SURFACE WATER IMPROVEMENT MANAGEMENT

Interim Plan for Biscayne Bay, Florida

September 30, 1988

Prepared by the Staff of the **South Florida Water Management District**
for the **Florida Department of Environmental Regulation**
in Compliance with Rule 17-43 F.S. F.A.C. and Ch 373. F.S.

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INTERIM

SURFACE WATER IMPROVEMENT AND MANAGEMENT (SWIM) PLAN

FOR

BISCAYNE BAY

Issued in compliance with the
Surface Water Improvement and Management Act
(Chapter 87-97, Laws of Florida)
and
Rule 17-43.035, F.A.C.
(Florida Department of Environmental Regulation)

South Florida Water Management District

September 30, 1988

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The plan is organized to consider the eleven-section format issued by the Florida Department of Environmental Regulation (DER), Chapter 17-43.035, F.A.C. and the five-section format that was proposed in the subsequent DER memorandum and provides the information required in Chapter 87-97, Laws of Florida.

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Recommendations

(These Recommendations are not necessarily listed in order of priority. Priorities are discussed in the SCHEDULE AND FUNDING section of this report)

The State Legislature and the South Florida Water Management District, through the SWIM program, should a) provide funding or develop long-term mechanisms to develop appropriate funding from other sources and b) provide technical and other support to initiate or continue the following activities within Biscayne Bay:

Need For Consistent State Water Quality Classifications within the Biscayne Bay Aquatic Preserve

1) **Reclassify the Miami River.** Support efforts by Dade County and the FDER to have the classification of the Miami River upgraded from its existing Class IV to a Class III water body.

Sanitary Waste and Stormwater.

2) **Separate Sanitary from Stormwater Sewers.** Assess the extent of interconnections between stormwater and sewage systems and upgrade, repair or replace facilities as necessary to eliminate these interconnections.

3) **Stormwater.** Continue to support local government efforts to retrofit (including the addition of treatment processes) existing stormwater systems that discharge into Biscayne Bay or tributary rivers and canals. Assist the county to obtain long-term funding for stormwater retrofitting. Encourage long term maintenance programs (greater than 10 years) on older stormwater retrofits and require that new retrofit projects include provisions for long term maintenance (greater than 10 years) of the systems. Priorities for retrofitting of facilities should be based on consideration of monitoring data concerning present water quality conditions in the Bay or tributary, residence times in receiving waters of the Bay, and land uses within the basin. Require synoptic storm event and dry period sampling programs to determine the effectiveness of retrofitting methods and projects that are implemented in this area.

4) **Sanitary Sewers.** Support ongoing programs to evaluate the sanitary sewer system of Dade County and define problems or conditions that result in the release of inadequately treated or untreated wastewater to the Bay through overflows, surface water discharges or groundwater seepage. The purpose of this study shall be to define the nature and extent of the impacts of this problem on Biscayne Bay and assist the county to obtain funding for actions that will improve water quality in the Bay.

5) **Improved Marine Sewage Contamination Standards.** Conduct basic research necessary to improve methods for evaluating sewage contamination in salt water areas, so that appropriate standards can be developed.

Summary of Recommendations (Continued)

Specific Water Quality Problems and Areas of Contamination

6) **Specific Water Quality Problems and Areas of Contamination.** Develop methods to assess known problems of contamination with toxic substances within the Bay. This program should include projects to address specific problems such as the following:

A. Target Areas
1. Miami River and tributaries such as Wagner Creek and Laurence Canal;
2. Military Canal;
3. Goulds Canal and Black Point Canal basins;
4. Little River and Biscayne Canal;
5. Munisport Landfill Site
6. Virginia Key Sewage Facility
7. Snake Creek/Maule Lake
8. Arch Creek

B. Target Contaminants
1. Phthalate acid ester (PAE) contamination;
2. Localized high levels of Arsenic and other heavy metals in sediments and biota;
3. High levels of petrochemicals in various tributary basins; and
4. Levels and environmental effects of Tributyltin compounds
5. PCB's
6. Polycyclic Aromatic Hydrocarbons
7. Pesticides/Herbicides
8. Anthropogenic organic contaminants

Monitoring

7) **Monitoring.** Continue, extend and improve existing water, sediment, biological, and ecological quality monitoring efforts in the Bay to provide a historical data base and identify problem areas. Consider the addition of a microbiological sampling program to better identify human health hazards. Expand the current Dade County and Biscayne National Park networks to include Card Sound and Barnes Sound. Analyze the existing data and network to eliminate redundant or inefficient sampling stations and add stations or new parameters in areas where data are inadequate or known problems exist, including upstream areas of tributary basins.

Need For Revised (Local) Water Quality and Other Standards

8) **Local Standards.** Encourage funding for the technical research efforts that are needed to develop water, sediment, and/or biological standards that are appropriate to protect the resources of Biscayne Bay. Two standards that should be reviewed immediately are the coliform standard as it applies to salt water and turbidity standards. Support interagency, legal and legislative efforts that are required to adopt, implement and enforce these standards.

Summary of Recommendations (Continued)

Compliance Monitoring.

9) **Permitting Requirements for Marina Facilities.** Recommend and encourage the FDER and DERM to develop rules requiring operating permits and associated monitoring, beyond those requirements for construction, of new and existing marina facilities. Marinas have uniformly been identified as an extreme problem and source of continued pollution by all regulatory agencies involved.

10) **Compliance Monitoring of Existing Permitted and Operating Systems.** Encourage regulatory authorities within Biscayne Bay to develop and implement a compliance monitoring process to ensure that marinas, boat building/repair operations, outfalls, dredging, etc. are operated and maintained in a manner that is consistent with their design specifications. Lack of compliance may be due to either operational or design problems. Operational problems shall be subject to enforcement action. Design problems should be addressed through enforcement or review of existing design criteria.

Enforcement

11) **Funding for Additional Enforcement.** Provide for additional personnel to enforce current regulations in Biscayne Bay, including stormwater management, wastewater treatment, marina operations, coastal construction and shipping. SWIM monies will be used to fund additional enforcement activities within Biscayne Bay and its watershed. Local governments are encouraged to provide additional support as a means to increase the level of enforcement possible. Local governments are encouraged to provide monies, manpower or document related expenditures to help support these enforcement activities.

12) **Enforcement Responsibilities.** Develop a multi-agency task force for enforcement, including local, state and federal enforcement entities, to meet on a quarterly or biannual basis. The purpose of this group would be to coordinate efforts of the diverse regulatory interests, prioritize, and review enforcement needs in Biscayne Bay. The Biscayne Bay Management Committee (BBMC) or the Miami River Coordinating Committee (MRCC) would provide an appropriate forum to coordinate the regulatory interests of these agencies. Perhaps a task force could be formed to address this issue.

Freshwater Inflow

13) **Freshwater Inflow.** Continue efforts to analyze the impacts of freshwater discharges from canals on Biscayne Bay and to mitigate adverse impacts of these discharges. This includes evaluation of a) methods to alter the amount and timing of freshwater releases from canals that discharge into North Bay; b) methods to restore sheet flow of freshwater into South Bay and extreme South Bay to alleviate periodic hypersaline conditions, help decrease the need for unnatural heavy pulses of freshwater, and to help restore transport of mangrove detritus into the Bay; and c) methods to mitigate or eliminate impacts of maintaining abnormal water levels in South Dade County canals.

Summary of Recommendations (Continued)

Circulation and Flushing

14) **Circulation and Flushing.** Ensure that all existing inter-unit connections remain unobstructed. Evaluate methods to improve circulation and flushing characteristics in localized problem areas, near stagnation points, finger canals, or in semi-enclosed basins, and ensure that such enclosed basins and blind canals are not constructed in the future. Circulation and flushing considerations should be incorporated into FDOT repairs and improvements to existing causeways, roads and structures.

Shoreline and Bottom Stabilization to Reduce Turbidity

15) **Shoreline and Bottom Stabilization.** Support efforts of county and municipal governments and other agencies and interests to develop and implement alternative methods for shoreline and bottom stabilization that use emergent vegetation and avoid or mitigate the construction of vertical bulkheads. Consider alternative methods for disposal of spoil materials from maintenance dredging that would avoid the deposition of unconsolidated materials on islands or other shoreline areas adjacent to the Bay. Consider the use of these spoil materials or perhaps artificial reef materials to fill deep holes that have been identified as persistent sources of turbidity.

Land Use and the Protection and Restoration of Natural Habitats

16) **Restoration and Preservation of Natural Habitats.** Explore, develop and implement alternative methods for purchasing, protecting, and restoring the integrity of wetlands and upland habitats and communities that provide water quality benefits to surface water and shallow groundwater systems. Appropriate techniques may include restoring water flow through previously-drained coastal wetlands, restoring natural topography and vegetation to filled or cleared areas, filling of deep holes in the Bay bottom, placement of artificial reefs, repair of propeller-scarred grassbeds, and restoration of abandoned agricultural lands to natural plant communities.

17) **Land Use.** Protect water quality and environmental resources within Biscayne Bay through careful regulation, primarily at the local government level, of land use and use of lower density zoning. Critical areas that have been identified near the Bay or its tributaries should have special restrictions on land uses and/or land and water management practices to protect the resources of Biscayne Bay. Remaining natural areas within the watershed, or sites that are suitable for restoration, should be protected, to the extent possible, through purchase of the property, protective easements or the placement of land use restrictions. .Local governments efforts in this area should be supported.

Summary of Recommendations (Continued)

Land Use and the Protection and Restoration of Natural Habitats (Continued)

18) **Manage Restoration Areas.** Initiate a cooperative effort among the SFWMD, counties, municipalities, Biscayne National Park, DER, DNR, FGFWFC, other agencies and other public or private interest groups to develop restoration and continuing management plans for individual tracts of land that have been identified as suitable for restoration. Determine priorities and sources of funding for purchase and/or management of these areas and implement appropriate restoration activities.

19) **Manage Preservation Areas.** Initiate a cooperative effort among the SFWMD, counties, municipalities, Biscayne National Park, DER, DNR, FGFWFC, other agencies and other public or private interest groups to develop preservation and continuing management plans for individual tracts of land that have been identified as suitable for preservation. Determine priorities and obtain funding from appropriate state programs such as CARL and Save Our Rivers, federal monies, or private conservation foundations for the purchase and/or permanent protection of these lands.

Submerged Land Ownership

20) **Submerged Land Ownership.** The lack of adequate ownership data severely handicaps efforts to restore and preserve the Bay. This inventory will require cooperative efforts among local, state and federal entities and should identify submerged land use patterns, areas that are privately owned, areas that are publicly owned, and areas that are leased to private interests. The SFWMD, DERM, BNP and FDER should work together with FDNR as lead agency to complete an inventory of the ownership and use of submerged lands and emergent marshlands in Biscayne Bay. The SFWMD, DERM, BNP and FDER should provide existing land use, landcover, and ownership data and technical assistance to help FDNR complete this inventory in a timely manner.

Card Sound and Barnes Sound Management.

21) **Card Sound and Barnes Sound Management.** Initiate management efforts to protect Card Sound and Barnes Sound, recognizing the unique resources and management problems of these areas and the need for cooperation among the SFWMD, FDER, FDNR, FDOT, USFWS, NPS, FGFWFC and local government entities in Monroe and Dade Counties. The DNR should review the aquatic preserve status of this system and include Barnes Sound in the existing Biscayne Bay/Card Sound Aquatic Preserve area.

Summary of Recommendations (Continued)

Centralized Data Bases

22) **Develop Centralized Data Bases.** Develop a centralized resource data base for Biscayne Bay and its drainage basins, incorporating existing land use/land cover data, water quality, hydrologic and fine scale ecological data from the District, other agencies and local governments. Location and species composition of natural communities of the Biscayne Bay watershed and the Bay bottom, including benthic communities, mangroves, freshwater and tidal wetlands, and coastal uplands, should be thoroughly mapped and the maps digitized. This work should be coordinated with the efforts of the Florida Natural Areas Inventory and would provide a basis for restoration and preservation projects and the evaluation of cumulative impacts of future development.

Public Education/Awareness

23) **Public Education/Awareness.** Support efforts by local governments, state agencies, the National Park Service and other interests to develop and implement multi-lingual and other educational programs to increase public awareness of, interest, and participation in addressing water quality related issues and problems in Biscayne Bay and aid existing interpretive efforts by local authorities and state agencies.

Identify Areas of Probable Historical Contamination

24) **Historical Contamination.** Commission a research investigation by a local historian to summarize existing information, examine historical records, and interview residents in Dade County to identify prior land uses that may continue to contribute to current water quality problems, such as historical agricultural sites and practices and industrial sites. This would result in a concise document that can then be used as a guide to designing future contaminant studies in the basin.

EXECUTIVE SUMMARY

I. INTRODUCTION

The introduction section of this report describes the legislative basis of surface water improvement and management (SWIM) plans, DER review criteria, plan format and the type of information that must be considered in the plan.

The SWIM Act (Chapter 87-97 Florida Statutes) mandated preparation of management plans for various water bodies throughout the state. Three water bodies within the South Florida Water Management District (SFWMD) were designated for initial development of management plans. These designated water bodies were Lake Okeechobee, Indian River Lagoon and Biscayne Bay. SWIM plans are to be developed and implemented by the water management districts, in cooperation with other state agencies and local governments. The legislation requires that funding requests for projects and programs must be submitted each year and that these requests must be consistent with the management plan.

The legislation defines information that must be provided in SWIM plans. The Biscayne Bay (the Bay) plan places primary emphasis on water quality and is intended to augment rather than replace any previous Bay management plans. This plan describes physical features, status of the system, existing water quality conditions, history of management actions, and potential sources of water quality degradation. Recommendations, programs and projects have been developed as a means to implement the management plan.

II.. SURVEY AND EVALUATION OF THE CURRENT STATUS OF BISCAYNE BAY

This section describes physical features, biological resources, uses, and a history of conditions that have led to the need for restoration and conservation of Biscayne Bay.

Physical Features. The study area is bounded on the north by the Broward county line, on the west by the C-111 canal/levee system, and on the south by the A1A causeway across Barnes Sound. Biscayne Bay is divided into four major hydrodynamic sections. Biscayne Bay is a depressional feature in a Pleistocene limestone basin. Natural sedimentary inputs are primarily derived from organisms within the Bay. Biscayne Bay is a well mixed estuary. Exchange with the ocean occurs via a number of tidal inlets. The dominant forcing mechanisms for mixing and transport in the Bay are tide and wind. Surface water primarily reaches the Bay as overflow from coastal canals during the wet summer months and occasionally during winter storms. Freshwater also reaches the Bay as groundwater seepage through the shallow aquifer throughout the year.

Biological Resources. The Biscayne Bay watershed supports diverse biological communities that help to preserve the integrity of the Bay. Under natural conditions, the Biscayne Bay ecosystem produces and maintains an aquatic environment that supports many plant and animal communities. If this biological diversity is lost, the system will lose its ability to adapt to changing conditions, water quality will decline, and the entire ecosystem will suffer.

Important habitats in the Biscayne Bay watershed include submerged aquatic, coastal wetlands, and coastal uplands. Submerged aquatic habitats consist of open water communities such as plankton, fishes, seagrasses and hard-bottom communities. Plankton appear to form the basis of the food chain in northern Biscayne Bay, whereas seagrasses and mangrove detritus provide the primary food source in southern Biscayne Bay. Coastal wetland communities include mangroves and saltmarshes. These plants provide habitat for numerous shoreline organisms, protection from erosion or storm damage, and, indirectly, an important source of food in the Bay. Coastal upland plant communities consist of hammocks, pinelands, and dune vegetation, and provide vital protection to the Bay from the effects of upland runoff and pollutant loading.

Additional biotic resources of the region include reptiles, birds, and mammals. Endangered, threatened, rare, or unique animals found in Biscayne Bay include the manatee, American Crocodile, American alligator, southern bald eagle, osprey, magnificent frigate bird, the white crowned pigeon, roseate spoonbill, the wood stork, the saltmarsh water snake, the mangrove fox squirrel, Key Largo Wood rat, Key Largo Cotton mouse, Schaus Swallowtail butterfly and various tree snails.

Water and Sediment Quality. Water quality in the Bay is generally good. However, in spite of the fact that water quality in Biscayne Bay does not generally violate existing state standards, both the Dade County Department of Environmental Resources Management (DERM) and the SFWMD feel that the Bay has substantial water quality problems. Water quality in North Bay is inferior to that of South Bay. Although, levels of phosphate and suspended solids have decreased slightly, nitrate concentrations have increased and dissolved oxygen levels have decreased at several stations in North Bay since 1979. Average chlorophyll, coliform bacteria, and turbidity levels are higher in North Bay than in South Bay. The Miami River and Little

River are sources of poor quality water. Except for some isolated instances of low dissolved oxygen and high bacteria concentrations, water quality of Biscayne Bay has met EPA, State and Dade County standards. However, these standards may not be adequate to protect the fragile resources of the Bay. Biscayne Bay sediments showed varying degrees of contamination. Major problem chemicals are polychlorinated biphenyls, herbicides, organochlorine insecticides, aromatic and petrogenic hydrocarbons, organotin compounds, and phthalic acid esters. The highest levels of these compounds were found near canals and rivers. Metals were detected in excess of natural background levels, primarily in canal or river sediments.

Historical and Current Uses and a History of Conditions that Have Led to the Need for Restoration and Conservation. Originally Biscayne Bay received sheet flow of fresh water from the Everglades system and was a brackish, estuarine system. Since the early 1900's, the Bay has been impacted by drainage of the Everglades; construction of the Intracoastal Waterway, dredging to fill mangrove shorelines or create causeways and islands, and the creation of inlets and ship channels. Problems that resulted from these activities include reduced circulation, increased turbidity, destruction of mangroves and grass beds, and altered salinity patterns. The opening of Baker's Haulover Inlet changed salinities in North Bay and Dumfoundling Bay from the natural fresh or brackish water to higher salinity conditions. Construction of MacArthur Causeway changed the tidal regime and severely decreased flushing in North Bay. Raw sewage was dumped into the Bay until construction of the first regional sewage treatment plant in 1955.

In recent years, increasing pollution trends in the Bay have been largely reversed through the use of improved treatment methods and the diversion of sewage discharges to ocean outfalls. Pollution problems have been moved offshore. Some sources of industrial pollution to the Bay have been closed. Effects of pollution from non-point sources have increased due to runoff from agricultural areas, increased stormwater discharges, and contamination of shallow groundwater. Many problems still exist in North Bay, primarily due to the cumulative and continued effects of past development practices as well as current actions. Future development in south Dade County and Monroe County may adversely impact the currently pristine areas of South Bay and associated areas of Card Sound and Barnes Sound.

Biscayne Bay currently falls under the jurisdiction of a number of entities, including federal and state agencies, a regional planning council, a regional water management district, two counties and 27 municipalities. The first management plan for the Bay was published by Dade County in 1981. The Biscayne National Park management plan was completed in 1983. The county completed a draft plan for the aquatic preserve area of the Bay in 1986. Recently, Dade County completed a proposed coastal management element of the Comprehensive Plan. Finally, the SFWMD has been mandated to prepare this Surface Water Improvement and Management (SWIM) Plan for Biscayne Bay.

A wide range of investigations have been conducted, primarily by researchers at the University of Miami. In recent years, with funding provided through the FDER, Dade County has commissioned a number of studies directed toward Bay management issues and problems. Results of these studies indicate that Biscayne Bay is threatened by a number of existing and potential sources of contamination. Sources of pollution in the Bay can be divided into two types, point and non-point. Point pollution sources are discharges to the Bay surface waters where discrete measures of flow and water quality may be taken and include domestic and industrial waste. Non-point source pollution has no direct point of origin and is usually associated with land use activities. Industrial, institutional, agricultural and urban land uses are the primary sources of non-point source pollution. Turbidity, chemical leaching from sediments and contamination from marinas and other water-dependent activities are *in situ* non-point sources of water quality degradation. In Biscayne Bay, stormwater discharge is a non-point source of pollutants that has been identified as a major problem. Retrofitting of stormwater systems was assigned a high priority in the SWIM legislation.

A wide variety of activities have taken place within the watershed during the past 100 years that may result in contamination of surface water or groundwater resources. Sources of contamination anywhere in the basin may potentially impact Biscayne Bay or its tributaries. Land use practices in upland areas of Dade County provide a continuing non-point source of contaminants to the Bay.

III. IDENTIFICATION AND ANALYSIS OF PRIORITY ISSUES

This section describes the complex problems and issues related to management of Biscayne Bay. These problems and issues were divided into three broad groups; problems and issues that occur throughout the Bay, problems and issues that occur in localized areas, and problems and issues that must be considered to meet specific requirements of the SWIM legislation and FDER rule.

Bay-Wide Projects and Programs. Bay wide problems and issues can be further divided into categories based on the need to restore conditions that are currently undesirable, or to preserve features that are still in good condition. Efforts are targeted toward three major issues--water quality, freshwater inputs, and habitat and living resources.

Water Quality. Water quality throughout most of the Bay is very good, although certain tributaries, such as Arch Creek, Miami River, Little River, Biscayne Canal, Maule Lake, Gould and Black Point canals, have severe water quality problems. Water quality issues that are relevant throughout the Bay include turbidity, sewage pollution, stormwater runoff and contamination with metals and anthropogenic chemicals. Major sources of turbidity are sedimentary input associated with the erosion of unstable shorelines, and the resuspension of fine and flocculent materials from dredged areas and deep holes. Actions that may be used to reduce turbidity levels in the Bay, include eliminating sources of fine sediments, controlling dissolved nutrients, stabilizing shorelines, stabilizing deep holes, reducing impacts of boats in certain areas, and modifying bulkheaded shorelines to attenuate wave activity.

Sewage contamination is a continuing problem in Biscayne Bay. Sewage pollution originates from point and non-point sources, such as ruptured sewage lines, dysfunctional lift stations, degraded pipes, cross-connected sanitary and stormwater lines, septic tank leachate, and discharges from boats. The Miami River, Little River, Maule Lake, and marinas where there are a large number of "liveaboard" boats have the worst sanitary sewage contamination problems.

Freshwater Inflow. Freshwater inflow to Biscayne Bay occurs from rainfall, groundwater seepage, and upland runoff and canal discharges. Stormwater runoff enters the Bay through a series of canals and waterways. Pollution studies have identified general problems associated with stormwater runoff for various land uses. Stormwater quality from various outfalls should be determined as a basis to develop priorities for retrofitting. Releases of water from coastal canals occasionally create local problems due to transfer of freshwater and polluted runoff into the Bay. The result of the water control works in South Florida has been to change spatial and temporal distribution of runoff to Biscayne Bay. Many negative impacts of freshwater inflows result from pulsed, large volume discharges that shock the system and are not readily mixed into the receiving waters. Impacts of freshwater inflows may reduced if discharges into North Bay could be modified to consider hydrodynamic features of the system, and if canal discharges into South Bay were redistributed to restore sheet flow through coastal wetlands.

