8 | 172 | 21 | 92 | 5 | 14 | 164 | 56 |
| 24 | Galveston Bay | 45 | 245 | 540 | 6 | 152 | 92 | 665 | 16 | 50 | 747 | 566 |
| 25 | Brazos River | 28 | 468 | 2 | 8 | 74 | <1 | 57 | 5 | 71 | 40 | 49 |
| 26 | Matagorda Bay | 59 | 503 | 422 | 7 | 53 | 78 | 26 | 2 | 58 | 113 | 46 |
| 27 | San Antonio Bay | 5 | 109 | 205 | 4 | 41 | 25 | 10 | 3 | 16 | 17 | 2 |
| 28 | Aransas Bay | 28 | 28 | 208 | 5 | 10 | 31 | 33 | 4 | 34 | 104 | 16 |
| 29 | Corpus Christi Bay | 20 | 176 | 192 | 8 | 12 | 42 | 152 | 5 | 47 | 183 | 21 |
| 30 | Upper Laguna Madre | 55 | 55 | 216 | 3 | 6 | 15 | 84 | 2 | 23 | 50 | 13 |
| | Baffin Bay | | 35 | 92 | 4 | 4 | 11 | 27 | 1 | 31 | 18 | 7 |
| 31 | Lower Laguna Madre | 58 | 58 | 366 | 3 | 3 | 26 | 19 | 4 | 42 | 79 | 41 |
| | TOTAL | 962 | 15,621 | 11,671 | 8 | 9,701 | 2,789 | 122 | 5 | 30 | 2,000 | 1,293 |

**(Source: USDOC, 1990b)**

## Table 2.5 Nutrient Discharge Indicators by Entire Watershed

Gulf of Mexico Component of the Nutrient Enrichment Potential Watershed Comparison System

Draft, September 1992

### Nutrient Discharge Indicators by Entire Watershed

| NEI Code | Estuary | Land Area ca. 1990 (sq. mi.) | Population ca. 1990 (persons) | Population Change 1990-2010 (persons) | Total Cropland ca. 1987 (sq. mi.) | Harvested Cropland ca. 1987 (sq. mi.) | Soil Loss from Cropland ca. 1987 (tons) | Agricultural Fertilizer Sold, Nitrogen ca. 1990 (tons) | Agricultural Fertilizer Sold, Phosphorus ca. 1990 (tons) | Nitrogen from Animal Waste ca. 1987 (tons) |
|---|---|---|---|---|---|---|---|---|---|---|
| G010 | Florida Bay | 410 | 381,410 | 47,820 | 20 | 20 | 30,540 | 1,970 | 1,330 | 0 |
| G020 | South Ten Thousand Islands | 1,140 | 734,860 | 92,690 | 40 | 40 | 56,500 | 3,680 | 2,480 | 0 |
| G030 | North Ten Thousand Islands | 1,810 | 261,700 | 67,080 | 80 | 50 | 18,170 | 7,650 | 3,620 | 0 |
| G040 | Rookery Bay | 180 | 13,280 | 6,440 | 10 | 10 | 810 | 880 | 410 | 0 |
| G050 | Charlotte Harbor | 4,490 | 729,330 | 224,390 | 650 | 380 | 170,490 | 41,720 | 11,980 | 320 |
| G060 | Sarasota Bay | 210 | 93,180 | 27,190 | 10 | 10 | 4,210 | 990 | 380 | 10 |
| G070 | Tampa Bay | 2,100 | 1,508,070 | 301,660 | 330 | 190 | 93,710 | 23,180 | 10,170 | 1,460 |
| G080 | Suwannee River | 8,580 | 443,540 | 80,870 | 1,580 | 900 | 5,422,150 | 35,120 | 11,270 | 3,300 |
| G090 | Apalachee Bay | 6,360 | 373,800 | 78,230 | 690 | 400 | 2,825,180 | 15,210 | 5,390 | 810 |
| G100 | Apalachicola Bay | 19,820 | 2,567,580 | 415,210 | 3,550 | 2,030 | 16,595,500 | 70,330 | 27,010 | 7,560 |
| G110 | St. Andrew Bay | 1,190 | 130,500 | 38,140 | 40 | 20 | 170,890 | 890 | 1,040 | 30 |
| G120 | Choctawhatchee Bay | 5,240 | 266,090 | 37,750 | 920 | 440 | 4,933,810 | 14,890 | 7,250 | 3,810 |
| G130 | Pensacola Bay | 6,580 | 458,140 | 85,980 | 680 | 350 | 3,381,510 | 16,910 | 9,360 | 1,830 |
| G140 | Perdido Bay | 1,140 | 190,860 | 41,850 | 140 | 100 | 779,610 | 4,490 | 2,390 | 60 |
| G150 | Mobile Bay | 43,540 | 3,731,580 | 456,280 | 5,250 | 2,620 | 22,603,870 | 78,030 | 33,350 | 19,530 |
| G160 | Mississippi Sound | 24,620 | 2,562,690 | 498,050 | 2,530 | 1,060 | 10,795,890 | 73,740 | 28,340 | 13,680 |
| G170 | Breton/Chandeleur Sounds | 680 | 69,240 | 12,990 | 0 | 0 | 2,360 | 20 | 10 | 0 |
| G180 | Mississippi River | 1,175,750 | 68,101,400 | 7,805,370 | 463,250 | 304,040 | 1,074,211,240 | 8,251,760 | 3,070,390 | 543,250 |
| G190 | Barataria Bay | 1,620 | 477,580 | 127,300 | 150 | 90 | 357,000 | 3,870 | 250 | 0 |
| G200 | Terrebonne/Timbalier Bays | 1,030 | 79,980 | 16,910 | 60 | 30 | 213,680 | 1,680 | 100 | 0 |
| G210 | Atchafalaya/Vermilion Bays | 99,340 | 3,608,730 | 652,790 | 26,180 | 14,240 | 59,808,340 | 409,350 | 114,020 | 36,650 |
| G220 | Calcasieu Lake | 4,200 | 257,730 | 29,410 | 620 | 290 | 2,216,250 | 10,540 | 4,540 | 170 |
| G230 | Sabine Lake | 19,850 | 1,252,820 | 258,140 | 2,800 | 860 | 2,789,710 | 46,590 | 13,090 | 9,060 |
| G240 | Galveston Bay | 23,550 | 7,613,380 | 2,165,480 | 5,370 | 2,090 | 9,851,420 | 106,210 | 29,170 | 2,210 |
| G250 | Brazos River | 45,470 | 1,924,560 | 431,140 | 15,830 | 7,540 | 29,302,060 | 239,560 | 75,240 | 10,870 |
| G260 | Matagorda Bay | 46,810 | 1,526,360 | 392,220 | 10,400 | 4,770 | 17,904,540 | 121,210 | 42,960 | 3,100 |
| G270 | San Antonio Bay | 9,950 | 1,535,190 | 317,250 | 2,190 | 790 | 4,389,190 | 28,690 | 9,830 | 3,480 |
| G280 | Aransas Bay | 2,560 | 80,520 | 17,990 | 640 | 380 | 852,380 | 9,870 | 3,100 | 30 |
| G290 | Corpus Christi Bay | 17,150 | 389,520 | 81,650 | 2,350 | 1,080 | 3,259,220 | 27,230 | 10,270 | 750 |
| G300 | Upper Laguna Madre | 5,470 | 242,900 | 45,890 | 970 | 600 | 1,825,700 | 9,800 | 3,120 | 190 |
| G310 | Lower Laguna Madre | 4,670 | 613,790 | 162,200 | 1,340 | 970 | 1,513,020 | 29,650 | 8,830 | 110 |
| **Gulf of Mexico Total** | | **1,585,510** | **102,220,310** | **15,016,360** | **548,670** | **346,390** | **1,276,378,950** | **9,685,710** | **3,540,690** | **662,270** |

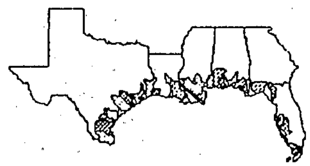
Note: All values rounded to tens. A zero (0) value for an indicator represents a number between 0.1 and 5.0

*Source: Pollution Sources Characterization Branch, NOAA*

## Table 2.6 Nitrogen Discharges in Tons, Circa 1987

Gulf of Mexico Component of the Nutrient Enrichment Potential Watershed Comparison System

Draft, September 1992



### Nutrient Discharge Indicators by Estuarine Drainage Area

| NEI Code | Estuary | WWTPs | Industries | Urban | Cropland | Pasture/ Range | Forestland | Upstream | TOTAL |
|---|---|---|---|---|---|---|---|---|---|
| | | Nitrogen Discharges in tons, circa 1987 | | | | | | | |
| G010 | Florida Bay | 0 | 0 | 20 | 0 | 0 | 0 | 0 | 20 |
| G020 | South Ten Thousand Islands | 0 | 0 | 50 | 10 | 20 | 0 | 0 | 80 |
| G030 | North Ten Thousand Islands | 0 | 0 | 60 | 0 | 90 | 0 | 0 | 150 |
| G040 | Rookery Bay | 10 | 0 | 10 | 0 | 10 | 0 | 0 | 30 |
| G050 | Charlotte Harbor | 390 | 560 | 570 | 10 | 1,430 | 0 | 0 | 2,960 |
| G060 | Sarasota Bay | 310 | 10 | 250 | 10 | 10 | 0 | 0 | 590 |
| G070 | Tampa Bay | 1,110 | 60 | 990 | 10 | 60 | 0 | 0 | 2,230 |
| G080 | Suwannee River | 0 | 0 | 70 | 170 | 1,800 | 0 | 5,300 | 7,340 |
| G090 | Apalachee Bay | 60 | 10 | 350 | 990 | 90 | 0 | 570 | 2,070 |
| G100 | Apalachicola Bay | 40 | 30 | 60 | 100 | 0 | 0 | 9,160 | 9,390 |
| G110 | St. Andrew Bay | 380 | 20 | 260 | 310 | 60 | 0 | 0 | 1,030 |
| G120 | Choctawhatchee Bay | 60 | 10 | 530 | 620 | 20 | 0 | 1,270 | 2,510 |
| G130 | Pensacola Bay | 250 | 340 | 910 | 1,330 | 1,250 | 0 | 990 | 5,070 |
| G140 | Perdido Bay | 120 | 50 | 260 | 650 | 2,230 | 0 | 0 | 3,310 |
| G150 | Mobile Bay | 910 | 650 | 550 | 1,210 | 3,960 | 0 | 14,190 | 21,470 |
| G160 | Mississippi Sound | 2,980 | 470 | 2,150 | 6,860 | 2,200 | 10 | 8,160 | 22,830 |
| G170 | Breton/Chandeleur Sounds | 0 | 50 | 10 | 0 | 30 | 0 | 0 | 90 |
| G180 | Mississippi River | 3,770 | 2,200 | 210 | 2,290 | 250 | 0 | 709,930 | 718,650 |
| G190 | Barataria Bay | 570 | 300 | 300 | 10 | 130 | 0 | 0 | 1,310 |
| G200 | Terrebonne/Timbalier Bays | 380 | 50 | 50 | 0 | 0 | 0 | 0 | 480 |
| G210 | Atchafalaya/Vermilion Bays | 1,900 | 810 | 900 | 5,870 | 440 | 0 | 8,640 | 18,560 |
| G220 | Calcasieu Lake | 360 | 3,880 | 210 | 80 | 30 | 0 | 1,160 | 5,720 |
| G230 | Sabine Lake | 860 | 1,290 | 760 | 890 | 1,450 | 0 | 1,770 | 7,020 |
| G240 | Galveston Bay | 7,900 | 1,520 | 1,410 | 2,690 | 80 | 0 | 6,230 | 19,830 |
| G250 | Brazos River | 830 | 20 | 170 | 1,570 | 60 | 0 | 24,100 | 26,750 |
| G260 | Matagorda Bay | 160 | 20 | 240 | 2,980 | 40 | 10 | 4,590 | 8,040 |
| G270 | San Antonio Bay | 20 | 90 | 70 | 50 | 120 | 0 | 7,490 | 7,840 |
| G280 | Aransas Bay | 100 | 0 | 200 | 650 | 20 | 10 | 0 | 980 |
| G290 | Corpus Christi Bay | 540 | 160 | 200 | 490 | 40 | 0 | 370 | 1,800 |
| G300 | Upper Laguna Madre | 70 | 0 | 160 | 690 | 5,570 | 0 | 0 | 6,490 |
| G310 | Lower Laguna Madre | 700 | 0 | 400 | 360 | 10,280 | 0 | 0 | 11,740 |
| **Gulf of Mexico Total** | | 24,780 | 12,600 | 12,380 | 30,900 | 31,770 | 30 | 803,920 | 916,390 |

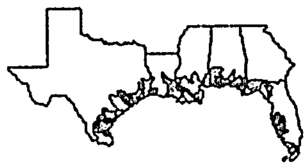
Note: All values rounded to tens. A zero (0) value for an indicator represents a number between 0.1 and 5.0

*Source: Pollution Sources Characterization Branch, NOAA*

# Table 2.7 Phosphorus Discharges in Tons, Circa 1987

Gulf of Mexico Component of the Nutrient Enrichment Potential Watershed Comparison System

Draft, September 1992



## Nutrient Discharge Indicators by Estuarine Drainage Area

### Phosphorus Discharges in tons, circa 1987

| NEI Code | Estuary | WWTPs | Industries | Urban | Cropland | Pasture/ Range | Forestland | Upstream | TOTAL |
|---|---|---|---|---|---|---|---|---|---|
| G010 | Florida Bay | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| G020 | South Ten Thousand Islands | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 10 |
| G030 | North Ten Thousand Islands | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 10 |
| G040 | Rookery Bay | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 10 |
| G050 | Charlotte Harbor | 150 | 450 | 90 | 0 | 10 | 0 | 0 | 700 |
| G060 | Sarasota Bay | 80 | 0 | 40 | 0 | 0 | 0 | 0 | 120 |
| G070 | Tampa Bay | 770 | 330 | 150 | 0 | 0 | 0 | 0 | 1,250 |
| G080 | Suwannee River | 0 | 0 | 10 | 0 | 20 | 0 | 40 | 70 |
| G090 | Apalachee Bay | 10 | 0 | 50 | 10 | 0 | 0 | 0 | 70 |
| G100 | Apalachicola Bay | 20 | 10 | 10 | 0 | 0 | 0 | 30 | 70 |
| G110 | St. Andrew Bay | 170 | 10 | 40 | 0 | 0 | 0 | 0 | 220 |
| G120 | Choctawhatchee Bay | 20 | 0 | 80 | 10 | 0 | 0 | 0 | 110 |
| G130 | Pensacola Bay | 40 | 50 | 140 | 10 | 10 | 0 | 0 | 250 |
| G140 | Perdido Bay | 100 | 0 | 40 | 10 | 20 | 0 | 0 | 170 |
| G150 | Mobile Bay | 400 | 40 | 80 | 10 | 40 | 0 | 160 | 730 |
| G160 | Mississippi Sound | 750 | 170 | 330 | 70 | 20 | 0 | 220 | 1,560 |
| G170 | Breton/Chandeleur Sounds | 0 | 30 | 0 | 0 | 0 | 0 | 0 | 30 |
| G180 | Mississippi River | 530 | 10,590 | 30 | 20 | 0 | 0 | 5,110 | 16,280 |
| G190 | Barataria Bay | 160 | 1,720 | 50 | 0 | 0 | 0 | 0 | 1,930 |
| G200 | Terrebonne/Timbalier Bays | 200 | 10 | 10 | 0 | 0 | 0 | 0 | 220 |
| G210 | Atchafalaya/Vermilion Bays | 840 | 230 | 140 | 60 | 0 | 0 | 220 | 1,490 |
| G220 | Calcasieu Lake | 100 | 2,180 | 30 | 0 | 0 | 0 | 70 | 2,380 |
| G230 | Sabine Lake | 520 | 350 | 120 | 10 | 10 | 0 | 640 | 1,650 |
| G240 | Galveston Bay | 4,900 | 730 | 210 | 30 | 0 | 0 | 100 | 5,970 |
| G250 | Brazos River | 520 | 10 | 30 | 20 | 0 | 0 | 380 | 960 |
| G260 | Matagorda Bay | 100 | 10 | 40 | 30 | 0 | 0 | 40 | 220 |
| G270 | San Antonio Bay | 10 | 50 | 10 | 0 | 0 | 0 | 100 | 170 |
| G280 | Aransas Bay | 60 | 0 | 30 | 10 | 0 | 0 | 0 | 100 |
| G290 | Corpus Christi Bay | 330 | 20 | 30 | 10 | 0 | 0 | 40 | 430 |
| G300 | Upper Laguna Madre | 40 | 0 | 20 | 10 | 60 | 0 | 0 | 130 |
| G310 | Lower Laguna Madre | 450 | 10 | 60 | 0 | 100 | 0 | 0 | 620 |
| | **Gulf of Mexico Total** | 11,280 | 17,000 | 1,890 | 320 | 290 | 0 | 7,150 | 37,940 |

Note: All values rounded to tens. A zero (0) value for an indicator represents a number between 0.1 and 5.0

Source: Pollution Sources Characterization Branch, NOAA

## Reversal of Eutrophication

This section provides three examples (Bayou Texar, Florida; Tampa Bay, Florida; and Houston Ship Channel, Texas) of the results of reversing eutrophication. These three studies document the obvious possibilities for recovery following a reduction in nutrient loading. When the causes of eutrophication are reversed, the symptoms may be reversed; but recovery varies with the cycling rate of various stored nutrients, and the flushing rate of the water body. Seagrasses, at least those that are inhibited by reduced light penetration that often accompanies eutrophication, may eventually recover over time.

**Bayou Texar, Florida.** The eutrophication of Bayou Texar, near Pensacola, Florida, was studied to determine the causes of and remedies for extensive fish kills (up to five weeks) and recreational closures. Dinoflagellate blooms (primarily *Ceratium* sp. and *Gymnodinium* sp.), chrysophytes (primarily from genera *Chrysochromulina* and *Chromulina*), diatoms (*Navicula* and *Cyclotella*), and high algal biomass all contributed to low dissolved oxygen levels (Moshiri *et al.*, 1981). In 1974, a retention reservoir and weirs in the upstream channels were built, and sewage treatment plants were repaired. The authors reported an almost total elimination of fish kills, a 90 percent reduction in phytoplankton primary production, and virtual elimination of algal blooms. However, fish kills in recent years (1988-1990) indicate that the problem has not completely disappeared.

**Tampa Bay, Florida.** In Hillsborough Bay, near Tampa Bay, Florida, results of water quality restoration have also been documented (Johansson and Lewis, 1992). Tampa Bay was determined to be highly eutrophic during the late 1960s. The City of Tampa's primary sewage treatment plant and runoff from fertilizer industry activities were considered as the major sources of excessive nutrient loading (Johansson and Lewis, 1992). A principal concern was the loss of submerged macrophytes (*Halodule wrightii*), presumably because of increased turbidity following eutrophication. Other concerns included anoxia and high coliform counts. Following improved sewage treatment (between 1979 and 1980), the nitrogen loading to Hillsborough Bay was reduced by 30 percent. It was not until four years later that the ambient chlorophyll *a* concentration decreased substantially, which was coincident with the decline in a nuisance planktonic blue-green algae, *Schizothrix calcicola sensu* Drouet.

A major increase in seagrasses, which had been reduced to 20 percent of the areal coverage of 100 years ago, occurred in 1984; followed by a doubling in areal coverage (Hillsborough Bay and Middle Tampa Bay) from 1986 to 1989. Seagrasses in most shallow areas, however, have not yet recovered, and high concentrations of chlorophyll *a* persist. Major sources of nitrogen and phosphorus are fertilizer plants and storage facilities, as well as leakage at loading terminals.

**Houston Ship Channel, Texas.** The Houston Ship Channel (HSC) is located in Harris County within the San Jacinto River Basin on the southeast Texas coast.

Water quality in HSC is influenced by a variety of point and nonpoint sources. Approximately 400 industrial and municipal facilities discharge into HSC and its tidal tributaries. The system is impacted by urban runoff from the cities of Houston, Pasadena, Deer Park, and others located on HSC and its tributaries. Other potentially important nonpoint pollutant pathways include ground water and atmospheric deposition. Long-term impacts result from the nearly constant ship traffic, periodic dredging, as well as episodic discharges and spills.

While water quality in HSC was believed to be improving, water quality trends until recently had not been adequately verified and documented. In 1991, USEPA--Region 6 conducted a preliminary study to evaluate and document water quality trends in HSC during the last 10-20 years (Crocker *et al.*, 1992). Mean concentrations of dissolved oxygen (DO) were lowest at the turning basin, and increased progressively moving downstream. Significant increasing trends in DO concentrations were apparent at the turning basin, Greens Bayou, and San Jacinto Monument. The trend for DO further downstream at Channel Marker 120 and Morgans Point is decreasing. The reason for this is not known, although it is possible that point source biochemical oxygen demand (BOD) loading in this segment may be increasing. Another possible reason is that there may be a decrease in higher DO concentrations resulting from supersaturation caused by phytoplankton blooms.

Significant downward trends in total organic carbon (TOC) were found, and the rate of reduction was similar at each sampling station. Average concentrations of ammonia-nitrogen are the greatest at the turning basin and decrease progressively downstream. As with TOC, significant declines in ammonium are occurring at each station. These findings appear to reflect the dramatic reductions in loading resulting from increased sewage treatment efficiency demonstrated during 1984-1991. As with ammonia-nitrogen, average concentrations of nitrate were greatest in the turning basin and decreased downstream, although differences by each station were much less extreme. Of great interest was the finding of significant increasing trends at every station with the rate of increase proportional to the average concentrations (*i.e.*, highest at turning basin, lowest at Morgans Point). The results suggest that municipal treatment plants are increasing efficiency with regard to discharges of ammonia-nitrogen, but the form of nitrogen is shifting to nitrate.

Average concentrations of nitrite were lowest at the turning basin and Morgans Point and about the same at the other three stations. In general, levels appear to be increasing although this was most significant at the Greens Bayou location. The weaker increases observed for nitrite may be due to effective oxidation to nitrate in treatment plants or in the receiving waters.

As with nitrogen compounds, average total Kjeldahl nitrogen concentrations were highest in the turning basin and decreased downstream. A bimodal trend was found with significant decreases over time at the three upstream stations, although no apparent trend was found at channel marker 120, and an upward trend was found at Morgans Point. Increases may be due to point source inputs. Again, for total phosphorus, the averages were highest upstream at the turning basin and decreased downstream. Significant decreasing trends were found for all sites.

The fish community serves as an overall indicator of ecological health of the system. Sampling in the late 1950s found the portion of HSC above the tidal San Jacinto River to be virtually devoid of aquatic life. By the mid-1970s, diversity and utilization of segment 1006 (San Jacinto River and Greens Bayou) had improved, with segment 1007 (Greens Bayou to turning basin) remaining unsuitable habitat. A 1991 study (Seiler *et al.*, 1991) documented further improvement and diversification of the fish community during 1988-1989. There was extensive use of the upper portions of HSC as habitat for juvenile fishes and invertebrates. Segment 1006 maintained a diverse, viable fish population throughout the year. During winter months richness and abundance in segment 1007 equaled or exceeded that of 1006. During periods of low dissolved oxygen, segment 1007 continued to sustain a viable shoreline assemblage of organisms. The study confirms a trend of improvement in abundance and diversity over time, which is most likely reflective of water quality conditions resulting from more stringent regulatory control of point source discharges. Overall, available data strongly indicate that all three HSC segments studies are supporting an aquatic life use.

## Summary of Status & Trends in Indicators of Nutrient Enrichment

Each of 58 estuaries in the Gulf of Mexico was placed within a category describing its condition (Rabalais, 1992). Categories were determined based on identifiable effects of nutrient enrichment, as well as the less obvious, indirect effects. Based on the literature and data available, classifications of each estuary by indicators of nutrient enrichment were treated as uniformly as possible. A summary of the status of each estuary is given in **Table 2.8** and **Figure 2.6** (Rabalais, 1992), with codes defined as follows:

| | | | |
|---|---|---|---|
| **Y** | - | **Yes** | There is a problem in estuarine condition due to nutrient enrichment. |
| **P** | - | **Potential** | There is a potential problem, no real data, but some indicators that the estuary, or a subunit of the estuary, may be on the brink of water quality problems. |
| **N** | - | **No** | There is not a problem. |
| **?** | - | **Insufficient Data** | There are insufficient data to make a determination, but limited data may support a tentative conclusion of Yes, No, or Potential. |

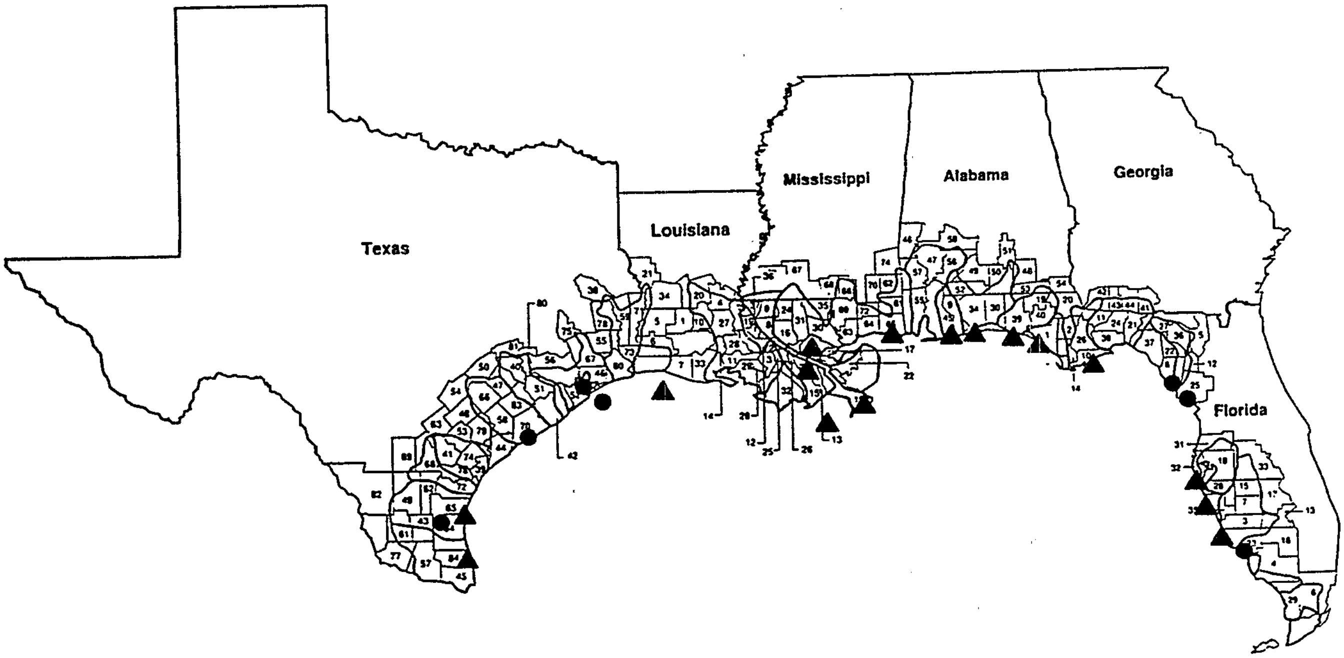
There are notable instances of "?"s, indicating lack of sufficient data to draw conclusions across many Gulf of Mexico estuaries. The "Yes" and "Potential" categories, however, are not short lists, and no state is excluded. Areas with known or potential problems related to nutrient enrichment should be addressed. The number of estuaries without problems (or unknown, but unsuspected), outweigh those with problems, or potential problems. These estuaries are still of concern because land use and water management practices may change and other human-induced changes or factors may impinge on these water bodies (*e.g.*, altered freshwater inflow, dredging, chemical pollution).

## Table 2.8 *Compilation of Status Matrix Indicators of Nutrient Enrichment*

| Yes | Potential | ?, but Yes | ?, but Potential | ?, but No | No |
|---|---|---|---|---|---|
| | | | | | |
| Charlotte Harbor | Caloosahatchee R. | Mississippi Sound | Mobile Bay | Chatham Bay | Whitewater Bay |
| Sarasota Bay | Suwanee R. | Pascagoula Bay | Breton/Chandeleur | Apalachee Bay | Big Lostman's Bay |
| Tampa Bay | Deadmans Bay | | Terrebonne Bay | East Miss. Sound | Flor. Inner Shelf (SW) |
| St. George Sound | Galveston Bay | | | St. Louis Bay | Crystal River |
| St. Andrews Bay | Matagorda Bay | | | Pearl River | Withlacoochee R. |
| Choctawhatchee Bay | Baffin Bay | | | Lake Borgne | Waccasassa Bay |
| Pensacola Bay | Texas Inner Shelf, part | | | Caillou Bay | Aucilla River |
| Perdido Bay | | | | Vermilion Bay | Ochlockonee Bay |
| Biloxi Bay | | | | Mermentau | Apalachicola Bay |
| Lake Pontchartrain | | | | Lake Calcasieu | Flor. Inner Shelf (Panhandle) |
| Louisiana Inner Shelf | | | | Sabine Lake | Alabama Inner Shelf |
| Mississippi River | | | | Brazos River | Mississippi Inner Shelf |
| Barataria Bay | | | | E. Matagorda Bay | Atchafalaya R./Bay |
| Upper Laguna Madre | | | | Colorado River | Texas Inner Shelf, part |
| Lower Laguna Madre | | | | San Antonio Bay | |
| | | | | Aransas Bay | |
| | | | | Corpus Christi Bay | |
| | | | | Rio Grande Tidal | |

**(Source: Rabalais, 1992)**

**Figure 2.6** ***Gulf of Mexico Estuaries & Coastal Areas With Symbols Indicating Status of Nutrient Enrichment***




**Note: As listed in Table 2.8, Status Matrix, and explained in text. In this case, category of "PROBLEM?" Closed Triangle (▲) = Yes; Closed Circle (●) = Potential.**

**(Source: Rabalais, 1992)**

## Alabama

The estuarine systems of Alabama are dominated by the Mobile River delta and Mobile Bay. Other significant water bodies include Mississippi Sound and Perdido Bay. The Mobile Bay system, which supports significant natural resources, is experiencing intensive growth and development of coastal areas and water quality stress (Horn, 1990). Population growth is evidenced by an upsurge of condominiums in Baldwin County. Waterborne transportation may increase with the completion of the Tennessee-Tombigbee Waterway with Mobile Bay as its southern terminus. Exploitation of mineral resources, particularly natural gas, will increase. There are 106 industrial, 15 sewage, and 29 semi-private/small service sources of wastewater discharging into the Bay. Nonpoint source contributions include agriculture, forestry, construction, and urban runoff.

Fish kills and closures of oyster shellfishing grounds, obvious indicators of poor water quality, have been historically prevalent in coastal Alabama (Crance, 1971). However, environmental regulations implemented during recent years that are increasingly protective of aquatic resources have assisted in the reduction of major fish kill occurrences. In 1990, there were 18 fish kill events in Alabama's coastal waters, six events in 1991, and four in 1992. The largest fish kill to occur in Alabama was attributed to domestic waste, which depleted oxygen in the receiving water body.

Progressive dilution of high nutrients in the Mobile River delta is evident with movement down the axis of Mobile Bay to the Gulf of Mexico. Although observed nutrient concentrations for Mobile Bay suggest that the system should have a relatively low susceptibility to nutrient enrichment, chlorophyll *a* concentrations (an indicator of phytoplankton biomass) are high in winter, and recurring hypoxic conditions are seen during summer. Stratification in Mobile Bay, on the other hand, is important in the low oxygen concentrations (Turner and Boesch, 1987).

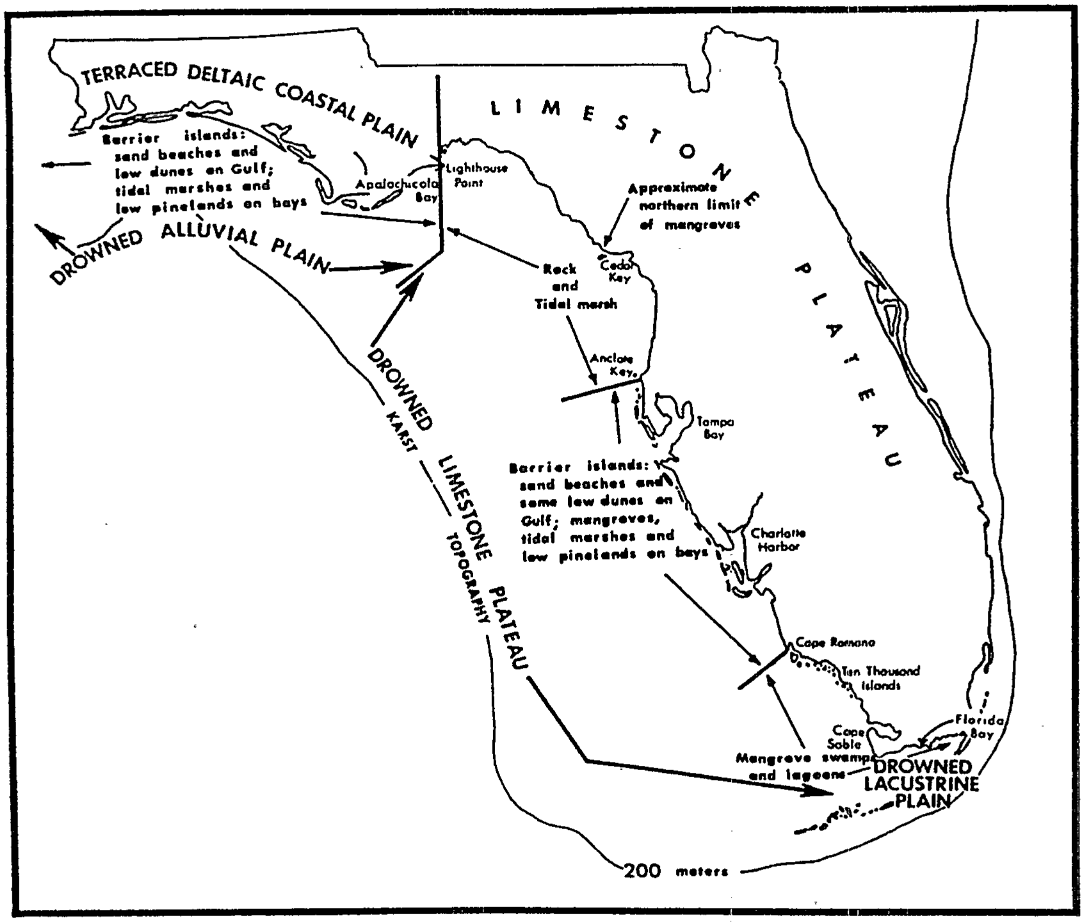
Although discharges are increasing and population is growing, water quality measurements over the last two years indicate that water quality standards in Mobile and Baldwin Counties have been met 86.7 percent of the time (Horn, 1990). Several management plans exist or are in preliminary stages for Mobile Bay and surrounding areas: 1) the South Baldwin County Environmental Impact Statement project with USEPA to develop and assess various wastewater management alternatives for coastal Baldwin County; 2) water quality modeling for Oyster and Wolf Bays; 3) the establishment of the Weeks Bay National Estuarine Research Reserve, which is managed by the state in a cooperative effort with NOAA; and 4) extensive water quality studies of Perdido Bay involving the States of Alabama and Florida, USEPA, NOAA, and Champion International.

Degradation of water quality conditions in Perdido Bay (bordering Alabama and Florida) has been documented in several ways, and this estuary has been assessed as having a problem regarding nutrient enrichment (see **Table 2.8** and **Figure 2.6**).

## Florida

The length 1,239 km (770 statute miles) and biological diversity of the Florida Gulf Coast exceed those of any other Gulf State (McNulty *et al.*, 1972). The climate varies from subtropical to temperate. Tidal swamps and marshes fringe the coast and submerged vegetation covers the seabed of most shallow-water bottoms. The mangrove swamps of the southern and central coasts are gradually replaced by tidal marshes north of Cedar Key (see **Figure 2.7**) (McNulty *et al.*, 1972).

**Figure 2.7** ***Major Coastal Types of the West Coast of Florida***




(Source: McNulty *et al.*, 1972)

There are many activities that impact Florida's estuaries (Estevez *et al.*, 1984). The Port of Tampa is the seventh largest port in the U.S. and largest on Florida's west coast. The impacts of maritime transportation and industry include dredge and fill activities, retention structure failure, long-term overall effects of increased turbidity, resuspension of contaminants, and filling of intertidal areas. Declines in fisheries have been attributed to pollution, overfishing, and habitat loss. Other habitat alterations result from dredging activities for fill material, either sand or oyster shell, and thermal effluents from power generating facilities. Western Florida has been and will continue to be the most rapidly growing area in the Gulf; its population is expected to increase by more than 1.5 million over the next two decades (Cuilliton *et al.*, 1990).

Several estuarine areas of Florida receive major flows of pollutants. Industrial pollution from wood processing and phosphate processing plants are prevalent along the western panhandle and southwest Florida coasts, respectively. Activities related to phosphate extraction are expected to increase in Manatee and Sarasota counties and may begin near Charlotte Harbor (Estevez *et al.*, 1984). A 1972 (McNulty *et al.*, 1972) study outlined high levels of domestic pollution in Tampa Bay, eutrophication, increased primary production and algal growth, decreased species richness of mollusks, and evidence of eutrophication in Boca Ciega Bay. While water quality has recently improved in the Tampa Bay area in response to advanced waste water treatment, control and management of the contributing nitrogen sources is still imperative in order to restore damaged seagrass habitats (Johansson and Lewis, 1992). The Fenholloway River carries heavy loads of paper mill wastes to the Gulf at Apalachee Bay. The St. Marks River is subject to domestic sewage pollution and occasional oil spills. Industrial pollutants have altered the water quality and biota of St. Joseph Bay. Fish kills and other evidence of pollution have been documented in Pensacola and Escambia Bays, and upper Escambia Bay may still experience periods of hypoxia. Heavy pollution has been documented in the northern part of Perdido Bay (McNulty *et al.*, 1972). Several of the Florida embayments have recorded fish kills attributed to low oxygen levels, eutrophication, or nutrients.

Several Florida estuarine areas were classified as having water quality problems, or potential problems, with respect to nutrient enrichment (see **Table 2.8** and **Figure 2.6**). These are the Caloosahatchee River, Charlotte Harbor, Sarasota Bay, Tampa Bay, Suwanee River, Deadmans Bay, St. George Sound, St. Andrews Bay, Choctawhatchee Bay, and Pensacola Bay. These estuaries receive the effluents of many of the human-based activities in the drainage areas as described above; as well as many other landscape alterations resulting from human activities. Several estuaries are experiencing rapid population growth. Where water quality management has reduced wasteload allocations, noticeable improvement has been seen in water quality in portions of the most eutrophied estuaries (*i.e.*, Tampa Bay and Pensacola Bay).

## *Louisiana*

Louisiana estuaries are experiencing some impacts from nutrient enrichment and eutrophication. Indicators of these impacts include: 1) the Louisiana Departments of Wildlife and Fisheries and Environmental Quality frequently receive reports of estuarine fish kills that they ascribe to low oxygen conditions, which are likely the result of high algal production; 2) chlorophyll *a* concentrations in several coastal water bodies frequently exceed 50 µg/L, which is high (Turner, personal communication); and 3) the dissolved silica:nitrate-nitrogen atomic ratio fluctuates between 2 and 0.5 in many estuaries, indicating potential chemical control of diatom abundance (Turner, personal communication). Major sources of this nutrient enrichment and eutrophication are fertilizer use, urban runoff, and industrial and wastewater treatment plant discharges, which have risen dramatically since the 1940s.

Although an in-depth analysis of the long-term trends in water quality of the Mississippi River has been completed (Turner and Rabalais, 1991a) and shows significant increases in concentrations of nitrate and loadings of nitrogen and phosphorus, other data for Louisiana remain unanalyzed. The water quality in southern Barataria Bay and Terrebonne Bay may be affected by changes in Mississippi River water quality because of its relatively large freshwater inflow and evidence that salinity in Barataria Bay is inversely related to river discharge (Wiseman and Swenson, 1987; Wiseman *et at.*, 1990). However, it is believed that most of Louisiana's estuaries receive significant nutrients from agricultural and urban runoff; this data for Louisiana remain unanalyzed. There is also sewage discharge from numerous small camps and towns.

Four Louisiana estuarine systems have been assessed with estuarine condition problems resulting from nutrient enrichment. These are Lake Pontchartrain, Barataria Bay, the Mississippi River, and the Louisiana inner continental shelf. Over the past 60 years, human population in the Pontchartrain drainage area has risen dramatically. Many indicators of eutrophication, such as increased phosphorus concentrations, increased turbidity, reduced coverage of submerged aquatic vegetation, and oxygen depletion in bottom waters, are documented for the area; however, many human activities not related to nutrient additions may contribute to these observed conditions. Within Barataria Bay there is a gradient along its axis of nutrient concentration, phytoplankton production, chlorophyll biomass, and turbidity; the upper end is classified as eutrophic (Witzig and Day, 1983; Madden *et al.*, 1988). While turbidity primarily limits phytoplankton production in the Mississippi River proper, the consequences of nutrient concentration increases and concomitant effects may also have significant effects on the adjacent continental shelf where extensive areas of severe oxygen depletion occur during most years in the summer.

## *Mississippi*

Mississippi Sound dominates the estuarine system of the state; this complex includes the small bays, marshes, bayous, and rivers along the northern shore. Mississippi Sound is an elongated, shallow [3 m (9.8 ft)] water body which is separated from the open Gulf of Mexico by a series of barrier islands (Eleuterius, 1976). Narrow peninsulas and shallow shell reefs connecting Dauphin Island to the Alabama mainland separate the Sound from Mobile Bay on the east. Freshwater enters the Sound on this eastern end from Mobile Bay. It is estimated (Austin, 1954; cited in Eleuterius, 1976) that one-fifth of the discharge from Mobile Bay is diverted into Mississippi Sound mainly via Grants Pass. On the western end, the Sound receives inputs from Lake Borgne and the Pearl River, indirectly from Lake Pontchartrain and the Mississippi River, and even more infrequently, when the Bonnet Carre spillway is opened. Several other major sources of freshwater enter the Sound directly: the Pearl River on the western end with a flow of 327.9 $m^3$/second (11,580 $ft^3$/second), and the Pascagoula River with an average flow of 378.6 $m^3$/second (13,369 $ft^3$/second). The Biloxi and Tchoutacabouffa Rivers [flows of 14 $m^3$/second and 12.4 $m^3$/second (494 and 437 $ft^3$/second), respectively] reach the Sound via Biloxi Bay. The Jourdan and Wolf Rivers empty into St. Louis Bay with average flows of 43.5 $m^3$/second and 20 $m^3$/second (1,535 and 706 $ft^3$/second), respectively. Tidal bayous contribute lesser amounts of freshwater. Connection through passes and over shoal areas along the barrier island chain permit the intrusion of higher salinity Gulf of Mexico waters.

Three navigation channels traverse Mississippi Sound. The ports at Pascagoula and Gulfport have deep water access with authorized depths of 13 and 11 m (36.1 and 42.6 ft) respectively. The third, Biloxi Channel, used primarily by barge, commercial fishing vessels, and pleasure craft, has an authorized depth of 4 m (13.1 ft). A fourth channel, the Gulf Intracoastal Waterway, spans the east-west axis of the Sound at an authorized depth of 4 m which is exceeded in most parts of the Sound by the natural bathymetry.

The greatest abundance of industrial development has occurred in the Pascagoula River, Escatawpa River, and Bayou Casotte (Lytle and Lytle, 1990). Biloxi Bay has a moderate degree of industrialization and St. Louis Bay and Heron Bay have little industrial development. Extensive work by Lytle and Lytle (1985, 1990 and references therein) has documented the distribution of organic pollutants. Sediment sampling was conducted over a three year period. Total organic carbon (TOC) values were greatest in the Pascagoula River with Biloxi Bay having considerably lower TOC values, and TOC in St. Louis Bay occurred at levels only slightly higher than the Sound and Gulf samples (see **Table 2.9**) (Lytle and Lytle, 1990). Using TOC as a gross indicator of pollution, the strongest evidence of pollution exists for discrete sample sites along the Pascagoula River, with some sites in Biloxi Bay also showing unusually high TOC. Ranges of TKN were less dramatic, although there were generally higher values in the bays and rivers compared to the Sound and Gulf, with isolated highs near municipal sewage discharges.

**Table 2.9** ***Pollutant Variables in Mississippi Sound Surface Sediments***

| Location | TOC | TKN (mg g⁻¹) |
|---|---|---|
| Pascagoula River (26 samples) | 4.05 ± 3.98<br>0.145 - 14.0 | 1.43 ± 1.21<br>n.d. - 4.24 |
| Biloxi Bay (19 samples) | 1.76 ± 0.832<br>0.315 - 3.67 | 0.88 ± 0.616<br>0.07 - 2.59 |
| St. Louis Bay (4 samples) | 1.45 ± 0.777<br>0.328 - 2.08 | 1.19 ± 0.200<br>0.97 - 1.39 |
| Mississippi Sound (15 samples) | 0.869 ± 0.420<br>0.096 - 1.36 | 0.568 ± 0.505<br>0.0045 - 1.55 |
| Gulf of Mexico (1 sample) | 1.09 | 0.73 |

Total Kjeldahl nitrogen and total organic carbon. Reported values are mean ± one standard deviation/minimum-maximum values. n.d. is not detected and entered as 0.0 in mean calculations.

**(Source: Lytle and Lytle, 1990)**

Although data concerning nutrient concentrations and loadings are sparse for Mississippi estuarine areas, based on the Mississippi Department of Natural Resources 1988 Water Quality Report, Biloxi Bay was listed as an area with a problem concerning nutrient enrichment and Pascagoula Bay with a potential problem. In these areas, degraded water quality was identified by high fecal coliform counts, depressed oxygen concentrations, elevated levels of ammonia, nitrogen and orthphosphorus, high hydrocarbon concentrations and TOC in sediments, and depressed benthic faunal communities.

## *Texas*

Similar to Florida, the coastline of Texas is diverse, crosses several latitudes, covers a gradient of estuarine types, and is influenced primarily by rainfall and freshwater inflow differences. With the exception of the Sabine and Galveston estuaries, the remaining Texas estuaries fall into a semi-arid habitat classification with rainfall averages of less than 61 cm/year (24 inches/year). Freshwater inflow into Texas estuaries is, therefore, disproportionate with dramatic decreases southward. Much of the rainfall along the Texas coast is aperiodic and extremely variable between years. Prolonged trends of moist periods and droughts last 10-25 years. Many streams and rivers in Texas are partially controlled by dams and reservoirs.

Texas is the second most rapidly growing state on the Gulf Coast (western Florida, first); its coastal population is expected to increase by over 1.1 million persons during the next two decades (Cuilliton *et al.*, 1990). Parts of the Texas coast are heavily urbanized and industrialized. These centers of point source discharges are located in Sabine Lake, Galveston Bay, and Corpus Christi Bay. Three Texas estuaries (Galveston Bay, Matagorda Bay, and Lower Laguna Madre) receive the greatest applications of fertilizer to agricultural lands among Gulf of Mexico estuarine drainage areas (USDOC, 1990b).

A synthesis of nutrient loadings into each of the major Texas estuaries was developed by Armstrong (1982) (cited in Armstrong, 1987) (see **Table 2.10**). The relative proportions of nutrients are influenced by several factors, including the amount of freshwater inflow and the receiving volume. The Sabine estuary receives the highest areal loading, because of its large freshwater inflows. There is a general decrease in areal loading rates with direction southward to the Laguna Madre. Nutrients derived from freshwater inflow dominate the nutrient budgets of all estuaries; marsh contributions and precipitation are minimal. Armstrong (1987) also provided a synthesis of the information concerning phytoplankton assemblages, primary production and zooplankton and nekton population estimates across the major Texas estuaries.

The Texas Parks and Wildlife Department collects surface water samples with its monthly gill net and bag seine samples throughout Texas estuaries during spring and fall collection periods. For all the Texas Bay systems sampled between 1975 and 1986, the surface oxygen levels were within the range expected, and there were no obvious trends for an increase in these values (Hegen, 1983; Rice *et al.*, 1988). Turbidity readings taken at the same time indicate that concentrations of suspended materials are controlled by meteorological events. Recent trends in increased turbidity within the Laguna Madre system, however, may be related to changes in land use on its periphery (*i.e.*, increased pastureland being converted to cropland).

Estuaries with problems, or potential problems, related to nutrient enrichment are the Laguna Madre system, Galveston Bay, Matagorda Bay, Baffin Bay, and upper reaches of the Texas inner continental shelf within the influence of the Mississippi-Atchafalaya River effluent (see **Table 2.8** and **Figure 2.6**). Studies in the Laguna Madre system indicate that one possible symptom of the nutrient enrichment problem may be brown tides.