Habitat and Living Resources. The Biscayne Bay watershed includes submerged aquatic, coastal wetland and coastal upland communities. These communities are integral components of the Bay ecosystem, providing shoreline stabilization, nutrient cycling, removal of suspended materials, habitat for numerous aquatic and terrestrial organisms and a basis for the aquatic food chain. The primary factors that limit the distribution of submerged benthic habitats are light penetration and substrate. Forces that impact these communities are water quality and physical disturbance. The greatest persistent threat to survival of benthic aquatic communities in Biscayne Bay is turbidity. Land development activities destroy submerged aquatic communities by the direct impacts of dredge and fill and by indirect effects of pollution and increased turbidity.

Coastal wetland habitats include mangroves, saltwater marshes and freshwater marshes. Mangroves are widely distributed along the shoreline of Biscayne Bay. The benefits of mangrove productivity to the Bay ecosystem are extensive and can best be realized if mangroves are periodically flushed by tidal exchange, freshwater flow, or upland runoff so that plant detritus from the floor of the forest and dissolved nutrients are transported into the Bay. In south Bay, some mangrove productivity has been lost because sheet flow of freshwater from the uplands has been redirected by construction of canals and levees. The integrity of the Biscayne Bay ecosystem is adversely affected by this decoupling of mangrove communities from their upland and back basin components. The integrity of mangrove communities is, in turn, affected by such factors as loss of species diversity, water level changes, salinity, filling, and extensive pruning. The most direct threat to the mangrove communities is land development activity along the shoreline and in adjacent uplands. Currently, Dade County codes and FDER rules limit the destruction of red, black and white mangroves and protect some other coastal communities.

Saltwater and freshwater marshes serve a similar function to mangroves within the Bay ecosystem and provide shoreline stabilization, nutrient cycling, removal of suspended materials, habitat, and a basis for the aquatic food chain. Prior to construction of the coastal canal system, marshes along the shore of Biscayne Bay were dominated by freshwater plants. Many of these areas have been extensively invaded by saltwater marsh species and

mangroves. Saltmarshes are not very abundant in Biscayne Bay, possibly because these communities tend to be invaded by mangroves.

The role of coastal upland communities in protection of the resources of Biscayne Bay is generally not appreciated. Coastal upland communities provide protection to the wetland marshes and forests by filtering runoff water before it enters the wetlands and the Bay and by reducing the velocity and distributing the flow of runoff. Many of these areas also provide recharge to the shallow aquifer system that provides groundwater flow to the Bay. Coastal upland habitats occupy upland environments that are most suitable for development and thus comprise probably the most endangered natural habitats in South Florida. Few, if any, attempts are made to mitigate the loss of upland communities.

Restoration and Mitigation. Proposed restoration or mitigation sites should be carefully selected for suitability based on substrate characteristics, water quality and other factors. Mitigation should only be used as a last resort, when all other remedies have failed. Although not currently required by federal law, these projects should be established, monitored, and proven effective before the original habitat is altered. Restoration efforts should be limited to projects where success is most likely. Planting of mangroves in properly prepared and stabilized substrate and planting of marsh vegetation are highly effective when the planting and maintenance are properly designed and supervised. Plantings of seagrasses are generally not effective. There has been significant success planting saltmarsh vegetation, especially *Spartina*, as a means to stabilize shorelines. Recent experiences with pruning of mangrove forests have resulted in the county regulating the cutting or trimming of these trees.

Preservation. Preservation is required for certain areas within Biscayne Bay that have unique environmental values and is recommended for most remaining natural habitats as a means to protect the quality of Bay resources. Some areas of the Bay are partially protected under one or more state and federal programs. Some of these areas may benefit by additional protection. Other areas that are not currently protected should become candidates for preservation. Three suggested preservation areas a) mangrove areas as identified in the Dade County Comprehensive plan; b) Coastal and island areas adjacent to Barnes and Card Sounds; and c) Coastal uplands adjacent to Biscayne National Park.

Public Awareness. A number of public information and awareness programs concerning Biscayne Bay are currently underway. These efforts, however do not focus on water quality problems in the Bay and the role of the public in managing these problems. A Public awareness program is needed to specifically address SWIM plans and management concerns.

Commercial and Recreational Resources and Activities. The design and construction of marinas, boat yards and some other water-dependent facilities are regulated by various entities including Florida Department of Environmental Regulation (FDER), Metro-Dade County Department of Environmental Resource management (DERM), and U. S. Army Corps of Engineers (USCOE). Permitting activities associated with the construction of these facilities are designed to ensure that they are built according to specifications and that these facilities do not cause environmental degradation. However, once construction is completed, no provisions have been made for continued monitoring to determine whether these facilities are operated and maintained according to design specifications or whether the original design criteria were adequate or appropriate for long-term management to prevent environmental degradation.

Problems and Resources Specific to Defined Areas. Certain areas within Biscayne Bay have localized problems and resources that need to be addressed through intensive monitoring and management programs.

Dumfoundling Bay. Dumfoundling Bay receives runoff from surrounding urban and industrial areas. The major tributary system is the Snake Creek/Maule Lake/Oleta River Complex. Problems in this area include stagnant areas associated with blind finger canals, sewage contamination, low dissolved oxygen, and contamination from polychlorinated biphenyls (PCB's), pesticides, aromatic hydrocarbons, and other anthropogenic chemicals. This area has had little intensive work and should be examined in more detail under the revised monitoring program.

North Bay. Turbidity is a major problem in North Bay. Primary sources of turbidity are scouring of shorelines, transport into the Bay through inlets, deep holes, and dredged areas. Some sediments sites in North Bay have much higher excessive amounts of phthalic acid esters (PAE's) than are found throughout the rest of the Bay samples. Commercial shipping activities at the Port of Miami pose a threat to North Bay due the possibilities of spills, contaminants and leaching from antifouling paints.

Several alternative dredging methods have been proposed to remove contaminated sediment from the Miami River. Depending on the methods

chosen, dredging the River to remove toxic sediments may have adverse impacts on Biscayne Bay and its associated waters. The dredging process mixes sediments and water. Toxic materials are released from the sediments, dispersed into the water column and are available for absorption by living organisms. Dewatering of the dredged sediments will potentially release toxic and bioavailable compounds from the contaminated areas. Preliminary studies by the USCOE indicate that safe and environmentally sound removal and disposal of water and spoil from the dredging of the Miami River could be very expensive. The District supports continued evaluation of the feasibility of environmentally sound removal and disposal of the sediments and dewatering from the Miami River.

The Miami River and Little River have been identified as sources of sewage contamination. Increased amounts of phytoplankton occur near the mouths of canals and rivers due to the influx of nutrients from upland areas. Arch Creek has high levels of phthalates, and may be receiving leachate from landfills and/or input from industrial sources. The Little River has a history of poor water and sediment quality, with high levels of lead and other trace metals, nutrients, coliform bacteria, turbidity, and hydrocarbon contaminants that may indicate persistent sources of these materials in the basin.

North Bay, between 79th St. Causeway and Julia Tuttle Causeway, contains unique environmental resources. This area has the largest and healthiest grassbed in North Bay. It is comparable to grassbeds found in South Bay and covers most of the submerged area in this region. This area represents an important healthy and diverse habitat for the entire Bay and it's preservation is particularly important to North Bay. This area also contains Bird Key, which has one of the largest pelican rookeries along the southeastern coast of Florida.

South Bay. Nine major tributaries discharge into South Bay. This region is better flushed and has less input of runoff from urban and industrial land uses than North Bay. Canals can provide a source of nutrient enrichment and pesticide contamination from agricultural runoff, contribute localized inflows of freshwater, and transport organic and trace metal pollutants from inland areas into this portion of the Bay. Other problems include interruption of sheet flow of fresh water, impacts from propeller scouring on bottom communities, and effects of further development on biotic resources. South Bay has extensive seagrass beds and other healthy marine and estuarine communities that depend on good water quality, adequate light penetration into the water column, and inputs from healthy upland systems to maintain their integrity.

Extreme South Bay- Card Sound and Barnes Sound. Card Sound and Barnes Sound are sensitive marine lagoons in the southernmost portion of Biscayne Bay. Card and Barnes Sounds are important habitats for a number of threatened and endangered species. Primary threats to this area are dumping, poaching of native species, unnatural fresh water pulses and future development. This area requires additional research to define preservation strategies and special management efforts to protect their unique natural resources.

Card Sound and Barnes Sound are areas of restricted circulation and freshwater flow. During the dry season, these areas become hypersaline however this condition may alternate with extreme discharges of fresh water. Reduced circulation aggravates any water quality problems. Placement of marinas, for example, poses severe water quality threats since the exchange and removal of contaminants would only occur over an extended period of time. Nutrient enrichment of these oligotrophic waters may cause adverse changes in plant and animal communities. Both Card and Barnes Sounds should be listed as Outstanding Florida Waters and designated as an Aquatic Preserve. These areas could also be considered for inclusion in Everglades National Park, Biscayne National Park, or Crocodile Lake National Wildlife Refuge.

Miami River. The Miami River is the second largest of two major natural tributaries into north Biscayne Bay. It has historically been used as a waterway for commercial and marine commerce. The Miami River has water quality problems due to the discharge of urban runoff and sewage from downtown Miami for many years. Water quality has been sampled in the River since 1984 and consistently violates coliform standards for Class III water bodies, is turbid due to effects of shipping, and has low levels of dissolved oxygen.

The Miami River has chronic and acute problems. Acute problems are primarily related to sewage pollution and stormwater runoff. Upgrade of the aging sanitary sewer system is a major public works project that should be funded by a county bond issue with state or federal assistance. Chronic problems in the Miami River include metal, tributyltin, and organic chemical contamination of sediment. Sediment concentrations of some metals are high when compared to similar water bodies throughout the state. Preliminary screening of the Miami River shows that concentrations of tributyltin (TBT) are above the maximum U. S. Environmental Protection Agency (USEPA)

recommended saltwater concentration of 10 pptr (parts per trillion). Organic chemicals in the main shipping channel into the Miami River occur primarily in association with the Port of Miami, but are also present in sediments from the River. A series of groundwater contaminant problems have occurred at the Miami International Airport that may be causing unquantified contamination of the River and Bay.

The Miami River is currently designated as Class IV by the state DER. This is inconsistent with designation of the remainder of Biscayne Bay as Class III and designation of both the River and the Bay as an aquatic preserve. The State should consider redesignation of the Miami River as Class III and adoption of state standards that are more closely tied with the requirements of the living systems that they protect. Other problems in the basin that need to be addressed include continued retrofitting of stormwater outfalls; dumping of fish wastes; and chronic turbidity problems.

Specific Requirements of the SWIM Legislation and DER Rule. The SWIM Act (Ch 87-97 F.S.) and FDER rule (17-43 F.A.C.) require that water management districts incorporate certain information and analyses into SWIM plans, including land use data, lists of point and non-point sources of pollution, and timetables for achieving compliance, restoration and management.

Adjacent Land Uses. The SFWMD has an extensive land use/land cover data base. The SFWMD initiated a contract with the South Florida Regional Planning Council (SFRPC) in 1986 to update land use data for eastern Dade County. The SFRPC has completed that effort and is providing the District with the final maps. Land use data are available on a series of 1:24,000 scale maps. The District also has a mapping program under contract to Dade County to develop higher-resolution land use mapping. The District uses a three-level land use classification scheme. The 75 categories at the most detailed level reflect characteristics that are applicable to water resources and management.

Point and Non-Point Sources of Pollution. SWIM plans should include the identification of point and non-point sources of pollution that are causing degradation of the water body. To meet this objective, the SFWMD has initiated a four step process. The first step is to identify areas that currently have violations of water quality standards, such as the Little River and Miami River.

The second step is to examine activities near those areas that may be responsible for the violations. The SFWMD has compiled data concerning waste disposal, chemical storage, code enforcement, and surface water management from FDER, DERM and SFWMD. Most enforcement cases involve problems with solid waste disposal and contamination of sediment and groundwater. Point sources include seven industrial discharges and one domestic discharge into Biscayne Bay or its tributaries. One facility in the watershed has a temporary operating permit.

The third step is based on recognition that existing state water quality standards may be inadequate to protect the Bay and that more stringent local standards may be required to adequately protect the resources of Biscayne Bay. The SFWMD is supporting efforts to develop such local standards for sediment and water quality.

The fourth step is to repair, replace or remove the source of water quality degradation. The District should continue to support efforts by DERM to reduce point and nonpoint sources of pollution by stabilizing shorelines as a method to reduce turbidity, identifying and control sources of chemical contamination, retrofitting stormwater outfalls and implementing an enhanced monitoring program.

Timetable and Schedule. The Swim Legislation requires that the SWIM plan include a timetable to bring point and non-point sources into compliance and a schedule for restoration and management of the water body. The details of schedules and timing will become evident as monitoring of the system is refined, sources of degradation are identified and methods are implemented to correct these problems.

The first milestone in the schedule is to achieve compliance with state water quality standards. Within the 5-years, the trend for declining dissolved oxygen levels in the Bay should have been stabilized or reversed due to reduction of non-point pollution, and coliform levels in the Little River and Miami River. The River should be in compliance with Class III water quality standards within 10 years.

Achieving compliance with state standards is one step toward restoration of the Bay. Efforts to further improve conditions in the Bay will depend on the development and implementation of adequate local standards. The water quality standards should be upgraded within 5-10 years and within 15 years the Bay and River should be in compliance with these new standards. Within 5-years, major point and non-point sources of contamination or pollution should be identified and efforts to correct these problems should be underway; standards for turbidity and some toxic materials should be in place; and freshwater sheet flow should have been restored into major tracts of mangroves adjacent to South Bay. Within ten years, more stormwater systems should be retrofitted. and turbidity levels

should have improved noticeably in North Bay with seagrass recovery in various areas.

Management of the Bay will be achieved when restoration efforts are underway to the extent that major sources of degradation have been controlled or eliminated, management mechanisms are in place for Card Sound and Barnes Sound, major tracts of land for preservation have been identified and purchased or authorized for purchase, and Biscayne National Park and Everglades National Park and other sensitive areas have been protected through the purchase of effective buffer areas or protective easements. Within 5-years, management issues concerning Card Sound and Barnes Sound should be resolved and land slated for acquisition; efforts will have been initiated at the Federal level to expand the area of Biscayne National Park to include some adjacent upland areas; and major tracts of land should have been identified for purchase as preservation areas within the Bay ecosystem. Within 10-years, large tracts of land will have been preserved adjacent to South Bay and Card Sound/ Barnes Sound.

IV. CONCLUSIONS AND RECOMMENDATIONS

This section of the plan consist of 24 recommendations based on conclusions that are divided into 16 categories. The recommendations are summarized in the beginning pages of the report. This section summarizes the conclusions that provided the basis for each recommendation.

Need For Consistent State Water Quality Classifications. The Miami River is currently classified by the FDER as a Class IV water body. This water quality classification has associated lower water quality standards than the remainder of Biscayne Bay, which is designated as Class III. Recommended action is to support ongoing efforts to have FDER reclassify the Miami River from Class IV to Class III.

Sanitary Waste and Stormwater. Sewage contamination is a continuing problem in Biscayne Bay. Although fecal coliform levels have declined throughout most of Biscayne Bay, they have increased or remained at pre-sewage treatment levels in localized areas, especially the Miami River, Little River, and Management Unit II. Stormwater drainage is another source of pollution. Retrofitting of stormwater outfalls was a priority in previous Bay management plans and the SWIM legislation. Impacts of stormwater discharges have been greatly increased due to cross-connections with sanitary sewer lines and sanitary sewer overflows. Assessment of the extent and magnitude of sewage contamination problems is hampered by lack of appropriate methods for measurement of sewage pollution in salt water. Recommended actions are to expedite needed repairs, provide better assessment of problems, find better methods for detection of fecal contamination in salt water, and continue to retrofit stormwater outfalls.

Specific Water Quality Problems and Areas of Contamination. Specific areas within the Bay have chronic resource management problems that are related to the input of toxic chemicals. In addition, a number of toxic chemicals have widespread distribution in the Bay and the ecological implications of these materials are largely unknown. Recommended actions are to develop methods to assess known problems of contamination within six specific target areas of the Bay and to assess the impacts of contamination by eight groups of toxic chemical contaminants. The identified target areas are the Miami River and tributaries; Military Canal; Goulds and Black Point Canals; Little River and Biscayne Canal; Munisport Landfill site; Virginia Key sewage facility and Snake Creek/Maule Lake. The target chemicals are phthalate acid esters; arsenic and other heavy metals; petrochemicals; tributyl tin compounds; polychlorinated biphenyls, polycyclic aromatic hydrocarbons; pesticides/ herbicides; and synthetic organic materials.

Monitoring. Monitoring is necessary to assess water quality and maintain habitat and system integrity. Continuation of ongoing monitoring efforts will provide background data for evaluation of known problems and identification of new problems, as well as a basis to preserve healthy areas. Existing monitoring networks should be expanded to include new areas, more intensive sampling of suspected problem areas, and sampling of tributaries above the salinity control structures. Six types of monitoring programs are suggested--tributary criteria, water quality, sediment quality, biological, microbial, and ecological.

Need For Revised (Local) Water Quality and Other Standards. Preservation of Biscayne Bay resources depends on the maintenance of appropriate environmental protection levels, including water quality and other standards that will ensure survival and continued health of the ecosystem. Currently, state standards allow contaminant and water quality levels that are much greater than occur locally as background levels in Biscayne Bay. Recommended actions are to work with other regulatory interests to develop more stringent and locally appropriate water quality and contaminant levels for Biscayne Bay.

Compliance Monitoring. State agencies and local governments issue permits regulating the

design and construction of numerous water-dependent and water-related activities and facilities within the Biscayne Bay watershed. The most important of these facilities are marinas. These permits do not adequately consider impacts of long-term operation and maintenance. Long-term monitoring is a recommended method to document impacts on Biscayne Bay, to aid in development and implementation of mitigation methods, and to improve design and construction criteria for future marina and other water-dependent facilities. Requiring operating permits is a means to implement compliance monitoring, mitigation, and a design review program.

Enforcement. Many agencies have regulatory authority within Biscayne Bay, but do not coordinate their enforcement activities or have sufficient personnel to adequately enforce local, state and federal laws and regulations. At the same time, each agency or authority is empowered to enforce certain laws but not others. Recommended actions are to provide additional enforcement personnel, support efforts to develop local funding sources for enforcement, and develop a multi-agency task force to review enforcement practices and needs.

Freshwater Inflow. Freshwater discharge occurs primarily to restricted areas of the Bay from the mouths of coastal canals. Releases of water from coastal canals occasionally create localized problems due to the introduction of freshwater and polluted runoff from urban and agricultural lands into the coastal waters and estuaries. Recommended action is to continue efforts to analyze impacts of freshwater discharges from canals on Biscayne Bay and to mitigate adverse impacts of these discharges.

Circulation and Flushing. Biscayne Bay has several areas where circulation and flushing are reduced due to hydrodynamic characteristics of the system, especially at tidal nodes and within semi-enclosed basins. Recommended action is to ensure that circulation and flushing conditions do not deteriorate and to evaluate methods to improve circulation and flushing characteristics in conjunction with normal FDOT and municipal modifications to existing structures.

Shoreline Stabilization to Control Turbidity. Turbidity is a major problem that is a continuous source of water quality degradation. Sources of turbidity are erosion of unprotected shorelines, and the resuspension of fines and flocculent material from dredged areas and deep holes. Recommended action is to support shoreline stabilization efforts and actions that avoid or mitigate the construction of vertical bulkheads.

Land Use and the Protection and Restoration of Wetlands and Upland Habitats. The natural relationships among coastal upland vegetation, shoreline vegetation, and submerged plant and animal communities should be protected throughout the watershed as a means to protect water quality and other resources of Biscayne Bay. In addition, certain land uses are not compatible with protection of water quality within the Bay. Recommended actions are to purchase, protect and restore wetlands and upland habitats; regulate land use to protect resources of the Bay; and identify suitable areas for restoration and preservation.

Submerged Land Ownership. Because ownership of submerged lands generally determines the type of use that will occur, this is an important issue for the protection of Bay resources. FDNR does not have adequate ownership maps. Recommended action is for FDNR to work cooperatively with DERM, SFWMD and other agencies and local interests to develop an official inventory of the ownership and use of submerged lands in the Bay.

Card Sound and Barnes Sound Management. Card Sound and Barnes Sound are sensitive marine lagoons that are threatened by a number of man's activities. These areas require additional research and special efforts to define management strategies to protect their unique natural resources. Recommended actions are to initiate a multi-agency study of Card Sound and Barnes Sound and request that FDNR review the aquatic preserve status of this system and consider inclusion of Barnes Sound in the existing Aquatic Preserve area.

Centralized Data Bases. Many entities throughout South Florida collect information that is relevant to management of Biscayne Bay. Agencies and local governments responsible for management of the Bay need access to a common, consistent source of information as a basis for management decisions and resource evaluation. Recommended action is that agencies and local governments work together to develop a central data base for Biscayne Bay that incorporates land use/land cover, water quality, hydrologic, and fine-scale ecological data.

Public Education/Awareness. Many entities have ongoing public information programs concerning Biscayne Bay. A public awareness program is needed to specifically address SWIM plans and management concerns. This program should provide multi-lingual materials in an effort to reach the large non-english speaking population of residents.

Identify Areas of Probable Historical Contamination. Land adjacent to the Biscayne Bay

has been developed since the late 1800's. A wide variety of activities have taken place within the watershed that may have resulted in contamination of sediments, surface or ground water resources. Recommended action is to conduct research to identify prior land uses that may continue to contribute to current water quality problems.

V. PROGRAMS

Management Strategies. Strategies for management of Biscayne Bay have been outlined in the final recommendations of this plan. These recommendations provide a framework to support current and future restoration and preservation efforts in Biscayne Bay. In conjunction with the recommendations, the District has implemented specific programs to address major management concerns in the Bay. The programs and schedule to address the management concerns of the Bay are based on the assumption that the legislature, the District and DERM will provide continuing support. A number of strategies for future support of these programs are defined.

Management Program and Projects. A variety of monitoring, implementation and research projects have been recommended for funding in Biscayne Bay under the SWIM program. Projects for FY 87-88 are currently underway. Additional projects have been proposed for FY 88-89, and these projects will be initiated, pending final approval and appropriation. Funds for additional programs are requested in the FY 89-90 budget which is outlined in this report and will be submitted to the legislature in March, 1989.

Projects for FY 87-88. Projects that are being funded in Biscayne Bay for the current fiscal year include continued retrofitting of stormwater basins, increased enforcement, water quality monitoring, shoreline stabilization, and support for the Miami River Coordinating Committee. Of these projects, enforcement, water quality monitoring and shoreline stabilization are being directly funded to Metro-Dade County DERM. Stormwater basin retrofitting is being done in cooperation with the City of Miami. In addition, funds were provided to match a city grant for staffing and operation of the Miami River Coordinating Committee.