**Table 2.10** ***Carbon, Nitrogen & Phosphorus Loading Budgets for Texas Estuaries***

| Nutrient | Estuary | Freshwater inflows ($10^6$kg/yr) | Marshes Tidal ($10^6$kg/yr) | Marshes Flood ($10^6$kg/yr) | Precipitation ($10^6$kg/yr) | Total ($10^6$kg/yr) | Areal loading (g/m$^2$/yr) |
|---|---|---|---|---|---|---|---|
| Carbon | Sabine Lake | 115.70 | 2.50 | 1.44 | | 119.64 | 672.20 |
| | Galveston Bay | 103.44 | 4.02 | 0.14 | | 107.60 | 75.20 |
| | Matagorda Bay | 75.75 | 5.35 | 0.14 | | 81.62 | 80.50 |
| | San Antonio Bay | 17.95 | 0.88 | 0.30 | | 19.13 | 34.10 |
| | Copano-Aransas Bays | 5.98 | | | | 5.98 | 12.90 |
| | Corpus Christi Bay | 8.21 | 9.11 | 0.42 | | 17.74 | 39.90 |
| | Laguna Madre | 6.00 | | | | 6.00 | 2.90 |
| Nitrogen | Sabine Lake | 9.32 | 0.02 | 0.36 | 0.04 | 9.75 | 54.80 |
| | Galveston Bay | 11.58 | 0.12 | 0.04 | 0.34 | 12.08 | 8.40 |
| | Matagorda Bay | 3.58 | 0.05 | 0.04 | 0.51 | 4.33 | 4.30 |
| | San Antonio Bay | 5.80 | 0.01 | 0.08 | 0.14 | 6.02 | 10.70 |
| | Copano-Aransas Bays | 0.44 | | | 0.11 | 0.55 | 2.00 |
| | Corpus Christi Bay | 0.55 | 0.02 | 0.01 | 0.11 | 0.68 | 1.52 |
| | Laguna Madre | 0.61 | | | | 0.61 | .28 |
| Phosphorus | Sabine Lake | 0.74 | 0.50 | 0.41 | 0.01 | 1.21 | 6.82 |
| | Galveston Bay | 3.63 | 0.09 | 0.04 | 0.04 | 3.81 | 2.66 |
| | Matagorda Bay | 1.31 | 0.11 | 0.04 | 0.04 | 1.54 | 1.52 |
| | San Antonio Bay | 1.00 | 0.02 | 0.09 | 0.02 | 1.12 | 2.00 |
| | Copano-Aransas Bays | 0.07 | | | 0.01 | 0.08 | 0.18 |
| | Corpus Christi Bay | 0.22 | 0.18 | 0.12 | 0.01 | 0.53 | 1.20 |
| | Laguna Madre | 0.72 | | | | 0.72 | 0.34 |

**(Source: Armstrong, 1987)**

## Conclusion

The bays and estuaries of the Gulf of Mexico are parts of a very productive sea. High productivity in any ecosystem requires the presence of nutrients in adequate amounts. Nitrogen, phosphorus, and silicate are the primary nutrients which limit productivity in coastal systems. Phosphorus tends to be the nutrient most limiting in fresh water systems, but nitrogen is commonly the most limiting in marine systems. The importance of silica and the relative proportions of the various nutrients are becoming increasingly obvious. Estuarine systems, where fresh and salt water mix, often show complex nutrient responses with seasonal changes and along salinity gradients.

Some areas of the Gulf of Mexico are receiving more nutrients than can be assimilated without adverse effects on the marine organisms in the system. Nutrient enrichment leads to eutrophication symptoms including low oxygen levels, high chlorophyll levels, and changes in community structure. Nutrient enrichment may result from: increased anthropogenic quantities or changes in seasonal loading rates from both point and nonpoint sources and changes in hydrology.

Nutrient enrichment within the Gulf which is associated with "on land" activities is almost sure to increase if no action is taken. The coastal regions of the Gulf of Mexico have experienced rapid population growth in recent years along with its associated burdens. The following is a list of potential results:

- Oxygen depletion episodes could intensify in duration and severity and the affected area or areas could become enlarged. Desirable living marine resources would then become less productive in bays, estuaries, and nearshore waters.
- Economic impacts of reduced fisheries could cost thousands of jobs within the Gulf region. Jobs related to commercial fisheries would be the most heavily impacted, as well as jobs associated with recreational fishing and tourism.
- Aesthetic qualities of Gulf waters could be adversely impacted by excessive algal blooms. Coastal residents, sightseers, swimmers, and recreational boaters would be discouraged by these excessive algae blooms.
- Decreased light penetration in shallow water areas, which will almost certainly become worse if nutrient loadings increase, could result in further loss of submerged aquatic vegetation. This vegetation is an important factor in the habitat requirements of many marine organisms.
- "Red tides" associated with anthropogenic nutrient enrichment could affect public health and the area's economy.

Nutrient enrichment in the Gulf of Mexico is caused by the practices of rural and urban residents far from the Gulf Coast, as well as those living near the coast. Plans to protect the Gulf must examine ways of influencing these practices. The particular nutrient which is the limiting factor in the Gulf ecosystem must be determined, however the determination of "limiting" nutrients in estuaries and other ecologically open coastal systems is still problematical. In addition, priority geographic areas must be determined. The contributions from the regions whose waterways flow to the Gulf vary widely, both by season and by nutrient, though there is not much consistency in these variations (Lovejoy, 1992). The proportion of nutrients coming from point sources and nonpoint sources also varies, though nonpoint sources appear to be the larger factor in those regions that provide the majority of the nutrients in most seasons (Lovejoy, 1992).

The viewpoint that eutrophication is a local and perhaps point source problem, manageable on a regional scale, is changing to an appreciation that eutrophication is the cumulative result of many small actions throughout the world, and whose scale of management is vastly expanded and more expensive (Turner and Rabalais, 1991a). Protection of the Gulf ecosystem requires a consideration of the full range of activities throughout the entire drainage area of river systems flowing into the Gulf of Mexico.

# 3 FEDERAL & STATE FRAMEWORK FOR ADDRESSING NUTRIENT ENRICHMENT

Many federal agencies are mandated by legislative statutes to address eutrophication. These agencies include: U.S. Environmental Protection Agency, U.S. Department of Commerce, U.S. Department of the Interior, U.S. Department of Defense, U.S. Department of Agriculture, and U.S. Department of Transportation. Each of the five Gulf of Mexico states also has a regulatory framework for addressing nutrient enrichment. (For a description, see **Appendix A**.)

# 4 THE UNFINISHED AGENDA -- *Both Current Commitments & Uncommitted Activities*

## Goal

This Nutrient Enrichment Action Agenda for the Gulf of Mexico sets forth an initial framework for conserving, protecting, and restoring Gulf waters that will minimize nutrient enrichment, thereby allowing the use and enjoyment of its resources. The Gulf of Mexico Program has established the following long-term goal for addressing nutrient enrichment:

- ❑ Protect the waters of the Gulf of Mexico from the deleterious effects of nutrient enrichment, from all contributing sources, and thereby enhance biodiversity, and aesthetic, recreational, and economic benefits.

This Action Agenda focuses on protecting the tidal, estuarine, and nearshore waters of the Gulf of Mexico. Freshwater transport from landward sources is addressed as a contributing source.

## Action Agenda Framework

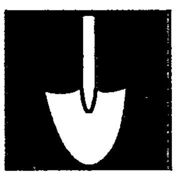
This chapter of the Action Agenda provides objectives, action items, and specific project descriptions for addressing the nutrient enrichment problem in the Gulf of Mexico and for meeting the long-term goal as stated above. Objectives and action items are clustered under three types of activity: 1) Characterization and Demonstration, 2) Source Reduction, and 3) Public Education and Outreach (see **Index of Objectives & Action Items**). The fifty-one action items represent the Committee's best judgment today, based on existing data and information, as to what must be done initially to tackle the nutrient enrichment problem in the Gulf of Mexico. As current action items are completed and future generations of this document are developed, it is anticipated that more geographically targeted actions will emerge. Also, since major sources of both nitrogen and phosphorus may originate far upstream in the Gulf watershed, the continuation and expansion of policies and activities directed toward decreasing nutrient runoff from upstream regions could have the biggest impact on the reduction of nutrient enrichment in the Gulf.

The Gulf of Mexico Program will maintain an overview of National Estuary Program activities which address nutrient enrichment in the Gulf and will provide coordination among related Gulf of Mexico Program Issue Committees to ensure the compatibility of objectives and approaches with the Nutrient Enrichment Action Agenda.

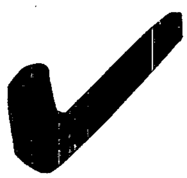
**Lead.** The Nutrient Enrichment Committee has identified a lead agency for each project--the agency with the most authority or jurisdiction over the particular issue. A proposed project may involve the execution of legislative or regulatory authorities or programmatic initiatives which derive from these authorities. In other cases, a proposed project may involve the facilitation or coordination of activities among several agencies or organizations. In these cases, and where there is no clear legislative authority involved, the "lead" could be the agency or organization who expresses an interest in taking on the task during Gulf of Mexico Program Committee deliberations, the action planning workshop or public comment period, or, in the Issue Committee's judgment, is best able to guide multiple parties in carrying out the activity. *This does not necessarily mean that the agency has agreed to carry out the activity or that the agency has the necessary funding. The Nutrient Enrichment Committee understands these action items will require commitments by agencies and organizations that are dependent on budget decisions.* However, the Committee members hope this document provides the rationale and support for such commitments and that future iterations of this document will include additional specific commitments.

**Initiation Date.** The date indicated represents a determination by the Committee of the most realistic *initiation date* for the project. As lead agencies begin implementation planning for specific projects, these initiation dates may change due to resource availability and prioritization within the individual agencies.

**Underway or Completed Action Items/Projects.** Some of the action item projects may already be underway or even completed. In these cases, short status reports are provided and completion dates are provided if known. These projects are designated with the following icons:



**Underway**



**Completed**

Some projects are cross referenced to other action items and projects and are designated with a "→" sign in the left hand column. This signals a close relationship among those action items and projects and a need for coordination.

The Gulf of Mexico Program recognizes the need to identify indicators of environmental progress relative to this Action Agenda for nutrient enrichment. Many of the action items and projects specified in Chapter 4 of this document will aid the Program in developing a baseline for measuring success in the future. For the time being, however, acceptance and completion of action items and projects specified in this Action Agenda will be considered a measure of success. As future iterations of this document are written, and current projects are completed, new action items and projects will be developed to better measure environmental progress.

# Index of Nutrient Enrichment Objectives & Action Items

## Characterization & Demonstration

**Objective:** Identify programs engaged in managing or regulating nutrient inputs and the ongoing and planned research related to nutrient enrichment for the watersheds draining into the Gulf of Mexico to support effective integration with Gulf initiatives.

**Action Item 1:** Develop an inventory report and data base on institutions engaged in managing or regulating nutrient enrichment activities in watersheds draining into the Gulf of Mexico.

**Action Item 2:** Develop an inventory report and data base on nutrient related research, evaluation, and monitoring programs that are relevant to the Gulf of Mexico.

**Objective:** Identify the location and quantities of nutrient loadings to Gulf of Mexico watersheds and evaluate the relative contribution of nutrients to the Gulf among these sources to support future targeting of control strategies and the measurement of success.

**Action Item 3:** Identify the primary land based sources and quantities of nutrients entering the Gulf of Mexico and its bays and estuaries from within the U.S. to establish a baseline for future monitoring.

**Action Item 4:** Assess the relative importance of atmospheric deposition to nutrient enrichment within the Gulf of Mexico drainage basin.

**Action Item 5:** Assess the relative significance of industrial and sanitary point source loadings of nutrients to the Gulf of Mexico drainage basin.

**Action Item 6:** Identify the various contributors to urban storm water runoff within the coastal zones of the five Gulf of Mexico states and quantify the relative contributions of nutrients from each source.

**Action Item 7:** Identify the various contributors to nonurban runoff within the coastal zones of the five Gulf of Mexico states and quantify the relative contributions of nutrients from each source.

**Action Item 8:** Produce an inventory of septic systems within the coastal zones of the five Gulf of Mexico states.

**Objective:** Identify the impacts and effects of nutrient enrichment on the bays, estuaries, and resources of the Gulf of Mexico to support the future geographic targeting of control strategies.

**Action Item 9:** Produce a summary report on the impacts and effects of nutrient enrichment in the 58 estuaries of the Gulf, based on existing literature and data bases.

**Action Item 10:** Expand and refine the assessment of nutrient enrichment impacts and effects in the Gulf of Mexico using the NOAA Estuarine Eutrophication Survey.

**Action Item 11:** Conduct field studies in the Gulf of Mexico on the effects of nutrient enrichment within wetlands on parasite/host relationships.

**Objective:** Identify and determine the relationships of sources of nutrients to resource impacts within the Gulf of Mexico to support optimum Gulfwide control strategies.

**Action Item 12:** Identify, quantify, and attempt to reduce human activity-related sources of nutrients which contribute to declines of seagrass and wetlands habitats in the Gulf of Mexico.

**Action Item 13:** Quantify the impact of human activity-related nutrient loadings to coastal ocean productivity near the Mississippi and Atchafalaya Rivers.

**Action Item 14:** Develop pilot watershed characterization reports in the Gulf of Mexico.

**Action Item 15:** Assess the need for a standardized information and synthesis capability for Gulf of Mexico nutrient data.

## Index of Nutrient Enrichment Objectives & Action Items (continued)

### Characterization & Demonstration (continued)

**Objective:** Develop demonstration projects on potential Gulfwide priority nonpoint and point sources that have a high probability of success within a reasonable time and have the potential for transferability Gulfwide.

**Action Item 16:** Demonstrate the use of chlorophyll meters for determining the need for and amount of nitrogen fertilizer in Gulf of Mexico agricultural operations.

**Action Item 17:** Evaluate the effectiveness of Gulf of Mexico agricultural irrigation management practices on nutrient loadings using water quality monitoring information from subsurface drains.

**Action Item 18:** Evaluate the economic feasibility of transporting animal waste for use as fertilizer.

**Action Item 19:** Evaluate and demonstrate the effectiveness of constructed wetland systems, and individual plant species, as a means of removing nutrients, organics, and oxygen-demanding materials from dairy and swine operations in the Gulf of Mexico region.

**Action Item 20:** Assess the feasibility of reformulating feeds to reduce the nutrient content of manures.

**Action Item 21:** Evaluate the effectiveness of constructed wetlands in removing nutrients from aquaculture operations in the Gulf of Mexico region.

**Action Item 22:** Evaluate the effects of increased volumes of water within aquaculture production ponds for reducing nutrient runoff to the Gulf of Mexico.

**Action Item 23:** Evaluate the effectiveness of constructed wetlands for residential wastewater treatment in the Gulf of Mexico region.

**Action Item 24:** Evaluate the effectiveness of sewage treatment alternatives for reducing eutrophication in unsewered areas within the Gulf of Mexico region.

**Action Item 25:** Collect and disseminate information on the use of wastewater treatment plant discharges for residential purposes in the Gulf of Mexico region.

**Action Item 26:** Evaluate the use of degraded wetlands for cleansing septic tank pumpdown water in the Gulf of Mexico region.

# Index of Nutrient Enrichment Objectives & Action Items (continued)

## Source Reduction Strategies

**Objective:** Evaluate the effectiveness of nutrient control technologies for the most significant industrial and municipal point source categories in the Gulf of Mexico.

**Action Item 27:** Identify the range of point source control technologies and pollution prevention approaches for nutrient reduction in the Gulf of Mexico.

**Action Item 28:** Conduct cost effectiveness analyses of point source control technologies for nutrient reduction in the Gulf of Mexico.

**Action Item 29:** Promote technology transfer of effective point source control technologies throughout the Gulf of Mexico drainage basin.

**Objective:** Implement appropriate Gulfwide or targeted control strategies to reduce significant nutrient loadings from point and nonpoint sources.

**Action Item 30:** Provide technical assistance for effective nutrient management on farms and ranches throughout the U.S. portion of the drainage area of the Gulf of Mexico.

**Action Item 31:** Determine the need for NPDES reporting requirements for nutrients in specific Gulf of Mexico watersheds.

**Action Item 32:** Develop and implement a Gulfwide strategy to support a national ban on phosphorus laundry detergents for general use.

**Action Item 33:** Accelerate the development of nutrient criteria for waters of the Gulf of Mexico to support the development of state water quality standards.

**Action Item 34:** Assess, and develop control strategies as appropriate, for reducing the movement of organic materials to Gulf of Mexico waters.

**Action Item 35:** Determine the impacts of nutrients in the New Orleans canal system on Lake Pontchartrain and develop an appropriate control strategy.

**Action Item 36:** Assess the nutrient contribution and impacts of coastal mariculture operations in the Gulf of Mexico.

**Action Item 37:** Assess and document the magnitude of the health and environmental problems associated with the use of septic tanks throughout the Gulf of Mexico region and the costs of conversion to public sewer systems.

**Action Item 38:** Develop and promote appropriate alternative systems for Gulf of Mexico coastal septic systems.

**Action Item 39:** Provide information and recommendations to urban areas throughout the Gulf of Mexico on successful approaches to urban runoff controls.

**Action Item 40:** Analyze the effectiveness of Gulf of Mexico State silviculture programs in controlling nutrient runoff.

**Action Item 41:** Develop a Gulfwide strategy to effectively transfer successful nutrient demonstration project techniques and approaches.

**Action Item 42:** Develop a nonpoint source nutrient reduction strategy for Week's Bay, Alabama.

**Objective:** Develop alliances with other organizations and associations to address appropriate control strategies for Mississippi River contributions to the Gulf of Mexico nutrient problem.

**Action Item 43:** Establish an interbasin commission of organizations that address health and welfare issues associated with the Mississippi River and Gulf of Mexico drainage basin.

## Index of Nutrient Enrichment Objectives & Action Items (continued)

### Public Education & Outreach

**Objective:** Develop a Gulfwide comprehensive public information and education program to promote involvement in nutrient reduction actions, through appropriate use of products and environmentally sound lifestyles.

**Action Item 44:** Encourage the efficient and proper use of fertilizers among homeowners and businesses in the Gulf of Mexico through an educational outreach initiative.

**Action Item 45:** Promote the appropriate use of septic systems in the Gulf of Mexico through an educational outreach initiative to potential users and inspectors.

**Action Item 46:** Develop a Gulfwide outreach initiative to inform citizens about the impacts of phosphorus laundry detergents on Gulf of Mexico resources.

**Action Item 47:** Develop a Gulfwide outreach program to improve wastewater treatment plant inspections.

**Action Item 48:** Develop a Gulfwide education program on the proper handling of residential nutrient sources.

**Action Item 49:** Initiate cooperative information exchange programs with other groups on nutrient reduction approaches.

**Action Item 50:** Develop a Gulfwide outreach program on the use of constructed wetlands for wastewater treatment.

✔ **Action Item 51:** Develop a Mississippi River outreach program designed to increase awareness of nutrients, water quality, and the health of the Gulf of Mexico, as well as relationships between the Gulf and the Mississippi River.

## Characterization & Demonstration

Information on nutrient sources and relative loadings provides the raw material for generating improvement actions. The Nutrient Enrichment Committee has completed initial work on nutrient loadings to watersheds within the Gulf of Mexico region. However, more work is needed on the relationships of sources of nutrients to cumulative loadings and impacts. Research is also needed to determine causes of oxygen depletion and other environmental and biological responses to nutrient enrichment by geographic area to support site specific control measures. Proposed Action Item 14 supports a pilot effort at this scale. Other demonstration projects are proposed as effective tools in pilot testing appropriate approaches to point and nonpoint source nutrient management.

Specific objectives, action items, and project descriptions follow:

**Objective:** Identify programs engaged in managing or regulating nutrient inputs and the ongoing and planned research related to nutrient enrichment for the watersheds draining into the Gulf of Mexico to support effective integration with Gulf initiatives.

**Action Item 1:** Develop an inventory report and data base on institutions engaged in managing or regulating nutrient enrichment activities in watersheds draining into the Gulf of Mexico.

**Project Description:** Develop a comprehensive inventory, and accompanying data base, of all institutions, including governmental, private, and non-profit, that manage or regulate nutrient enrichment activities in the watersheds that drain into the Gulf of Mexico. The data base will include information on statutory and regulatory roles and responsibilities, specific projects that are underway and time frames, and opportunities for coordination with the Gulf of Mexico Program.
**Lead:** Gulf of Mexico Program--Nutrient Enrichment Committee.
**Initiation Date:** 1995
→ 2

**Action Item 2:** Develop an inventory report and data base on nutrient related research, evaluation, and monitoring programs that are relevant to the Gulf of Mexico.

**Project Description:** Develop a comprehensive inventory, and accompanying data base, on ongoing and planned research, evaluation, and monitoring programs, such as the U.S. Environmental Protection Agency's Environmental Monitoring and Assessment Program (EMAP), that are relevant to Gulf of Mexico Program nutrient-related activities and decisions. The data base should be compatible with the data base produced under Action Item 1 and should include information on research/monitoring parameters, objectives and anticipated products, time frames, key contacts, etc.
**Lead:** Gulf of Mexico Program--Nutrient Enrichment Committee.
**Initiation Date:** 1995
→ **1**

**Objective:** Identify the location and quantities of nutrient loadings to Gulf of Mexico watersheds and evaluate the relative contribution of nutrients to the Gulf among these sources to support future targeting of control strategies and the measurement of success.

**Action Item 3:** Identify the primary land based sources and quantities of nutrients entering the Gulf of Mexico and its bays and estuaries from within the U.S. to establish a baseline for future monitoring.

**Project Description A:** Phase 1 - Develop a report which provides an initial assessment of nutrient loadings to the Gulf by watershed.
Lead: Soil Conservation Service.
**Initiation Date:** 1989 **Completion Date:** 1992
**Status:** Report with one year's data was completed by Purdue University and is being reviewed.

**Project Description B:** Phase 2 - Develop a report which links major tributaries in the Gulf of Mexico drainage area with significant loadings of nutrients in the Mississippi River system.
**Lead:** U.S. Geological Survey.
**Initiation Date:** 1993 **Completion Date:** 1994
**Status:** An interagency agreement has been negotiated with U.S. Geological Survey for a summarization of nutrient data in the Mississippi River for two years--one a high flow year (October 1990-September 1991) and the other a low flow year (October 1987-September 1988).

**Project Description C:** Phase 3 - Develop a report that characterizes the primary land based sources of nutrients throughout the U.S. portion of the drainage area of the Gulf of Mexico, estimates the quantities of nutrients discharged from these sources, and examines the relative contributions of nutrient discharges among sources. This report will synthesize into a comprehensive report the information developed under Action Items 4, 5, 6, 7, 8, and 9.
**Lead:** Gulf of Mexico Program--Nutrient Enrichment Committee.
**Initiation Date:** 1994 **Completion Date:** 1996
→ **4, 5, 6, 7, 8, 9, 14**

**Action Item 4:** Assess the relative importance of atmospheric deposition to nutrient enrichment within the Gulf of Mexico drainage basin.

**Project Description:** Evaluate and select an appropriate methodology for assessing the contribution of atmospheric deposition to nutrient enrichment in the Gulf, using an Environmental Defense Fund (EDF) Chesapeake Bay model and the National Oceanic & Atmospheric Administration's Atmospheric Nutrient Input to Coastal Areas (ANICA) model. Apply the EDF methodology to Galveston Bay, TX, Tampa Bay, FL, and the Upper Mississippi Drainage Basin above the confluence of the Mississippi and Ohio Rivers. Conduct the assessment for the Gulf and produce a report which documents the findings and provides an assessment of the relative contribution of atmospheric deposition, compared to other sources, of nutrient enrichment within the Gulf of Mexico drainage basin.

**Lead:** U.S. Environmental Protection Agency and National Oceanic & Atmospheric Administration.

**Initiation Date:** 1993

**Status:** In 1988, EDF estimated the various sources of nitrogen to the Chesapeake Bay, including atmospheric deposition (both nitrate and ammonia). The U.S. Environmental Protection Agency is reviewing and evaluating this methodology and implementing procedures to reproduce their results using commonly available data sources for the Gulf of Mexico (*e.g.* USEPA/state waste discharges, emission inventories, soils and meteorologic data bases).

NOAA, under its ANICA study is also developing methods for assessing the importance of atmospheric input. In 1991, the ANICA program was initiated with a focus on the Chesapeake Bay watershed. ANICA will develop methods for assessing the importance of atmospheric input and provide direct experimental quantification of areal deposition rates of atmospheric nutrients with the objective of introducing this information into models.

→ **3C**

**Action Item 5:** Assess the relative significance of industrial and sanitary point source loadings of nutrients to the Gulf of Mexico drainage basin.

> **Project Description:** Identify specific categories of industrial and sanitary point sources which contribute nutrient loadings to the Gulf of Mexico drainage basin within priority watersheds, as identified by the report in Action Item 9. Using information developed in Action Items 6 and 7, which characterize nonpoint source discharges, determine whether these point source loadings are significant, compared to nonpoint source contributions. If significant, report on the type (*e.g.* nitrogen, phosphorus) of nutrients found in each category and identify appropriate continuing information needs, such as NPDES permit information requirements.
> **Lead:** National Oceanic & Atmospheric Administration.
> **Initiation Date:** 1996
> → **3, 6, 7, 9, 31**

**Action Item 6:** Identify the various contributors to urban storm water runoff within the coastal zones of the five Gulf of Mexico states and quantify the relative contributions of nutrients from each source.

> **Project Description:** Synthesize information from the five Gulf States on the contributors to urban storm water runoff (industrial sites, golf courses, residential lawns, etc.) and quantify the relative contribution of nutrients from each source on both a Gulfwide and priority watershed basis, as identified by Action Item 9.
> **Lead:** Cooperative Extension Service and state water quality agencies, in coordination with state nonpoint source programs.
> **Initiation Date:** 1995
> → **3, 5, 9, 44**

**Action Item 7:** Identify the various contributors to nonurban runoff within the coastal zones of the five Gulf of Mexico states and quantify the relative contributions of nutrients from each source.

> **Project Description:** Synthesize information from the five Gulf States on the contributors to nonurban runoff and quantify the relative contribution of nutrients from each source on both a Gulfwide and priority watershed basis, as identified by Action Item 9.
> **Lead:** Cooperative Extension Service, Soil Conservation Service, U.S. Forest Service, and state water quality agencies, in coordination with state nonpoint source programs.
> **Initiation Date:** 1995
> → **3, 5, 9**

**Action Item 8:** Produce an inventory of septic systems within the coastal zones of the five Gulf of Mexico states.

> **Project Description:** Produce a comprehensive inventory and data base of septic systems within the coastal zones of the five Gulf States. Septic systems are a suspected significant contributor to nonpoint source loadings of nutrients to the Gulf. The data base should include information on state regulations concerning septic systems and ongoing inspection and maintenance programs within the five Gulf States.
> **Lead:** State health departments and nonpoint source programs, in conjunction with Gulf of Mexico Program--Nutrient Enrichment and Public Health Committees.
> **Initiation Date:** 1994
> → **3C, 24, 38, 45**

**Objective:** Identify the impacts and effects of nutrient enrichment on the bays, estuaries, and resources of the Gulf of Mexico to support the future geographic targeting of control strategies.

**Action Item 9:** Produce a summary report on the impacts and effects of nutrient enrichment in the 58 estuaries of the Gulf, based on existing literature and data bases.

**Project Description:** Produce a summary report on the known and potential impacts and effects of nutrient enrichment in the Gulf of Mexico, including its bays and estuaries. The summary report should be based on existing literature and data bases and should concentrate on nitrogen, phosphorus, silicon, organic carbon and oxygen demanding parameters as well as an evaluation of dissolved oxygen.
**Lead:** Gulf of Mexico Program--Nutrient Enrichment Committee, in conjunction with U.S. Environmental Protection Agency.
**Initiation Date:** 1991 **Completion Date:** 1992
**Status:** Report is complete (see Rabalais, 1992) and synthesis information is presented in Chapter 2 of this document.
→ **3C, 5, 10**

✔

**Action Item 10:** Expand and refine the assessment of nutrient enrichment impacts and effects in the Gulf of Mexico using the NOAA Estuarine Eutrophication Survey.

**Project Description:** Use the results of the National Oceanic & Atmospheric Administration's Estuarine Eutrophication Survey to expand and refine the assessment of nutrient enrichment impacts and effects in the Gulf of Mexico undertaken in Action Item 9. NOAA's Survey will be administered to over 200 carefully selected local and regional experts nationwide to assess the current and historic conditions of algae, nutrient, and dissolved oxygen concentrations and the ecosystem response to nutrient inputs. Thirty-one estuaries in the Gulf of Mexico region will be evaluated. Once compiled and analyzed, the results of the survey can be used to characterize existing conditions, refine the ability to predict and anticipate future problems, and provide an information base to guide future research and monitoring.
**Lead:** National Oceanic & Atmospheric Administration.
**Initiation Date:** 1993 **Completion Date:** 1994
**Status:** The survey is currently being distributed to local and regional experts.
→ 9

**Action Item 11:** Conduct field studies in the Gulf of Mexico on the effects of nutrient enrichment within wetlands on parasite/host relationships.

**Project Description:** Conduct field studies in Florida on the effects of nutrient enrichment on parasite/host relationships. The studies will include both created and natural wetlands and will also document the infection rate in wading bird populations. *(NOTE: Crosswalk to Habitat Degradation Action Agenda.)*
**Lead:** Gulf of Mexico Program--Habitat Degradation Committee and U.S. Fish & Wildlife Service, in conjunction with University of Florida, Florida Game and Freshwater Fish Commission and Southwest Florida Water Management District.
**Initiation Date:** 1994

**Objective:** Identify and determine the relationships of sources of nutrients to resource impacts within the Gulf of Mexico to support optimum Gulfwide control strategies.

**Action Item 12:** Identify, quantify, and attempt to reduce human activity-related sources of nutrients which contribute to declines of seagrass and wetlands habitats in the Gulf of Mexico.

**Project Description:** Identify and quantify man-related sources of nutrients which contribute to declines of seagrass and wetlands habitats within the five Gulf States. Investigations should include industrial and municipal effluents and nonpoint source discharges. Work will be coordinated with activities of the Gulf of Mexico Program Habitat Degradation Committee to determine relative contributions from all sources, such as dredge and fill activities and habitat conversions. *(NOTE: Crosswalk to Habitat Degradation Action Agenda.)*
**Lead:** Gulf of Mexico Program--Nutrient Enrichment Committee, in conjunction with Habitat Degradation Committee, National Oceanic & Atmospheric Administration, U.S. Army Corps of Engineers, U.S. Fish and Wildlife Service, Soil Conservation Service, and Gulf States.
**Initiation Date:** 1995

**Action Item 13:** Quantify the impact of human activity-related nutrient loadings to coastal ocean productivity near the Mississippi and Atchafalaya Rivers.

**Project Description:** Quantify the impact of human activity-related nutrient loadings to coastal ocean productivity near the Mississippi and Atchafalaya River outflows. Develop a model to predict the effects of changes in nutrient loads on productivity and the likelihood of hypoxic/anoxic events as a function of physical, chemical, biological, and geological parameters.
**Lead:** National Oceanic & Atmospheric Administration--Coastal Ocean Program Office.
**Initiation Date:** 1990 **Completion Date:** 1994
**Status:** The Nutrient-Enhanced Coastal Ocean Productivity (NECOP) study is a collaborative effort by the National Oceanic & Atmospheric Administration (NOAA) and academic scientists. NOAA initiated NECOP in 1989 as the first multidiciplinary field effort of the Coastal Ocean Program. NECOP is now in its fourth year of research on five components: 1) Retrospective Analysis, 2) Productivity of the Shelf/Plume System, 3) Hypoxia Research, 4) Research Modeling, and 5) Carbon Flux.

**Action Item 14:** Develop pilot watershed characterization reports in the Gulf of Mexico.

**Project Description:** Based on information generated from Action Items 9 and 10 and other related Gulf of Mexico Committee products, several Gulf of Mexico watersheds will be selected for the development of a comprehensive watershed characterization report. These pilot characterizations will compile and integrate information to 1) identify nutrient sources and quantify nutrient loadings, 2) examine the environmental and ecological impacts of increasing or decreasing nutrient inputs, 3) identify the limiting nutrient(s), and 4) predict the economic and social ramifications of changing nutrient inputs. The feasibility and utility of applying this approach Gulfwide will be assessed, including the cost of compiling/developing the information and its reliability for decision-making. As part of each pilot report, the information compiled and any conclusions derived will be presented in a format to support effective decision-making at the state and local levels. *NOTE: As pilots are selected, individual project descriptions will be developed.*
**Lead:** National Oceanic & Atmospheric Administration, in conjunction with U.S. Environmental Protection Agency.
**Initiation Date:** 1995
→ **3, 9, 10**

**Action Item 15:** Assess the need for a standardized information and synthesis capability for Gulf of Mexico nutrient data.

**Project Description:** Assess the need for a standardized information and synthesis capability for Gulf of Mexico nutrient data, such as a geographical information system. Produce a report with recommendations including the appropriate implementation characteristics of a system: study area, scale, data content, type of computer system, and need for integration with other Gulf of Mexico Program issue areas, etc.
**Lead:** National Oceanic & Atmospheric Administration, in conjunction with U.S. Environmental Protection Agency.
**Initiation Date:** 1995

**Objective:** Develop demonstration projects on potential Gulfwide priority nonpoint and point sources that have a high probability of success within a reasonable time and have the potential for transferability Gulfwide.

**Action Item 16:** Demonstrate the use of chlorophyll meters for determining the need for and amount of nitrogen fertilizer in Gulf of Mexico agricultural operations.

**Project Description:** Provide funding to purchase chlorophyll meters and train selected agricultural professionals on their use. Chlorophyll meters provide one way by which scientific determinations can be made as to when and how much nitrogen fertilization is needed. The project will initially focus on rice production in selected Texas counties. The intent is to expand the demonstration to other crop types (corn, cotton, wheat, and sorghum) and to other states within the Gulf drainage basin.
**Lead:** Cooperative Extension Service, in coordination with Soil Conservation Service, local Soil & Water Conservation Districts, state nonpoint source programs, and experiment stations.
**Initiation Date:** 1991
**Status:** Four chlorophyll meters have been purchased through the Texas Soil & Water Conservation Board for use in rice production in Colorado, Wharton, and Matagorda Counties, TX. The meters are located at the local soil and water conservation district offices and used by district and Soil Conservation Service personnel to provide technical assistance to landowners. The meters have been used consistently by eight landowners and periodically by four others. The estimated reduction in the application of nitrogen as a result of meter use is approximately 15 percent. In addition to the four meters, six rice producers have purchased their own individual meters and one county agent has purchased a meter for use in his job. No problems have been encountered with use or maintenance.

**Action Item 17:** Evaluate the effectiveness of Gulf of Mexico agricultural irrigation management practices on nutrient loadings using water quality monitoring information from subsurface drains.

**Project Description:** Evaluate the effectiveness of various agricultural irrigation management practices on nutrient loadings in the lower Rio Grande Valley of Texas using water quality monitoring information from subsurface drains. The evaluation will cover factors such as the timing and volume of irrigation waters. As data are available, results will be transferred to other states and localities throughout the Gulf of Mexico drainage system.
**Lead:** Gulf of Mexico Program--Nutrient Enrichment Committee, in cooperation with Texas State Soil & Water Conservation Board, Soil Conservation Service, involved Soil & Water Conservation Districts, and other appropriate conservation and agricultural agencies in Texas.
**Initiation Date:** 1992 **Completion Date:** 1995
**Status:** As of January 1993, the instrumentation is in place on three hydrologically isolated fields in the Rio Grande Valley. One of the fields will be used for the production of cotton; one will be used for grain sorghum; and one will be used for vegetable production. Sampling and analyses were initiated in the Spring of 1993.

**Action Item 18:** Evaluate the economic feasibility of transporting animal waste for use as fertilizer.

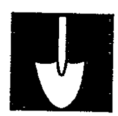
**Project Description:** Evaluate the economic feasibility of collecting, processing and transporting animal waste for use as fertilizer to locations within the state of Texas. The project will include an analysis of potential transport distances, suitable soils that could benefit from the waste, and quantities that can be economically transported.
**Lead:** Soil Conservation Service and Texas A&M University.
**Initiation Date:** 1989
**Status:** The Soil Conservation Service (SCS), in cooperation with Texas A&M University, the Erath County Soil and Water Conservation District and the Leon-Bosque Resource Conservation and Development project conducted a study in 1990-1991 to determine the economic viability of various animal waste management systems, including (but not limited to) the long distance transport of sterilized dairy waste. This approach was not economically feasible at the time of the study. SCS sponsored studies (in cooperation with Texas A&M University) are continuing to generate economically viable options for dairy waste disposal in the State of Texas. Emphasis is no longer exclusively on Erath County.

**Action Item 19:** Evaluate and demonstrate the effectiveness of constructed wetland systems, and individual plant species, as a means of removing nutrients, organics, and oxygen-demanding materials from dairy and swine operations in the Gulf of Mexico region.

**Project Description A:** Evaluate and demonstrate the effectiveness of a constructed wetland system in Newton County, MS, for removing nutrients, organics, and oxygen-demanding materials from dairy lagoons. Compare the several plant species to determine which remove the greatest proportion of materials. It is anticipated that the evaluation will provide valuable information which will be transferable to other similar dairy operations across Mississippi, as well as in several other states. It is also anticipated that the project will solve the on-site water quality problems associated with waste water from that particular dairy operation. The evaluation should last approximately four years (through 1995) to determine whether the cells become saturated with nutrients or organics.
**Lead:** Newton County, MS, Soil & Water Conservation District, under interagency agreement with U.S. Environmental Protection Agency.
**Initiation Date:** 1990 **Completion Date:** 1995

**Project Description B:** Evaluate and demonstrate the effectiveness of a constructed wetland system at two sites in northern Alabama to treat effluent from swine lagoons. This project will investigate both surface water and groundwater impacts and will provide both qualitative and quantitative analyses of these impacts.
**Lead:** Soil & Water Conservation District, in coordination with Soil Conservation Service, Alabama A&M University, Auburn University, and appropriate state agencies.
**Initiation Date:** 1991 **Completion Date:** 1996

**Project Description C:** Evaluate and demonstrate the effectiveness of a constructed wetland system at a site in central Georgia to treat outflow from dairy waste holding ponds. This project will investigate surface water impacts.
**Lead:** University of Georgia, in coordination with Soil Conservation Service, U.S. Environmental Protection Agency--Athens Lab, and appropriate state agencies.
**Initiation Date:** 1991 **Completion Date:** 1995



**Project Description D:** Evaluate and demonstrate the effectiveness of a constructed wetland system at five sites located throughout Kentucky to treat effluent from swine waste facilities. This project will investigate surface water quality and the impact on reducing land application area associated with each waste management system.
**Lead:** Kentucky Department of Environmental Quality, in coordination with University of Kentucky, Soil Conservation Service, and appropriate state agencies.
**Initiation Date:** 1991 **Completion Date:** 1995

**Project Description E:** Evaluate and demonstrate the effectiveness of the constructed wetlands technology to treat effluent from swine and dairy lagoons and waste storage ponds. Use ongoing evaluations of constructed wetlands sites in Mississippi, Alabama, Georgia, Kentucky (see Project Descriptions A, B, C, and D), and one to be initiated in North Carolina to determine appropriate design criteria for sizing the wetland, loading rates (volume and concentration), plant species, and operation and maintenance strategies. Data from these various evaluations including management strategies, surface and groundwater quality, and vegetative health have been collected since 1990. Data resides in various offices of the Soil Conservation Service and will be brought together in a comprehensive report in the next three years. A workshop will be conducted to exchange information.
**Lead:** Soil Conservation Service, with cooperating federal, state, and local agencies.
**Initiation Date:** 1996
**Status:** Constructed wetland evaluations are underway in Alabama, Georgia, Kentucky, and Mississippi; with new evaluations beginning in Alabama and North Carolina. Limited water quality data available for two years on some sites show a great deal of unexplained variability, but consistent effluent treatment.

**Action Item 20:** Assess the feasibility of reformulating feeds to reduce the nutrient content of manures.

**Project Description:** A project is underway in cooperation with Alcorn State University to: 1) provide a free animal waste nutrient analysis to dairy producers in Pike and Amite counties, MS, to determine the nitrogen and phosphorus content of animal wastes being applied on their fields, and 2) create a data base to establish reasons for the sometimes substantial differences in the nutrient content (especially phosphorus) of dairy manures. It is speculated that this variance is due to the wide differences in the type and amount of phosphorus added to feeds as a mineral supplement for cows. When this data base is complete, it is anticipated that it will be used to aid dairy feed producers in determining whether feed reformulations can be made to allow for continued high milk production while reducing the amount of nutrients entering the water. The analysis will also include whether any nutrient reduction might significantly affect water quality in the tributaries and in the Gulf of Mexico.

**Lead:** Alcorn State University, Mississippi, in cooperation with Soil Conservation Service and Gulf of Mexico Program--Nutrient Enrichment Committee.

**Initiation Date:** 1992

**Status:** Some field samples have been taken and some assistance has been given to dairy producers on the management of their animal waste. This phase of the project will continue at least through the end of 1993. Other projects should address the feasibility of reformulating feeds for catfish, swine, broilers, other poultry, and feedlot cattle to reduce the nutrient content of manures.

**Action Item 21:** Evaluate the effectiveness of constructed wetlands in removing nutrients from aquaculture operations in the Gulf of Mexico region.

**Project Description:** Demonstrate, evaluate, and document the effectiveness of a constructed wetland in removing nutrients from a commercial catfish facility near Hattiesburg, MS. Findings are expected to have applications throughout the catfish growing area of the South. The Gulf of Mexico Program will initiate widespread technology transfer efforts.
**Lead:** University of Southern Mississippi--Biology Department, Mississippi State Soil & Water Conservation Commission, Mississippi Department of Environmental Quality, and Gulf of Mexico Program--Nutrient Enrichment Committee.
**Initiation Date:** 1990 **Completion Date:** 1993
**Status:** This project is underway on the Truman Roberts catfish production farm near Hattiesburg, MS. Dr. Gary Anderson of the University of Southern Mississippi is gathering data on the effectiveness of various plant species at removing nutrients, organic materials, and oxygen demanding materials from the water.

**Action Item 22:** Evaluate the effects of increased volumes of water within aquaculture production ponds for reducing nutrient runoff to the Gulf of Mexico.

**Project Description:** Evaluate the effects of increased volumes of water within catfish production ponds for reducing nutrient runoff. A project will be selected in either Mississippi or Alabama and will include a demonstration of an expanded facility with 1.5 feet additional water volume above that normally held.
**Lead:** Gulf of Mexico Program--Nutrient Enrichment Committee, in cooperation with agencies and individuals to be identified.
**Initiation Date:** 1994

**Action Item 23:** Evaluate the effectiveness of constructed wetlands for residential wastewater treatment in the Gulf of Mexico region.

**Project Description:** Establish one or more demonstration projects of constructed wetlands for the purpose of treating wastewater from individual homes in areas where conventional septic systems are prone to failure. Potential locations include the Grand Lagoon area of Florida and a heavy clay soil environment in eastern Texas. An information exchange workshop will be hosted to provide the data and results to all states within the drainage basin.
**Lead:** Appropriate health and water quality agencies within selected states, in conjunction with the Cooperative Extension Service and Soil Conservation Service.
**Initiation Date:** 1995
→ **50**

**Action Item 24:** Evaluate the effectiveness of sewage treatment alternatives for reducing eutrophication in unsewered areas within the Gulf of Mexico region.

**Project Description:** Evaluate sewage treatment alternatives for reducing eutrophication in Grand Lagoon, FL. The results should have application in other bays which are unsewered and have actively eroding soils nearby.
**Lead:** Florida Bay County Soil & Water Conservation District, in conjunction with Gulf of Mexico Program--Nutrient Enrichment Committee.
**Initiation Date:** 1994
→ **8, 38, 45**

**Action Item 25:** Collect and disseminate information on the use of wastewater treatment plant discharges for residential purposes in the Gulf of Mexico region.

**Project Description:** Collect information from St. Petersburg, FL, and other pilot areas on the use of wastewater treatment plant discharges for residential purposes. This involves the use of separate water distribution systems in towns and cities to allow plant discharges to be used by residents to water lawns. Distribute the information to state and local agencies throughout the Gulf of Mexico.
**Lead:** Gulf of Mexico Program--Nutrient Enrichment Committee.
**Initiation Date:** 1996

**Action Item 26:** Evaluate the use of degraded wetlands for cleansing septic tank pumpdown water in the Gulf of Mexico region.

**Project Description:** Septic tanks in low lying, high rainfall areas tend not to work very well. In southern Louisiana, there are numerous communities that rely on septic tanks and are surrounded by levees such that all the water that leaves the community leaves via forced drainage (pumpdown) systems. One such community is in Plaquemines Parish; its pumpdown water enters "Ollie Canal" and ultimately flows from there into Barataria Bay. This pumpdown water has been shown to be high in nutrients and coliform bacteria and Barataria Bay oyster beds are being impacted. This project will evaluate the use of a degraded wetland which adjoins Ollie Canal as a water cleansing system for this pumpdown water. The use of the wetland can be made possible by building a minimum amount of water control structures.
**Lead:** Gulf of Mexico Program--Nutrient Enrichment Committee and Soil Conservation Service, Plaquemines Parish.
**Initiation Date:** 1996

## Source Reduction Strategies

The effective prevention of the harmful effects of nutrient enrichment in Gulf of Mexico waters will require cooperation from many federal agencies, state and local governments, and private and public user groups, as well as a long-term commitment of financial and organizational resources. Over the longer term, the Gulf of Mexico Program will assess the vulnerability of Gulf estuaries to nutrient enrichment and will work to develop or transfer appropriate management approaches for tackling problems at the state and local levels. In some cases, source reduction policies for the entire Gulf of Mexico drainage basin may be developed based on the results of the research, characterization , and demonstration projects within this Action Agenda. Source reduction policies could cover each of the major sources of nutrient enrichment in the Gulf as identified in **Table 2.3**:

| Nonpoint Sources | Point Sources |
|---|---|
| **Agricultural** | **Industrial** |
| Crop Production | **Municipal Wastewater Treatment Plants** |
| Livestock Production | |
| Silviculture | |
| **Urban & Suburban** | |
| **Atmospheric Deposition** | |

In the shorter term, the following action items specify projects to: 1) identify the universe of control strategies that might be appropriate to apply Gulfwide or on a targeted geographic basis and 2) reduce contributions from known or suspected significant contributors.

Specific objectives, action items, and project descriptions follow:

**Objective:** Evaluate the effectiveness of nutrient control technologies for the most significant industrial and municipal point source categories in the Gulf of Mexico.

**Action Item 27:** Identify the range of point source control technologies and pollution prevention approaches for nutrient reduction in the Gulf of Mexico.

**Project Description:** Work with Gulf of Mexico industry and municipalities (and other local entities) to identify the range of control technologies and pollution prevention approaches for significant industrial and municipal categories. Produce a report which summarizes these findings.
**Lead:** Gulf of Mexico Program--Nutrient Enrichment Committee, in conjunction with U.S. Environmental Protection Agency.
**Initiation Date:** 1994
→ **28**

**Action Item 28:** Conduct cost effectiveness analyses of point source control technologies for nutrient reduction in the Gulf of Mexico.

**Project Description:** Select specific point source control technologies and approaches from those identified in Action Item 26 for further analysis. Conduct cost effectiveness analyses for these control technologies and pollution prevention approaches and produce a report on findings and recommendations.
**Lead:** U. S Environmental Protection Agency.
**Initiation Date:** 1995
→ **27**

**Action Item 29:** Promote technology transfer of effective point source control technologies throughout the Gulf of Mexico drainage basin.

**Project Description:** Develop a technology transfer program to encourage and promote the use of effective point source control and pollution prevention technologies by municipal and industrial point source dischargers throughout the Gulf of Mexico region.
**Lead:** Gulf of Mexico Program--Nutrient Enrichment Committee, in conjunction with U.S Environmental Protection Agency.
**Initiation Date:** 1995
**→ 47**

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**Objective:** Implement appropriate Gulfwide or targeted control strategies to reduce significant nutrient loadings from point and nonpoint sources.

**Action Item 30:** Provide technical assistance for effective nutrient management on farms and ranches throughout the U.S. portion of the drainage area of the Gulf of Mexico.

**Project Description:** Farms and ranches will be targeted for nutrient reduction actions using the Action Item 9 report and other Gulf of Mexico Issue Committee information. Technical assistance will include soil testing and recommended application rates for all types of crops. The product is a conservation plan/agreement between the landowner and the local Soil & Water Conservation District which incorporates the beneficial and efficient use of animal wastes, supplemental sludges, and commercial fertilizers, and addresses other requirements under the Conservation Reserve Program and Farm Bill of 1990, Swampbuster provisions of the Food Security Act, and conservation compliance.
**Lead:** State conservation agencies, in conjunction with local Soil & Water Conservation Districts and Soil Conservation Service.
**Initiation Date:** 1994
**→ 9**

**Action Item 31:** Determine the need for NPDES reporting requirements for nutrients in specific Gulf of Mexico watersheds.

**Project Description:** Based on information generated by Action Item 5, determine the need for National Pollutant Discharge Elimination System (NPDES) permittees in specific Gulf of Mexico watersheds to report nitrogen and phosphorus concentrations or loadings within their regular Discharge Monitoring Reports (DMRs). Work with specific permittees to incorporate these requirements in the permit renewal process.
**Lead:** U.S. Environmental Protection Agency, in conjunction with Gulf of Mexico Program--Nutrient Enrichment Committee and state regulatory agencies.
**Initiation Date:** 1995
→ **5**

**Action Item 32:** Develop and implement a Gulfwide strategy to support a national ban on phosphorus laundry detergents for general use.

**Project Description A:** Working with other interested organizations and associations, collect and synthesize information nationwide on the number and types of statewide legislation that currently exist on phosphorus detergent limitations and bans, the types of impacts that have been documented from the use of such detergents, and any "success stories" that have been documented resulting from the bans.
**Lead:** Gulf of Mexico Program--Citizens Advisory Committee.
**Initiation Date:** 1995
→ **46**

**Project Description B:** Develop an informational package targeted to Gulf of Mexico Congressional delegations and state legislators on the current status of phosphate detergent bans and the potential impacts of too much phosphorus in the rivers, bays, and estuaries of the Gulf of Mexico. Arrange and conduct appropriate briefings throughout the Gulf of Mexico region.
**Lead:** Gulf of Mexico Program--Citizens Advisory Committee.
**Initiation Date:** 1995
→ **46**

**Action Item 33:** Accelerate the development of nutrient criteria for waters of the Gulf of Mexico to support the development of state water quality standards.