Proposed Projects for FY 88-89. Proposed projects for the FY 88-89 Biscayne Bay SWIM program include continued funding for shoreline stabilization, stormwater basin retrofitting, and water quality and sediment monitoring. New projects are proposed for redistribution of canal flows, improved circulation, habitat and water quality monitoring in Barnes Sound, and planning for future projects. The detailed scope of work for these programs will be determined after funding for FY 88-89 SWIM programs has been allocated by the Legislature and the SFWMD Governing Board.

Proposed FY 89-90 Projects. Specific work has not yet been defined for FY 89-90 projects, since the amount of funding that may be available for these efforts is uncertain. Shoreline stabilization, Miami River Coordinating Committee stormwater outfall retrofitting, and future project planning will be continued. The canal flow redistribution project will continue at about the same level of funding. Monitoring will be expanded to include stormwater events. New programs are proposed to address data needs, restoration and preservation project planning, circulation, non-point pollution from prior land uses and Card Sound/Barnes Sound management. The scope of each of these programs will be further defined as data from other projects and agencies become available and are analyzed.

Storm Event Monitoring. Storm event monitoring is a new program that will be instituted to evaluate the success of outfall retrofitting.

Restoration/Preservation Project Planning. A great deal of land use data has been collected from Biscayne Bay by the SFWMD, DERM, FDNR and other agencies. This program is designed to compile these data in a computerized data base, identify suitable areas for restoration and preservation projects and initiate necessary design, permit acquisition or purchase activities.

Circulation Maintenance. This project will address areas in the Bay where inadequate circulation and flushing is causing degradation of water quality or natural communities. Areas adjacent to SFWMD canals have been identified identified as target areas that may have circulation and flushing problems. The District may consider a study to examine the design of canals, downstream of coastal salinity control structures in South Bay, to determine if changes can be made to avoid stagnation in these channels.

Black Point Water Quality. Groundwater contamination is suspected to have occurred in the Black Point Canal/Goulds Canal Basin. The source and fate of the leachate are currently unknown. A project has been proposed to monitor groundwater seepage from this area into the Bay.

Card Sound/Barnes Sound Preservation. This area contains healthy natural systems and should be protected from any further development. Currently, no management plans exist for these systems. This project will begin efforts to initiate or coordinate the development of a management plan, to address problems in this area.

Historical Contamination. This project involves collection and analysis of historical data from local residents, public records, and other plans

to describe prior practices and land uses that may result in current contamination problems.

VI. SCHEDULE, FUNDING, AND PRIORITIES

Schedule and Funding. The general schedule for compliance, restoration and management of Biscayne Bay is discussed in the section of this report that deals with specific requirements of the SWIM legislation. The above programs and schedule depend on an estimated funding support of approximately $2 million per year from the legislature or other outside sources in addition to the support of the SFWMD, DER, DERM, the City of Miami, Biscayne National Park , etc. Theschedule for initiating an funding SWIM projects in Biscayne Bay is summarized in Table ES-1.

Priorities. Priorities for FY 89-90 funding are divided into three groups. Very high priority efforts include retrofitting of stormwater systems; continuation, expansion, and redirection of monitoring programs; protection of the existing resources of South Bay, Card Sound and Barnes Sound, and development of data bases. High priority efforts include turbidity abatement projects and studies of special problem areas. Medium priority efforts include development of educational materials (public awareness); historical contamination; Miami River Committee; circulation maintenance; canal getaway channel modification.

Table ES-1. Biscayne Bay SWIM Programs, Projects and Budget

Item No.	Project Title/Description	Funding (000's)			Recommendation No.
		87-88	88-89*	89-90*	
1	Stormwater Outfall Retrofit Program a. Miami River Stormwater Systems	1,190	919	1,130	1,2
2	Enforcement Program Enforcement	150			9,10,11
3	Monitoring Program a. Water Quality/Biological Monitoring b. Tributary Sediment Monitoring c. Stormwater d. Biological Materials	300	300 50	300 150 100	2,5,6, 7,21
4	Turbidity Abatement Program a. Oleta River Stabilization	735		300	14
5	Bay Management Program a. Miami River Committee b. Preservation/Restoration Project Planning c. Card Sound/Barnes Sound Management. d.Planning and Permitting for Future Projects	25	 50	20 25 50 50	15,16,17, 20,21
6	Circulation and Flushing Program a. Canal Discharge Redistribution b. Flow Culverts at Mowry Canal c. Canal Getaway Channel Modification d. Circulation Maintenance		200 30	200 30 50	12,13
7	Research Program a. Historical Contamination			20	23
8	Public Education/Awareness Program a. Educational Materials (multi-lingual)			50	22
9	Special Problem Areas and Contaminants a. Black Point Canal Basin Water Quality			30	24
	TOTALS	2,400	1,549	2,505	

*Proposed

Surface Water Improvement and Management (SWIM) Plan for Biscayne Bay

I. INTRODUCTION

A. Legislative requirements for Surface Water Improvement and Management (SWIM) plans

The Surface Water Improvement and Management (SWIM) Act (Chapter 87-97 Florida Statutes) was passed by the legislature in 1987. This act mandated the creation of a priority list of water bodies of regional and state-wide significance, the design and implementation of surface water improvement and management (SWIM) plans for these water bodies, and the creation of the SWIM trust fund to provide financial support for the necessary planning and implementation efforts. The intent of this legislation was to prevent the further decline in the quality of Florida's surface water resources. A copy of the SWIM legislation is provided in Appendix A.

The SWIM Act expressed the concern that "...the declining quality of the state's surface waters has been detrimental to the public's right to enjoy these surface waters and it is the duty of the state, through the state's public agencies and subdivisions, to enhance the environmental and scenic value of surface waters." Contributing factors listed for the decline are the input of point and non-point sources of pollution and the destruction of natural systems of aquatic life that purify surface waters. Functions of surface waters in Florida, as defined by the SWIM Act, are as follows :

"1. Providing aesthetic and recreational pleasure for the people of the state;
2. Providing habitats for native plants, fish, and wildlife, including endangered and threatened species;
3. Providing safe drinking water to the growing population of the state; and
4. Attracting visitors and accruing other economic benefits."

Florida's aquatic resources exist in a delicate hydrologic balance, providing water for agricultural and urban water supply, support of natural systems and recreational and aesthetic use. The Biscayne Bay ecosystem includes the bay itself, the various tributaries that discharge into the Bay and the upland areas that are drained by these tributaries. Under natural conditions, the Biscayne Bay ecosystem produces and maintains an aquatic environment that is habitable for a diverse array of plant and animal communities. The natural resilience of living systems generally helps to maintain a balance within the Bay, such that many forms of degradation can be sustained without causing permanent damage to the system. This balance is achieved through biological diversity and the interrelationships that exist in a complex network of living organisms. As diversity is lost or reduced in an aquatic system, the system loses its ability to adapt or respond to changing conditions, the ability of a system to maintain surface water quality declines and the components of the ecosystem, including man, suffers.

A three-fold approach is required to restore water quality and maintain it in the condition expected by visitors and those who use the Bay: a) reduce or eliminate the input of pollution; b) clean up, isolate or remove the pollutants that are already in the system; and c) restore, preserve and protect the Biscayne Bay ecosystem, including its inland watershed components.

Based on the concerns expressed in the legislation and these scientifically accepted concepts, the South Florida Water Management District (SFWMD) has determined that the the primary focus of the SWIM planning efforts should be placed on water quality, including those beneficial and detrimental factors and ecosystems that affect and determine water quality, and those factors and resources that are, in turn, affected by water quality. The objective of these plans is to improve and manage surface waters as a public trust for current residents and future generations of Floridians. The legislature intends to achieve this objective by the creation and continued update of SWIM plans.

SWIM plans are to be developed and implemented by the State's five regional water management districts, in cooperation with other state agencies and local governments, as described in the legislation. The SWIM Act specifies that the Florida Department of Environmental Regulation (FDER) is responsible for development and organization of the tasks associated with this legislation and will act as primary reviewers of the SWIM plans that are developed by the water management districts. In addition, the Florida Department of Natural Resources (FDNR), the Florida Game and Fresh Water Fish Commission (FGFWFC), the Florida Department of Agriculture and Consumer Services (FDACS) and local governments will work with the water management districts in the development and review of SWIM plans.

Three specific lakes and estuaries within the SFWMD were designated by the legislation as being among the highest-priority water bodies in the state for initial development of management plans--Lake Okeechobee, the Indian River Lagoon and Biscayne Bay. Although no specific date was set by the legislation for the development of management plans for these water bodies, the legislation requires that the water management District present a proposed budget to the state in September of each year to support SWIM management efforts for the subsequent fiscal year. This budget and proposed management actions must be consistent with the SWIM plan. Thus, in order to ensure funding for planning and management efforts in Biscayne Bay during the 1989-1990 fiscal year, the SFWMD decided to prepare this initial Biscayne Bay SWIM plan by September, 1988.

The legislation defines certain information that must be provided in SWIM plans. The plans must provide a description of the water body system (historical uses, current uses, hydrology, and conditions that have led to the need for restoration); identification of governmental units within a 1-mile perimeter of the Bay and a description of adjacent land uses; and "a list of the owners of point and non-point sources of water pollution that are discharged into each water body and tributary thereto and that adversely affect the public interest, including separate lists of those sources that are:

1) Operating without a permit;
2) Operating with a temporary operating permit; and
3) Presently violating effluent limits or water quality standards."

Based on the requirements of the legislation, the FDER developed Rule 17-43 F.A.C. that defined the scope and format of SWIM priority and management plans. The plans must be developed in cooperation and coordination with other state agencies and local governments. The required content and format of SWIM plans was further explained in a DER memorandum. Copies of the DER rule and memorandum are also included in Appendix A.

B. The Iterative Nature of the SWIM Planning Process

SWIM plans are iterative in nature and will evolve and improve each year as work is completed, new problems arise, and new management priorities and strategies are defined for the system. The legislation provides for annual updates to the plans, if needed, as part of the budgeting process. SWIM plans will thus be modified continually to consider the changing needs and concerns of the various management entities.

SWIM plans provide a method and opportunity to reevaluate past research and management actions and incorporate the results of this work to maintain or enhance resource management in new areas. The plan is not a static entity, but rather serves as a guide to support the completion of past goals; definition of new goals; and the development and implementation of strategies and actions to achieve these goals. Many of the recommendations in this plan are broad in scope and may include or require the participation of local governments and other agencies to accomplish the required changes. Only some recommendations can be accomplished using SWIM funding alone. Other recommendations are included in this plan to encourage the cooperation and participative funding that are needed to preserve, restore or enhance water quality and environmental resources within the Bay. Since this plan is not a static entity, recommendations and project funding will change each year to reflect new information and priorities.

C. Integration and synthesis of the Biscayne Bay SWIM Plan with previous management plans

The SWIM planning process places primary emphasis on water quality. The SWIM program is not intended to supplant, replace, or supersede previous management plans that have been developed for Biscayne Bay. The SWIM plan can be used as a tool to supplement or support water quality aspects of these plans; to provide further indication of the nature and extent of water quality problems in the Bay; suggest additional methods that can be considered or applied to the solution of these problems; and to recommend funding for the support of specific projects or management efforts that address these concerns.

Water quality is affected by various uses and features of the system. Water quality, in turn, has impacts on recreational and commercial (primarily fishing) uses, and natural features of the ecosystem such as the presence of endangered species. This plan examines the history of management actions in Biscayne Bay, the physical area and status of the system, existing water quality conditions, and potential sources of water quality degradation. These factors are assessed within specific areas of the Bay and recommendations are developed to improve water quality conditions. This plan will be revised or updated periodically to ensure continued accurate assessment of condition and management of the system.

The first step in the development of a SWIM plan for Biscayne Bay is to identify political entities and agencies that have jurisdiction within the Bay and review past management efforts. The second step is to describe the current status of Biscayne Bay, based on physical and biological features and existing research data. The third step is to identify known and potential sources of pollutants that cause water quality degradation. The fourth step is to identify methods that can be used to reduce or eliminate pollution from these sources. Finally, the plan includes recommendations of specific management actions that should be taken to maintain and enhance the Bay and its resources.

D. DER Review Criteria

Chapter 373.455(2) requires DER, in reviewing SWIM plans, to make three specific determinations to judge the sufficiency of the plan prior to submission for DER review. The required determinations are described below.

(1) "Whether the costs described in the plan, as projected by the water management districts, are reasonable estimates of actual costs of programs in the plan." This determination requires an understanding of: (a) objectives of the work as related to the plan; (b) specific program elements involved; (c) responsibilities of the participants; and (d) specific budget requirements in summary form (personnel, equipment, supplies, travel, contracts, etc.)

(2) "The likelihood of the programs described in the plan resulting in significant improvements in water quality in the priority surface waters designated in the plan." This determination requires that the plan demonstrate clear linkages between each program and the program elements being implemented. Programs and their elements must be clearly designed to address specific management needs of the water body. Research programs need to be linked to specific management strategies. The plan needs to provide clear understanding of how research will be channeled and coordinated to meet management needs for the water body.

(3) "The combination of programs which can be funded based upon available revenues within the SWIM Trust Fund". This determination requires an understanding of the relative importance of the proposed work on a priority basis within the District. In order to facilitate this, the plan should provide at least a general ranking of programs and projects submitted for SWIM funding in terms of the level of support they provide for carrying out the strategies contained in the plan.

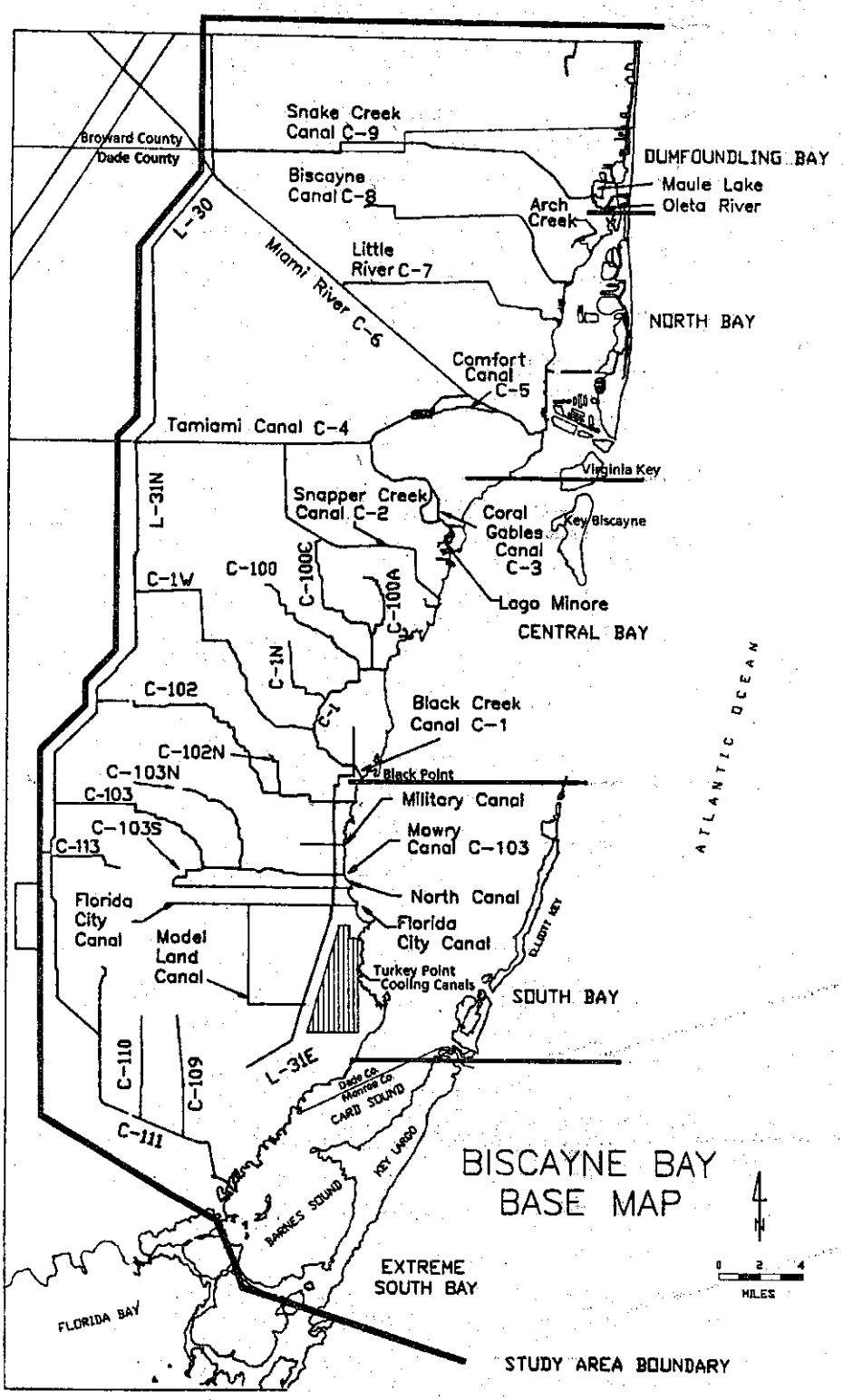
II. SURVEY AND EVALUATION OF THE CURRENT STATUS OF BISCAYNE BAY

A. System Description

1. Physical and Hydrologic Features.

Description. Biscayne Bay is a shallow subtropical estuary found along the southeastern coast of Florida, primarily located in Dade County (Figure 1). Historically, the Bay had an average natural depth of 3 to 9 feet (1 to 3 meters). Much of this area has since been modified and dredged. Currently, average depths range from 6 ft to 10 ft (2 to 3 meters), except in deeper dredged areas and main channels (Harlem, 1979). Nearly half (49%) of North Bay has been dredged to a depth between 10 and 16 feet (3 to 5 meters) (Metro-Dade County Planning Department, 1986; Harlem, 1979). The study area for this plan is bounded on the north by Dumfoundling Bay and includes the Intracoastal Waterway north to the Broward county line. The western boundary is the L-30 and L-31 levee system and the southern boundary is the A1A bridge across Barnes Sound. Barnes Sound and Card Sound were added to include drainage from the C-111 basin. The Biscayne Bay SWIM Plan thus includes the entire coastal portion of Dade County that lies east of the Everglades National Park SWIM planning area. These boundaries were chosen

Figure 1. Major Features of the Biscayne Bay SWIM Study Area



to allow continuous coverage from one plan to the next within the SWIM planning process.

Subdivisions. For the purpose of the Aquatic Preserve Management Plan, that was developed by the Dade County Planning Department, Biscayne Bay was divided in to four major regions on the basis of hydrologic and and hydrodynamic characteristics. The larger regions are, in turn, divided into hydrologic units. Descriptions of the regions, units and the major tributaries that enter the bay within each unit are as follows:

Dumfoundling Bay -The region from the mouth of the Oleta River to the Broward County line. Tributaries that flow into this unit include Maule Lake, Snake Creek Canal, and the Oleta River

North Bay - The region from Dumfoundling Bay to Rickenbacker Causeway. The units within this region generally follow those areas as defined in the Draft Biscayne Bay Aquatic Preserve Management Plan and are listed as follows:

Unit I	Sunny Isles to just south of the Oleta River (excluding the Oleta River)
Unit II	Broad Causeway to 79th St. Causeway
Unit III	79th St. Causeway to Julia Tuttle Causeway
Unit IV	Julia Tuttle Causeway to Venetian Causeway
Unit V	Venetian Causeway to MacArthur Causeway
Unit VI	MacArthur Causeway to the Port of Miami
Unit VII	Port of Miami to Rickenbacker Causeway

Tributaries that flow into North Bay include North and South Arch Creek, Biscayne Canal, Little River, and the Miami River

South Bay - This region extends from Rickenbacker Causeway south to the Arsenicker Keys. Based on the Aquatic preserve Management Plan (Metro-Dade County Planning Department, 1986), and the report by Metro-Dade County, Department of Environmental Resource Management (Metro-Dade County DERM, 1985), this region of the Bay is considered in two parts.

Central Bay. - The portion of the South Bay region that extends from the Rickenbacker Causeway south to a line extending form the northern end of Sands Key westward to one mile south of Goulds Canal. Tributaries that enter this portion of the bay include the Coral Gables Waterway, Lago Minore, Snapper Creek Canal, C-100, and Black Creek-Goulds Canal

South-Bay Proper. - The area that extends from the Sands Key-Goulds Canal line south to the Arsenicker Keys. Tributaries that enter this portion of the bay include North Canal, Military Canal, Mowry Canal, Florida City Canal and C-102.

Extreme South Bay - Card Sound and Barnes Sound south from the Arsenickers to the new A1A bridge at Cross Key. The major tributary that flows into Card Sound is the southern outflow of cooling ponds of Florida Power and Light Company's Turkey Point Nuclear Power Station. The major tributary into Barnes Sound is the C - 111 canal.

Hydrodynamics. Biscayne Bay is a shallow, well mixed estuary, which receives fresh water from surface runoff and a series of drainage canals along it's western shore. Exchange with the Atlantic Ocean occurs via a number of tidal inlets along the eastern barrier islands. The dominant forcing mechanisms for mixing and

transport within the Bay are tide and wind (Lee, 1975). Tides in the Bay are semi-diurnal with ranges from 2.5 ft (77 cm) in North Bay, (van de Kreeke and Wang, 1984) decreasing to 1.6 ft (50 cm) over Featherbed Banks, and to less than 1.0 ft (30 cm) in Card Sound (Swakon and Wang, 1977). Wind speeds are less than 10 mph (16 kph) 75% of the time. The predominant wind directions are east and southeast. Higher wind speeds are associated with wind from the east and northeast (van de Kreeke and Wang, 1984). Stratification occurs occasionally along the western boundary due to freshwater input and varies with the hydrologic cycle and drainage control activities (Chin Fatt and Wang, 1987). Circulation within Biscayne Bay can be divided into sub-sections based on hydrodynamic patterns as described by van de Kreeke and Wang (1984).

North Biscayne Bay encompasses the area bounded on the north by Bakers Haulover inlet, and on the south by Rickenbacker Causeway and is crossed by a number of causeways to form seven units (Figure 2). Transport of water between units is dependent on the cross-sectional area of the main inlets and sizes of the openings in the causeways (van de Kreeke and Wang, 1984). North Bay is connected to the ocean by three tidal inlets--Bakers Haulover inlet in Unit 1, Government Cut in Unit 6, and Norris Cut in Unit 7. Units 2,3, and 4 are not directly connected to the ocean and flushing occurs via adjacent units. The hydrodynamics of this area have been modeled by Wang and van de Kreeke (1984). The tidal nodal point, where tides entering the Bay from Bakers Haulover inlet meet with tides that enter Government cut, occurs in Unit 2. Circulation and exchange in this unit are minimal due to the presence of the nodal point. This means that waters in Unit 1 and the northern portion of Unit 2 exchange with the ocean via Bakers Haulover Inlet and waters in the southern portion of Unit 2 flush via Government Cut. Unit 7 has very little exchange with the rest of the north Bay and, based on flushing characteristic and circulation, should more appropriately be considered as part of Central Bay (van de Kreeke and Wang, 1984). Residence time (the average time a theoretical water particle remains in the Bay) depends upon the exchange characteristics of each unit. For example, the residence time for Unit 1, which exchanges directly with the ocean via Baker's Haulover inlet, is 3.2 days while southern Unit 2, which has no direct connection to the ocean, has a residence time of 13.2 days (van de Kreeke and Wang, 1984). In order of importance, the main freshwater sources for this area are Snake Creek Canal, Miami River, Biscayne Canal and the Little River (Metro-Dade County Planning Department, 1986).

South Bay includes two subdivisions--Central Bay and South Bay proper and extends from Rickenbacker Causeway south to the Arsenicker Keys. The hydrodynamics of this area were modeled by Swakon and Wang (1977) and a transport model was developed by Chin Fatt and Wang (1987). Exchange with the ocean occurs via three inlets--Safety Valve, Bear Cut and Ceasar's Creek (Chin Fatt and Wang, 1987). Central Bay is generally an area of high salinity that is controlled by flow over the safety valve region. South Biscayne Bay is a well mixed, vertically homogeneous area with salinity contours that run in a north-south direction, parallel to the western shoreline (Chin Fatt and Wang, 1987). Vertical stratification has, however been observed along the western shore after periods of large freshwater inflow from drainage canals. Rate of exchange in south Bay is primarily controlled by tidal fluctuations and wind driven circulation due to the large amount of open water and long fetch (Metro-Dade County Planning Department, 1986). Estimated residence times for this area are 6-22 days. South Bay Proper has a smaller tidal range than the more northern portions of the bay and has correspondingly smaller tidal velocities, less circulation and longer residence

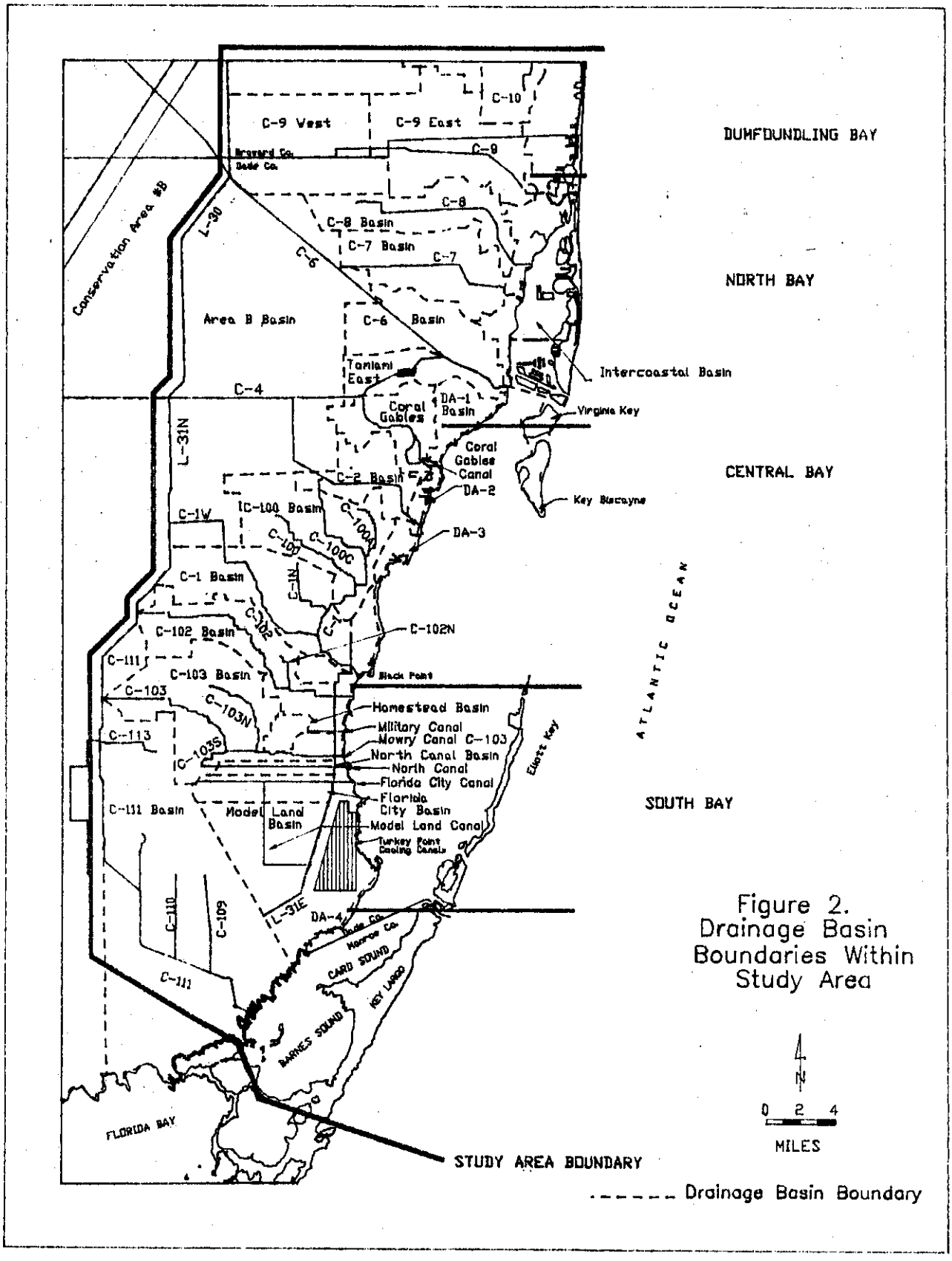


Figure 2.
Drainage Basin
Boundaries Within
Study Area

times. Due to these factors, hypersaline conditions occur at certain times of the year (Lee, 1975).

Extreme South Bay, Card Sound and Barnes Sound have poor circulation and long residence times. Tidal flushing, which occurs via Angelfish Creek and Broad Creek, is limited because of the small tidal range and circulation is primarily wind driven (Lee, 1975). Tidal ranges, measured at Pumpkin Key, were 0.75 ft (0.24 meters) (Swakon and Wang, 1977). Lee (1975) reports salinities of 33-40 ppt during the wet season and 39-46 ppt during the dry season. Little exchange occurs between water in South Bay and Card Sound because this area is effectively divided by Cutler Bank ridge (Lee and Rooth, 1972). Tidal residence times in this area were estimated to be on the order of one year (Lee and Rooth, 1972). Wind induced circulation is thought to be capable of reducing residence time by a factor of 10-100 depending on magnitude, direction, and duration of the wind (Lee and Rooth, 1972). Major wind flushing occurs during the winter with the passage of cold fronts generating winds up to 20 knots (35 kph) (Lee and Rooth, 1972; Lee, 1975).

Geology. Biscayne Bay is a depressional feature in a Pleistocene limestone basin and is bounded in the west by the Atlantic Coastal Ridge and in the east by the Key Largo Limestone Formation (Wanless *et al.*, 1984). The geological formations associated with south Florida are found in Table 1. The ridge, composed of the Key

Table 1. South Florida Geologic Formations (after J. Hoffmeister, 1974, *Land from the Sea*)

Geologic Age (Epoch)	Formation	Characteristics	Thickness (in Ft)	Age (in yrs)
Pleistocene (Ice Age)	Pamlico Sand	Quartz sand, white to black or red. Mantles part of Miami and Anastasia formations. Occurs in sand dunes and old beach ridges.	0-60	100.000
" "	Miami Limestone	White to yellowish. Massive to stratified and cross-bedded. Oolitic and bryozoan facies.	0-40	100,000
" "	Anastasia Formation	Coquina, sand, calcareous sandstone, and shell marl. Probably composed of deposits equivalent in age to marine members of Fort Thompson and Miami limestone.	1-120	100,000+
" "	Key Largo Limestone	Coralline reef rock. Hard and cavernous. Interfingers with bryozoan facies of Miami limestone and probably with Fort Thompson. Excellent aquifer.	0-200+	100,000+
" "	Fort Thompson Formation	Alternating marine and freshwater marls, limestones, and sandstones. Main component of Biscayne aquifer in eastern Dade and Broward counties. Northeastern extension much less permeable.	1-150	Upper Part 100,000+
Pliocene	Caloosahatchee Marl	Sandy marl, clay, silt, sand and shell beds. Poor to fair aquifer.	0-25	2,000,000+
Miocene	Tamiami Limestone	Cream, white and greenish-grey clayey marl, silt, and shelly sands and sand marl, locally hardened to limestone. The upper part, where permeability is high, forms the basal part of the Biscayne aquifer. The lower and major part of the formation is of low permeability.	0-100	6,000,000

Largo Formation, is the underlying structure on which Miami Beach, Key Biscayne, and the more southern barrier islands were generated. During the Holocene rise in sea level, the depression that is now the Bay began to fill with sea water. Because of the method of its formation, Biscayne Bay is not a drowned river valley and has no rivers that bring in significant amounts of terrigenous sediments. Instead, the rigid basin defines sedimentary input and limits the available amount of this material

(Metro-Dade County Planning Department, 1986; Wanless *et al.*, 1976). Natural sedimentary inputs into this system are primarily quartz sand, (carried in longshore coastal transport), carbonate shell sand, carbonate mud and organic material that is derived from organisms within the Bay or generated by coastal processes (Metro-Dade County Planning Department, 1986).

Sediments. Wanless *et al* (1984) identified eleven sedimentary environments in Biscayne Bay as follows: rocky bottoms, dredged rocky bottoms, sandy bottoms, quartz sands, barrier island sands, skeletal carbonate sands, muddy bottoms, barren mud bottoms, carbonate muds, spoil margins and mangrove soils (Metro-Dade County Planning Department, 1986).

Rocky bottoms consist of exposed limestone or have 6 inches (15 cm) or less of sediment cover (Wanless *et al*, 1984). [In some areas, this thin layer of sediment has become heavily colonized by seagrasses since the last major hurricane struck Dade County in 1966. These seagrasses are not expected to survive a major storm due to an insufficient amount of substrate to adequately anchor the grasses during this type of disturbance (Wanless *et al*, 1984)]. The water column above rocky bottom communities tends to remain clear during storm events since these areas are colonized by hard bottom communities such as sponges, mollusks, corals and soft corals (Wanless *et al*, 1984). Extensive areas of rock bottom exist in south Bay, especially within Biscayne National Park (Metro-Dade County Planning Department, 1986). The depth of dredged rocky bottoms have been lowered to levels that are sufficient to prevent the growth of seagrasses or algae mats (Metro-Dade County Planning Department, 1986). These areas generally act as sinks for fine sediments and flocculated material that then become continually resuspended by wave energy (Wanless *et al*, 1984).

Sandy bottom areas are composed of three types of sands--quartz, barrier island, and skeletal carbonate. Carbonate and sandy mud bottoms are found throughout the middle and eastern portions of north and central Biscayne Bay.

Barren mud bottoms are predominately found in deep dredged areas and in naturally deep areas which are poorly flushed. Barren mud bottoms also frequently have an associated overlying layer of flocculent material that results in an increasing density gradient at the bottom, in which there is no identifiable interface with the sediment. This flocculent material is easily resuspended into the water column. Carbonate muds, are composed of coarse molluscan material interspersed with a layer of mud and are presumed to indicate areas undergoing active erosion that will potentially be resuspended during storms.

Spoil margins are unstabilized areas that have a mixture of mud, sand, shell, and gravel. Spoil margins tend to be persistent sources of fine sediment released during heavy winds and storms. Mangrove swamp soils often contain high levels of organic material and naturally-occurring nutrients.

Hydrology. Current land use, water use and water management practices in the Biscayne Bay basin have altered the quantity and timing of fresh water releases into the Bay. Surface water historically flowed to the Bay throughout most of the year from the freshwater marshes of the Everglades. Land development and drainage activities have greatly altered the distribution of fresh surface water that now flows into Biscayne Bay and have altered the timing of these discharges. Surface water primarily reaches the Bay as overflow from the canals during the wet summer months and when heavy rainfall occurs during dry winter months.

All of eastern Dade County is underlain by the Biscayne Aquifer System. The United States Environmental Protection Agency (USEPA) has designated this system as the sole source aquifer that provides drinking water for Dade County. The Biscayne Aquifer is extremely permeable and groundwater in this system is very mobile. Before the construction of drainage canals, high levels of freshwater in inland marshes caused extensive amounts of groundwater to be discharged through the shallow aquifer system to Biscayne Bay. Such seepage historically was a major source of freshwater inflow. Groundwater levels throughout Dade County have been reduced by loss of natural recharge areas, construction and use of water supply or irrigation wells, urban consumption of potable water and the construction and operation of water management canals. These influences have changed the hydrologic cycle so that much less water enters Biscayne Bay as groundwater seepage or freshwater springs.

Hydrologic features of the main drainage basins that discharge into Biscayne Bay are described in a recent report by the South Florida Water Management District (Cooper and Lane, 1987). Drainage Basins of the Biscayne Bay watershed are defined on the basis of the primary canal systems that drain these areas. Locations and extent of the major hydrologic basins are shown in Figure 2. Major features of each of these basins are summarized in the tables in Appendix B.

In addition, the SFWMD compiles rainfall and other climatological data, groundwater stage data from monitoring wells, and flow data from the major canals. The kinds of data that are compiled by the District are summarized in Appendix C.

With continued land development and construction of impervious surfaces, the amount of freshwater reaching the Bay as stormwater discharge can be expected to increase. The amount of groundwater seepage is based on the water levels that are maintained in the canals and is expected to remain near current levels.

2. Biological Resources

Introduction. Biological resources within Biscayne Bay and its surrounding watershed are extensive and function as a whole to preserve the integrity of the Bay. Any attempt to deal with water quality problems in the Bay without considering the effects of uplands, freshwater wetlands, hammock communities, coastal saltwater communities and submerged communities risks failure. A holistic view of the system is required to adequately evaluate impacts of human activities on the ability of the Bay to function. A system is defined as "regularly interacting and interdependent components forming a unified whole." In the case of biological systems, "living organisms and their non-living (abiotic) environment are inseparably related and interact upon each other" (Odum, 1971). A population is composed of groups of individuals of a specific organism, a community is comprised of the populations of different organisms that occupy a given area, and an ecosystem is the system formed by the interaction of all of the various communities and their non-living environment (Odum, 1971).

An ecosystem is based on required relationships, interdependence, and coupling of the various components. The entire system responds to the perturbation of any member (Odum, 1971; Burns, 1976). Under natural conditions, the Biscayne Bay ecosystem produces and maintains an aquatic environment that is habitable for a diverse array of plant and animal communities. Whenever the function of any component of this ecosystem is altered, the entire system responds--for better or for

worse. The natural resilience of living systems generally helps to maintain a balance within the Bay, such that many forms of degradation can be sustained without causing permanent damage. This balance is achieved through biological diversity and the interrelationships that exist in a complex network of living organisms. As diversity is lost or reduced in an aquatic system, the system loses its ability to adapt or respond to changing conditions; the ability to maintain surface water quality declines; and the entire ecosystem suffers.

A habitat is the location where an organism, population, or community lives (Odum, 1971). Important habitats in the Biscayne Bay ecosystem include submerged aquatic, coastal wetlands, and coastal uplands. Submerged aquatic habitats are primarily defined by bottom type and water quality. Submerged habitats are composed of open water communities such as plankton and fishes, and bottom-dwelling communities including hard bottom, seagrasses, seagrass-algae, and barren bottom communities with their associated infauna (Metro-Dade County Planning Department, 1986). Coastal wetland plant communities are defined by a variety of abiotic and biotic factors including shoreline morphology and elevation, sediment and soil characteristics, hydrologic regime, proximity to a water source, transport and availability of seed sources and nutrients (Teas, 1976; Teas *et al.*, 1976; Snedaker, 1982). Coastal upland plant communities are defined by various factors including elevation, soil characteristics, nutrient availability, hydrologic regime, and availability of seed sources. Submerged aquatic, coastal wetland and coastal upland communities function together as interdependent components of the Biscayne Bay ecosystem.

Intertidal Communities

The intertidal zone of Biscayne Bay consists of sandy and muddy shores, mangroves, and rocky shores including bulkheads and rip-rap. The major components of these communities were described by Voss and Voss (1955) and Voss (1976). Some of these areas are inundated at every tidal cycle. However many marshes may be located above the normal high tide level, but are inundated on exceptionally high tides or by freshwater runoff from uplands. These high marshes may seasonally support freshwater brackish or saltwater organisms and are especially important as forage habitat and as source of nutrients and food that are transported into the Bay by runoff and tidal flushing.

Sandy and Muddy Shores. Sandy and muddy shores that are exposed at low tide may also contain algae, as well as occasional emergent vegetation. Characteristic animals of this area include burrowing animals such as fiddler crabs (*Uca*), clams (e.g. *Tagelus*) and marine annelids (e.g. *Chaetopterus* sp.); and grazing animals, including snails (*Bittium* and *Melongena*) and crabs such as land crabs (*Gecarcinus* and *Cardisoma*), hermit crabs (*Clibanarius*), and marine crabs, (*Callinectes* and *Cancer sp.*). These areas do not generally support high numbers of larger organisms but often contain extensive microscopic interstitial meiofaunal communities.

Rocky Shores. Natural rock substrate occurs along the shorelines of Biscayne Bay in areas such as Soldier Key, Elliot Key, and along the Key Biscayne side of Bear Cut. In such areas the amount of rock surface exposed during the tidal cycle may be extensive. Such natural rock substrate areas support a wide range of sea life, including numerous bryozoans, hydroids, tunicates, anemones, gastropods, false limpets, (*Siphonaria*) chitons, mussels, sponges, clams. echinoderms, soft

corals, sea urchins (*Echinometra*) and crustaceans. Numerous swimming forms of shrimps and crabs, and occasional octopuses live in shallow tide pools (Voss, 1976).

Other rocky shores consists of man-made rip-rap, rock jetties, and seawalls. Rip-rap shorelines and jetties can have extensive crevices, holes and caverns that provide substrate and shelter for numerous intertidal organisms. Juvenile and larval fish of certain species use rip-rap shoreline in preference to vertically bulkheaded shorelines (Table 2). Vertical seawalls offer less surface area for the

Table 2. Occurrence of Juvenile and larval fish (number of fish found) along two seawall sites, with and without Rip-Rap (unpublished data from Ken Lindemann, NMFS).

Fish by Family	Leeward Channel Site: WCFL			Mainland Site: MEH	
	Rip-Rap	No Rip-Rap		Rip-Rap	No Rip-Rap
Haemulidae	7	1		4*	0
Lutjanidae	5	1		2	0
Sciaenidae	2	1		1	0
Mullidae	1	0		0	0
Pempheridae	1	0		0	0
Serranidae	2	0		0	0
Kyphosidae	2	0		0	0
Pomacentridae	4	2		3*	1
Labridae	3 +	0		1	0
Scaridae	3 +	0		2	0
Sphyraenidae	1	0		1	0
Acanthuridae	2	0		0	0
Tetrodontidae	1	0		1	0
Gerreidae	2	1		1	1
Centropomidae	1	0		1	0

attachment of organisms and provide little or no protection from the effects of wave action (Lindeman unpublished data). Communities that live on vertical seawalls are often very limited and consist of sponges, limpets, gastropods such as *Nerita* and *Littorina* and the Isopod, *Ligea*, with occasional attached oysters and mussels.

Mangrove Shorelines. Mangrove communities often provide support for an extensive invertebrate community that lives attached to the prop roots, especially in areas that are actively flushed during the tidal cycle. Organisms that live on prop roots are similar to those that live attached as fouling organisms on boats and seawalls. These communities consist of tunicates, sponges, oysters (*Crassostrea*), mussels (*Brachidontes*) clams, (e.g. *Arca*) barnacles, snails (such as *Melampus* sp.), shrimp (e.g. *Palaemon, Periclimenes, Thor*), crabs, (notably the mangrove crab, *Aratus*), juvenile spiny lobster (*Panulirus*) flatworms, polychaetes, hydroids, and hydrozoans. The wood-boring isopod, *Sphaeroma terebrans,* is an important parasite on mangrove prop roots (Odum *et al.*, 1982). These communities also function as

important nursery habitat and serve as protective refuge for fish and invertebrates (Thayer *et al*, 1987).

Submerged Aquatic Communities

Plankton. Plankton are free-floating plants or animals that drift in the water column. Planktonic plants (phytoplankton) and animals (zooplankton) play significant roles in the food web of Biscayne Bay. Phytoplankton are important as a basis of the aquatic food chain. Phytoplankton primary productivity (the rate of storage of radiant energy as organic materials (Burns, 1976)) is dependent on the availability of nutrients and light. The most important phytoplankton in coastal waters are diatoms and dinoflagellates. These microscopic algae provide food for numerous types of zooplankton, including the larvae of many bottom-dwelling (benthic), free-swimming (neritic), and open water (pelagic) animals.

Recent phytoplankton surveys by Brand (1988) showed uniformly low levels of phytoplankton biomass (as measured by chlorophyll *a* concentration) in South Bay. Levels of phytoplankton productivity were higher in open waters of North Bay and the highest levels were found in the small basins north of Broad Causeway. Dumfoundling Bay showed the largest fluctuations in phytoplankton productivity over time, while levels of phytoplankton productivity at each canal mouth fluctuated independently of levels at other canal mouths. Chlorophyll levels and rates of phytoplankton growth are highest near the shore of Biscayne Bay and decrease toward the Gulf Stream (Roman *et al.* 1983). Phytoplankton may be the principal sources of primary productivity in North Bay, whereas seagrasses and algae are principal primary producers in Central and South Bay (Roman *et al.*, 1983; Brand, 1988). Phytoplankton primary productivity is 5-8 times greater in North Bay than in South Bay with phytoplankton less than 5 µm in size as the dominant group of organisms (Brand, 1988). The dominant phytoplankton class throughout the Bay were coccoid cells (Brand, 1988). The limiting nutrient for phytoplankton growth in Biscayne Bay was phosphorus (Brand, 1988).

Zooplankton includes many types of free-floating animals, ranging from microscopic protozoans to very large forms such jellyfish. Zooplankton also includes the larvae and early juvenile stages of most species of mollusks (clams, oysters, and various shellfish), decapod crustaceans (such as shrimp and crab species) and fishes. The biomass of zooplankton in Central Biscayne Bay is greatest in the near-shore zone and decreases toward the Gulf Stream (Roman *et al.*, 1983) Zooplankton are less abundant in Card Sound and extreme South Bay than in North Bay (Baker, 1973; Houde and Lovdal, 1984). Detritus or benthic algae may be an alternate source of food for zooplankton in Central Bay. Most fish species inhabiting the Bay as juveniles or adults spawn offshore, and their offspring enter the Bay at a post larval stage in their life cycles (deSylva, 1976; Roman *et al.*,1983). Total numbers of fish eggs and larvae were greatest in the spring and summer, coinciding with seasons of high phytoplankton and zooplankton abundance (Houde and Lovdal, 1984).

Seagrasses. Seagrasses that are found within Biscayne Bay include turtle grass (*Thalassia testudinum*); manatee grass (*Syringodium filiforme*); shoal grass (*Halodule wrightii*); and species of *Halophila*. Growth and distribution of seagrasses are controlled by light levels, photoperiod, temperature, salinity, and sediment type. These grasses may be found as communities composed of seagrasses alone or in association with several species of green, red and brown algae. These habitat types comprise the major benthic plant communities in Biscayne Bay (Thorhaug, 1976).