**Project Description:** Accelerate the development of a nutrient methodology to produce criteria for Gulf of Mexico waters at the watershed level. The methodology should be designed to be simple and enable local authorities to incorporate a limited amount of site specific information. When completed, provide technical assistance to U.S. Environmental Protection Agency Regions 4 and 6 and the Gulf States to develop appropriate limits for discharges.
**Lead:** U.S. Environmental Protection Agency.
**Initiation Date:** 1994

**Action Item 34:** Assess, and develop control strategies as appropriate, for reducing the movement of organic materials to Gulf of Mexico waters.

**Project Description:** Assess, and develop control strategies as appropriate, to reduce the movement of organic materials to Gulf waters. As organic soils subside and erode, large amounts of organic carbon and nutrients may move into eutrophic areas of the Gulf, thus further enriching these waters.
**Lead:** Gulf of Mexico Program--Nutrient Enrichment Committee, in conjunction with Habitat Degradation and Coastal & Shoreline Erosion Committees and Soil Conservation Service.
**Initiation Date:** 1995

- **Action Item 35:** Determine the impacts of nutrients in the New Orleans canal system on Lake Pontchartrain and develop an appropriate control strategy.

> **Project Description:** Determine the impacts of nutrients in the canal water of the City of New Orleans on Lake Pontchartrain. Determine the sources of these nutrients (and coliform bacteria) to the canal water of the City of New Orleans (and other cities as appropriate). Develop appropriate control strategies.
> **Lead:** Gulf of Mexico Program--Nutrient Enrichment Committee, in conjunction with Public Health and Toxic Substances & Pesticides Committees, Lake Pontchartrain Basin Foundation, Louisiana Departments of Environmental Quality and Health & Hospitals, and Parishes of Orleans and Jefferson.
> **Initiation Date:** 1996

**Action Item 36:** Assess the nutrient contribution and impacts of coastal mariculture operations in the Gulf of Mexico.

> **Project Description:** Evaluate nutrient loadings from shore-based and open-water mariculture operations along the Gulf Coast to determine whether additional action should be taken to minimize or control nutrient discharges from these operations.
> **Lead:** State water quality agencies in conjunction with U.S. Fish & Wildlife Service and National Marine Fisheries Service.
> **Initiation Date:** 1996

**Action Item 37:** Assess and document the magnitude of the health and environmental problems associated with the use of septic tanks throughout the Gulf of Mexico region and the costs of conversion to public sewer systems.

> **Project Description:** Septic tanks in low lying, high rainfall areas tend not to work very well. There are dozens of small communities in the coastal areas of the Gulf Coast that do not have community sewers. A new "constructions grants program" for building and modernizing public sewerage treatment facilities may be needed in these coastal areas. This project will assess and document the magnitude of the health and environmental problems associated with the use of septic tanks throughout the Gulf of Mexico region and the costs of conversion to public sewer systems.
> **Lead:** U.S. Environmental Protection Agency and state water quality agencies.
> **Initiation Date:** 1995
> → **38**

**Action Item 38:** Develop and promote appropriate alternative systems for Gulf of Mexico coastal septic systems.

> **Project Description:** Conduct a multi-state workshop, geared to Gulf State and local agencies, on alternative systems for coastal septic systems. Workshop will address appropriate and innovative technologies based on soil types and hydrologic characteristics, as well as potential funding sources.
> **Lead:** Gulf of Mexico Program--Nutrient Enrichment Committee, in conjunction with Public Health Committee, state nonpoint source programs, and state departments of health.
> **Initiation Date:** 1993
> **Status:** A workshop was held on August 16-17, 1993, and a summary report is currently being prepared.
> → **8, 24, 38, 45**

**Action Item 39:** Provide information and recommendations to urban areas throughout the Gulf of Mexico on successful approaches to urban runoff controls.

**Project Description:** Track and compile information on successful state approaches, both within and outside of the Gulf of Mexico region, for urban runoff controls, to include ordinances, riparian areas, detention/retention, growth (zoning), and wetlands/urban forests. This project will include the following steps: 1) work with the states to compile information; 2) organize a forum to determine "successful" approaches; and 3) make recommendations through states to local urban communities throughout the Gulf on successful approaches.
**Lead:** Gulf of Mexico Program--Nutrient Enrichment Committee, in conjunction with state nonpoint source programs and coastal zone management programs.
**Initiation Date:** 1995
**→ 48**

**Action Item 40:** Analyze the effectiveness of Gulf of Mexico State silviculture programs in controlling nutrient runoff.

**Project Description:** Compile and analyze existing state regulatory and non-regulatory programs related to the control of forestry nonpoint source pollution, including the Best Management Practices (BMPs) currently recommended in the five Gulf States and the phases of operation that contribute to nutrient enrichment. Determine the extent to which compliance with BMPs has been documented in the states and the methodologies employed in each. The sharing of information on program application and effectiveness should help strengthen the silvicultural nonpoint program (sediment and nutrient reduction) in the Gulf States.
**Lead:** Gulf of Mexico Program--Nutrient Enrichment Committee, in cooperation with U.S. Forest Service, state forestry organizations, state nonpoint source programs, and Southern Group of State Foresters.
**Initiation Date:** 1996

**Action Item 41:** Develop a Gulfwide strategy to effectively transfer successful nutrient demonstration project techniques and approaches.

**Project Description:** Conduct a comprehensive evaluation of demonstration project results, Action Items 16 - 26. Design and conduct a Gulfwide workshop to inform participants of successful and cost effective approaches based on these results.
**Lead:** Gulf of Mexico Program--Nutrient Enrichment Committee.
**Initiation Date:** 1996
→ **16-26**

**Action Item 42:** Develop a nonpoint source nutrient reduction strategy for Week's Bay, Alabama.

**Project Description:** Conduct an agricultural nonpoint source control project within the drainage area of Week's Bay National Estuarine Research Reserve in Baldwin County, AL, to reduce nutrients, sediments, and pesticides entering the Bay from agricultural nonpoint sources within the drainage area. Week's Bay is not especially impacted by nutrients from point sources but the watershed is an intensively farmed area and parts of it are being converted to rural residences on small acreages (mostly 1-5 acres per homesite) and small subdivisions. Some of the soils are well suited to use of conventional septic tanks while others are not. Week's Bay is one of two "Outstanding National Resource Waters" identified in Alabama.
**Lead:** Baldwin County Soil & Water Conservation District, in cooperation with Soil & Water Conservation Service, Cooperative Extension Service, Soil Conservation Service, Week's Bay National Estuarine Research Reserve, Gulf of Mexico Program--Nutrient Enrichment Committee, and Alabama Department of Environmental Management.
**Initiation Date:** 1993 **Completion Date:** 1995
**Status:** A planning meeting was held in Baldwin County in March 1993 to begin finalizing the project plan.

**Objective:** Develop alliances with other organizations and associations to address appropriate control strategies for Mississippi River contributions to the Gulf of Mexico nutrient problem.

**Action Item 43:** Establish an interbasin commission of organizations that address health and welfare issues associated with the Mississippi River and Gulf of Mexico drainage basin.

**Project Description:** Establish an interbasin commission of existing organizations and associations that are engaged in health and welfare issues associated with the Mississippi River and Gulf of Mexico drainage basin to include the Mississippi Interstate Cooperative Resource Agreement, Upper Mississippi River Conservation Commission, Missouri River Natural Resources Commission, Ohio River Fish Management Team, and Lower Mississippi River Conservation Commission. The Commission should review and address appropriate control strategies for nutrients, to include riparian restoration and wetland preservation, restoration, and utilization.
**Lead:** Gulf of Mexico Program using expertise within appropriate committees.
**Initiation Date:** 1994
→ **49**

## Public Education & Outreach

People living in two-thirds of the U.S. ultimately affect the environmental quality of the Gulf of Mexico. Effective management of nutrients will require an ongoing commitment from an informed citizenry throughout the Gulf drainage basin. Public outreach nurtures such a commitment. Public information, education, and involvement are three components of an effective outreach strategy, which can reap significant benefits both for the Gulf of Mexico and for citizens utilizing its resources. More and more, public outreach is recognized as an effective resource management tool to address problems resulting from individual actions and to create a sense of stewardship within the community. A committed citizenry presents both a supplement and an alternative to enforcement programs.

Public outreach can foster recognition of the Gulf as a regional and national resource; stimulate civic, governmental, and private sector support for changing lifestyles; and develop the financial commitments necessary to preserve the resource. A strong outreach program showing the effects human activities have on the health of the Gulf will enable all individuals, whether living on the coast or along the upper stretches of the Mississippi, to see themselves as caretakers of a vital, shared resource.

Public education and outreach is an integral part of the overall Nutrient Enrichment Action Agenda, designed to support and promote all other action items contained in the Agenda. All action items will incorporate activities and/or materials that are geared to specific public audiences who are targeted as being critical to the success of the actions.

The specific public education and outreach objective, action items, and project descriptions follow:

**Objective:** Develop a Gulfwide comprehensive public information and education program to promote involvement in nutrient reduction actions, through appropriate use of products and environmentally sound lifestyles.

**Action Item 44:** Encourage the efficient and proper use of fertilizers among homeowners and businesses in the Gulf of Mexico through an educational outreach initiative.

> **Project Description:** Develop a Gulfwide public information and education initiative to encourage efficient/proper use of fertilizers on lawns, golf courses, industrial sites, etc. Target homeowners and businesses, including professional lawn care companies, for information.
> **Lead:** Gulf of Mexico Program--Public Education & Outreach Operations, in conjunction with Cooperative Extension Service, Soil Conservation Service, state coastal zone management programs, and SeaGrant.
> **Initiation Date:** 1995
> → **6**

**Action Item 45:** Promote the appropriate use of septic systems in the Gulf of Mexico through an educational outreach initiative to potential users and inspectors.

> **Project Description:** Develop a public information and education effort targeted to users and inspectors of septic systems in the Gulf of Mexico. Information will include appropriate installation and pump-out procedures.
> **Lead:** Gulf of Mexico Program--Public Education & Outreach Operations, in conjunction with state nonpoint source programs, state departments of health, and SeaGrant programs.
> **Initiation Date:** 1995
> → **8, 24, 38**

**Action Item 46:** Develop a Gulfwide outreach initiative to inform citizens about the impacts of phosphorus laundry detergents on Gulf of Mexico resources.

> **Project Description:** Develop a public information and education initiative to explain the potential impacts of phosphate detergents on Gulf of Mexico resources. The objective is to encourage the consuming public throughout the Gulf of Mexico to buy only those detergents which have low or no phosphorus and to generate support for a national ban on phosphate laundry detergents for general use. Materials and activities will be geared to a variety of target audiences and coordinated with other ongoing efforts nationwide.
> **Lead:** Gulf of Mexico Program--Public Education & Outreach Operations, in conjunction with Nutrient Enrichment Committee and others to be identified (possibly include Auxiliary of the National Association of Conservation Districts, Associations of Garden Clubs, Associations of Home Demonstration Clubs, colleges, SeaGrant programs, and universities).
> **Initiation Date:** 1996
> → **32A, 32B**

**Action Item 47:** Develop a Gulfwide outreach program to improve wastewater treatment plant inspections.

> **Project Description:** Develop an outreach program, including training and materials, targeted to inspectors of wastewater treatment plants. The objective is to improve inspections and ensure that appropriate operations and maintenance procedures are followed.
> **Lead:** Gulf of Mexico Program Public--Education & Outreach Operations, in conjunction with U.S. Environmental Protection Agency and SeaGrant programs.
> **Initiation Date:** 1996
> → **29**

**Action Item 48:** Develop a Gulfwide education program on the proper handling of residential nutrient sources.

> **Project Description:** Develop a public information and education effort in urban and suburban areas of the Gulf to encourage proper disposal methods for garden fertilizers and animal waste.
> **Lead:** Gulf of Mexico Program--Toxic Substances & Pesticides Committee, in coordination with SeaGrant programs.
> **Initiation Date:** 1996
> → **39**

**Action Item 49:** Initiate cooperative information exchange programs with other groups on nutrient reduction approaches.

> **Project Description:** Identify groups and organizations throughout the Gulf of Mexico drainage basin, as well as other countries, that conduct nutrient reduction programs. Initiate a cooperative information exchange network with these groups.
> **Lead:** Gulf of Mexico Program--Public Education & Outreach Operations, in coordination with Nutrient Enrichment Committee and SeaGrant programs.
> **Initiation Date:** 1994
> → **43**

**Action Item 50:** Develop a Gulfwide outreach program on the use of constructed wetlands for wastewater treatment.

> **Project Description:** Develop an outreach and education program on the use of constructed wetlands to remove nutrients and organics from wastewater treatment plant and residential effluents. The program should highlight advantages and disadvantages of this approach.
> **Lead:** Gulf of Mexico Program--Public Education & Outreach Operations, in coordination with Nutrient Enrichment Committee and SeaGrant programs.
> **Initiation Date:** 1996
> → **23**

**Action Item 51:** Develop a Mississippi River outreach program designed to increase awareness of nutrients, water quality, and the health of the Gulf of Mexico, as well as relationships between the Gulf and the Mississippi River.

**Project Description:** Develop an outreach and education program designed to increase public awareness about: 1)the relationship between feeder rivers, the Mississippi River, and the health of the Gulf of Mexico; 2) the impact of pollutants on the marine environment; 3) and what individuals can do to make a difference. The Mississippi River Project should link groups with a common interest in protecting the nation's water bodies through education and coordinated action.

**Lead:** Gulf of Mexico Program--Nutrient Enrichment Committee, in coordination with Public Education & Outreach Operations, Soil Conservation Service, Soil & Water Conservation Districts, U.S. Army Corps of Engineers, Mote Marine Laboratory, Clorox Foundation, U.S. Environmental Protection Agency, U.S. Geological Survey, states, and Tennessee Valley Authority.

**Initiation Date:** 1993

**Status:** Materials were developed and provided to selected schools along the Mississippi River. Sessions taught by Soil Conservation Service (SCS) personnel addressed the relationships between waterbodies, the impact of pollutants on the marine environment, and what actions individuals can take. On May 12, 1993, 1000 students in 10 states along the Mississippi River (Minnesota, Wisconsin, Iowa, Illinois, Missouri, Kentucky, Tennessee, Arkansas, Mississippi, and Louisiana) conducted a real water quality test for phosphates and nitrates. SCS personnel conducted a field test, as well. Samples were sent to Mote Marine Laboratory for analysis and a report surveying the results will be made available. The U.S. Geological Survey in Colorado participated in the May 12 activities by testing for pesticide residues in water and will develop a fact sheet. Local television stations in central Florida sponsored a public education initiative and local lakes were tested. Towns in Indiana and Wisconsin conducted testing on feeder rivers to the Mississippi River.

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# In Closing...

We intend this document to be a beginning, not an end. Our hope is that this Action Agenda will serve as an inspiration and a call to action for the millions who live and work in the Gulf of Mexico region. Together, our coordinated actions can make a difference in controlling and substantially reducing nutrient enrichment and its damaging effects and restoring the ecological and economic health of the Gulf of Mexico.

**The Gulf of Mexico Program**
**Nutrient Enrichment Committee**

GULF OF MEXICO PROGRAM

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# FEDERAL LEVEL

## U.S. Environmental Protection Agency (USEPA)

The U.S. Environmental Protection Agency (USEPA) has historically supported research, interagency work, and regulatory activities aimed at reducing adverse impacts from nutrient loading.

- **Clean Water Act of 1977, as amended by the Water Quality Act of 1987.** The goal of the Clean Water Act (CWA) is to "allow for protection and propagation of fish, shellfish, and wildlife and to allow for recreation in and on the water," otherwise known as the fishable/swimmable goal. The objective of the CWA is to "restore and maintain the chemical, physical, and biological integrity of the nation's waters." CWA creates a national permit system with minimum standards for the quality of the discharged waters. CWA does not set specific standards for water bodies, but does provide guidance to the states. States, however, are required to establish standards based on the designated uses of these waters. As part of this process, states establish total maximum daily loads for pollutants to achieve their water quality standards.

  CWA establishes types of pollution to be regulated and categories of industries to be regulated. Conventional pollutants, toxic or "priority" pollutants, and non-conventional pollutants are regulated under the CWA. Federal numerical "criteria" designating allowable concentrations in receiving waters have been established for the priority pollutants.

  Ambient Water Quality Criteria. USEPA has published 40 marine water quality criteria, including ammonia, nitrate/nitrite (drinking water only), and elemental phosphorus, based upon the presumed toxicity of the compounds.

  Water Quality Standards for Wetlands. USEPA has published a guidance document for developing water quality standards for wetlands. This document provides guidance to states which must include wetlands in their definitions of state waters and thus protect the quality of those waters. As a part of that process, states will have to identify "beneficial uses," adopt criteria, and apply antidegradation policies to their wetlands. It is likely that nutrient criteria are going to be necessary in order for states to promulgate even narrative water quality standards for wetlands since uses are impacted by nutrient enrichment.

  Biological Criteria. USEPA has published guidelines for developing biological criteria for streams and rivers. These guidelines can be used by states to identify, protect, and maintain the biological integrity of their surface waters, especially when biocriteria are used as triggers to set-off more indepth evaluation and management activities. Biological criteria should allow water resource managers to account for the effects of seasonality. Biocriteria may serve as excellent assessment tools to derive site-specific nutrient criteria, especially for rivers and streams.

National Pollutant Discharge Elimination System (NPDES). CWA requires that direct point source dischargers obtain National Pollutant Discharge Elimination System (NPDES) permits that regulate their discharges to attain effluent standards or state water quality standards. Specific wastewater dischargers into storm water drainage systems must also receive permits. CWA requires direct point source industrial dischargers to control conventional, as well as toxic and non-conventional, pollutants.

Municipal wastewater treatment plants are required to meet standards different from those for direct industrial dischargers. However, both municipal and industrial dischargers are required to meet the same ambient water quality standards. Technology-based regulation of discharges focuses almost exclusively on conventional pollutant control through the requirement for secondary (85 percent removal of suspended solids and biochemical oxygen demand) levels of treatment. To meet state water quality standards, some municipal wastewater treatment plants have been required to go to more advanced levels of treatment (tertiary treatment).

Nonpoint Source Program. Section 319 of the CWA also establishes a program for managing contaminated runoff from nonpoint sources of pollution. Each state identifies all water body segments that fail to meet water quality standards for designated uses due to runoff, boating wastes, faulty septic systems, and other sources of nonpoint pollution. The source category codes used by states to identify nonpoint source impairments are listed in **Table A.1**. Each state has submitted a four-year management program for controlling these pollutant sources.

National Estuary Program (NEP). Sections 317 and 320 of the Clean Water Act (as amended in 1987) established the National Estuary Program (NEP). The mission of the Program is "to promote long-term planning and management in nationally significant estuaries threatened by pollution, development, or overuse...and to promote the preparation of comprehensive conservation and management plans (CCMP) to ensure their ecological integrity." At present, there are twenty-one estuaries in the National Estuary Program; five in the Gulf of Mexico (Galveston Bay, Tampa Bay, Sarasota Bay, Corpus Christi Bay, and the Barataria-Terrebonne Estuarine Complex). Each of the Gulf NEPs are addressing eutrophication problems, from point and/or nonpoint sources.

## Table A.1 *Source Category Codes Used by States to Identify Nonpoint Source Impairments**

| | |
|---|---|
| **10** | **Agriculture** |
| 11: | Non-irrigated crop production |
| 12: | Irrigated crop production |
| 13: | Specialty crop production (e.g., truck farming and orchards) |
| 14: | Pastureland (Grazing) |
| 15: | Rangeland (Grazing) |
| 16: | Feedlots—all types |
| 17: | Aquaculture |
| 18: | Animal holding/management areas |
| 19: | Unspecified &/or Odd |
| **20** | **Silviculture** |
| 21: | Harvesting, reforestation, residue management |
| 22: | Forest management |
| 23: | Road construction/maintenance |
| 29: | Unspecified |
| **30** | **Construction** |
| 31: | Highway/road/bridge |
| 32: | Land development |
| 38: | Railroads |
| 39: | Unspecified |
| **40** | **Urban Runoff** |
| 41: | Storm sewers (source control) |
| 42: | Combined sewers (source control) |
| 43: | Surface runoff |
| 45: | Shipyards |
| 46: | Marinas |
| 49: | Unspecified |
| **50** | **Resources Extraction/Exploration Development** |
| 51: | Surface mining |
| 52: | Subsurface mining |
| 53: | Placer mining |
| 54: | Dredge mining |
| 55: | Petroleum activities |
| 56: | Mill tailings |
| 57: | Mine tailings |
| 59: | Unspecified |
| **60** | **Land Disposal (Runoff/Leachate from Permitted Areas)** |
| 61: | Sludge |
| 62: | Wastewater |
| 63: | Landfills |
| 64: | Industrial land treatment |
| 65: | On-site wastewater systems (septic tanks, etc.) |
| 66: | Hazardous waste |
| 69: | Unspecified |
| **70** | **Hydrologic/Habitat Modification** |
| 71: | Channelization |
| 72: | Dredging |
| 73: | Dam construction |
| 74: | Flow regulation/modification |
| 75: | Bridge construction |
| 76: | Removal of riparian vegetation |
| 77: | Shoreline for lakes/streambank modification/ destabilization/erosion |
| 78: | Ag streambank erosion (Sub of 10) |
| 79: | Unspecified |
| **80** | **Other** |
| 81: | Atmospheric deposition |
| 82: | Waste storage/storage tank leaks |
| 83: | Highway maintenance and runoff |
| 84: | Spills |
| 85: | In-place contaminants |
| 86: | Natural |
| 87: | Recreational activities |
| 88: | Growth urban |
| 89: | Unspecified &/or Odd |
| **90** | **Source Unknown** |

*This may include both point and nonpoint sources.

**(Source: USEPA, 1992)**

- **National Environmental Policy Act of 1969, as amended (NEPA).** NEPA requires that all federal agencies recognize and give appropriate consideration to environmental amenities and values in the course of their decision-making. In an effort to create and maintain conditions under which man and nature can exist in productive harmony, NEPA requires that federal agencies prepare an environmental impact statement (EIS) prior to undertaking major federal actions that significantly affect the quality of the human environment. In some cases, issuing a discharge permit may constitute a "major federal action." Within these statements, alternatives to the proposed action that may better safeguard environmental values are to be carefully assessed.

- **The Clean Air Act of 1970, 1977, and 1990 Amendments (CAA).** The CAA requires USEPA to control air pollution by specifying maximum acceptable levels for pollutants in outdoor air; limiting the release of hazardous substances; developing standards for new stationary and motor vehicle emissions; and requiring states to develop and enforce state implementation plans that spell out measures that will be taken to achieve acceptable air quality.

  Section 112 of the CAA addresses hazardous air pollution - "air pollution to which no ambient air quality standard is applicable and which in the judgment of the Administrator causes, or contributes to, air pollution which may reasonably be anticipated to result in an increase in mortality or an increase in serious irreversible or incapacitating reversible, illness."

  Section 112(m) of the 1990 CAA Amendments requires USEPA and NOAA to estimate the importance of atmospheric deposition of hazardous air pollutants to the Great Waters. This section requires documentation of gross atmospheric contaminant loadings to each water body, as well as quantification of the relative importance of those loadings compared to those from all other possible sources. Further, the agencies are required to determine whether atmospherically-derived contamination results in exceedences of water quality standards and to estimate the fraction of contaminants accumulating in biota which are derived from the atmosphere. Simply stated, Section 112(m) requires the agencies to construct quantitative chemical mass balances for relevant contaminants in each of the Great Waters.

- **Safe Drinking Water Act and Amendments of 1974 and 1986 (SDWA).** The SDWA authorizes USEPA to establish national standards for drinking water from both surface and groundwater sources and to protect aquifers against contamination from the disposal of wastes by injection into deep wells.

## U.S. Department of Agriculture (USDA)

- **Farm Bills of 1985 and 1990 (Food Security Act of 1985 and Food, Agriculture, Conservation & Trade Act of 1990).** The conservation provisions of the 1985 Farm Bill created several new USDA programs and/or program requirements. For the first time, eligibility for most USDA program benefits was tied to compliance with the conservation provisions. Important conservation provisions created in the 1985 Farm Bill, some of which were subsequently modified and strengthened by the 1990 Farm Bill include the following:

  Conservation Reserve Program. This is a long-term land retirement program applicable to agricultural land that is eroding at excessive rates or is otherwise environmentally sensitive, including prior converted wetlands that could be restored to stands or hardwood trees and filter strips along streams. Approximately 40 million acres of previously farmed land has been converted to long-term stands of grasses or trees under this program. The program contracts are usually for ten year periods.

  Sodbuster. This provision provides that any highly erodible farm land which is converted from perennial vegetation, such as grass or trees to cultivated agriculture, be given appropriate erosion control treatment prior to planting an agricultural commodity.

  Swampbuster. This provision provides severe economic disincentives for conversion of wetlands for the production of agricultural commodities (land converted after December 23, 1985).