Benthic plant communities are a major source of primary productivity in the aquatic food chain through a detrital food chain (Thorhaug, 1976). In addition, these plants stabilize the sediments and provide habitats and shelter for a wide variety of benthic organisms (Metro-Dade County Planning Department, 1986).

Adequate levels of sunlight are essential to seagrass and algal growth. The amount of light that penetrates the water column is generally controlled by the clarity of the water rather than the depth. In Biscayne Bay this relationship has been modified due to the reduction in water clarity from turbidity, so that deep, dredged areas can no longer support plant growth. Water clarity in the Bay is strongly influenced by the re-suspension of fine particles and blooms of phytoplankton (Wanless *et al.*, 1984).

In the northern portion of the Bay, manatee and shoal grasses predominate wherever light penetration is sufficient to permit plant growth. Species of *Halophila* are found sporadically in north Bay, frequently associated with dredged or nearly barren areas (Metro-Dade County DERM, 1983c). Some of the most extensive grass-algal beds occur in Unit III north of the Julia Tuttle Causeway; on both sides of the Intracoastal Waterway south of Little River; on the lee side of Virginia Key; adjacent to the channel south of the Port; on both sides of the Intracoastal Waterway north of Rickenbacker Causeway; south of the Julia Tuttle Causeway on the mainland side along the Intracoastal Waterway; and on the island side west of Meloy Channel. Mixed grasses and algae occur east of the Intracoastal Waterway, one-half mile east of Biscayne Canal and in undredged areas south of Biscayne Canal.

Turtle grass predominates in central and south Bay (Metro-Dade County Planning Department, 1986). In the southern portion of Biscayne Bay, seagrasses form extensive beds along the east side of the Bay. Hard bottom communities (dominated by corals and sponges), frequently mixed with seagrasses, cover much of the central portion of south Biscayne Bay. Offshore from Chapman Field north to the Rickenbacker Causeway, mixtures of seagrasses and algae overlie a rocky substrate. Along the bayward margin of this area is a strip of shoal grass. The middle of this section of the bay is barren even though the area has not been dredged. On the eastern side of the bay, mixed seagrasses predominate off the southwest point of Key Biscayne. Turtle grass dominates to the south and west of Crandon Marina.

Benthic Organisms. The wide variety of organisms that comprise the benthic communities in Biscayne Bay live in, upon, or attached to, the substrate and include clams, snails, worms, corals, sponges, crustaceans and small fishes (Metro-Dade County Planning Department, 1986). Benthic communities in Biscayne Bay are dynamic and complex. Schroeder (1984) reported 850 species of benthic organisms and noted that although altered by human activities, north Bay stations were only slightly less diverse than south Bay stations. The numbers and diversity of benthic animals were somewhat correlated with the presence of seagrass, especially manatee grass and, to a lesser extent, turtle grass.

Of twelve sites that were sampled by Schroeder (1984), the four richest areas were a) The large, highly productive grass-algal bed north of Julia Tuttle Causeway in Unit III; b) The area north of the Rickenbacker Causeway east of the Intracoastal Waterway in Unit VII that is covered with thick turtle grass; c) A benthic community near the western shore just north of the Julia Tuttle Causeway in Unit III that contained *Halophila* seagrass and filamentous algae; and d) The area near the western shore, just south of Biscayne Canal in Unit II, that had a bottom community of mixed seagrasses.

The four areas sampled by Schroeder (1984) that had fewer numbers of organisms and taxa than other sampling areas were a) The sandy shore of a spoil island opposite Bakers Haulover inlet that is subjected to currents, boat wakes and wind action; b) The area near Snapper Creek in central Bay that is subjected to changes in salinity and currents due to canal discharges; c) The barren, mud area in the middle of Unit V, south of DiLido Island; and d) The relatively deep area almost due east of Chapman Field that has sparse seagrasses.

Metro-Dade DERM has initiated a long term benthic habitat monitoring program to establish a quantitative data base and permanent record of abundance of seagrasses and macroinvertebrates at selected locations in the Bay.

Grass Beds. Grass Bed and macroalgae communities cover extensive areas of the Bay bottom and are highly productive. Species diversity and number of organisms per square meter can be very high. Different species of plants tend to dominate in different areas and support different invertebrate communities. Numerous species of small shrimps, crabs, worms, clams, and snails, and echinoderms inhabit these areas as well as commercial species such as shrimp, conchs, stone crabs, and lobsters.

Hard Bottom. (based on Metro-Dade County DERM, 1983c) Much of Biscayne Bay is covered by hard-bottom communities, especially in the central portion of South Bay. These communities generally occur in areas that have exposed hard materials such as rock or metal and/or less than 6 inches (15 cm) of sediment. Hard bottom communities consist primarily of sponges, alcyonarians and various inshore corals. The most common soft corals are the angular sea whip (*Pterogorgia anceps*) and the double forked plexaurella (*Plexaurella dichotoma*). The dense hard bottom community characteristically has a greater diversity of soft corals, including the purple sea plume (*Pseudopterogorgia acerosa*), slimy sea plume (*Pseudopterogorgia americana*) and numerous species of the genus *Eunicea*. These dense assemblages of of soft corals and sponges, along with their large physical size (up to one meter) provide an excellent refuge for fish and various kinds of invertebrates, including numerous species of shrimps, crabs, worms, brittle stars, sea urchins and other species that live in holes and crevices.

The most common sponges in the hard bottom community are the loggerhead sponge (*Spheciospongia vesparia*) and the basket sponge (*Ircinia campana*). Numerous commercial sponge species also occur in this community in Central and South Bay. These include the sheepswool (*Hippiospongia lachne*), yellow (*Spongia barbara*), grass (*Spongia germinea*), and glove (*Spongia cheiris*) sponges. Hard corals occasionally found within this community include the finger coral (*Porites* sp.) star coral (*Solenastrea* sp.) and starlet coral (*Siderasterea* sp). In addition, fire coral, (*Millepora* sp.) is typically present.

Bare Bottom. Bare bottom communities occur in areas where sediment depth, sediment quality or water quality will not support the growth of seagrasses. Organisms that live in these communities may include worms, mollusks, tunicates, nematodes, crabs, shrimp, cumaceans, amphipods, clams, snails and sea cucumbers

Fisheries. Biscayne Bay is fished commercially and recreationally. An important component of the wildlife of the Bay are the fishes, crustaceans and mollusks associated with the fishing effort. The major economic fisheries include sport fish, food finfish and shellfish (primarily crustaceans), and bait. These groups

include the following: a) sport fish such as tarpon, bonefish, snook, and permit; b) food fish such as groupers, pompano, snappers, hogfish and mackerels; c) crustaceans such as shrimps, spiny lobster, and crabs; and d) bait fish; pilchard, ballyhoo, pinfish, mullets, thread herring, Spanish sardines and anchovies. Commercial fisheries include bait shrimp, blue crabs, stone crabs, mullet, lobster, sponges and "sardines" (Berkeley, 1984). Sponges are gathered from the southern portion of the bay, primarily within Biscayne National Park. Table 3 outlines the estimated total commercial catch (as of 1984) and value from Biscayne Bay. The dockside value of

TABLE 3. Estimated Total Commercial Fisheries Catch in Biscayne Bay (in pounds). Source: (Berkeley, 1984 as presented in Dade County, 1986).

	1982	1983	Approximate Ex-Vessel Value	Approximate Retail Value
Bait Shrimp	287,836	272,573	$4.00/1b	$2,214,657
Mullet	45,000*	44,161**	$0.30/1b	$ 45,000
Stone Crab	43,686	26,991	$3.00/1b	$ 212,031
Blue Crab[1]	---***	42,345	$0.50/1b	$ 42,345
Pilchards	241,000****	241,000	$0.30/1b	$ 241,000
Totals	617,522	627,070		$ 2,755.033

1 Most are not sold; they are caught and used by the same fishermen
* April 1982-March 1983
** 9 months only, April 1983 - November 1983
*** No estimate for 1982
**** Assuming 30 boat
sNOTE: "The accuracy of these estimates varies by species. We feel that the shrimp estimates are good; mullet estimates represent a minimum catch and almost certainly are an underestimate of actual landings; stone crab and blue crab estimates require assumptions about total effort which are difficult to validate but do not seem unreasonable; pilchard landings seem high but we believe they are reasonable and may actually underestimate actual landings." (Berkeley, 1984)

the commercial fishing industry in Biscayne Bay is approximately $1.3 million. At the retail level, the commercial catch from the Bay (excluding lobster and sponges) is worth approximately $2.75 million for the period examined. These figures include only the dockside value of the commercial fish, and do not take into account income which is generated within the fishing industry itself or from sport fishing. Pink shrimp is the most important species harvested (by weight) in Biscayne Bay, accounting for 29% of the total recreational harvest. Gray snapper, white mullet, pilchard (scaled sardine), white grunt, and spotted seatrout are the five most abundant finfish harvested recreationally and together account for 35.5% (by weight) of the total recreational harvest (Berkeley, 1984).

Berkeley (1984). found that the richest fisheries areas of Biscayne Bay are a) the area from the Rickenbacker Causeway south to the old Biscayne National Monument boundary; b) the extreme south Bay; and c) the grass beds north of the Julia Tuttle Causeway. The highest crustacean biomass occurred in seagrass beds along the mainland shore. The primary factor in determining abundance of most juvenile fish is seagrasses (Berkeley, 1984). As seagrass density increases, so does the abundance of many fish species. Hard bottom areas in central and southern Biscayne Bay also support a high diversity of fishes. Certain important species, including hogfish, yellow snapper, and lane snapper, use hard bottom communities as nursery areas. These areas require stable salinities and temperatures, better water circulation and better water clarity than seagrass areas (Berkeley 1984). Dredged and barren bottom communities were the least productive fishing areas in Biscayne Bay.

Coastal Wetland Communities

Mangroves. Mangroves are shoreline trees that live in the intertidal zone and form extensive forests along parts of Biscayne Bay. Four species of trees are considered as mangroves in South Florida--red mangrove (*Rhizophora mangle)*, white mangrove (*Laguncularia racemosa*), black mangrove (*Avicennia germinans*) and buttonwood (*Conocarpus erecta*). In North Bay, mangroves line the mainland shore of the the Oleta State Recreation Area and the Oleta River, some of the spoil islands, Bird Key, and the western shore of Virginia Key and adjacent islands. In Central Bay, mangroves line the northwestern shore of Key Biscayne and dominate the shore from Matheson Hammock south along the mainland and along almost the entire shoreline of Biscayne National Park, Card Sound and Barnes Sound. Mangrove communities provide numerous contributions to the Bay systems. Coastal mangroves protect the shoreline from severe storm erosion. The extensive prop root systems dissipate wave energy, reduces tidal currents and promote deposition of suspended sediment. Prop roots also provide surfaces for the attachment of marine organisms and protection for juvenile fishes from predators.

Export of mangrove detritus is vitally important to the continued functioning of coastal ecosystems. Fragments of marine grasses and mangrove leaves are mechanically broken down and chemically attacked by bacteria, fungi, or protozoa. These particles are eaten by crustaceans such as amphipods, mysids, copepods, or shrimp and some small or juvenile fish species. Detritus feeders are eaten by carnivorous worms, snails, and numerous juvenile fish, which are, in turn, eaten by larger predators such as snappers, barracuda, sharks, and various marsh and birds. Each of these higher level consumers contributes waste materials which are acted upon by bacteria and fungi to become part of subsequent detrital food chains.

Mangrove communities are sensitive to alterations in drainage patterns, tidal inundation, overland runoff and water quality. Changes in any of these factors may result in alterations in rates of leaf fall, changes in species distributions, increased tree mortality, or changes in the rates and kinds of exported material to surrounding bays.

(The following sections on saltmarsh, coastal hammocks, pine flatwoods, beaches and dunes are compiled from the April, 1988 draft of the Coastal Zone Management Section of the Dade County Comprehensive Plan).

Saltmarsh. Inland from the mangrove forest, and covering much of the region between US 1 and Turkey Point, communities of halophytes, which are salt to brackish water plants, predominate. Plants typical of these salt marsh communities include salt grass, *Distichlis spicata,* black rush, *Juncus roemerianus*, cord grass, *Spartina, spp.* glasswort, *Salicornia spp.*, salt wort, *Batis maritima,* sea purslane, *Sesuvium portulaca,* and seaside daisy, *Borrichea frutescens.* Many of the plant stalks and the surrounding marl soils are covered by a periphyton mat. Salt marshes can be further divided into two types: the seasonally dry saline flats which are dominated by sea purslane and salt wort and the slightly higher and more inland estuarine marshes consisting of the spartina grasses and rushes. Salt marsh communities continue west of US 1, through Everglades National Park, interspersed in the areas bordering Florida Bay and related water bodies.

Much of the salt marsh vegetation grows in deep marl soils, in association with small regions of peat accumulations that support mangrove and buttonwood tree islands. The salt marsh flats tend to be at slightly higher elevations than the

nearby white and black mangroves. Due to modification of freshwater runoff patterns and the rising sea level, this region serves as an ecotone, or transition zone, from freshwater to salt tolerant species. With heavy precipitation or intense storm tides, the ecotone may shift toward land or the bays and sounds. In this very fluctuating environment, freezes and hurricanes can, at least temporarily, increase the area of salt marsh at the expense of destroyed mangrove or buttonwood. Fire, on the other hand, can burn parts of the more inland salt marsh, but usually spares the mangrove zone.

The functions of salt marsh plants are similar to those of mangroves. Therefore, the salt marsh, often considered inhospitable in human terms, is very valuable as a filter of upland pollutants, as a source of nutrient-enriched detritus, as a wildlife habitat for migratory birds and other non-game wildlife species, and as a nursery for fish and crustaceans. The marsh provides a varied diet for its animal inhabitants and visitors. Further, the salt marsh provides another buffer against storm surges for upland areas.

Coastal Upland Communities

Coastal Hammocks. Hammocks of the coastal ridge may be divided into two broad categories: oak-palm hammocks, found the northern portion of the County and tropical West Indian hammocks, found more frequently in the southern section. The former exist only as impacted remnants of older plant communities. The latter are usually dominated by broad-leaved evergreen trees and are limited to relatively small areas growing on seasonally flooded upland soils. Tropical hammocks are climax forests and contain a wide variety of southern temperate to tropical species.

Coastal tropical hammocks share most species with their inland counterparts but have some species which appear to be found only in coastal areas. The shared species include gumbo limbo, poisonwood, wild tamarind, lancewood and pigeon plum in the canopy, and stoppers and wild coffee in the understory. Coastal hammocks can also include crabwood, bitterbush, holly, pithecelloium species and redberry stopper, not generally found in inland hammocks.

In theory, dense vegetation holds high humidity within the hammock, creating a microclimate that is cooler in summer and warmer in winter than the surrounding area. The combination of the high humidity, along with the moist soil created by litter on the forest floor, keeps out most fires. Frequently, an impenetrable fringe of shrubs or saw palmetto helps to keep interior humidity high while providing conditions which allow certain hammock species to invade surrounding pinelands.

The humidity of the hammock interiors provide suitable habitat for many tropical terrestrial and epiphytic plants including bromeliads and orchids. Acidic humus, formed from decaying leaf litter, can erode the bedrock into a myriad of solution holes, caves, arches and pinnacle rock, providing additional complex and unique habitats within the hammock setting.

Pinelands. Slash pine (*Pinus elliottii* var. *densa*) is the dominant canopy species with a rich and diverse understory. Numerous endemic species and endangered plant species listed for Dade County can be found in the pinelands. Because pinelands are a fire sub-climax community, such areas should be managed to limit encroachment of hardwood hammock species, and to perpetuate the fire tolerant pineland species.

Beaches and Dunes. Beach/Dune communities evolved on the high energy shoreline facing the Atlantic Ocean, primarily on the eastern shores of the barrier islands. This natural community, with its vital shoreline protective functions and its unique organisms has been virtually eliminated from Dade County except for isolated patches on the keys of Biscayne National Park and Key Biscayne. The natural dune communities in Crandon Park and Cape Florida State Recreation Area have been partially revegetated, but are still largely natural and representative of a vegetative community which once dominated the Atlantic shore of South Florida.

The beach above the normal high tide levels is normally dominated by pioneer plants such as grasses and vines. The plants of the pioneer zone are adapted to survive in conditions of extreme heat, wind salinity and drought. Most of the adaptations aid retention of physiological water and include succulent leaves and stems, protective cuticles, wax or hair coatings on leaves; low growing habit; deep root systems; and leaf curling. As dunes are stabilized by the roots of the pioneer species, woody plants begin to replace the grasses and vines. These plants form the scrub zone. In locations where well stabilized dunes have been allowed to survive, trees typical of tropical coastal hammocks are found on the upland side of the scrub zone. At Crandon Park, many plants of the pioneer, scrub and forest zones can be observed along the relatively undisturbed northern tip of the beach. Some remnants of beach and dune vegetation also remain on Virginia Key.

Biotic Resources

Reptiles and Amphibians. Herpetofauna discussed in this section are limited to species that occur in areas that are directly influenced by salt water. Upland drainages, coastal freshwater wetlands and areas that are not directly influenced by saltwater contain species of reptiles and amphibians that are found throughout South Florida (P. Molar personal communication) and may occasionally occur in Biscayne Bay (Duellman and Schwartz, 1958; Wilson and Porras, 1983). No amphibians are found in salt water, however several threatened and endangered species of amphibians occur in upland drainages and coastal freshwater wetlands. Protected species are discussed in the section on threatened and endangered species.

Turtles that occur in Biscayne Bay and its associated salt water areas are the diamond back terrapin (*Malachlemys terrapine tequesta*), the mangrove saltmarsh terrapin (*Malachlemys terrapin rhizophorerum*) and potentially five species of sea turtles--the green sea turtle (*Chelonia mydas*), the hawksbill (*Eretmochelys imbricata*), the leatherback (*Dermochelys coriacia*), the kemps ridley (*Lepidochelys kempi*), and the loggerhead (*Caretta caretta*) (Connally personal communication). The diamond backed terrapin (*M. terrapine tequesta*) is found throughout Biscayne Bay, Card Sound and Barnes Sound. It nests along sand banks and forages on small crustaceans, mollusks, and opportunistically on fish. Their habitats and behavior are discussed by Duellman and Schwartz (1958). The mangrove terrapin (*M. terrapine rhizophorerum*) is closely related to the diamond backed terrapin and is found exclusively in the lower Keys and may incidentally occur in Key Largo and along Barnes Sound. The mangrove terrapin is found in coastal estuarine mangrove habitat and nests along sand beaches and banks.

Sea turtles that occur in the Bay are the green (*C. mydas*), the loggerhead (*C. caretta*) and occasionally the hawksbill (*E. imbratica*). Hawksbill nests have been recorded along the outer keys of Biscayne Bay and leatherback nests have been

recorded in Miami and on Key Biscayne (Connally personal communication). The leatherback (*D. coriacia*) and Kemps ridley (*L. kempi*) have been reported sporadically off the coast or as strandings but do not occur regularly in the Bay. Little work has been done on the distributions of these species within Biscayne Bay, the coastal islands and the southern sounds. Historically, the turtle fishery was a major source of income and meat for local settlers (deSylva, 1976). Only the loggerhead and the green sea turtles are reported as commonly utilizing forage habitats within the Bay. These habitats include the extensive grass beds for green turtle and the hard bottom communities for the loggerheads. Important habitats for chelonian species are therefore grass beds, hard bottom communities, coastal wetlands, saltmarshes, and barrier island nesting beaches.

Snakes that are found in Biscayne Bay include the mangrove water snake (*Nerodia clarki compressicauda*), which is non-venomous and occurs along coastal saltwater areas of the Bay and Sounds.

Crocodylians naturally found in this area are the American Alligator (*Alligator mississippiensis*) and the American Crocodile (*Crocodylus acutus*). The american alligator is found only in freshwater areas but is closely associated with the fringing marsh of the coastal freshwater wetlands bordering the saltwater wetlands (Duellman and Schwartz, 1958). The alligator is listed as a state species of special concern and occupies a habitat niche that is considered very important to the maintenance of habitats and many species within the system.

The American Crocodile is an endangered species. The South Florida and Keys population represents the only population found in the mainland United States. This species is found in the West Indies, along both the Atlantic and Pacific coasts of Central America and the northern portion of South America. It is one of three species of saltwater crocodiles found worldwide. Extensive habitat loss and poaching threaten this species and it is listed as endangered throughout its range (an "appendix one" species) by the United States Fish and Wildlife Service (Ogden, 1978; Kushlan and Mazzotti, 1973). Habitat loss in the United States is primarily responsible for its decreased numbers. Crocodiles are shy, are rarely seen by day, even if they are close to human dwellings, are not aggressive and are not considered to pose a threat to man. Human disturbance causes reproductive disruption since these animals are much more sensitive to human presence than alligators (Mazzotti, personal communication). Crocodiles emerge at night to feed in creeks, canals and open bays. South Biscayne Bay, Card Sound and Barnes Sound represent one third of the nesting areas that were known in 1987 (P. Molar personal communication). The remaining nesting areas are in the northeastern Everglades, Florida Bay and the Turkey Point cooling canals adjacent to southern Biscayne Bay (Gaby, *et. al.*, 1985).

Since the turn of the century, historic crocodile habitat gradually has been eliminated from much of Dade County due to shoreline development (P. Molar personal communication). Biscayne Bay and its associated sounds currently represent a significant portion of the habitat utilized by this endangered species (Gaby, *et. al.*, 1985; P. Molar personal communication). In 1987, four nests were located along the Turkey Point cooling canals, 17 in northeast Florida Bay in Everglades national Park and eight on northern Key Largo in Barnes Sound (P. Molar personal communication). Historically, these animals were found along sheltered mangrove shorelines and lagoons in coastal salt ponds and canals. There is little information on crocodile populations in and around Homestead. Biscayne National Park reports some increased usage of the canals north of the Turkey Point

Florida Power and Light Company property by these animals (Richard Curry, personal communication.). The fact that the crocodile may be attempting to extend its present range, indicates that efforts should be made to provide additional protection for potential habitats for his species in other areas of the Bay. In addition, efforts should be initiated to preserve existing habitat that occurs on the westward side of Biscayne National Park. This area is currently under pressure for intensive development.

Birds. This section is primarily based on material from the Aquatic Preserve Management Plan (Metro-Dade County Planning Department, 1986) and the report by Owre (1976). The avifauna of Biscayne Bay is perhaps the most conspicuous of the Bay's wildlife. Many species are permanent residents of the Bay, other species migrate through the area, and still others are winter or summer residents. The Bay has numerous areas where migratory species roost and forage. A number of major bird rookeries occur within the Bay, including Bird Key and Chicken Key in Central Bay; the mangrove shoreline south of Matheson Hammock extending south through Biscayne National Park, in the trees along the shore of Key Biscayne, the mangrove islands of North Bay just east of Greynolds Park and north of the Sunny Isles Causeway, and mangrove islands in the West Lake area. Birds found in and around the Bay are described by Owre (1976) based on their foraging strategies. Foraging strategies are divided into open water feeding during flight and while swimming, parasitic or predatory feeding, foraging along the Bay margin, and foraging in the adjacent habitats in coastal wetlands and upland areas.

Birds that forage primarily in the open water of the Bay while swimming submerged include cormorants (*Phalacrocorax* sp.), mergansers (*Mergus* sp., *Lophodytes* sp.), coots (*Fulica* sp.) and diving ducks (subfamily *Aythyinae*). Food sources for these birds include fish, invertebrates, plants, and animals. Birds that forage by plunging from flight to feed on fish from the upper centimeters of surface waters include pelicans (*Pelecanus* sp.), ospreys (*Pandion haliaetus*), terns, (subfamily *Sterninae*) and kingfishers (*Megaceryle alcyon*). The Black Skimmer (*Rynchops nigra*) feeds primarily on small fish and macroinvertebrates by skimming the waters surface during flight. Birds that primarily utilize airborne foraging strategies (picking up food over the Bay or land) include eagles (*Haliaetus leucocephalus)* and frigatebirds (*Fregata magnificens*). Gulls (*Larus* sp.) are ubiquitous throughout the Bay and surrounding area, they forage by landing and swimming to food. Dabbling ducks (subfamily *Anatinae*) and coots forage for invertebrates and plants from swimming positions at the Bay's surface.

Some bird species are found in the shallow perimeters of the Bay and its islands. They feed on aquatic vertebrates and invertebrates. These birds include herons (family *Ardeidae*), Roseate spoonbills (*Ajaia ajaja),* ibises (*Plegadis* sp., *Eudocimus* sp.) and oystercatchers (*Haematopus palliatus*). Plovers (*Pluvialis* sp., *Charadrius* sp.) and sandpipers (family *Scolopacidae*) pick and probe for invertebrates on the shore and exposed tidal flats, while vultures (family *Cathartidae*), gulls,and grackles (*Quiscalus* sp.) pick for dead organisms and refuse. Walking birds and waders, such as rails (*Rallus* sp., *Coturnicops* sp.) and night-herons (*Nyctanassa violacea*), forage for invertebrates beneath the mangrove forest. Birds which feed on insects and sap in or beneath the bark and twigs of the mangroves include woodpeckers (family *Picidae*), vireos, (*Vireo* sp.) and some warblers (family *Parulidae*). Birds that forage in the canopy of these forests for insects include cuckoos (*Coccyzus* sp.), vireos and warblers. Kingbirds and other flycatchers (family *Tyrannidae*) forage in the forest canopy for insects, while swallows (family *Hirundinidae*) forage for insects during flight above the canopy.

Within the the whole Bay ecosystem, predatory birds such as hawks (*Buteo* sp.), falcons (*Falco* sp.) and owls (family *Strigidae*), feed on birds and other animals, while frigatebirds prey on eggs and young birds, as well as the food being carried to the young. Scavengers such as vultures and gulls feed on dead materials and refuse.

Biscayne Bay is a major stop-over in the autumn migration of North American shorebirds. Several species of shorebirds overwinter in Biscayne Bay, making extensive use of shorelines and intertidal areas (Wattendorf, personal communication). Migrating shore birds can be found feeding and roosting in the Virginia Key area. Raptors are found in many areas, roosting in mangroves. Bald Eagles are classified as endangered on the Federal List and can be found in the Bay and surrounding area. Osprey populations, which have undergone severe reductions throughout the United States, have remained relatively stable in South Florida. Falcons and hawks occasionally stop on Biscayne Bay during seasonal migrations to other areas. Waterfowl found in the Bay area are migrants from Canada and the northern United States. The brown pelican (*Pelecanus occidentalis*) is found roosting and feeding throughout the Bay, and Bird Key is one of the largest pelican rookeries along the southeast coast of Florida (Wattendorf, personal communication). Large numbers of white-crowned pigeons (*Columba leucocephala*) leave Florida in the winter and return in the summer to nest in lower portions of Biscayne Bay. Extreme southern Florida and tropical hardwood hammocks in the Keys provide critical habitat for this species (Wattendorf, personal communication).

Marine Mammals. Biscayne Bay provides foraging habitat for two species of marine mammals, the bottlenose dolphin (*Tursiops truncatus*) and the West Indian manatee (*Trichechus manatus*). These animals commonly occur in the Bay, its tributaries, or its associated sounds (Odell, 1976). Both species are protected by the Marine Mammal Protection Act of 1972 (making it illegal to take, injure, molest, or kill any marine mammal) (Anonymous, 1973;1975). The West Indian manatee is additionally listed an "appendix one" species (endangered world wide) by the U.S. Fish and Wildlife Service (USFWS) under the endangered species act (Anonymous, 1973;1975; Odell, 1976). Other marine mammals occasionally use the Bay and nearshore areas but animals within the Bay are primarily known from stranding information (Odell, personal communication). Strandings of other species reported in the Bay are as follows: a Risso's dolphin in South Bay, a Gulf Stream beaked whale (*Mesoplodon europaeus*) in Coconut Grove, and false killer whales (*Pseudorca spp.*) from 1918 in South Bay (Odell personal communication; Miller, 1920). A specimen of Couviers beaked whale was found stranded of the Ocean side of Elliot Key (Odell, personal communication). Biscayne Bay, due to its location, basin configuration, and proximity to the Gulf Stream, may have sightings or strandings of a variety of marine mammals (Odell personal communication). Offshore areas are used by a variety of species and this information can be obtained from the Marine Mammal Stranding Coordinator, Southeast Fisheries Center, 75 Virginia Beach Blvd., Virginia Key, Miami, FL 33149.

Bottlenose Dolphin. The bottlenose dolphin is the common dolphin of inshore Florida waters, and normally forages in open waters of the Bay, feeding on mullet and other available species of fish (Odell, 1979). While federal protection has aided the recovery of this species from past hunting and collecting pressure, dolphins have not recovered to their original numbers in Biscayne Bay (Metro-Dade County Planning Department, 1986). The western Atlantic bottlenose dolphin population was additionally stressed by an undiagnosed epizootic resulting in a large die-off during 1987-88. This disease has had an unknown effect on the numbers of dolphins in south Florida and Biscayne Bay (Odell, personal communication). For these

reasons, it is necessary to continue to consider the Bay and its sounds as important habitats for this species.

West Indian Manatee. The West Indian manatee has severely reduced numbers throughout its range. This decline is due to fishing pressure, habitat loss and boat inflicted injuries. Protection of manatees has not effected a recovery of the population due to a variety of causes including continued boat injury and habitat loss (Odell, personal communication). These animals occur in open waters and tributaries of Biscayne Bay. Critical habitat is designated by the USFWS for this species in north Biscayne Bay, Maule Lake, and South Bay, including Card and Barnes sounds. FDNR, NMFS, and USFWS are currently working to develop improved census techniques and methods to assess remaining populations and habitat requirements. In 1984, an estimated 1,000 manatees inhabited Florida's coastal waters including possibly 100 in Biscayne Bay or its tributaries (Metro-Dade County Planning Department, 1986). Manatees appear to concentrate in the protected channels at Chapman Field and Black Point (Metro-Dade County Planning Department, 1986), which would make the siting of a marina inappropriate for this area due to the incompatibility of manatees and motor boats. Increasing boat traffic and boat speed have important negative impacts on these animals. Utilization of Biscayne Bay its tributaries, and sounds by manatees is expected to increase over time due to the naturally warm temperatures that occur year round in the Bay (Metro-Dade County Planning Department, 1986). The construction of additional marina and port facilities in Biscayne Bay is expected to increase mortality and injury of this severely endangered species through direct contact with boats. In addition, decreasing availability of food and habitat may occur from turbidity and mechanical damage to grassbeds (Odell personal communication; Metro-Dade County Planning Department, 1986).

Two significant types of injuries must be addressed to protect manatees -- injuries that occur due to boat propellers and injuries that occur due to operation of coastal salinity control structures. Reduction of boat injuries is a more difficult problem to solve, because manatees use the entire Bay system. However, areas where manatees are observed regularly should be posted and boat speeds should be moderated in these areas to lessen the potential for collision. Dade County has established an "Idle Speed No Wake" zone in the Miami River and tributaries. Black Creek, east to 87th Avenue, is a state designated manatee sanctuary, and is also protected by a year-round Idle Speed Zone. Since many manatees are killed each year in the salinity control structures, experimental measures have been undertaken to prevent them from swimming through the open gates. Research should be continued until solutions are found and implemented.

Threatened and Endangered Species. Endangered and threatened animals of the coastal area that have been discussed in previous sections of this report, such as the West Indian manatee and American crocodile, are not included in this section. Endangered and threatened species that occur in Biscayne Bay include the Atlantic saltmarsh water snake (*Nerodia fasciata taeniata*), Miami black-headed snake (*Tantilla oolitica*), least tern (*Sterna albifrons*), wood stork (*Mycteria americana*), and the mangrove fox squirrel (*Sciurus niger avicennia*). Federally designated critical habitats are defined for only seven species in Florida. Three of these species occur in the area covered by this plan--the American crocodile (*Crocodylus acutus*), West Indian manatee (*Trichechus manatus*) and the Everglades snail kite (*Rostrhamus sociabilis plumbeus*). Critical habitat is not officially designated for species that fall under heavy collection pressure such as butterflies

and orchids. For this reason, other critical habitat may exist in Biscayne Bay but is not officially recognized.

Several endangered, threatened, rare, or unique animals are found on the islands of Biscayne National Park, including the brown pelican (*Pelecanus occidentalis carolinensis*), southern bald eagle (*Haliaetus leucocephalus*), osprey (*Pandion haliaetus*), and magnificent frigate bird (*Fregata magnificens*). The white crowned pigeon (*Columba leucocephala*) remains in the Florida Keys during the winter and spends summers in pinelands of the Atlantic Coastal Ridge. The Schaus Swallowtail butterfly (*Papilio aristodemus)* has disappeared from mainland Dade County, probably due to loss of habitat and collecting, but can still be found in Biscayne National Park where its host plant is a pioneer species of coastal tropical hammocks. Several endangered or threatened sea turtles use Park waters but local nesting is not adequately surveyed to estimate the extent of this use.

The upper Keys hammocks provide habitat for *Liguus* snails. North Key Largo contains one of the last remaining tropical West Indian hardwood hammocks in the United States and is currently a high priority on the state and federal land acquisition list. This area contains the diverse and unique fauna and flora. Endangered animals in this area include the Key Largo cotton mouse (*Peromyscus gossypinus allapaticola*), the Key Largo wood rat (*Neotoma floridana smalli*), the eastern indigo snake (*Drymarchon corais couperi*), the American crocodile (*C. acutus*), and various species of invertebrates, and plants.

Species of Special Concern. A species of special concern is defined by FS ch. 39-27 as having a significant vulnerability to habitat modification, environmental alteration, human disturbance or human exploitation which, in the foreseeable future, may result in its becoming a threatened species unless appropriate protective of management techniques are initiated or maintained. Some species may already meet certain criteria for designation as a threatened species, but conclusive data are limited or lacking. Some species may also occupy an unusually vital or essential ecological niche. If such species should decline significantly in numbers or distribution, other species would be adversely affected to a significant degree. Several species of special concern are found in Biscayne Bay in addition to threatened and endangered species. In the coastal area, these include the little blue heron, (*Egretta caerulea*), snowy egret, (*Egretta thula*), reddish egret (*Egretta rufescens*), and American oystercatcher, (*Haematopus palliatus*). The brown pelican is found in the islands of Biscayne Bay, while the upper Keys hammocks provide habitat for *Liguus* snails.

3. Water and Sediment Quality

The Metro-Dade County Department of Environmental Resources Management (DERM) has monitored Biscayne Bay water quality on a monthly basis since 1979 as part of the Biscayne Bay Restoration and Enhancement Program. Information on water quality in this section is taken from Metro-Dade County DERM (1985) and Metro-Dade County DERM (1987). Information on sediments is based on a study of sediment chemistry in Biscayne Bay and its tributaries that was undertaken by Corcoran, *et al.*, (1983;1984),

The goals of the Biscayne Bay Water Quality Monitoring Program are to establish an adequate baseline of data, detect water quality trends, identify areas that are in need of improvement, and to augment other studies. The purpose of the sediment quality study was to determine concentrations of synthetic and naturally

derived organic chemicals and metal contaminants in the sediments. Organic compounds and metals are poorly soluble in water, tend to bind to particles that are suspended in the water column and become concentrated in bottom sediments as these particles settle. Sediments are a sink for organic compounds and metals and provide a long-term record of their introduction into the coastal environment.

Monthly water samples were collected by DERM at 48 stations, distributed throughout Biscayne Bay. Parameters that were measured in the field or in the laboratory are listed in Table 4. Total coliform and fecal coliform bacteria, which are

Table 4. Water Quality Parameters Measured by DERM

Field Parameters	Laboratory Parameters
1. Time (24 hours)	1. Turbidity (Nephelometric Turbidity Units)
2. Air Temperature (degrees C)	2. Total non-filterable residue (mg/L)
3. Water temperature (degrees C)	3. Color (Platinum Cobalt Units)
4. Dissolved oxygen (mg/L)	4. Ammonia nitrogen (mg/L)
5. Specific Conductance (micromhos/cm:)	5. Total oxides of nitrogen (mg/L)
6. Secchi Disc visibility (ft.)	6. Organic nitrogen (mg/L)*
7. Water depth (sp.)	7. Total phosphate phosphorus (mg/L)*
8. Wind speed (mph)	8. Chlorophyll a(ug/L)*
9. Wind direction (Compass degree)	9. Phaeophytin d (ug/L)*
10. Cloud cover (%)	10. Calcium (ug/L)*
	11. Copper (ug/L)*
	12. Iron (ug/L)*
	13. Lead (ug/L)*
	14. Zinc (ug/L)*
	* Samples not collected at all stations.

indicators of possible sewage contamination, were analyzed by the Florida State Department of Health and Rehabilitative Services. Sediment samples from 45 locations were analyzed for 7 metals, 9 insecticides, 3 herbicides, 3 polychlorinated biphenyls and 7 phthalic acid esters by various laboratories, using quality control procedures. The contaminants that were determined are listed in Table 5.

Table 5 Metals and Synthetic Organic Compounds Analyzed in Biscayne Bay Surface Sediments.

PESTICIDES	HERBICIDES
Aldrin	2,4-D
DDE	2,4,5-T
DDD	Silvex
DDT	
Dieldrin	
Methoxychlor	POLYCHLORINATED BIPHENYLS
Endosulfan	Aroclor 1016
Heptachlor epoxide	Aroclor 1254
Toxaphene	Aroclor 1260
METALS	PHTHALIC ACID ESTERS
Arsenic	Butylbenzyl
Chromium	Butylglycolbutyl
Cadmium	Di-butyl
Copper	Di-ethylhexyl
Mercury	Di-ethyl
Lead	Di-isobutyl
Zinc	Di-methyl

Conclusions from the report by Metro-Dade County DERM (1985) were as follows:

Water Quality Conditions.

1. Water quality in Biscayne Bay is determined by physical characteristics and the dissolved and particulate materials contained in the water. These parameters are primarily influenced by physical factors such as ocean tides, canal discharge, storm and freshwater runoff, and weather patterns. Water quality in the Bay has not changed dramatically from 1979 through 1983. However, several significant trends and patterns have been identified.

2. Although overall water quality in the Bay is generally good, water quality in north Biscayne Bay is inferior to that of central and south Bay. The concentrations of nitrate and phosphate-phosphorus, which are dissolved nutrients that can stimulate algae blooms, are greater in north Bay than in central and south Bay. Nitrate concentrations have increased since 1979 at several stations in north and central Biscayne Bay, but are still below levels that were present when sewage was being discharged to the Bay. Phosphate levels have decreased slightly, especially in northernmost portions of the Bay.

3. Average chlorophyll, coliform bacteria, and turbidity levels are also relatively higher in north Biscayne Bay. Chlorophyll, an estimate of phytoplankton abundance, and coliform bacteria concentrations have not shown significant changes over time. High turbidities are usually associated with areas having barren or dredged bottoms. The lowest turbidity in north Biscayne Bay occurred in an area north of the Julia Tuttle Causeway that is densely vegetated with seagrass, emphasizing the importance of seagrass in maintaining water quality. The level of suspended solids in the water has decreased throughout the Bay since 1979. This may be related to an increase in seagrass cover that has occurred in recent decades as a result of the lack of hurricanes in south Florida.

4. Highest oxygen saturation generally occurs in portions of central and south Biscayne Bay that are vegetated with seagrasses or that exchange freely with the ocean. Oxygen levels have decreased at an average rate of 0.3 mg/l/yr, especially in north Biscayne Bay, since 1979. Biological Oxygen Demand (BOD) is a measure of nutrient input and relative decomposition. This parameter is still high in parts of the Miami River and North Bay, especially in Unit II,. Unit II is area of the Bay containing a tidal node (van de Kreeke and Wang, 1984), The physical constraints resulting from this feature may include poor flushing and may result in accumulation or retention of any substances or nutrients introduced into this area.

Effects of Canals Discharges.

5. Canal and river discharges have a recognizable impact on Biscayne Bay water quality. Compounds found in canal discharges in Biscayne Bay have been linked to various fish pathologies (Skinner, 1982). The Miami River contributed water to north Biscayne Bay which was consistently in violation of the Dade County coliform bacteria standards. The areas near the mouth of the Miami River that were apparently influenced by coliform bacteria were restricted to Claughton Island and Bayfront Park. Only stations near the Miami River exceeded the fecal coliform criterion as established by the U.S. Environmental Protection Agency. The canals which drain into Biscayne Bay carry highly colored water. Color in water results primarily from the decomposition of naturally occurring organic matter. Colored water carries naturally-occurring dissolved nutrients, changes the characteristics of light penetration and may therefore affect bottom communities. At the mouths of

several canals, there are consistently higher concentrations of bacteria, nitrate and phosphate. Lower oxygen saturation values were also consistently found at the mouths of canals.

6. The poorest water quality in Biscayne Bay was found at the mouth of the Little River Canal. Water clarity was low, and higher concentrations of macro-nutrients and trace metals were detected consistently. The water quality at the mouth of the Miami River was almost as poor as that of the Little River, and if evaluated for sanitary quality alone, the Miami River would actually be worse than the Little River. These instances of poor water quality are, fortunately, the exception and the effects are not widespread. Also, except for some isolated and infrequent instances of low dissolved oxygen and high bacteria concentrations, the water quality of the Biscayne Bay has met EPA, State and, where applicable, more stringent Dade County standards. However, these standards may not be adequate to protect the Bay from degradation.

Sediments.

7. Biscayne Bay and Miami River sediments showed varying degrees of contamination. Phthalic acid esters (PAE'S), a group of compounds used in the production of polyvinyl chloride and other plastics, were the most widely distributed synthetic organic compounds. These substances occurred in 96% of the samples analyzed. This distribution is not surprising, since PAE's are extensively used.

8. Polychlorinated biphenyls (PCB's) were used in the United States prior to 1970 in hydraulic fluids, transformers and capacitors, and as plasticizers, but due to their persistence in the environment and toxicity at high levels, their use has been restricted. PCB's were found in 69% of the sediments tested. They were concentrated primarily in north Biscayne Bay and in canals and rivers. Concentrations of PCB's in some sediments from Biscayne Bay proper (not including rivers or canal mouths) were more than ten times higher than in sediments from Galveston Bay, the Mississippi delta or the Gulf coast.

9. Herbicides were detected in 78% of the sediment samples. The highest levels of these compounds occurred in the vicinity of canals and rivers, although significant concentrations were also found in the Bay proper. Their widespread distribution is expected, since herbicides are extensively used in agriculture to manage aquatic weeds and by the homeowner.

10. Organochlorine insecticides, including DDT and its breakdown products DDE and DDD, were detected in 38% of the samples analyzed. DDT was found only at five locations where canals or rivers enter the Bay. DDE was very widely distributed in Biscayne Bay. DDD and endosulfan were also found near some canal or river mouths. Heptachlor epoxide was detected in only two samples, one from north and one from south Bay. Dieldrin occurred in only one sample from central Biscayne Bay. Aldrin, toxaphene and methoxychlor were not detected in any of the sediments tested. Most of the insecticides detected are no longer in use or are restricted; therefore, over a long period of time their levels are expected to decline.

11. Metals enter the environment through numerous pathways. They are found in industrial wastes, sewage, and domestic products such as paints, dyes. drugs, preservatives, soap and paper. They are also released during combustion of gasoline and other fossil fuels. Metals that were detected in excess of natural background levels in Biscayne Bay were chromium, copper, mercury, lead and zinc.

Contaminated samples were all collected from canal or river sediments. Nine of the samples collected, however, contained non-detectable levels of any of the metals analyzed.

12 In general, the relatively higher concentrations of both synthetic organic compounds and metals occurred north of Rickenbacker Causeway and in the canals and rivers entering the Bay. The only exception to this generalization was the PAE's, which were found throughout the study area. The elevated concentrations of PAE's in north Bay would be expected, since this is the area of greatest urbanization and industrialization. The high concentrations of contaminants in the sediments of canals entering central and south Bay represent a potential source of pollutants into what is considered a relatively pristine portion of Biscayne Bay. However, since sediments yield an integrated, long-term record, the present status of these inputs is still unknown. Further study is needed to determine if these contaminants are still entering the bay and its tributaries.

4. Description of Historical and Current Uses and a History of Conditions that Have Led to the Need for Restoration and Conservation.

Excellent summaries of historical changes within Biscayne Bay are found in the Aquatic Preserve Management Plan (Metro-Dade County Planning Department, 1986; Harlem, 1979; Wanless *et al.*, 1984).

Pre-History and Early Development. Originally the Bay received sheet flow of fresh water and existed as an extension of the Everglades system. The principle outlet for fresh water drainage from the Everglades was the Miami River and secondary outlets were Little River, Arch Creek, and Snake Creek (Harlem, 1979). Biscayne Bay was a brackish, estuarine system. Freshwater springs originated from groundwater and welled up in the open bay and perhaps even on the reef tracts. Historical records show this water was a source of some drinking water for passing ships. Prior to 1890 the Bay and surrounding wetlands existed in their natural state. In 1896, the Florida East Coast Railroad opened and from this period to 1900 Miami's population increased from 1,500 to 4,955 (Harlem, 1979). Sometime prior to 1896 the construction of a channel was begun, which eventually became the Intracoastal Waterway. The next major channelization project extended from the Miami River to Cape Florida and formed the beginning of Miami Harbor (Harlem, 1979). Dredging of Government Cut began in 1904.