  Conservation Compliance. This provision provides that highly erodible land used for production of agricultural crops before the passage of the 1985 Farm Bill must have a conservation plan developed by January 1, 1990, and that the plan be completely applied by January 1, 1995.

  Conservation Easements. This provision allows for "write-downs" on farm loans held by the Farmer's Home Administration (FmHA) in return for perpetual easements on wetlands or other environmentally sensitive lands. In appropriate cases, FmHA may retain perpetual conservation easements on wetlands owned by the agency before disposing of that land.

  Wetland Reserve Program. This program was created by the 1990 Farm Bill as a pilot program to determine the feasibility of USDA purchasing perpetual easements on prior converted wetlands. The land would then be re-established to wetland vegetation (mostly trees in the southern states). To date, there has been one "sign-up" period under this program and the response from land users was very positive.

Compliance and/or participation in each of these conservation programs is voluntary. Noncompliance may result in economic consequences of substantial proportions for those agricultural producers who participate in USDA programs, such as price supports, farm commodity loans, etc. All of these programs and requirements should have a beneficial effect on soil erosion control, as well as improving quality of runoff from applicable fields.

## Soil Conservation Service (SCS)

The Soil Conservation Service (SCS) is USDA's primary technical assistance agency in the areas of soil and water conservation and in water quality. SCS focuses its assistance on non-federal land. It works primarily with private landowners in planning and applying measures to reduce soil erosion, conserve water, protect and improve water quality, and protect other renewable natural resources such as plants, animals, and air. The guiding principle is the use and conservation treatment of the land and water in harmony with its capabilities and needs.

SCS has an office in almost every county in the U.S. where it works closely with local subdivisions of state government called Soil and Water Conservation Districts. The conservation districts are governed by local people and typically have legislative mandates to plan and implement comprehensive soil and water conservation programs within their boundaries. These boundaries usually coincide with county lines.

SCS's basic authorities were created by PL (74) - 46, PL (83) -566, and PL (78) - 534. Program authorities were added under various Farm Bills including those enacted in 1961 (Resource Conservation and Development Program), 1985 (Swampbuster, Sodbuster, Conservation Compliance and Conservation Reserve Program), and 1990 (Wetlands Reserve Program and others).

SCS also performs soil surveys and operates a system of some 27 Plant Material Centers for selecting, developing, testing, and releasing plants for use in conservation programs.

SCS works with private landowners and others to preserve, protect, and restore wetlands and to develop wildlife and fisheries habitat.

## Agricultural Stabilization & Conservation Service (ASCS)

The Agricultural Stabilization & Conservation Service (ASCS) administers the following programs: Agricultural Conservation Program, Conservation Reserve Program, Wetland Program, as well as others. In addition, ASCS administers various agricultural commodity production programs designed to balance production of those commodities which are in demand. Commodities affected include cotton, rice, corn, wheat, peanuts, tobacco, and others. Commodity Program decisions dramatically affect land use and nutrients applied to land. ASCS also has an office in essentially every county in the U.S. SCS and ASCS work closely on implementation of conservation programs.

### Cooperative Extension Service (CES)

The Cooperative Extension Service (CES) is the education and outreach branch of land grant colleges and institutions. Funding for this program is provided through a cooperative effort between the U.S. Department of Agriculture, individual states, and local governments. CES staff are located in each county, with specialists at the state level to support their activities. CES focuses on four main areas: 1) agriculture and natural resources, 2) home economics, 3) 4H, and 4) community and rural development. CES promotes the wise use of fertilizer through a public education/outreach program and other activities, such as applied demonstrations on agricultural fields, to illustrate the proper and efficient use of fertilizer.

### Farmers Home Administration (FmHA)

The Farmers Home Administration (FmHA) administers various rural financial assistance programs for rural residents and small communities. These programs include loans for construction of homes in rural areas and small towns, loans and grants for rural water and sewerage projects, and loans for small watershed project sponsors.

### U.S. Forest Service (USFS)

The U.S. Forest Service (USFS) administers large units of land called "National Forests" in most of the fifty states, as well as "National Grasslands" in some states. USFS is directly responsible for management of natural resources in the National Forests and Grasslands. In addition, USFS assists with forestry and silvicultural matters on private lands as appropriate. The Service manages 44 national wildlife refuges [366,925 hectares (906,660 acres)] and ten national fish hatcheries [436 hectares (1,078 acres)] in the Gulf of Mexico drainage basin, and utilizes Best Management Practices in management of these lands to reduce nonpoint source pollution.

USFS State & Private Forestry programs are implemented cooperatively through the various state forestry organizations and are guided by the Southern Group of State Foresters. Funding is granted to the state foresters to provide technical assistance and financial incentives to forest landowners and cooperators through a variety of federal programs. These federal/state cooperative programs are aimed at protecting and enhancing the quality of all forest resources including watershed, timber, and wildlife values. USFS provides technical assistance for developing, implementing, and monitoring silvicultural best management practices, programs, and plans to control nonpoint pollution from forest management activities.

USFS's Bay/Estuary Program is a nationwide effort, focusing on specific bay and estuary systems, to integrate and coordinate all Service functions affecting conservation of coastal living resources in these systems. Bay/Estuary Programs work in partnership with other agencies and non-governmental organizations to develop and implement ecosystem-based policies and programs that protect and enhance coastal living resources. Where appropriate, actions to address nutrient enrichment problems are integrated into individual Bay/Estuary Programs. Bay/Estuary Programs have either begun or have been proposed for seven estuarine systems in the Gulf of Mexico. In some systems, the Bay/Estuary Program complements the Environmental Protection Agency National Estuary Program.

USFS's Partners for Wildlife Program identifies opportunities and implements wetland habitat restoration, creation, or improvement projects on private lands in partnership with landowners. Such projects ultimately contribute to nutrient reduction due to the nutrient removal function of healthy wetland habitats. Areas appropriate for such projects are identified through review of Farmers Home Administration inventory properties or other landowner contacts. The Service assists landowners in developing projects through outreach, technical support, and arranging for land use payments.

## U.S. Department of Commerce (USDOC)

### *National Oceanic & Atmospheric Administration (NOAA)*

- **Coastal Zone Management Act of 1972 (CZMA).** The Coastal Zone Management Act of 1972 encourages coastal and Great Lakes states to develop and implement management programs to achieve wise use of land and water resources in the coastal zone and authorizes the National Oceanic and Atmospheric Administration (NOAA) to issue grants for state coastal management programs.

  Coastal Zone Act Reauthorization Amendments of 1990 (CZARA). Section 6217 requires states to establish coastal nonpoint programs, which must be approved by both NOAA and USEPA. Once approved, the coastal nonpoint programs will be implemented through changes to the state nonpoint source pollution program approved by USEPA under Section 319 of the CWA and through changes to the state coastal zone management program approved by NOAA under Section 306 of the Coastal Zone Management Act (CZMA). Beginning in fiscal year 1996, states that fail to submit an approvable coastal nonpoint program to NOAA and USEPA face statutory reductions in federal funds awarded under both Section 306 of the CZMA and Section 319 of the CWA.

The central purpose of Section 6217 is to strengthen the links between federal and state coastal zone management and water quality programs in order to enhance state and local efforts to manage land use activities that degrade coastal waters and coastal habitats. This is to be accomplished primarily through the implementation of 1) management measures in conformity with guidance published by USEPA under Section 6217(g) of the CZARA and 2) additional state-developed management measures as necessary to achieve and maintain applicable water quality standards.

The Section 6217 program guidance identifies and explains provisions state coastal nonpoint programs must include in order to be approved by USEPA and NOAA. Four of the many requirements for state programs are: 1) identify critical coastal areas adjacent to coastal waters which are impaired or threatened by nonpoint source pollution; 2) implement additional management measures for land uses or critical coastal areas as necessary to achieve and maintain water quality standards; 3) establish mechanisms to improve coordination among state and local agencies responsible for land use programs and permitting, water quality permitting and enforcement, habitat protection, and public health and safety; and 4) modify coastal zone boundaries as the state determines is necessary to implement NOAA's recommendations under Section 6217(e) of the CZARA. (This section requires NOAA and USEPA to determine whether the landward coastal zone of each coastal state extends far enough inland to control significant upland sources of nonpoint source pollution.)

- **Strategic Environmental Assessments (SEA) Division Programs.** NOAA's Strategic Environmental Assessments (SEA) Division develops comprehensive information about environmental quality as it relates to estuarine and oceanic resources. These data are used for national and regional assessments to develop practical strategies to balance conservation requirements and use demands.

  This Division is conducting the Estuarine Eutrophication Survey, a national survey of the conditions and trends of nutrient enrichment and eutrophication in the estuaries of the contiguous U.S. The goal is to assess the scale and scope of existing problems and provide an information base to identify future research and monitoring needs. Using a standard survey instrument that will be administered to over 200 local and regional experts, the assessment will collect information on the current and historic conditions of algal, nutrient, and dissolved oxygen concentrations and ecosystem response for 102 major estuaries in the nation. The project, scheduled for completion in 1994, will improve the understanding of the relationship between eutrophication status and nutrient input.

  The Estuarine Eutrophication Survey builds on early work by the SEA Division (FY89) that evaluated the susceptibility of estuaries to nutrient enrichment using flushing dilution characteristics, rate of freshwater inflow, estuarine volume, and estimated nutrient loadings. The results of this work were presented in a series of regional reports that summarized the physical dimensions, pollution susceptibility indices, estimated loadings, predicted concentrations status, land use, and point and nonpoint source loadings of nitrogen and phosphorus for each estuary in the region. Also included was a brief interpretation of the information for each estuary and an estimate of the effect of changes in nutrient loadings.

The National Coastal Pollution Discharge Inventory (NCPDI) is a data base and computational framework for characterizing the sources, location, timing, and magnitude of pollution discharges from land-based sources in coastal areas. It includes seasonal and annual estimates for point, nonpoint, and upstream sources discharging to the estuarine, coastal, and oceanic waters of the contiguous U.S. (excluding the Great Lakes). The estimates in NCPDI are intended for first order assessments of the relative contributions of pollutant discharges among sources within and across watersheds.

NCPDI estimates for the watersheds draining to the Gulf of Mexico are for a base year of 1987, and will be updated to a 1991 base year in FY94. As part of the update, the study area will be expanded to incorporate more inland areas and the methods used to estimate discharges will be improved for all sources.

- **National Marine Fisheries Service (NMFS).** The National Marine Fisheries Service (NMFS) acts primarily under the auspices of the Fish and Wildlife Coordination Act (FWCA) as an advisory agency to federal construction and permitting agencies. The FWCA requires any federal agency, permitting construction in the waters of any stream or other body of water, to first consult with NMFS and other federal and state natural resource agencies, with a view toward the conservation of fish and wildlife resources. The FWCA directs NMFS to take such steps as may be required for the conservation and protection of marine and estuarine fishery resources and their habitats. NMFS recommendations are provided to USACE for proposed Department of Army permits under Section 404 of the CWA and Section 10 of the Rivers and Harbors Act. NMFS information is also used in developing environmental documents required by the National Environmental Policy Act.

- **Coastal Ocean Program (COP).** The Coastal Ocean Program (COP) is a cross-cutting NOAA effort to provide the highest quality science delivered in time for important coastal policy decisions. COP activities are organized around four goals. These address the major coastal ocean issues of Environmental Quality, Fisheries Productivity, and Coastal Hazards; and the fourth, Information Delivery, operates at the science-policy interface. One of the COP themes, Nutrient Enhanced Productivity, is examining the effects of human-induced nutrient enrichment on the productivity of the Gulf of Mexico at the

Mississippi and Atchafalaya Rivers. A smaller effort in the Chesapeake Bay area is addressing the role of the atmosphere in nutrient input.

Nutrient-Enhanced Coastal Ocean Productivity (NECOP)--Mississippi/ Atchafalaya River Study. The Nutrient-Enhanced Coastal Ocean Productivity (NECOP) study is a collaborative effort by NOAA and academic scientists. NOAA initiated NECOP in 1989 as the first multidiciplinary field effort of the Coastal Ocean Program. NECOP is a five year study that is now in its fourth year of research on the physical, chemical, biological, and geological processes that relate to anthropogenic nutrient enrichment and productivity in the vicinity of the Mississippi/Atchafalaya River outflows. The NECOP study has five major research components: 1) Retrospective Analysis, 2) Productivity of the Shelf/Plume System, 3) Hypoxia Research, 4) Research Modeling, and 5) Carbon Flux.

NECOP researchers are quantifying the impact of anthropogenic nutrients on coastal productivity. Long-term objectives of the NECOP study include developing a capability to predict the impact that nutrient control strategies are likely to have on productivity and a capability to predict the likelihood of hypoxic/anoxic events as a function of physical, chemical, and biological parameters. A model is being developed that will permit estimates of the effects of changes in nutrient loads to the system.

- **National Sea Grant College Program.** The National Sea Grant College Program provides a major effort in the Gulf regarding research, education, and outreach activities. The Sea Grant education program is an important environmental program in the Gulf, affecting many tens of thousands of students and citizens annually. The outreach program provides the public a marine agent in each coastal county in all of the Gulf States. The Nutrient-Enhanced Coastal Ocean Productivity (NECOP) program is managed through Sea Grant programs in each state.

## U.S. Department of the Interior (USDOI)

### *U.S. Fish & Wildlife Service (USFWS)*

The Fish & Wildlife Service (USFWS) focuses attention on nonpoint source pollution problems in a number of areas. USFWS has conducted research to define the scope and effect of pollutants from urban and agricultural runoff, mining, silviculture, and hydromodification on fish and wildlife species and their habitats. USFWS has also conducted special information and education efforts to encourage farm owners to participate in the USDA Conservation Reserve Program and worked with the Agricultural Extension Service to develop a pamphlet emphasizing the benefits of riparian vegetation in reducing nonpoint source pollution.

In accordance with USDOI's Irrigation Drainwater Program, USFWS is determining the causes and degree of problems associated with excessive levels of micronutrient (*e.g.*, selenium, boron) in irrigation wastewaters. Controls and alternatives to help mitigate these problems are under development.

USFWS routinely provides recommendations to construction/regulatory agencies on best management practices to control nonpoint source pollution when reviewing permit/license applications, federal project construction and operation plans, resource management plans, conservation easements, and other types of land management activities. Measures to mitigate damage to fish and wildlife resources or their habitats are included in these recommendations.

### *Bureau of Land Management (BLM)*

The Bureau of Land Management (BLM) focuses its efforts on assisting states to identify affected bodies of water and develop nonpoint source management plans. The foundation for these efforts was provided by the Clean Water Act Section 208 Program. The Bureau and the U.S. Forest Service jointly developed a training program for managers, planners, and natural resource staffs on the role and responsibility of each agency in nonpoint source pollution control. Congress provided specific funding for the Bureau's Riparian Management Program. This program has had and will continue to have a significant effect on improving water quality on stream reaches under Bureau management and will remain one of the Bureau's highest priorities.

### *Bureau of Reclamation*

The Bureau of Reclamation operates under the authority of the 1902 Reclamation Act and Amendments and Executive Orders. In 1987, Reclamation announced a redirection in its mission. Instead of concentrating primarily on water resource development, Reclamation is placing greater emphasis on more efficient operation of existing projects and resource management issues, such as water quality and environmental restoration. Several initiatives address nonpoint source pollution, including irrigation drainage research, technology development, cooperative basin water quality studies, and a national irrigation water quality program.

### *U.S. Geological Survey (USGS)*

The mission of the U.S. Geological Survey (USGS), Water Resources Division, is to provide the hydrologic information and understanding needed for the optimum utilization and management of the nation's water resources for the overall benefit of the people of the U.S.

## U.S. Department of Defense (USDOD)

### *U.S. Army Corps of Engineers (USACE)*

Nonpoint source pollution control efforts by the U.S. Army Corps of Engineers (USACE) include those made by the agency in its own operating projects and support of state nonpoint source management programs. Efforts within the agency's operating projects focus on sedimentation and water quality in flood control reservoirs and navigation channels.

The Water Resources Development Act of 1986, Section 1135, authorized USACE to make modifications in the structures and operations of water resources projects which are feasible, consistent with the authorized project purpose, and will improve the quality of the environment in the public interest. Nonpoint source pollution control activities may be incorporated into such projects.

USACE has reviewed state assessments and management programs for nonpoint source control to: 1) plan future steps for federal projects; 2) provide for technical coordination so that the best practicable control measures can be achieved; and 3) facilitate the review of consistency between such projects and state nonpoint source management programs.

## Tennessee Valley Authority

The Tennessee Valley Authority (TVA) carries out its statutory authority related to land management, administration of land rights, and permitting jurisdiction under Section 26a of the TVA Act to protect or enhance the quality of the environment on its reservoir properties. In conducting its own operations and construction activities, TVA ensures the use of BMPs to control nonpoint source pollution.

In compliance with Section 401(a) of the Clean Water Act, TVA requires that applicants proposing activities that may result in discharges into navigable waters provide state certification that they will comply with applicable provisions of the CWA. In addition, TVA requires that any permit approval, contract, license, or other authorization of any activity required by TVA that will disturb the land contain the following condition: "The applicant will conduct all land-disturbing activities in accordance with best management practices as defined by section 208 of the CWA and implement these practices to control erosion and sedimentation so as to prevent adverse water quality and related aquatic impacts."

TVA has established erosion control measures that help to mitigate nonpoint source pollution on the agency's lands [over 8,094 hectares (20,000 acres)]. Control measures include no-till cropping, crop rotation, contour plowing, terracing, winter cover crops, and uncultivated buffer strips along TVA reservoirs and streams. Only land that is not highly erodible and is not hydric is licensed for row crop use. Best management plans for cropland and grassland are reviewed by Soil Conservation Service personnel.

To reduce nonpoint source pollution from crop production, TVA conducts fertilizer research and development at its national laboratory at Muscle Shoals, AL, and works with the land grant universities and USDA.

# STATE LEVEL

## Alabama

### *Regulatory Agencies & Programs*

- **Department of Environmental Management (ADEM).** The Department of Environmental Management (ADEM) is responsible for establishing and enforcing water quality standards, in accordance with criteria contained in the Clean Water Act. ADEM sets and enforces water quality standards for point source discharges. ADEM's resource management responsibilities include regulation of construction in wetlands and monitoring of biological resources, in conjunction with enforcement of water quality standards and coastal program regulations.

- **Department of Conservation & Natural Resources (ADCNR).** The Department of Conservation & Natural Resources (ADCNR), in addition to other responsibilities, has review and comment responsibility in regard to coastal construction. The state Land Division of ADCNR manages use of state bottoms, including removal of sediment, buried oyster shell, hydrocarbons, sand, and gravel. It also leases such bottomlands for commercial uses such as marinas, private oyster reefs, and oil and gas extraction. As noted above, approval for construction and discharge activities is administered by ADEM (USACE must approve construction in bay and delta waters and wetlands).

- **State Docks Department (ASD).** Any construction in water bottoms or wetlands also requires approval and licensing by the Alabama State Docks Department (ASD). ASD is also the local sponsor of navigation improvements in the Port of Mobile and is therefore responsible for designing, securing, and maintaining disposal sites for dredged material. Use of such sites requires approval of ADEM and USACE.

- **Silvicultural Nonpoint Source Management Plan.** Alabama's Silvicultural Nonpoint Source Management Plan calls for a voluntary best management practices (BMP) program. There are no state laws which regulate forestry practices in Alabama. However, state law prohibits deposition of any pollutant into waters of the state from any activity, including forestry. The primary emphasis of the program is on education, training, technical assistance, and implementation monitoring.

  Education. *Alabama's Best Management Practices for Forestry* was last revised in March 1993. The manual offers non-regulatory guidelines for complying with all state and federal water quality laws up to that time. Color illustrations demonstrate practical techniques for controlling pollutants and protecting water quality. News releases, radio and television programs, and public presentations are used to inform the forestry community and the general public of the availability, effectiveness, and practicality of using BMPs during all forestry operations.

Training. Forest landowners, loggers, and foresters are trained on practical applications of BMPs as standard operating procedures. Training aids include slides, videos, BMP demonstration sites, and field tours to active operations. Pre-harvest consultations are provided by Forestry Commission personnel to help avoid problems through planning prior to initiation of forestry activities.

Technical Assistance. Forestry Commission personnel provide technical advice and assistance to landowners who wish to stabilize roads, firelanes, skid trails, log landings, and stream crossings. Technical assistance is also offered to help mitigate any water quality problems that do result from forest operations. Every effort is made to resolve problems without having to refer cases to regulatory agencies.

Monitoring. Forestry Commission personnel monitor sites on a random basis to determine trends in BMP implementation and effectiveness. Approximately 400 sites are visited each year in Alabama. Visits with active operations are turned into on-the-job training opportunities. Serious problems discovered are mitigated between parties responsible.

- **Local Management Activities.** Alabama counties are responsible for management of storm water drainage, except in the City of Mobile, which has enacted stringent restrictions on modification of areas within the 100 year flood zone.

  Water quality is affected significantly by storm water runoff, partly as a result of seepage from septic systems in or near the coastal zone. County Boards of Health are responsible for issuance of permits to install septic tanks and seep systems and to enforce restrictions on septic system use in areas where soil conditions are unsuitable. Many systems around the coast are located in unsuitable soils or do not operate properly and are responsible for an unknown amount of fecal coliform bacteria contamination of surface waters.

  The South Alabama Regional Planning Commission (SARPC) was established to improve local management and planning, with respect to both natural and human resources of Mobile, Baldwin, and Escambia Counties. SARPC provides local oversight for a variety of estuary studies and management projects, including land use planning, water quality management planning (USEPA 208 program), and storm water management planning. In addition, SARPC is responsible for planning guidance for other local entities with regard to demographics, outdoor recreation, industrial development, and other considerations in coastal zone resource use.

### *Statutes & Initiatives*

Alabama Water Pollution Control Act
Alabama Coastal Area Act
Alabama Coastal Area Management Plan

## Florida

### *Regulatory Agencies & Programs*

Florida's nonpoint source implementation activities include enforcement of regulations that require BMPs for erosion and sediment control during and after construction; enforcement of wetland protection regulations; public education programs; monitoring; BMP evaluation; and providing technical assistance.

Florida's growth management program and the Surface Water Improvement and Management Program (SWIM) have greatly expanded awareness of nonpoint source water quality problems and the implementation of watershed management strategies. SWIM plans have been approved for the priority waterbodies listed in the Florida assessment.

Florida has undertaken several initiatives to address storm water runoff. The state worked with USEPA to refine the draft NPDES storm water regulation published in December 1988. In addition, comprehensive storm water management legislation developed by the state government passed the 1989 Florida Legislature. This legislation integrates the storm water regulatory program, the SWIM program, and the growth management program into a comprehensive watershed approach to reducing storm water pollution loadings.

To assist with implementation of the legislation, the state government has provided technical assistance to water management districts, local governments, and the private sector. In addition, the department continues to conduct research on the efficiency of various storm water BMPs.

Florida has also helped local governments revise their land development codes to include ordinances that will further reduce nonpoint source pollution. The state also has recommended that local governments establish storm water utilities to provide a dedicated source of revenues for the development and implementation of storm water master plans.

Florida began public education efforts in the late 1970s and has continued these efforts throughout the 1980s. The most recent example of public education is the distribution of nearly 1,200 copies of the *Florida Development Manual: A Guide to Sound Land and Water Management* to local governments, state agencies, consulting engineers, planners, and citizens.

## Louisiana

### *Regulatory Agencies & Programs*

- **Department of Environmental Quality (LADEQ).** Office of Water Resources (OWR). The Office of Water Resources, Department of Environmental Quality is composed of four divisions that provide for regulation and management of the quality of Louisiana surface and ground waters. The mission of OWR is to manage the quality of Louisiana's surface and ground waters by upgrading the quality where man's activities have caused degradation and by preserving the integrity of those waters where good quality exists. The OWR divisions typically consist of the following programs and activities: Administration, Enforcement, Engineering, Permitting, Quality Assurance, Standards and Water Quality Management, and Surveillance. OWR administers its programs under authority of the State Water Control Law and Title 33 Part IX of the Louisiana Administrative Code, as well as the Federal Clean Water Act.

- **Department of Health & Hospitals (DHH).** The goal of programs within the Department of Health and Hospitals (DHH) is to provide for the protection of the public health of the citizens of Louisiana, as well as provide for prevention of death and disease. DHH is responsible for the administration of the State Sanitary Code. This involves the implementation of the Federal Safe Drinking Water Act, which includes the monitoring of public water supplies and the regulation of water treatment and distribution systems, including the proper design, construction, operation, and water quality in public water supplies; regulation of sewage treatment, sanitary sewage disposal, and other wastewater matters, including on-site wastewater treatment systems (*i.e.* septic systems, mechanical plants); and bacteriological/chemical analyses of sewage water, raw water, and drinking water.

  Additionally, DHH has responsibility for evaluating the potential adverse human health effects caused by exposure to the presence of toxic substances in the environment and for providing recommendations for correction and/or prevention.