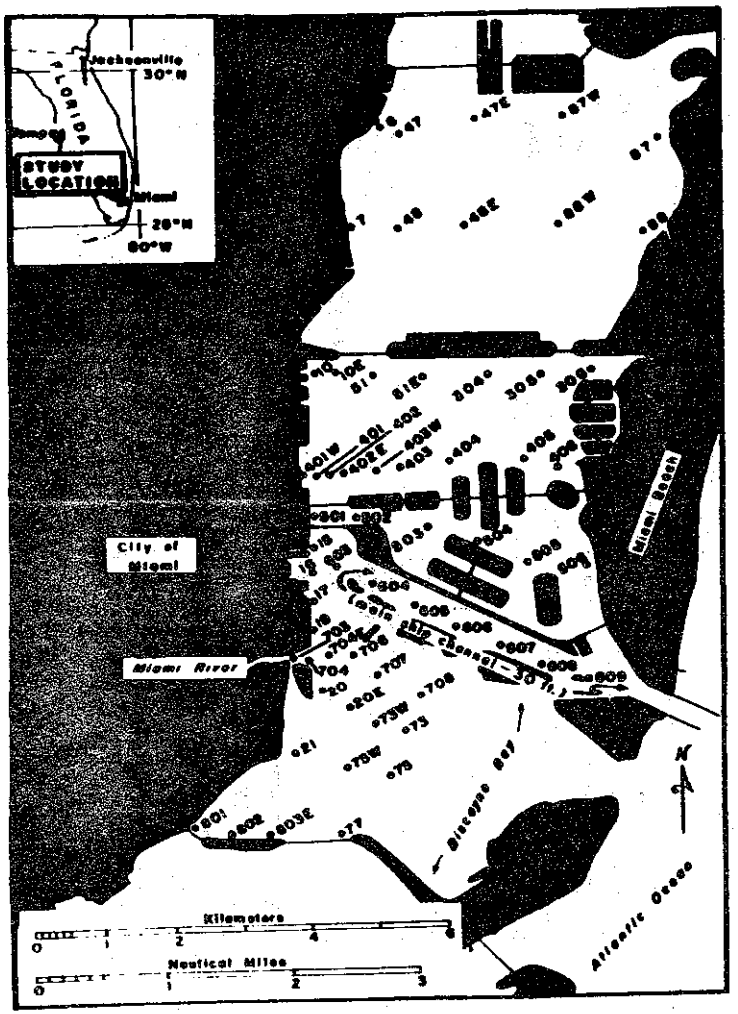
Water Management Features. Drainage of the east Everglades started about 1903. The Everglades Drainage District was created in 1906 (Tebeau, 1974) and, by 1910, 4.25 miles of the Miami Canal was complete (Harlem, 1979). The rapids of the Miami River were dynamited in 1908 (Harlem, 1979). The Everglades Drainage District went bankrupt in 1929, so that little additional drainage work was undertaken for the next 20 years. The extensive water management system that exists today was created primarily in response to the extensive flooding that occurred in 1928 and again in 1947-48. In the 1949 the Central and Southern Florida Flood Control District was created and adopted the works of the Everglades Drainage District. The Central and Southern Florida Flood Control District became the South Florida Water Management District in 1976. The water management system consists of a series of dikes, levees, pumps, structures, and dams that were initially designed for navigation, drainage and flood control. These facilities were later modified to provide water supply from Lake Okeechobee and the Water Conservation Areas to coastal communities and prevent saltwater intrusion.

Shoreline Development. Between the period marked by the beginning of the Everglades drainage projects and 1925, various dredging projects were undertaken whose net result was to forever change the basin in North Biscayne Bay (Metro-Dade County Planning Department, 1986). During this period much dredged spoil was used to fill mangrove shoreline and create various causeways and islands including; MacArthur Causeway, Belle Island, Venetian Causeway, Hibiscus Island, San Marino Island, and San Marco Island (Harlem, 1979). In 1925, Bakers Haulover cut was opened. This inlet opened the primarily freshwater mangrove system of Oleta River and Dumfoundling Bay to saltwater and forever changed this areas ecology (Metro-Dade County Planning Department, 1986). Extensive deep water dredging was undertaken in 1933, 1935, and 1938-39 in the areas of the Turning Basin for the port, Government Cut, and the Miami Ship channel (McNulty, 1970; Harlem, 1979). Dredging history is presented in detail in Harlem (1979). Rickenbacker causeway was finished and opened in 1947. The southern mangrove area of Key Biscayne, was bulkheaded and filled at this time.

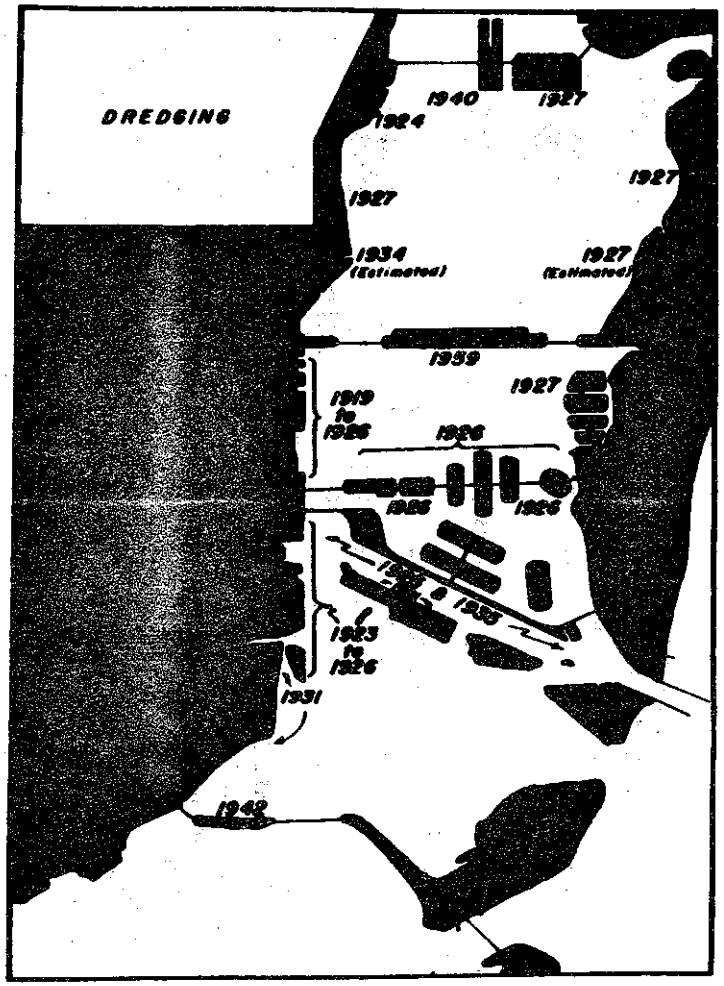
Pollution and Environmental Disturbance. The history of pollution problems and environmental disturbance in Biscayne Bay began with the extensive dredging and construction of causeways and spoil islands in North Bay. During the period from 1900 to 1935 the most extensive environmental modifications occurred within this system (Figure 3, from McNulty, 1970). Resulting problems include reduced circulation, increased turbidity, destruction of natural filtering portions of the ecosystem (mangrove fringe and grass beds), and altered natural salinity regimes. Increased population, associated sewage, and boat traffic added stress to the already altered system within Biscayne Bay. Raw sanitary sewage was generally dumped directly into the Miami River or Biscayne Bay (McNulty, 1970). Eventually this problem reached proportions that were threatening to tourism and the local population. Public demand resulted in the construction of the area's first regional sewage treatment facility, located on Virginia Key (McNulty, 1970). This plant came on line in 1955 and treated between 136 to 227 million liters (36 to 60 million gallons) per day of domestic sewage at that time (McNulty, 1970). Until 1970 many Dade County canals and portions of the Bay were still receiving millions of gallons of raw or poorly treated sewage (Metro-Dade County Planning Department, 1986).

Recent Trends. In recent years, the trend of increasing pollution from point source discharges has been largely reversed through the use of improved treatment methods and diversion of sewage discharges to ocean outfalls. In addition, some of the major sources of industrial pollution that historically discharged to the Bay have been identified and closed. The effects of pollution from non-point sources remain, due to runoff from agricultural areas, increased stormwater runoff from urban development, and increasing contamination of shallow ground water. Shoreline development and dredge and fill activities have declined in recent years and large areas of the Bayfront have been placed in public ownership. Increased emphasis is currently placed on the use of vegetation and rip-rap for shoreline stabilization rather than the construction of vertical bulkheads. Many problems still exist in the Bay, however, primarily due to cumulative effects of past management practices and current development trends in South Bay.

Figure 3. Environmental Modifications in Biscayne Bay (Figure from McNulty, 1970)



Location of stations



Years of major dredge and fill projects
(*Source*: U.S. Army Corps of Engineers)

B. Present and Past Management Efforts

1.History of Management Actions in Biscayne Bay

Early Management Efforts. Sewage pollution and turbidity problems associated with dredging and dredged areas were compounded by the extensive shipping interests facilities that developed into the Port of Miami. The resource management problems of the Bay became so severe that local citizens and the county began to solicit help from state and federal programs. Several legislative efforts were initiated in response to the continuously degrading condition of Biscayne Bay. In 1968, Biscayne National Monument was designated by the federal government in response to development threats in lower Biscayne Bay. The Bay was listed for Outstanding Florida Water status and became the Biscayne Bay Aquatic Preserve in 1974. A monitoring system for water quality was instituted by Metro-Dade County's Department of Environmental Resource Management (DERM) to obtain information necessary to address questions about the status of the system. This monitoring network has been continuously sampled since this 1979.

Biscayne National Park. Biscayne National Monument was designated by the President in 1968 in response to development threats in lower Biscayne Bay. The monument was later designated as Biscayne National Park in 1980 by congress. One of the first tasks of the park staff was to develop a management plan to protect the area's natural and historic resource integrity. This plan was completed in 1983.

Aquatic Preserve. The Biscayne Bay Aquatic Preserve was created by the state in 1974. The county later designated the Bay, north of Biscayne National Monument, as an "Aquatic Park and Conservation Area" and commissioned a plan "to provide a unified management system for the entire Bay system that will, upon implementation, effectively maintain and enhance those physical, chemical, biological, and aesthetic qualities that provide the basic character and values of this resource" (Metro-Dade County Planning Department, 1986).

Biscayne Bay Management Plan. In spite of these efforts, the Bay still exhibited severe management problems. The need was eventually recognized for the development of a Bay-wide management plan. The first such plan was developed and published in 1981 (Metro-Dade County DERM and Metro-Dade County Planning Department, 1981). The Biscayne Bay Management Committee was created by county ordinance in 1981. The county established the Biscayne Bay Management Committee to oversee progress toward the goals of the 1981 plan (Metro-Dade County Planning Department, 1986). The primary goal of the 1981 plan was to design "a unified, county-wide management plan for the entire Bay system, including its adjacent wetlands, embayments and contiguous developed shorelines in a manner that will maintain, or enhance where necessary, those physical, chemical, biological and aesthetic qualities that provide the basic character and value of this resource" (Metro-Dade County Planning Department, 1986).

Aquatic Preserve Management Plan. A draft of this second management plan for Biscayne Bay was completed in 1986 under a coastal zone Management grant from FDER and FDNR. This plan was formulated to address the needs of the Aquatic Preserve Management Area and problems associated with preservation and enhancement of surface waters of Biscayne Bay, its tributaries and associated wetlands.

Dade County Comprehensive Plan. Recently, Metro-Dade County Planning Department has completed the Proposed Coastal Management element of the Comprehensive Development Master Plan (April, 1988). This plan also includes the Executive Summary of the Comprehensive Master Plan for the Port of Miami.

Biscayne Bay SWIM Plan. Finally, the SFWMD has been mandated to prepare the Surface Water Improvement and Management (SWIM) Plan for Biscayne Bay by the Florida State Legislature under FS 87-97. This Act and the resulting plan places major emphasis on preservation and restoration of water quality and natural habitats.

2. Governmental Jurisdictions within the Bay

Federal. Federal jurisdiction on Biscayne Bay involves the regulatory responsibilities of the U.S. Army Corp of Engineers (USACOE), the U.S. Environmental Protection Agency (USEPA), the U.S. Coast Guard (USCG), National Oceanic and Atmospheric Association (NOAA), the U.S. Fish and Wildlife Service (USFWS), and the National Park Service (NPS). Their main regulatory functions include dredge and fill activities, maintaining navigability of waters of the U.S., clean-up of pollution spills and the protection of endangered species. The NPS operates and maintains the facilities, conducts research, and enforces rules and regulations within Biscayne National Park. These agencies also contribute to management and data collection efforts in Biscayne Bay along with the U.S. Geological Survey, Sea Grant Program, National Marine Fisheries Service,the U.S. National Park Service,the National Weather Service, the United States Environmental Protection Agency, the Immigration and Naturalization Service and the U.S. Customs Service.

State. Many state agencies are involved with both the management and regulation of activities in Biscayne Bay. The Florida Department of Environmental Regulation (FDER) and the Florida Department of Natural Resources (FDNR) are leading state agencies in the protection and management of Biscayne Bay. Their jurisdiction includes the protection of the water quality and marine resources of Biscayne Bay. Other state agencies which have a role in managing Biscayne Bay include the Florida Department of Health and Rehabilitative Service, Florida Inland Navigation District, Florida Department of Community Affairs, Florida Game and Freshwater Fish Commission, Florida Department of Agricultural, Florida Department of Transportation, and the Florida Marine Fisheries Commission.

Regional. At the regional level, the South Florida Water Management District and the South Florida Regional Planning Council have jurisdiction over Biscayne Bay. The South Florida Water Management District's authority is to manage and protect all the surface water and groundwater in their jurisdiction. The South Florida Regional Planning Council has jurisdiction to develop regional policies and comprehensive plans for protection of Biscayne Bay, provide assistance to local governments on related issues, and determine impacts of proposed development on the Bay. The South Florida Regional Planning Council has adopted the Regional Plan for South Florida which includes goals and policies designed to aid in the protection of all surface and ground waters in the Region, including Biscayne Bay. The Council also provides technical assistance to local governments and evaluates the impacts anticipated from Developments of Regional Impact (DRI's) on regional resources, such as the Bay.

Local. The Biscayne Bay SWIM planning area includes all of the coastal area of Dade County and a small portion of the coastline of northern Monroe County adjacent to Card Sound and Barnes Sound. This area includes all of the 27 municipalities in Dade County (see Table 6). These local governments have the

Table 6. Dade County Municipalities

Municipality	Population	Municipality	Population
1. BAY HARBOUR ISLANDS	4,845	15. ISLANDIA	12
2. BISCAYNE PARK	3,070	16. MEDLEY	540
3. CITY OF MIAMI	379,392	17. MIAMI SPRINGS	12,053
4. CORAL GABLES	42,281	18. NORTH BAY VILLAGE	4,703
5. CITY OF MIAMI BEACH	96,913	19. NORTH MIAMI	42,420
6. CITY OF SOUTH MIAMI	10,742	20. NORTH MIAMI BEACH	36,381
7. CITY OF BAL HARBOUR VILLAGE	3,012	21. OPA LOCKA	14,658
8. EL PORTAL	1,985	22. SURFSIDE	3,943
9. FLORIDA CITY	6,315	23. SWEETWATER	9,515
10. GOLDEN BEACH	627	24. VILLAGE OF MIAMI SHORES	9,100
11. HIALEAH	157,680	25. VIRGINIA GARDENS	2,166
12. HIALEAH GARDENS	5,443	26. WEST MIAMI	5,904
13. HOMESTEAD	22,179	27. Unincorporated Dade County	931,300
14. INDIAN CREEK VILLAGE	107		

authority to control land use adjacent to the Bay through their comprehensive plan policies and land development codes. Other sectors that exist on the local government level include, Metro-Dade County Department of Resource Management (DERM), Metro-Dade Count Planning Department, the Miami Dade Water and Sewer Authority (WASA), Metro-Dade police, port authority and inlet commissions, and soil and water and conservation districts. Although these sectors may work under the authority of a state agency, their management of the resources is focused on a local level. Metro-Dade county is currently developing comprehensive plans for future development and preservation of resources found in Dade county. These plans will be incorporated on a regional level to help better understand the potential impacts of development and management on Biscayne Bay.

C. Survey of Existing Research on Biscayne Bay

A survey of existing research in Biscayne Bay indicates that a wide range of investigations have been conducted over the years, primarily by researchers at the University of Miami, Rosenstiel School of Marine and Atmospheric Sciences. This research has been summarized in the reports by Rosendahl (1975) and Thorhaug and Volker (1976). Much of this work is basic research concerned with assessment description and monitoring of resources within the Bay. In recent years, with funding provided through the FDER, Dade County has commissioned a number of studies directed toward Bay management issues and problems. This research provides an excellent understanding the resources of the Bay, its management problems and potential solutions to these problems. Biscayne National Park has also compiled a computerized bibliography of literature related to Biscayne Bay. Much of this research is discussed in other sections of this report.

D. Existing and Potential Sources of Contamination within Biscayne Bay

1. Point Sources.

Point pollution sources can be defined as discharges to the Bay surface waters where discrete measures of flow and water quality may be taken. Point sources are usually considered as pipe or culvert discharges from a wastewater treatment facility or institutional facility. Permitted point sources are summarized in Table 7.

Table 7. Point Source Permit Data Obtained for the Biscayne Bay SWIM Plan

Class/Agency	Type of Information	Data Fields Included
DOMESTIC WASTE		
DER	Copy of permits for Monroe county	Permittee Location of site - Lat/Long Expiration Date System Site Design Capacity
DERM	Waste Water/Utility Engineering Status Report - Dade County	Facility Name Location Method of Treatment Design Capacity OPERATING HISTORY FOR 1987 Ave. Monthly Flow (% capacity) High Month Flow (% capacity) BOD,TSS,Eff pH,Fecal Coliforms Notes and Enforcement activity Ave. Cl_2
INDUSTRIAL WASTE DERM	Listing of Class IW 2,3,4,5 Permits Listing of Tank Permits List of Warning Notices List of Civil Violation List of Complaints List of DER Warning Notices	Permittee Expiration Date Amt of Discharge Type of Permit Location - Address

More detailed listings are contained in Appendices F and G. Point sources for Biscayne Bay can be divided into two categories, domestic and industrial waste. The discharge of either of these effluents to surface waters requires a National Pollution Discharge Elimination System (NPDES) permit. These permits are issued through the EPA, Florida DER and Dade County DERM. Specific effluent limits are based on the presumption that the assimilative capacity of the receiving water is sufficient to handle these additional pollutant loads.

Domestic Wastewater. Within the basin, there are approximately 50 domestic wastewater treatment facilities. Only one facility currently discharges to Biscayne Bay system and this plant is scheduled to be phased out of operation during the coming year. This plant currently discharges approximately 0.02 million gallons per day (MGD) of effluent into a tributary to the Miami River. Several alternative methods of disposal have been implemented within the basin, primarily the use of ocean outfalls, deep well injection, and percolation ponds. Most of the wastewater treatment facilities within the basin are connected to the regional system that is operated by the Miami-Dade Water and Sewer Authority (WASA).

Industrial Discharges. Examination of the information provided by Dade County on industrial waste permits indicates that industrial facilities generally discharge directly to sanitary sewers or septic tanks rather than directly to surface waters. Discharge to septic tanks raises the concern that these materials may leach into the surrounding groundwater and contribute to non-point pollution problems. Exceptions are the discharge of cooling water used in electrical power generation and pumpage from the dewatering of construction sites. Currently, there are no plans to change or restrict these industrial waste discharges.

2. Non-point Sources.

Definition. Nonpoint source pollution is usually associated with land use activities that do not have a discrete point of origin. These pollution sources are usually delineated into rural and urban sources. Rural nonpoint sources are induced by stormwater runoff or are produced as a result of base flow and are associated with agricultural activities. Stormwater runoff from these activities carries pollutants such as fertilizers, pesticides and other agricultural chemicals. Urban nonpoint sources are also primarily conveyed by stormwater and contain pollutants associated with urban land uses. The sources of these pollutants range from those transported by direct precipitation to pollutants resulting from automobile tire wear and construction activities (Wanielista, 1983). In addition, the large pulses of freshwater resulting from stormwater itself may prove to be a pollutant to saline systems. Due to the identification of known nonpoint pollutant sources in the Biscayne Bay area, such as superfund sites and landfills, a third classification of nonpoint source pollution will be discussed under the general terminology of industrial land use.

Permitted vs. Non-Permitted. For Biscayne Bay, nonpoint source permit information is currently being collected for each of the tributary sub-basins Non-point permit data are listed in Appendix D and summarized in Table 8. These

Table 8. Non-Point Permit Data Obtained for the Biscayne Bay SWIM Plan

Class/Agency	Type of Information	Data Fields Included
SOLID WASTE/LANDFILLS		
DER	Listing of Landfills in Dade & Monroe Counties	Name of Site Location S-T-R DER Permit # Status Class
CONSTRUCTION PERMITS CLASS 1		
DERM	Listing of Class 1 Construction Permits Dade County	Name of Permittee Street Address Proposed Work Issue Date
OUTFALL CLASS 2		
DERM	List of Permitted Outfalls Discharging to Surface Water	Permit Number Permittee Location S-T-R Job Description
SURFACE WATER MANAGEMENT		
SFWMD	Listing of Surface Water Management Permits Issued By SFWMD in Dade County (The District Has Delegated Dade County to Issue Permits to Projects that are less than 320 Acres)	Permit Number Permittee Location S-T-R Receiving Body Type of Facilities Rate of Discharge(cfs) Size of Project(acres)

data will be organized into a data base from which sources that have permits, have no permit, have a temporary operating permit, or are in violation of water quality standards can be identified. Sub-basin maps may then be prepared to locate permitted and non-permitted activities. Non-point permits that will be assessed include surface water and stormwater programs of DERM and SFWMD, FDER stormwater permits and selected DNR and USCOE dredge and fill permits.

Land Use Impacts on Water Quality. Land use patterns within the Biscayne Bay watershed primarily determine the nature of non-point pollution that occurs to the Bay

Industrial Land Use. The industrial area in northern Dade County contains the majority of the USEPA designated superfund sites for the County (Table 9). These sites include oil industry sites, landfills and storage facilities and

are located above the Biscayne aquifer, a highly porous aquifer that represents the sole source of drinking water for the greater Miami metropolitan area. Direct connection with the surficial Biscayne aquifer provides a direct conduit to Biscayne Bay and its tributaries for pollutants via sub surface flow.

Table 9. Superfund Sites in Dade County as of June 1986

Rank	Company/Site	Location and Address	Date Proposed or Announced	Group #
1.	Gold Coast Oil Corp.	Miami	10/81	67
2.	Miami Drum Services	Miami, once listed as part of Biscayne aquifer	10/81	121
3.	Munisport Landfill	North Miami	12/82	584
4.	Northwest 58th St Landfill	Hialeah	10/81	174
5.	Pepper Steel &Alloys Inc	Medley	9/83	606
6.	Varsol Spill	Miami	10/81	267

Florida has 32 sites that are listed on the EPA National Priorities List and 7 that are proposed non-federal sites (USEPA, 1986). A list of industrial permits for Dade County is found in Appendix F. In addition, known landfill locations and descriptions are provided in Appendix D. Due to the highly permeable nature of the shallow Biscayne aquifer throughout eastern Dade County, subsurface land use is an extremely important potential source of contamination. Appendix H lists permitted subsurface storage facilities in Dade County.