- **Department of Agriculture & Forestry.** Office of Agriculture & Environmental Sciences. The Office of Agriculture and Environmental Sciences is responsible for the Federal Insecticide, Fungicide & Rodenticide Act (FIFRA), and Resource Conservation & Recovery Act (RCRA) dealing with pesticide waste. The Department participates in pesticide analyses of water, sediment, and/or biological samples and conducts agricultural related nonpoint source pollution studies. The Department is responsible for carrying out the Louisiana pesticide law, which provides regulatory authority over the use and management of pesticides and the handling of pesticide waste in the state.

Office of Soil & Water Conservation. The State Soil & Water Conservation Committee, under the Office of Soil & Water Conservation, has legislative authority to establish soil and water conservation districts and to oversee activities of established districts. There are 43 districts covering all 64 parishes in the state. Conservation districts established by the State Committee have the responsibility and authority to carry out appropriate corrective measures to conserve soil resources, control and prevent soil erosion, prevent floodwater and sediment damages, and further the conservation, development, utilization, and disposal of water. To protect soil and water resources, they have the authority to adopt land use regulations through local referendum, discourage and discontinue land use practices contributing to soil erosion, implement works of improvement for flood prevention and disposal of water, assist land owners to plan and install practices that control soil erosion, prevent flooding and sediment damage, and assist land owners in the disposal of water. Districts are authorized to design, construct, improve, operate, and maintain such structures as required to address their erosion, flood prevention, and sediment control responsibilities.

Office of Forestry. The Office of Forestry provides technical assistance related to state programs, including administrative, supervisory, protection, and preservation functions involving water quality. In the fall of 1991, the Office of Forestry conducted a survey of selected forestry operations throughout Louisiana. The objectives of this BMP implementation survey were to determine: 1) the percentage of BMP implementation; 2) educational needs; 3) areas of the state where water quality may be adversely affected by silvicultural practices; and 4) the future direction of Louisiana's forestry community on implementing silvicultural BMPs. Results of the survey showed that the overall implementation of forestry BMPs in Louisiana was 66 percent. Sixty-three percent of the 151 sites had a higher than state average of implementation. These results indicate that the total BMP implementation of 66 percent in 1991 represents substantial progress (compared to less than ten percent in 1985). Continued efforts are needed to further implement forestry BMPs.

- **Department of Wildlife & Fisheries.** The Department of Wildlife and Fisheries executes laws and implements policies enacted for the protection, conservation, and replenishment of wildlife and aquatic species within Louisiana. The Department is charged with the responsibility for management of all renewable resources on all wildlife management areas, refuges, and preserves that it may own or lease, which would include some regulatory powers over water quality for those water bodies within its jurisdiction.

  The State Natural and Scenic Rivers System is administered by the Department with statutory authority which specifically prohibits channelization, clearing and snagging, channel realignment, and reservoir construction, and which empowers the Department to regulate other activities affecting system streams through permit restrictions.

The Department also participates in the environmental review process, conducts water analysis in conjunction with studies of productivity of Louisiana's water, and regulates the use of toxicants for fishing.

- **Department of Transportation & Development (DOTD).** The mission of the Department of Transportation and Development (DOTD) is to move people and goods safely and efficiently by the planning, design, construction, maintenance, and operation of a statewide transportation system. DOTD also is charged to provide a statewide flood control system.

  Office of Engineering & Operations. The Office of Engineering and Operations administers the programs relating to the establishment, design, construction, extension, improvement, repair, maintenance, and regulations of roads, highways, expressways, bridges, and matters pertaining to them; and develops, prepares, and finalizes the annual highway construction program authorized by Act 334 of 1974.

  Public Works is a subprogram responsible for administering the disbursement of monies appropriated under the Public Improvement Fund and the Statewide Flood Control Program. These programs provide administrative, engineering, and technical services and benefits to the State of Louisiana and citizens in the field of water resources by providing planning, coordination, and orderly development of natural resources and geographic areas, including the development of protection systems for floods, hurricanes, etc. Public Works is also responsible for providing engineering support in administering certain statewide programs to assure adequate, safe, effective, and efficient public works facilities and services. Programs include the following: Statewide Flood Control Program (Act 351 of 1982), Louisiana Water Resources Program (Water and Sewage Systems - Act 625 of 1983), Watershed Program (U.S. Soil Conservation Service - Public Law 566), and State Review of Water Resources Permits.

  The Public Hearings and Environmental Impact Section was organized as a result of the passage of the National Environmental Policy Act of 1969. Since a large portion of the Louisiana Department of Transportation and Development's construction program is federally funded or requires a federal permit, NEPA applies. The Environmental Unit is responsible for the administration, planning, and development of the Department's environmental clearance program. The Public Hearings Unit is responsible for the Department's public involvement program.

- **Department of Natural Resources (DNR).** Office of Conservation. The Office of Conservation under the Department of Natural Resources (DNR) is responsible for regulating production from oil and gas wells and from salt domes. The Office also regulates subsurface oil and gas disposal wells and hazardous waste underground injection wells to prevent groundwater contamination. The Office administers the Underground Injection Control (UIC) program, as well as the regulations and guidelines of the Louisiana Surface Mining and Reclamation Act, including water resources quality. Geothermal energy programs including re-injection of geothermal wastewater is also regulated by this office.

Coastal Management Division. The Coastal Management Division (CMD) of DNR is charged with implementing the Louisiana Coastal Resources Program (LCRP) under authority of the Louisiana State and Local Coastal Resources Management Act of 1978 (Act 361, LRS 49:213.1). This Act seeks to protect, develop, and, where feasible, restore or enhance the resources of the state's coastal zone. Its broad intent is to encourage multiple uses of resources and adequate economic growth while minimizing adverse effects of one resource use upon another without imposing undue restrictions on any user.

Besides striving to balance conservation and resource use, the policies of LCRP also help to resolve user conflicts, encourage coastal zone recreational values, and determine the future course of coastal development and conservation.

State Act 6 (1989). The 1989 Louisiana Legislature passed Act 6 which requires the State of Louisiana to annually develop a Coastal Wetlands Conservation and Restoration Plan from both a short and long range perspective. The Coastal Restoration Division of DNR has the responsibility of implementing this plan which is designed to restore, preserve, and enhance Louisiana's coastal wetlands. Current restoration techniques include freshwater diversion, sediment diversion, marsh management, sediment capturing, shallow bay terracing, and structural shoreline erosion abatement devices.

- **Department of Culture, Recreation & Tourism.** The Department of Culture, Recreation, and Tourism is responsible for regulating the draining or dumping of refuse waste in state parks or on public lands. The Department is also responsible for water resources protection in state parks.

- **Louisiana State University (LSU).** Agricultural Center. The Louisiana State University Agricultural Center was established in 1972 as one of eight campuses in the LSU System. The three main components are the Louisiana Agricultural Experiment Station, the Louisiana Cooperative Extension Service, and the Office of International Programs.

Louisiana Agricultural Experiment Station. Organized in 1886, the Louisiana Agricultural Experiment Station became a part of LSU in 1887, and was given statewide responsibility for research in agriculture and natural resources including forestry, wildlife and fisheries, home economics, food science, and other areas. Support is provided by state and federal sources, research grants, and self-generated income. The Station's headquarters are in Baton Rouge where its scientists conduct research projects in 21 departments. Research specific to geographical areas of the state is conducted through a statewide network of 17 branch stations and other off campus facilities.

Louisiana Cooperative Extension Service. For nearly a century, the mission of the Louisiana Cooperative Extension Service has been to take the information developed by the Agricultural Experiment Station, U.S. Department of Agriculture, universities, and private researchers to Louisiana's citizens. The Extension's educational programs are cooperative--supported by local, state, and federal governments. Although the Extension Service headquarters is located in Baton Rouge, each of the state's 64 parishes has an Extension Service office staffed by county agricultural agents and home economists. The Extension's educational program priorities, such as Water Conservation and Conservation and Management, have a multidiciplinary approach.

## *Local Groups & Programs*

- **Parishes, Municipalities & Levee Boards.** Probably the most significant authority parishes and municipalities have with regard to water resources pertains to the erection, operation, and regulation of water works and the construction, operation, and regulation of sewerage systems; subject, of course, to state and federal laws regarding health and water pollution standards. Police juries may regulate causeways, dikes, dams, and levees, and the clearing of the banks of rivers and natural drains within their respective parishes for the purpose of enhancing the passage of boats and other watercrafts; build dams to prevent saltwater inflow into freshwater streams; and expropriate property to facilitate the construction and operation of canals. This authority of police juries is in some, but not all, instances subject to regulation by the Office of Public Works.

  Waterworks districts are created by police juries within their respective parishes, and, when created, may do what is reasonably necessary to establish and operate waterworks systems, including acquiring property by expropriation and cooperating with other districts within their respective parishes, or with private individuals, associations, corporations, or municipalities.

  Irrigation districts may be created by police juries upon petition of landowners within the parish, but located outside of incorporated towns and cities. The basic purposes of irrigation districts are to conserve water for the benefit of the inhabitants and property owners within the district boundaries and to provide water for irrigation and other uses, both within and outside the district. They are authorized to construct, lease, acquire, maintain, and operate dikes, dams, reservoirs, storage basins, locks, levees, flumes, conduits, and to acquire or lease private canals and other bodies of water for district purposes.

Drainage districts are concerned with drainage problems and programs. There are a number of statutes relating to their operation. They have control over all public drainage channels within their boundaries, and they may contract with the Office of Public Works for technical and financial aid for their projects.

The authority of levee boards to construct levees and drainage channels is explicitly made subject to the supervision and approval of the Office of Public Works.

### *Statutes*

PL 100-4, Water Quality Act of 1987
LRS 30:4
LRS 30:901-902
LRS 30:1051 *et seq*., Louisiana Environmental Affairs Act
LRS 30:1061
LRS 30:1201
LRS 36:201-209
LRS 36:258D
LRS 36:358
LRS 36:359
LRS 36:601-610
LRS 38:216
LRS 40:4-5
LRS 47:646.4
LRS 56:1840-1856

## Mississippi

### *Regulatory Agencies & Programs*

- **Mississippi Department of Environmental Quality (MDEQ).** The Mississippi Department of Environmental Quality (MDEQ) is responsible for most environmental programs in Mississippi. Permitting, monitoring, enforcement, emergency response, and pollution prevention for various programs, including air, surface water, and ground water are all responsibilities of MDEQ.

Monitoring. There are 61 established sampling stations in the state's monitoring program, of which 11 are located along the Mississippi coast. Water samples are analyzed for conventional water quality parameters and metals. Coastal waters are evaluated biologically using fish diversity, health, and assessment, as well as algal biomass population and diversity. MDEQ biologists hope to begin work standardizing rapid bioassessment for estuarine waters in the near future. A number of special studies have been and are being conducted by MDEQ to evaluate coastal waters.

- **Mississippi Forestry Commission.** Since the inception of Mississippi's Silvicultural Best Management Practices under Section 319 of the Water Quality Act, the Mississippi Forestry Commission, in coordination with the Cooperative Extension Service and the Mississippi Forestry Association, has been heavily involved with the educational and training aspects of this program. The Forestry Commission provides technical assistance to landowners, loggers, and company foresters, as well as assists MDEQ in determining the efforts needed to correct silvicultural problems.

  Mississippi has sponsored over 20 workshops across the state, attended primarily by professional foresters. Beginning in early fall 1993, there will be formal presentations made to various landowner associations across the state. All public agency foresters have received formal instructions in actual field situations as to the implementation of the Water Quality Program in all incentive programs and management plans done for private non-industrial landowners. The 1,500+ individuals instructed through this program have either direct supervision or management responsibilities for 1,031,857 hectares (2,549,683 acres) of timberland in Mississippi.

  The Mississippi Forestry Commission recently published a manual detailing silvicultural BMP guidelines for maintaining and improving water quality. The Commission met with the Mississippi Forestry Association and Mississippi Cooperative Extension Service to plan a statewide training program for loggers, foresters, and landowners on using BMPs to control silvicultural nonpoint source pollution. In addition, Forestry Commission management staff have been directly involved in assisting various forest industries in incorporating approved BMPs into their company policies. In cooperation with the Mississippi Cooperative Extension Service, a BMP video is being developed to demonstrate pre-planning activities such as harvesting, site preparation, and regeneration, as well as information on forest activities detrimental to water quality. The forest industry in Mississippi has donated land, equipment, and resources for the production of the video and for the location of a future demonstration site.

  The Forestry Commission has completed an implementation evaluation consisting of grading silvicultural activities on randomly selected sites. This preliminary evaluation showed that better than 60 percent of the sites inspected were in compliance with silvicultural BMPs.

- **Bureau of Pollution Control (BPC).** Mississippi's Bureau of Pollution Control (BPC) drafted the statewide Erosion and Sediment Control Law. This law provides a useful tool to reduce nonpoint source impacts from construction activities.

- **Mississippi State Department of Health.** The Mississippi wastewater regulations and policy do not have any specifically declared regulatory authority dealing with nutrients in sewage effluent. The present regulations were designed in an attempt to ensure water quality from the standpoint of pathogens. In view of the stringent nature of the present wastewater laws, the Mississippi State Department of Health believes that in most cases nutrients are adequately removed. Nitrogen is the only nutrient that may pose a potential problem.

### *Statutes*

- **Mississippi State Drinking Water Act, Section 41-26-1 through Section 41-26-23, Mississippi Code of 1972, Annotated.** The regulation of nitrate/nitrite in drinking water is provided for through the Mississippi State Board of Health Environmental Regulations (Division 300 - Part 301, Public Water Systems Primary Drinking Water Regulations). Part 301.7 of the above regulation specifies that all inorganic chemical maximum contaminant levels shall apply to community and non-transient non-community public water systems as stipulated in the National Primary Drinking Water Regulations published under Title 40, Code of Federal Regulations, Section 141.13 or any subsequent revisions thereto.

## Texas

### *Regulatory Agencies & Programs*

- **Texas Natural Resource Conservation Commission (TNRCC).** The Texas Natural Resource Conservation Commission has the responsibility of protecting surface and groundwater quality. The Commission issues wastewater treatment plant operator certificates, regulates water well drilling and petroleum storage tanks, and sets water rates for certain privately owned public water/wastewater systems. The Commission also has jurisdiction over water quality monitoring and management, abandoned waste site cleanup, and oil and hazardous material spill response coordination. In addition to these responsibilities, the Commission oversees surface water rights administration, dam safety management, the National Flood Insurance Program and flood control improvement project administration, injection well program administration, waste minimization initiatives, and water district supervision.

- **Texas State Soil & Water Conservation Board (TSSWCB).** The Texas State Soil & Water Conservation Board has the responsibility to plan, implement, and manage programs and practices for abating agricultural and silvicultural nonpoint pollution. The State Board also administers a voluntary conservation program with and through 212 local soil and water conservation districts which encompass over 99 percent of the surface acres of Texas. With the voluntary program, conservation practices are being applied by over 215,000 cooperating landowners on more than 48.6 million hectares (120 million acres).

- **Texas General Land Office (GLO) and School Land Board (SLB).** The Texas General Land Office, in conjunction with the School Land Board, manages the state's coastal public lands. The Board may grant leases to certain governmental bodies for public purposes; leases for mineral exploration and development; easements to littoral landowners; channel easements to surface or mineral interest holders; leases to educational, scientific, or conservation interests; and permits for limited use of previously unauthorized structures. The commissioner of GLO may issue permits for geological, geophysical, and other investigations within the tidewater limits of the state. The commissioner may also grant easements or leases for right-of-way across state lands for pipelines and other transmission lines. In addition, he is responsible for technical assistance and compliance under the Dune Protection Act and implementation of the Texas Coastal Preserve Program.

  GLO has developed a coastal management plan for Texas beaches and the state-owned submerged land underlying the Gulf of Mexico. The Governor of Texas has given notice to the U.S. Department of Commerce that Texas will submit a coastal management plan for approval under the federal Coastal Zone Management Act.

- **Texas Agricultural Extension Service (TAEX).** The Texas Agricultural Extension Service (TAEX), a state agency affiliated with the Texas A&M University System, provides technical and educational leadership for training, informing, and educating farmers, ranchers, homeowners, commercial pest control specialists, agribusiness, suppliers, and others about a number of issues, including water quality management and protection. TAEX water quality programs in agriculture include proper use of nutrients, pesticides, and other chemicals; contamination of rural wells; irrigation water management, including salinity control; and reduction of runoff and leaching of water containing pesticides, nutrients, and animal wastes.

- **Texas Department of Agriculture (TDA).** The Texas Department of Agriculture (TDA) has programs in regulation, marketing, producer outreach, agricultural resource protection, agricultural research, and economic analysis. The primary responsibility of TDA regarding water quality lies in pesticide registration and labeling, and certification and training of applicator activities.

- **Texas Forest Service.** The Texas Forest Service is responsible for the Texas Silvicultural Nonpoint Source Project, a cooperative project designed to reduce nonpoint source water pollution from forestry activities by encouraging widespread adoption of voluntary Silvicultural Best Management Practices in Texas. The Project was funded by a Section 319 grant from USEPA. The Project embodies the following six objectives:
  1) education of the forestry community using a variety of media;
  2) integration of BMPs into all relevant state forestry management programs;
  3) demonstration of various BMPs using two demonstration areas developed for use as an educational tool; 4) cooperation between agencies and the forestry community to ensure a coordinated, effective program; 5) evaluation of program and implementation of revisions as needed; and 6) monitoring BMP compliance and effectiveness through a program of on-site inspections of silvicultural activities. Educational efforts have reached an approximate audience of over 20,000 individual landowners, foresters, loggers, silvicultural contractors, and the general public.

  A successful start has been made in encouraging the widespread adoption of voluntary forestry BMPs in East Texas. It is estimated that stream sedimentation has already been reduced by 40 percent over a "no BMP" level. The initial results are encouraging, but also point out the need for a sustained, cooperative educational effort. This should be supported by additional cycles of compliance monitoring to document continued improvement and to focus continued attention on reducing nonpoint source pollution.

- **Texas Parks & Wildlife Department (TPWD).** The Texas Parks & Wildlife Department operates the state parks system and wildlife refuges. A permit must be obtained from the Department for the disturbance or dredging of sand, shell, or marl in public waters not authorized by other state or federal agencies. Public waters are defined as all the salt and fresh waters underlying the beds of navigable streams under the jurisdiction of the Parks and Wildlife Commission. The Department is responsible for reviewing and commenting on state and federal permits affecting Texas wildlife resources.

### *Nonregulatory Programs*

- **Clean Texas 2000.** On April 7, 1992, the Texas Water Commission (now the Texas Natural Resource Conservation Commission) kicked off its Clean Texas 2000 campaign. This campaign includes programs that, if fully implemented, will result in reduced nonpoint source pollution. These include expanding the citizens monitoring program (Texas Watch), providing technical assistance and funding to help cities establish household chemical collection programs, and funding and sponsorship of annual agricultural pesticide container collection days. Clean Texas 2000 contains a public education component which encourages reduction in the creation of household hazardous wastes and exchange of environmental education. Excellent environmental accomplishments will be recognized through an awards and recognition program.

- **State Education Program.** Technology transfer and general education are components of all 319 federal grant funded nonpoint source demonstration projects. Projects examining the effectiveness of construction erosion/sedimentation controls, roadway runoff water quality controls, urban wetponds, and animal waste management techniques will report the results of the studies in a manner such that others will benefit from the information.

- **State Wellhead Protection Program.** Congress amended the Safe Drinking Water Act in 1986 to provide for USEPA approved state wellhead protection programs. These programs, to obtain USEPA approval, have to establish means for designation of public water supply wellhead protection areas and have to include contingency plans for public water supply in the event of groundwater contamination. The amendment did not explicitly direct that approved programs encompass nonpoint source pollution prevention. The federal inducement for states to adopt wellhead protection programs is the authorization of funding for grants with which to operate the programs; unfortunately, due to budget constraints, federal appropriation levels for the grants have been low.

### *State Laws*

- **Texas Water Code Section 26.177.** Section 26.177 requires cities with populations of 5000 or more to develop and have approved by the Texas Natural Resource Conservation Commission water pollution abatement programs. The programs may address nonpoint source pollution, which the statute specifically notes to include urban runoff from rainwater. The cities may extend the controls of their water pollution abatement programs into their extraterritorial jurisdictions. The Texas Water Commission assesses fees to recover the costs of administering Section 26.177. About 300 Texas cities have populations in excess of 5000. Section 26.177 does not contain deadlines for implementation. The Texas Water Commission has not adopted rules to implement Section 26.177.

- **Texas Agriculture Code, Section 201.026.** Section 201.026 gives the Texas State Soil & Water Conservation Board (TSSWCB) the responsibility for planning, implementing, and managing programs and practices for abating agricultural and silvicultural nonpoint source pollution. TSSWCB drafted and obtained USEPA approval of the agricultural and silvicultural components of the nonpoint source management program developed pursuant to Section 319 of the Clean Water Act. Although under funded, TSSWCB is in the process of implementing the program through, and in cooperation with, Texas soil and water conservation districts.

- **Senate Bill 818: The Clean Rivers Act.** The Clean Rivers Act, passed in 1991, directs the Texas Natural Resource Conservation Commission to ensure a comprehensive regional assessment of water quality in each watershed and river basin in Texas. The purpose of the Act is to provide sufficient information to regulatory entities in order to take necessary corrective action to maintain and improve water quality in Texas.

# PRIVATE ORGANIZATIONS

There are numerous private organizations that focus their efforts on nutrient enrichment from point and nonpoint sources. Descriptions of a few of these organizations follow:

- **National Academy of Sciences--National Research Council (NAS - NRC).** The National Academy of Sciences is a private, nonprofit, self-perpetuating society of distinguished scholars engaged in scientific and engineering research, dedicated to the furtherance of science and technology and to their use for the general welfare. Upon the authority of the charter granted to it by Congress in 1863, the Academy has a mandate that requires it to advise the federal government on scientific and technical matters.

  The National Research Council was established by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and of advising the federal government. The Council operates in accordance with general policies determined by the Academy under the authority of its Congressional charter. The Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in the conduct of their services to the government, the public, and the scientific and engineering communities.

- **National Council of the Paper Industry for Air & Stream Improvement, Inc. (NCASI).** The National Council of the Paper Industry for Air & Stream Improvement, Inc. (NCASI) was founded in 1943, with the charge of conducting research on technical issues of importance to the environmental quality protection needs of the forest products industry. NCASI is a non-profit organization and is supported primarily on the basis of dues paid by member companies. These member companies are responsible for the production of greater than 90 percent of the pulp and paper manufactured in the U.S. There are six regional laboratories/experimental stations operated by NCASI, most of which are either located on the campuses of, or are affiliated with, universities in Corvallis, OR, Anacortes, WA, Kalamazoo, MI, Medford, MA, New Bern, NC, and Gainesville, FL. The professional staff of NCASI is composed of engineers, chemists, biologists, hydrologists, soil hygienists, and modeling experts. The results of the investigations which NCASI conducts or manages are distributed to member company representatives, academic institutions, and USEPA, and are a matter of public record.

- **Mississippi River Basin Alliance.** The Mississippi River Basin Alliance is in the formative stages, and is conceived as a loose network of private organizations working together to protect the Mississippi River Basin. The Sierra Club Field Office in Madison, Wisconsin, is leading the effort to form this alliance.

- **McKnight Foundation.** The McKnight Foundation is a private charitable foundation with primary interests in assisting poor and disadvantaged people, strengthening the communities and community organizations, enriching peoples' lives through the arts, and encouraging preservation of the natural environment. In 1991, the foundation committed to providing $9 million in grants relating to the Mississippi River over a five-year period.

- **Upper Mississippi River Conservation Committee (UMRCC).** The Upper Mississippi River Conservation Committee (UMRCC) was established in 1943 to promote the preservation and wise use of the natural and recreational resources of the upper Mississippi River and to formulate policies, plans, and programs for conducting cooperative studies. Although the state fish and wildlife agencies of the five upper Mississippi River states comprise the UMRCC, four of the state water quality agencies are affiliated with the UMRCC as cooperating agencies.

- **Missouri River Natural Resources Committee (MRNRC).** The Missouri River Natural Resources Committee (MRNRC) was organized in 1989 to promote and ensure the good stewardship of the Missouri River. The MRNRC is comprised of the fish and wildlife agencies within the Missouri River basin.

- **Lower Mississippi River Conservation Committee (LMRCC).** The Lower Mississippi River Conservation Committee (LMRCC) is currently being formed. The purpose of the LMRCC is to promote the protection, restoration, enhancement, understanding, awareness, and wise use of the natural resources of the lower Mississippi River, through coordinated and cooperative efforts involving research, planning, management, information sharing, public education, and advocacy. LMRCC is comprised of both the fish and wildlife and water quality agencies along the lower Mississippi River.

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| ADCNR | Alabama Department of Conservation & Natural Resources |
| ADEM | Alabama Department of Environmental Management |
| AL | Alabama |
| ANICA | Atmospheric Nutrient Input to Coastal Areas |
| ASCS | Agricultural Stabilization & Conservation Service |
| ASD | Alabama State Docks Department |
| BLM | Bureau of Land Management |
| BMP | Best Management Practices |
| BNR | Biological Nutrient Removal |
| BOD | Biochemical Oxygen Demand |
| BPC | Bureau of Pollution Control--Mississippi |
| CAA | Clean Air Act |
| CAC | Citizens Advisory Committee--Gulf of Mexico Program |
| CCMP | Comprehensive Conservation & Management Plan |
| CES | Cooperative Extension Service |
| CMD | Coastal Management Division |
| COP | Coastal Ocean Program |
| CWA | Clean Water Act |
| CZMA | Coastal Zone Management Act |
| CZARA | Coastal Zone Act Reauthorization Amendments |
| DHH | Department of Health & Hospitals--Louisiana |
| DIN | Dissolved Inorganic Nitrogen |
| DMR | Discharge Monitoring Report |
| DNR | Department of Natural Resources--Louisiana |
| DO | Dissolved Oxygen |
| DODT | Department of Transportation & Development--Louisiana |
| EDA | Estuarine Drainage Area |
| EDF | Environmental Defense Fund |
| EIS | Environmental Impact Statement |
| EMAP | Environmental Monitoring & Assessment Program |
| FmHA | Farmers Home Administration |
| FIFRA | Federal Insecticide, Fungicide & Rodenticide Act |
| FL | Florida |
| FWCA | Fish & Wildlife Coordination Act |
| GLO | General Land Office--Texas |
| GMP | Gulf of Mexico Program |
| HSC | Houston Ship Channel |
| LA | Louisiana |
| LADEQ | Louisiana Department of Environmental Quality |
| LCRP | Louisiana Coastal Resources Program |
| LMRCC | Lower Mississippi River Conservation Committee |
| LSU | Louisiana State University |
| M | Mole |
| MC | Management Committee--Gulf of Mexico Program |
| MDEQ | Mississippi Department of Environmental Quality |
| MMS | Minerals Management Service |

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| MRNRC | Missouri River Natural Resources Committee |
| MS | Mississippi |
| MSD | Marine Sanitation Device |
| MWTP | Municipal Wastewater Treatment Plant |
| N | Nitrogen |
| NAS | National Academy of Sciences |
| NASA | National Aeronautics and Space Administration |
| NCASI | National Council of the Paper Industry for Air & Stream Improvement |
| NCPDI | National Coastal Pollution Discharge Inventory |
| NECOP | Nutrient-Enhanced Coastal Ocean Productivity |
| NEP | National Estuary Program |
| NEPA | National Environmental Policy Act |
| NMFS | National Marine Fisheries Service |
| NOAA | National Oceanic & Atmospheric Administration |
| NPDES | National Pollutant Discharge Elimination System |
| NPS | Nonpoint Source |
| NRC | National Research Council |
| OCS | Outer Continental Shelf |
| OSDS | On-Site Sewage Disposal Systems |
| OWR | Office of Water Resources (Louisiana) |
| P | Phosphorus |
| POTW | Publicly-Owned Treatment Works |
| PRB | Policy Review Board--Gulf of Mexico Program |
| QA/AC | Quality Assurance/Quality Control |
| RCRA | Resource Conservation & Recovery Act |
| SARPC | South Alabama Regional Planning Commission |
| SAV | Submerged Aquatic Vegetation |
| SCS | Soil Conservation Service |
| SDWA | Safe Drinking Water Act |
| SEA | Strategic Environmental Assessments |
| Si | Silicate |
| SLB | School Land Board--Texas |
| SNC | Significant Noncompliance |
| SWIM | Surface Water Improvement Management Program |
| TAC | Technical Advisory Committee--Gulf of Mexico Program |
| TAEX | Texas Agricultural Extension Service |
| TDA | Texas Department of Agriculture |
| TKN | Total Kjeldahl Nitrogen |
| TNRCC | Texas Natural Resources Conservation Commission |
| TOC | Total Organic Carbon |
| TP | Total Phosphorus |
| TPWD | Texas Parks & Wildlife Department |
| TSSWCB | Texas State Soil & Water Conservation Board |
| TVA | Tennessee Valley Authority |
| TX | Texas |
| UIC | Underground Injection Control |

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| UMRCC | Upper Mississippi River Conservation Committee |
| USACE | U.S. Army Corps of Engineers |
| USCG | U.S. Coast Guard |
| USDA | U.S. Department of Agriculture |
| USDOC | U.S. Department of Commerce |
| USDOD | U.S. Department of Defense |
| USDOE | U.S. Department of Energy |
| USDOI | U.S. Department of the Interior |
| USDOTD | Department of Transportation & Development |
| USEPA | U. S. Environmental Protection Agency |
| USFDA | U.S. Food & Drug Administration |
| USFS | U.S. Forest Service |
| USFWS | U.S. Fish & Wildlife Service |
| USGS | U.S. Geological Survey |
| WWTP | Waste Water Treatment Plant |

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| **aerobic** | Presence of free oxygen (oxygen gas). |
| **algae** | Any of a group of aquatic plants, including phytoplankton and seaweeds, ranging from microscopic to several meters in size. |
| **algal blooms** | Sudden spurs of algal growth, which can affect water quality adversely. Often, excessive blooms indicate nutrient enrichment. Some species cause potentially hazardous changes in local water chemistry. |
| **alternative technologies** | Technological improvements utilizing physical or biochemical means of increasing oxygen in addition or in lieu of nitrogen source controls. |
| **ambient** | Referring to average concentrations of substances in the surrounding media (water, air, or sediment). |
| **anaerobic** | Absence of free oxygen (oxygen gas). |
| **anoxia** | Absence of dissolved oxygen in water (<0.1 mg oxygen/L). |
| **anoxia volume-day** | A unit that represents a cubic meter of water which has a daily mean dissolved oxygen concentration less than 1.0 mg/L. |
| **anthropogenic** | Relating to, or resulting from, the influence of human beings on nature. |
| **atmospheric deposition** | The accretion of chemicals including nitrogen and phosphorus, attached to dust materials during dry weather or as part of raindrops, sleet, snow, hail, etc. during wet weather, which are deposited onto the land or water surfaces from the air. |
| **benthic** | Of or pertaining to the bottom or near bottom of a stream, lake, or ocean. |
| **benthos** | All marine organisms (plant and animal) living on or near the bottom of a stream, lake, or ocean. |
| **best management practices (BMPs)** | Pollution control techniques developed by farmers, scientists, and administrators for managing nonpoint source nutrient discharges. BMPs cover two broad areas of management: 1) constructing facilities to contain nutrients, and 2) employing farming practices that decrease the use and/or runoff of fertilizers and manure. |
| **biochemical oxygen demand (BOD)** | A measure of the quantity of dissolved oxygen removed from water by the metabolism of microorganisms. Excessive BOD results in oxygen-poor water. |
| **biological nutrient removal (BNR)** | Wastewater treatment processes that: 1) create specific biological environments which enhance phosphorus removal; and 2) utilize chemical energy drawn from the wastewater itself to remove nitrogen. |
| **biota** | Plants and animals inhabiting a given region. |
| **biotic community** | A naturally-occurring assemblage of plants and animals that live in the same environment and are mutually sustaining and interdependent. |

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| **bloom** | Excessive growth of plankton in concentrations sufficiently dense to cause discoloration of water and reduced light penetration. |
| **brackish** | Salty, but not as salty as sea water. Brackish water occurs in estuaries, creeks, and deep wells. |
| **characterization** | The process of bringing together a number of information sources to synthesize overall patterns or make a statement of current conditions. |
| **chelate** | Relating to, or having a ring structure, that usually contains a metal ion held by coordination bonds. |
| **chlorophyll** | Green pigment in plants that is essential for photosynthesis. One type of the pigment (chlorophyll *a*) is commonly used as a measure of phytoplankton abundance. |
| **coastal runoff** | Storm water and the materials it carries from land surrounding a coastal area. |
| **coastal zone** | Lands and waters adjacent to the coast that exert an influence on the uses of the sea and its ecology, or inversely, whose uses and ecology are affected by the sea. Legally, the definition varies from state to state. |
| **combined sewer overflows** | Discharges from a sewer system that carry both sewage and storm water runoff. Normally, its entire flow goes to a wastewater treatment plant but, during a heavy storm, the storm water volume may be so great as to cause overflows. When this happens, untreated mixtures of storm water and sewage may flow into receiving waters. Storm water runoff may also carry toxic chemicals from industrial areas or streets into the sewer system. |
| **compliance** | Conformance to the rules and regulations regarding wastewater discharges. |
| **conservation tillage** | In agriculture, the utilization of a tillage system appropriate for the soil properties, climate, and farming system that is also compatible with the goals of reduced soil erosion and effective nutrient application. |
| **control program** | The methods used to reduce nutrient releases from both point sources and nonpoint sources. |
| **controllable** | Those sources of nutrients that arise or result from the impact of human activities and are not attributable to background loads. "Controllable" does not imply that these loads are scheduled for control or that they can all be managed, only that they can be controlled given the technologies available. |
| **conventional pollutants** | Pollutants typically discharged by municipal sewage treatment plants and a number of industries. The category includes wastes with a high biochemical oxygen demand (BOD), total suspended solids, fecal coliform, pH, grease, and oil. |
| **criteria** | Acceptable limits in various media (*e.g.*, water, sediments) for pollutants derived by USEPA. When issued by USEPA, the criteria provide guidance to the states on how to establish their standards. |
| **cumulative impacts** | Combined effects resulting from more than one action. |

**cyanobacteria**
Blue-green algae, which occurs in fresh and salt water (planktonic and benthic), in soils, and as nitrogen-fixing symbionts.

**decomposition**
The breakdown of matter by bacteria and fungi. It changes the chemical make-up and physical appearance of materials being broken down and may cause changes in the environment as well.

**demersal**
Living near, deposited on, or sinking to the bottom of the sea.

**denitrification**
A biochemical process in which specific bacteria extract oxygen bound up in molecules of nitrate, resulting in the release of harmless nitrogen gas into the atmosphere. This process occurs naturally in salt marshes and wetlands and can be established in wastewater treatment plants to remove nitrogen from wastewater.

**diatoms**
Any of various tiny planktonic algae of the class *Bacillariophyceae*, with siliceous cell walls consisting of two overlapping symmetrical parts.

**direct discharger**
A municipal or industrial facility that introduces pollution through a defined conveyance or system; a point source.

**dissolved oxygen (DO)**
Concentration of oxygen in water, commonly employed as a measure of water quality. Low levels adversely affect aquatic life. Most finfish cannot survive when DO falls below 3 mg/L for a sustained period of time. SEE ANOXIA AND HYPOXIA

**drainage basin**
The land area drained by a river or stream and its tributaries.

**dry weather overflows**
Illegal discharges of untreated wastewater from combined sewer overflows and storm drains unrelated to rainfall events. During rainstorms such discharges are referred to as "wet weather overflows."

**ecological impact**
The effect that a human or natural activity has on living organisms and their non-living (abiotic) environment.

**ecosystem**
An ecological community consisting of living organisms and their physical and chemical environment.

**effluent**
Discharge or emission of a liquid or gas, usually from a point source (*e.g.*, pipe or stack), into the environment.

**emission**
Pollution discharged into the atmosphere from smokestacks, other vents, and surface areas of commercial or industrial facilities; from residential chimneys; and from motor vehicle, locomotive, or aircraft exhausts.

**enrichment**
The addition of nutrients (*e.g.*, nitrogen, phosphorus, carbon compounds) from sewage effluent, runoff, or atmospheric deposition to surface water. This process greatly increases the growth potential for algae and aquatic plants.

**epifauna**
Benthic fauna living on the substrate (as a hard sea floor) or on other organisms.

**estuary**
A semi-enclosed body of water, connected to the open sea, in which sea water is measurably diluted with fresh water from inland sources.

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| **fall line** | Area in a tributary where tidal waters meet free-flowing fresh water, often called the "head of tide." This is a transition zone at which water quality is most easily related to the rate of river flow. |
| **fertilizer** | Materials such as nitrogen and phosphorus that provide nutrients for cultured plants. Commercially sold fertilizers may contain other chemicals or may be in the form of processed sewage sludge. |
| **freshwater** | Water that generally contains less than 1,000 milligrams-per-liter of dissolved solids. |
| **ground water** | Subsurface water saturating soil or porous rock which often returns, with its nitrogen loads, to surface streams during dry periods. |
| **habitat** | The place where a population (*e.g.*, human, animal, plant, microorganism) lives and its surroundings, both living and non-living. |
| **hypoxia** | Low levels of dissolved oxygen in water, defined as less than 2 mg/L. |
| **indirect discharge** | Introduction of pollutants from commercial and industrial facilities into a sewage treatment plant. |
| **infauna** | Benthic fauna living in the substrate, especially in a soft sea bottom. |
| **land use** | Refers to the ways in which a community or area makes use of its natural resources. |
| **light attenuation** | A measure of how quickly light disappears with increasing depth in the water. Low light attenuation means increased levels of light penetrate further down in the water column. SEE WATER CLARITY |
| **limiting nutrient** | A nutrient (*e.g.*, nitrogen, phosphorus) that limits the growth of a population (*e.g.*, plants) or determines the carrying capacity of the environment by its scarcity. |
| **living resources** | Plant and animal life. |
| **loading** | Quantity of contaminants, nutrients, or other substances introduced into a waterbody. |
| **marine** | Pertaining to the ocean or sea. |
| **marine sanitation device (MSD)** | Any equipment installed on board a vessel to receive, retain, treat, or discharge sewage and any process to treat sewage. |
| **mesohaline** | Water of medium salinity--5-18 parts/thousand. SEE SALINITY |
| **meteorological conditions** | Atmospheric phenomena, such as precipitation, wind, and temperature, which ultimately drive the surface and groundwater flow of water and nutrients. |

**microgram atomic weight** — Microgram atomic weight of a chemical element is the amount of the element with the weight equal to its atomic weight measured in micrograms. For example, the atomic weight of nitrogen is 14, thus 14 μg of nitrogen is 1 microgram atom. A solution containing 14 μg of nitrogen in 1 liter of water would produce a concentration of 1 μg atom of nitrogen/liter.

**model** — A simplified mathematical representation of reality. Water quality modeling is used to study Gulf of Mexico processes and project effects of varying environmental conditions or management actions.

**modeling** — An investigative technique using a mathematical or physical representation of a system or theory, usually on a computer, which accounts for all or some of its known properties. Models are often used to test the effect of changes of system components on the overall performance of the system.

**mole (M)** — The gram-molecular weight of a substance. It is the amount of the substance having a weight equal to the molecular weight of the substance in grams. A micromole (μM) is 1 one-millionth of a mole.

**monitoring** — Observing, tracking, or measuring some aspect of the environment to establish base line conditions and short or long-term trends.

**National Pollutant Discharge Elimination System (NPDES)** — A provision of the Clean Water Act that prohibits discharge of pollutants into waters of the U.S. unless a special permit is issued by USEPA, state, or (where delegated) a tribal government on an Indian reservation.

**nitrate** — A compound containing nitrogen and oxygen ($NO_3$) that can exist in the atmosphere or as a dissolved gas in water and that can have harmful effects on humans and animals. For example, high concentrations of nitrates in drinking water can cause severe illness in infants.

**nitrification** — The biochemical process in which specific bacteria convert ammonia and organic nitrogen to nitrate. In wastewater treatment plants, ammonia and organic nitrogen come from human wastes and dead plant and animal matter. The nitrifying bacteria are cultured for use at the plants to convert ammonia to nitrite and nitrate. Nitrification occurs naturally in ecosystems such as saltmarsh and wetlands and can be established in wastewater treatment plants to remove ammonia and nitrogen from wastewater.

**nitrogen** — A nutrient essential for life. May be organic or inorganic (ammonia, nitrate, nitrite). Elemental nitrogen constitutes 78 percent of the atmosphere by volume.

**nonpoint source pollution** — Toxicants, other contaminants, nutrients, or soil entering a waterbody from sources other than discrete discharges, such as pipes. Includes pollution on the land which originates as atmospheric deposition, as well as farm and urban runoff.

**NPDES permits** — National Pollutant Discharge Elimination System Permits to discharge treated wastewaters to the waters of the U.S. issued by either USEPA or the state.

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| **nutrients** | Chemicals required for growth and reproduction of plants. Excessive levels of the nutrients nitrogen and phosphorus can lead to excessive algae growth. |
| **nutrient enrichment** | Nutrient enrichment increases primary productivity in a waterbody, eventually resulting in depletion of dissolved oxygen essential to aquatic life (also called eutrophication). |
| **nutrient flux** | The rate of transfer of nutrients across a surface, usually the sediment/water column interface. |
| **oligohaline** | Water of low salinity--0.5 to 5.0 parts/thousand. |
| **organic** | (1) Referring to or derived from living organisms. (2) In chemistry, any compound containing carbon. |
| **organic matter** | Carbonaceous waste contained in plant or animal matter and originating from domestic or industrial sources. |
| **organism** | Any living thing. |
| **outfall** | The place where an effluent is discharged into receiving waters. |
| **oxygen demand** | Consumption of oxygen by bacteria to oxidize organic matter. |
| **pelagic** | Of or relating to the open ocean. |
| **periphytic** | Of or relating to organisms (as some algae) that live attached to underwater surfaces. |
| **permit** | An authorization, license, or equivalent control document issued by USEPA or an approved state agency to implement the requirements of an environmental regulation, *e.g.*, permit to discharge from a wastewater treatment plant or to operate a facility that may generate harmful emissions. |
| **phosphorus** | A nutrient essential for life found in both organic and inorganic forms. |
| **phylogenetic** | Based on natural evolutionary relationships. |
| **phytoplankton** | Microscopic plants that live in water such as algae. |
| **point source pollution** | Contamination from waste effluent discharged into a waterbody through pipes or conduits. |
| **pollutant** | Generally, any substance introduced into the environment that adversely affects the health of plants and animals, or the usefulness of a resource. |
| **pollution** | Generally, the presence of matter or energy whose nature, location, or quantity produces undesired environmental effects. Under the Clean Water Act, for example, the term is defined as the man-made or man-induced alteration of the physical, biological, and radiological integrity of the water. |
| **polyhaline** | Water with a salinity of 18 to 30 parts/thousand. |

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| **pretreatment** | Processes used to reduce, eliminate, or alter the nature of wastewater pollutants from non-domestic sources before they are discharged into publicly-owned treatment works. |
| **primary waste treatment** | First steps in wastewater treatment. Screens and sedimentation tanks are used to remove most materials that float or will settle. Primary treatment results in the removal of about 30 percent of carbonaceous biochemical oxygen demand from domestic sewage. |
| **priority pollutant** | A pollutant that is listed by USEPA as a pollutant of concern. |
| **productivity** | Process by which plants remove dissolved carbon dioxide and micro-nutrients from the water and, using solar energy, convert them to complex organic compounds of high potential energy. |
| **publicly-owned treatment works** | A waste-treatment works owned by a state, unit of local government, or Indian tribe, usually designed to treat sewage and other domestic wastewaters. |
| **qualitative** | Pertaining to the non-numerical assessment of a parameter. |
| **quality assurance/ quality control (QA/QC)** | A system of procedures, checks, audits, and corrective actions to ensure that research design and performance, environmental monitoring and sampling, and other technical and reporting activities are of the highest achievable quality. |
| **quantitative** | Pertaining to the numerical assessment of a parameter. |
| **receiving waters** | A river, lake, ocean, stream, or other watercourse into which wastewater or treated effluent is discharged. |
| **residual** | Amount of a pollutant remaining in the environment after a natural or technological process has taken place, *e.g.*, the sludge remaining after initial wastewater treatment or particulates remaining in air after the air passes through a scrubbing or other pollutant removal process. |
| **restoration** | The act of returning something such as habitat or water quality to its condition prior to human disturbance. Measure taken to return a site to natural conditions. |
| **resuspension** | Lifting of in-place bottom sediments into the water column by waves, bottom currents, or other mechanical disturbance. |
| **riparian zone** | Areas adjacent to rivers and streams. |
| **runoff** | Drainage of precipitation over the soil or a non-porous surface (*e.g.*, asphalt) to a stream, river, or other receiving body of water. |
| **salinity** | Amount, by weight, of dissolved salts in 1,000 units of water (reported as parts/thousand). |
| **sanitary sewers** | Underground pipes that carry only domestic or industrial waste, not storm water. |

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| **secondary treatment** | The second step in most sewage treatment plants in which bacteria consume the organic parts of the waste. It is accomplished by bringing together waste, bacteria, and oxygen in trickling filters or in an activated sludge process. This treatment removes floating and settleable solids and about 90 percent of the oxygen-demanding substances and suspended solids. Disinfection is the final stage of secondary treatment. |
| **sediments** | The loose solids, (*e.g.*, soil from erosion or runoff) that settle to the bottom of a waterbody or its tributaries which can be sources of nitrogen and phosphorus. |
| **septic tank** | An underground storage and treatment tank for wastes from homes having no sewer line to a treatment plant. The waste goes directly from the home to the tank, where the organic waste is decomposed by bacteria and the sludge settles to the bottom. The effluent flows out of the tank into the ground through drains; the sludge is pumped out periodically. |
| **sewage** | The waste and wastewater produced by residential and commercial establishments and discharged into sewers. |
| **sewer** | A channel or conduit that carries wastewater and storm water runoff from the source to a treatment plant or receiving stream. Sanitary sewers carry household, industrial, and commercial waste. Storm sewers carry runoff from rain or snow. Combined sewers are used for both purposes. |
| **side treatment** | Treatment of wastewater or its by-products physically separate from secondary treatment plant processes. |
| **significant noncompliance (SNC)** | Includes instances of NPDES permit violations (*e.g.*, monthly average permit limits) or violation of administrative or judicial orders that meet certain screening criteria for frequency and duration. Permit holders on SNC lists are targeted first for enforcement actions. |
| **standards** | Prescriptive norms that govern action and actual limits on the amount of pollutants or emissions produced. USEPA, under most of its responsibilities, establishes minimum standards. States can issue stricter standards if they choose. |
| **stoichiometric** | 1) Of or relating to the quantitative relationship between two constituents in a chemical substance. 2) Of or relating to the quantitative relationship between two or more substances, especially in processes involving chemical or physical changes. |
| **storm sewer** | A system of pipes (separate from sanitary sewers) that carries only water runoff from building and land surfaces. |
| **storm water** | Runoff caused by precipitation. |
| **stratification** | The layering of fresh water over salt water due to differences in relative density and temperature. |
| **stream** | A body of water, including brooks and creeks, that moves in a definite channel in the ground driven by a hydraulic gradient. |

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| **submerged aquatic vegetation (SAV)** | Vegetation that grows underwater along the fringes and in shallow water. |
| **surface water** | All water naturally open to the atmosphere (rivers, lakes, reservoirs, streams, impoundments, seas, estuaries, etc.); also refers to springs, wells, or other collectors that are directly influenced by surface water. |
| **Total Kjeldahl Nitrogen (TKN)** | Forms of nitrogen quantified in a Kjeldahl test; usually the sum of total ammonia-N and organic N, excluding nitrate-N and nitrite-N. |
| **total maximum daily load** | The maximum amount of a substance, such as metals or nutrients, that can be discharged in a day by permitted wastewater treatment plants, industries, or nonpoint sources and continue to meet water quality standards. |
| **toxic** | Harmful to living organisms. |
| **tributary** | A stream, creek, or river that flows into a larger stream, creek or river. |
| **trophic level** | A successive stage of nourishment as represented by links in the food chain. Primary producers (phytoplankton) constitute the first trophic level, herbivorous zooplankton the second trophic level, and carnivorous organisms the third and higher trophic level. |
| **turbidity** | Reduction of water clarity caused by suspended sediments and organics in the water. |
| **wastewater** | The spent or used water that contains dissolved or suspended matter from individual homes, a community, a farm, or an industry. |
| **wastewater treatment** | Processes to remove pollutants, commonly categorized as primary, secondary, and advanced (tertiary) levels of treatment. |
| **wastewater treatment plant** | A facility containing a series of tanks, screens, filters, and other processes by which pollutants are removed from water. |
| **water clarity** | A general term which describes the transparency of water in an aquatic system. Water clarity is reduced with increased amounts of particulate materials (*e.g.*, suspended sediments) in the water column. SEE LIGHT ATTENUATION |
| **water column** | A vertical extent of water reaching from the surface to the bottom substrate of a waterbody. |
| **water quality** | Status or condition of a waterbody in terms of defined variables characterizing the "health" of the water. |
| **water quality standards** | State-adopted and USEPA-approved ambient standards for water bodies. The standards cover the use of the water body and the water quality criteria that must be met to protect the designated use or uses (*e.g.*, drinking, swimming, fishing). |
| **watershed** | Land area from which precipitation drains into a given body of water. |

**wetlands** An area that is regularly saturated by surface or ground water and subsequently is characterized by a prevalence of vegetation that is adapted for life in the soil conditions. Examples include: swamps, bogs, fens, and marshes. Often defined based on soil characteristics.

**zooplankton** Animal plankton of widely varying size that drift or swim weakly in the water. They consume the primary producers and are a second link in the food chain or food web.

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