Institutional Land Use. A special source of pollutant occurs from institutional land uses. Institutional land uses include such entities as hospitals, schools and military bases. A wide variety of contaminants and pollutants may originate from such sources, including exotic industrial and research chemicals, radioactive waste and hazardous biological waste that is not detectable through routine monitoring procedures. These materials may enter surface or shallow groundwater and be released to the Bay due to improper waste management procedures, spills, stormwater runoff and/or seepage from underground storage facilities. A number of such facilities are located in the Biscayne Bay watershed. The locations of these facilities need to be carefully documented. As problems are suspected, specific monitoring programs will be designed to assess these concerns.

Agricultural Land Use. Stormwater from agricultural land areas may contain pollutants due to application of nutrients, pesticides and other agricultural chemicals. DERM has an extensive data base of water quality and contaminant concentrations in the South Dade Agricultural areas. Dade County's agriculture produces 50 percent of the nation's winter vegetables and covers about 80,000 acres (Howie, 1986). Agricultural land use in the Biscayne Bay watershed is concentrated in southern Dade county, and is located above the highly porous Biscayne Aquifer. Agricultural management practices may contribute nutrients and pesticides to surface and shallow ground waters. Samples collected from shallow ground water test wells in the agricultural areas of south Dade County have documented the presence of various inorganics and toxic organic compounds on an infrequent basis (Howie, 1986). Research from the SFWMD has also identified isolated low level inorganic and pesticide pollutants in wells in the south Dade agricultural area (SFWMD, 1988 - in preparation). Although the Biscayne Aquifer is capable of readily transporting pollutants through the shallow ground waters, the large

quantity of water movement dilutes the pollutants associated with agricultural land uses in Dade County, thus masking the impact of such pollution sources.

Effects of nutrients and pesticides from agricultural sources on Biscayne Bay are largely unknown. Nutrient enrichment has not been documented as a major problem in Biscayne Bay. Pesticides occur in the Bay and may affect the system in a variety of ways, including impacts on submerged and emergent vegetation, benthic communities, plankton and fisheries. Southern Biscayne Bay, which receives the canal discharges from adjacent agricultural lands, includes Biscayne National Park and the Biscayne Bay Aquatic Preserve and contains some of the healthiest natural areas within the Bay. Future stormwater monitoring conducted by DERM will aid in quantifying both agricultural and urban non-point source pollution.

Urban Land Use. Stormwater from urban land areas has been documented to contain significant levels of various pollutants, including oxygen demand, solids, nutrients, priority pollutants and heavy metals (Field and Szeely, 1974). Documentation of the relationship between urban land uses and stormwater quality has been developed over the past two decades and is selectively summarized for South Florida (Whalen and Cullum, 1988).

Three studies have been completed for the Biscayne Bay area that utilized water quality data typical of specific land uses to compute pollutant loadings to the Bay (Metro-Dade County DERM, 1981; Miami River Task Force, 1984; and City of Miami, 1986). These studies utilized water quality data from either Tampa, as part of the National Urban Runoff Program (USEPA, 1983), or Dade and Broward County as part of a USGS program (Mattraw *et al.*, 1981). While these reports provide rough estimates of the relative contributions of pollutants to a receiving water from a given land use, they are not site specific. Any design or management decisions in the Biscayne Bay watershed should be based on direct measurements of local conditions.

In Biscayne Bay, stormwater discharge from urban areas has been identified as a major problem by previous studies (Metro-Dade County Planning Department, 1986). In order to address this problem, retrofitting of stormwater outfalls that discharge into Biscayne Bay was assigned a high priority in the SWIM legislation. Of the $1.9 million that was appropriated for Biscayne Bay under the SWIM program, the legislature recommended that $1.4 million should be spent for retrofitting of 55 stormwater outfalls and that $500,000 should be spent for restoration of the Miami River, which is located in the most highly developed urban watershed in the Biscayne Bay area. Retrofitting of stormwater outfalls in the highly developed area of Miami is very expensive, however depending on size and location.

Impacts on Groundwater. As was either stated or inferred in the previous three sections, the majority of the Biscayne Bay watershed lies above the Biscayne Aquifer, a highly porous, shallow, aquifer system that is the sole source of drinking water for the greater Miami metropolitan area. Any land use that contributes pollution to the surface water system in Dade County will simultaneously contaminate the Biscayne Aquifer.

***In Situ* Sources of Water Quality Degradation.** This category includes such problems as turbidity, chemicals released from sediment deposits, and various of man's activities that occur in the bay itself. Turbidity is a major cause of the declining quality of water in Biscayne Bay. Turbidity, as defined by Wanless . (1976), is ". . .the fine particles in water that reduce water clarity by absorbing or reflecting light." Historical dredging within the Bay has left deep holes that act as temporary sinks that concentrate fine sedimentary materials. These fine sediments generally have a high content of organic materials and tend to concentrate

petrogenic and pyrogenic hydrocarbons, and metals that are associated with or bound to the organic compounds (Corcoran *et al.*, 1983). These deep holes serve as a continual source of turbidity and pollutants in the bay when the unstable fine materials are disturbed by wave action during storm events.

Chemical contamination of sediments and the subsequent release of these contaminants into the water column is a problem in many areas, especially in North Bay and in tributaries such as the Miami River and Little River. These problems are discussed in more detail in the portion of this report that deals with problems of the individual sections and management units.

Marinas and other water-dependent activities provide additional sources of non-point pollution to the bay. Such operations may produce a variety of contaminants and pollutants, including fuel and oil spills, sewage and waste disposal, boat wash water and leachate from marine anti-fouling paints. The water quality impacts of marina facilities are a recognized problem in Biscayne Bay. Unfortunately the SFWMD does not have significant regulatory authority over marina facilities and District staff did not have the time and resources necessary to address this complex issue in this SWIM report. This issue will be given additional consideration in future SWIM programs and reports. Research is needed in Biscayne Bay to determine the impacts of marinas and to develop and define appropriate construction and operating criteria for marina facilities that will minimize adverse impacts on the Bay.

3. Documentation of Historical Land Uses that are Possible Pollutant Sources

Land adjacent to Biscayne Bay has been developed since the late 1800's. During the past 100 years, a wide variety of activities have taken place within the watershed that may have resulted in contamination of surface or ground water resources. The presence of the extensive network of drainage canals in the Biscayne Bay watershed and the high permeability of the Biscayne Aquifer makes groundwater and surface water virtually interchangeable. Sources of contamination anywhere in the basin thus may impact Biscayne Bay or its tributaries.

Efforts should be made to identify areas that, due to past land uses, may currently be releasing toxic materials. Similar studies were completed by DERM in eastern Dade County and were included in the Aquatic Preserve Management Plan (Metro-Dade County DERM, 1986). Examples of past land uses that may be negatively impacting current water quality conditions are old landfills, agricultural practices, and abandoned dump sites.

Closed or inactive landfills were mapped in conjunction with the preparation of the Aquatic Preserve Management Plan (Metro-Dade County Planning Department, 1986). Many of these sites continue to leach contaminants into the environment. Currently, Key Biscayne and its surrounding waters contain high levels of arsenic. that may have resulted from an old landfill or old agricultural practices. Many sites that were historically used for industry are now under residential or other land uses. Any historical contamination at such locations may go unnoticed. The Little River and Arch Creek areas currently have no significant amounts of industrial or commercial land use, and yet, these basins exhibit unusually high levels of contaminants. The Miami International Airport has extensive groundwater contamination problems. The impact of these contaminants on surface waters is unknown, but this area is located near the Miami River. Seepage from this site may be impacting waters of the River, the adjacent canal systems and Biscayne Bay.

III. IDENTIFICATION OF PRIORITY ISSUES AND ANALYSES

Biscayne Bay has complex problems and management issues. These problems and issues can be divided into three broad groups -- 1) problems that occur throughout most of the bay; 2) problems that are localized to specific areas or sub-basins; and 3) specific problems and issues that were identified in the SWIM legislation and FDER Rule. Each type of problem requires a different management approach. Both Bay-wide and localized problems require identification of problem sources and the development and implementation of appropriate management strategies to address them.

A. Bay Wide Problems and Programs.

Bay-wide problems and issues can be divided into two categories--the general need to restore, or improve conditions that are currently undesirable and the need to preserve and protect features that are still in good condition.

1. Restoration

The need for restoration is based on the assumption that some areas have been significantly degraded below the quality of undisturbed natural sites by pollution, structural change or other human activities. Restoration activities are designed to reduce the influx of excessive amounts of nutrients or pollutants, and to make structural changes as needed to restore appropriate biotic communities, substrate, hydrologic, or physical conditions that will accelerate recovery of the system. Bay-wide restoration efforts are targeted toward three major issues--water quality, freshwater inputs, habitat and living resources. This section presents a general overview of these issues and problems in Biscayne Bay and its associated Sounds. The water quality, freshwater and turbidity issues as they apply to specific sub-basins, are discussed in greater detail in section III. B.

Water Quality. A review of water quality investigations in Biscayne Bay has shown that water quality in most of the Bay is good, although certain areas continue to have severe water quality problems. Some water quality issues pertain to many areas throughout the Bay. These problems include turbidity, sewage pollution, stormwater runoff, and contamination with man-made chemical substances.

Turbidity. Historically, Biscayne Bay was a clear, shallow coastal estuary (Wanless, 1976). Today, turbidity is a major problem in Biscayne Bay and has been a continued cause of water quality degradation since extensive dredging and filling of North Bay began in the early 1900's. A map of dredged areas, based on a report by Metro-Dade County DERM (1983) is found in Figure 4. Major sources for continued turbidity are sedimentary input associated with the erosion of non-stabilized spoil, resuspension of fine and flocculent materials from dredged areas and deep holes, stormwater runoff, and phytoplankton blooms associated with abnormally high nutrient content (Wanless, 1976; Wanless *et al.*,1984). Increased wave action serves to resuspend fine sediments and flocculent materials as well as to increase erosion of spoil margins (Wanless *et al.*, 1984; Wanless, 1976; Metro-Dade County Planning Department, 1986). Harlem (1979) found an increase in turbidity as determined from aerial photographs of the Bay, during the period from 1925 to 1976.

The following is a summary of the process by which fine materials create turbidity problems within Biscayne Bay (Wanless et al., 1984):

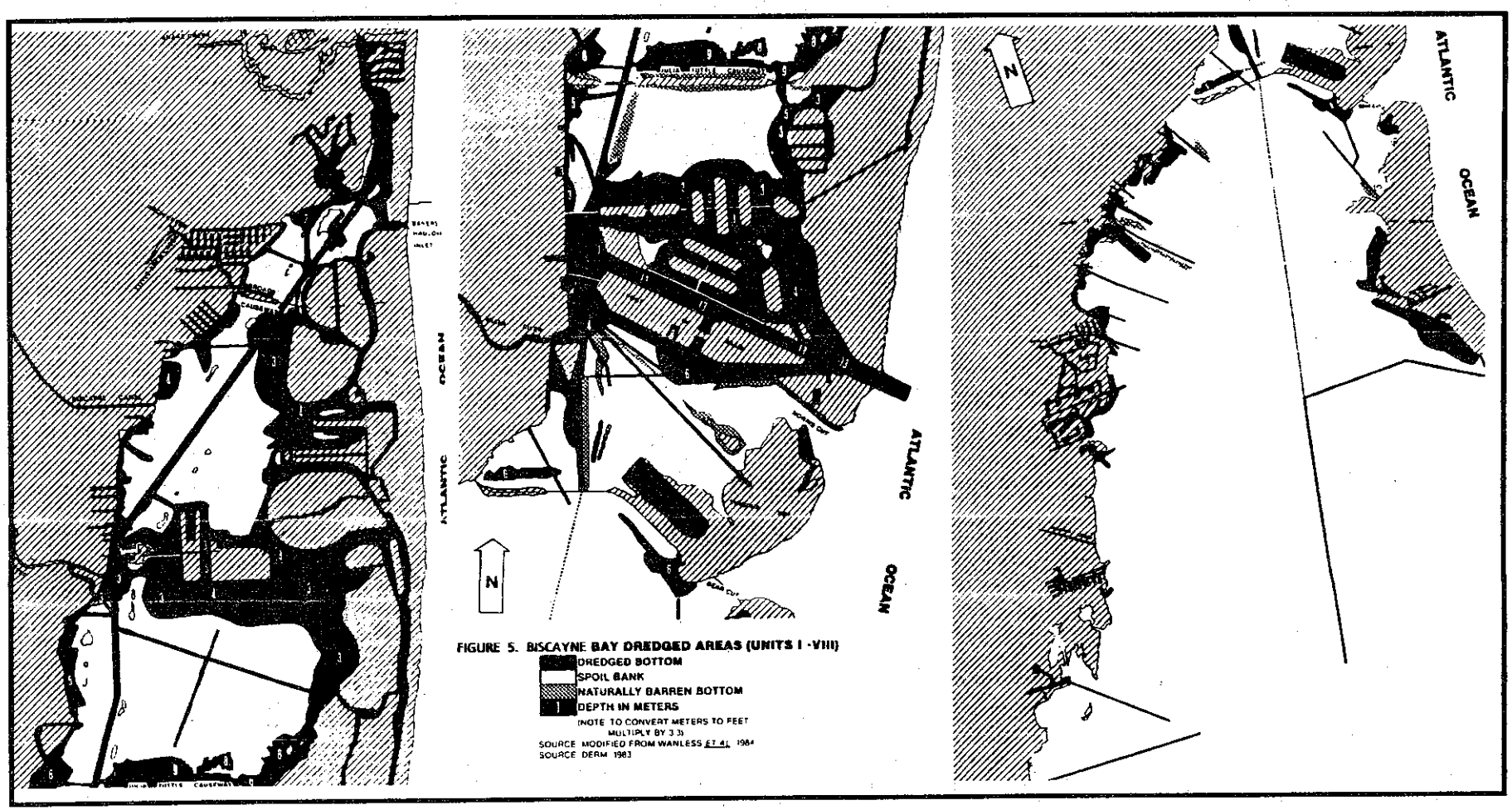


FIGURE 4. Dredged Areas in Biscayne Bay (from DERM, 1983)

1) Deep holes and dredged areas serve as sinks and sources for these materials.
2) Unconsolidated spoil islands and margins are sources of sedimentary input through continual erosion by wave action.
3) Vertically bulkheaded shorelines aggravate turbidity conditions. Bulkheads reflect wave energy with little or no attenuation. Wave action resuspends sediment fines from deep holes and unconsolidated or eroding spoil margins. Wave action may be due to natural causes such as winds or tidal currents or it may be due to unnatural causes such as boat wakes.
4) Increases in the number of marinas and boats and an increase in the linear feet of vertically bulkheaded shoreline are believed to be responsible for increased wave action and bottom scour in North Biscayne Bay (Harlem, 1979; Wanless, 1976; Metro-Dade County Planning Dept., 1986)
5) Continual input of fine sediments occurs from overland runoff and storm water drainage (Whalen and Cullum, 1988).

Dredged areas within the Bay act to increase turbidity through a positive feedback mechanism. Natural bottom communities are removed when the area is dredged. Lack of these communities prevents sediments from being stabilized by biological activity. Deep areas act as reservoirs for fine materials. Wind action and the passage of boats continually resuspends this material, increases turbidity and reduces light penetration. Decreased light penetration through the water column prevents recolonization by submerged aquatic plants and associated benthic communities, which otherwise would filter materials from the water column and help stabilize sediments.

Increased wave action results from boat wakes, natural wave action associated with wind and tides, and reflected wave energy. North Biscayne Bay has large areas of dredged bottom, deep holes, and spoil margins and contains a high proportion of vertically bulkheaded shoreline. Vertically bulkheaded shorelines result in a "bathtub" effect, where wave energy is reflected back and forth across the basin rather than dissipated on sloping shorelines or other natural features. This wave action resuspends fine materials from the bottom, increases erosion of unprotected shorelines, and contributes to turbidity problems of the Bay.

Plankton is another source of turbidity in the Bay. Pulsed influxes of dissolved nutrients, such as occur from stormwater or canal discharges, can result in localized blooms of phytoplankton and zooplankton. The presence of these microscopic organisms in the water column causes turbidity and reduces light penetration.

Various restoration actions may be used to reduce turbidity levels in the Bay. Stabilization of unconsolidated dredge spoil, stabilization or filling of deep holes, and stabilization of other eroding shorelines can be used as a method to address this problem. Effects of boat wakes may be reduced by limiting the size or speed of boats within certain areas of the Bay and thereby reducing bottom scouring, sediment resuspension and erosion from wave energy. Metro-Dade County DERM has developed ordinances that require rip-rap in front of vertical bulkheads to dissipate wave energy. The FDER supports the use of vegetation in addition to, or in place of, rip-rap for this type of stabilization. No-Wake Zones are currently being proposed and instituted in various parts of the Bay, primarily for safety reasons. However, decreased wave energy may also help to decrease turbidity. FDNR has instituted a rule designating No-Wake zones. DERM has put in signs and will add more signs to improve awareness of the No-Wake areas. Dade County has passed an ordinance and posted signs to designate the Miami River as a No-Wake zone.

A study will be initiated this year as part of the Indian River Lagoon SWIM program to reevaluate the state turbidity standard. The purpose of this study is to develop alternate methods to measure turbidity and its effects and perhaps define new turbidity standards that are more closely related to the needs of the communities that these standards are intended to protect. This effort is currently being coordinated with DERM personnel and DERM monitoring information is being added so that data from both areas will be comparable. Wanless (1976) and Harlem (1979) provide further discussion of turbidity within the Bay including historic setting, current status, and the relative importance of various types of input.

Sewage Pollution. Sewage contamination has been a problem in Biscayne Bay since the early growth of the Miami area (Harlem, 1979; Wanless, 1976). Large volumes of raw sewage were discharged into these waters from 1920-1955 (Wanless, 1976; McNulty, 1970). The first regional sewage treatment facility was located on Virginia Key and became operational in 1955 (McNulty, 1970). Until that time, much of the City of Miami's domestic raw sewage was discharged directly into canals, tributaries, the Miami River, or Biscayne Bay (McNulty, 1970). The Miami River and much of Biscayne Bay still frequently have concentrations of total or fecal coliforms that are above the suggested maximum levels for human contact with water (Metro-Dade County DERM, 1985; 1987). The Miami River has consistently high fecal coliform counts from raw sewage discharge (Metro-Dade County DERM, 1985; 1987). Waite (1976) suggested that high coliform levels may correspond with the rainy season and result from septic tank leachate. Dade County records indicate that, although fecal coliform levels have declined for many areas throughout Biscayne Bay, they have increased or remained at pre-sewage treatment levels for the Miami River (Metro-Dade County DERM; Metro-Dade County Planning Department, 1986).

Sewage pollution originates from both point and non-point sources, including ruptured sewage lines, disfunctional lift stations, degraded sanitary sewer pipes, cross-connected sanitary and stormwater lines, septic tank leachate, discharge from commercial ships and private "liveaboard" boats. Surveys in Dade County indicate that the Miami River has the worst sewage contamination problem. Other problem areas include Biscayne Canal, Little River, Maule Lake, Flamingo Marina, Dinner Key Marina, and other marinas that have large numbers of "liveaboard" boats.

Assessment of the extent and magnitude of this problem is hampered by the inadequacy of methods available for detection of sewage contamination in marine systems (Buck, 1976; McCorquodale, 1986; Pierce and Brown, 1986). Coliform bacteria occur in human and mammalian fecal waste. These bacteria are generally used to indicate the presence of human waste contamination. The presence of coliform bacteria in a water sample indicates that pathogenic organisms, which are less easily detectable, may also be present. The current fecal coliform standard was developed for use in freshwater and is not necessarily directly applicable in marine systems (Metro-Dade County DERM, 1986; Schaiberger, *et al.*, 1982). The survival of these organisms is dependent upon a variety of factors including light intensity, temperature, and salinity (H. Kator, personal communication). The survival time of these organisms in the system under evaluation should be calibrated by an *in situ* measurement of survival rate. Additionally, other indicators may be used to detect human fecal contamination. DERM is currently evaluating the use of alternate methods for the detection of human fecal pollution in marine systems.

Stormwater Runoff. Stormwater runoff from industrial, agricultural and urban land uses enters Biscayne Bay through a series of canals and modified rivers and streams that transect upland areas of the watershed. Estimates of pollution loads have been generated for these land use types and serve to identify general problems associated with stormwater runoff entering the Bay. Direct measurements of stormwater quality have not been made for these areas. Until such measurements are made, management decisions that are dependent on such data should be carefully evaluated and preferably not made until data are available. Retrofitting of stormwater outfalls has been identified as a priority by the SWIM legislation. Documentation of the water quality that is associated with discrete outfall sampling may help to prioritize such outfalls for retrofitting. This documentation will also provide baseline data to evaluate the success of the retrofit.

Enforcement action for discharges that violate state standards is an issue that will be discussed later in this management plan. The ability to enforce these standards through licensing, fees, clean up, or fines based on water quality violations, will be aided by a stormwater monitoring program that samples at discrete locations. Additionally, long term (>10 yrs) monitoring must be incorporated in this process along with requirements for long term maintenance of the retrofit.

Freshwater Input and Effects. Freshwater inflow to Biscayne Bay occurs from three primary sources--rainfall, groundwater seepage, and upland runoff. Runoff occurs directly from lands adjacent to the Bay or is conveyed from lands within the watershed by means of the canal system.

Prior to construction of major drainage projects in the greater Miami area during 1900-1925, Biscayne Bay received freshwater primarily as groundwater seepage and sheet flow of surface waters across the adjacent marshlands (Parker, 1974). This freshwater flow maintained the salt front far seaward of its present location. Freshwater covered the marl soils of the eastern "glades" and occurred over most of the coastal flatlands between the ridges and Biscayne Bay. Freshwater sawgrass marshes formed the border of southern Biscayne Bay (Wanless, 1976). Prior to completion of the Bakers Haulover Inlet, much of north Biscayne Bay was a freshwater or brackish embayment (Harlem, 1979).

Construction of most of the major drainage canals along the coast was complete by 1932. Canals were either uncontrolled or inadequately controlled, allowing salt water movement inland, uncontrolled drainage, and saltwater intrusion into the shallow aquifer (Buchanan and Klein, 1976). Continuous drainage resulted in lowered groundwater levels and seawater intrusion into the Biscayne Aquifer in the Miami Area (Klein and Hull, 1978; Buchanan and Klein, 1976). After the 1943-45 drought, canals through the coastal ridge were equipped with salinity structures, which prevented overdrainage and seawater intrusion during dry periods (Klein and Hull, 1978). The major canals now form a primary water supply and drainage system that serves three main functions as follows:

1) The Miami Canal serves as a primary drainage outlet for excess water from the Everglades Agricultural Area and the Water Conservation Areas (WCA's) and as secondary outlet for excess water from Lake Okeechobee. Releases from this canal are made periodically throughout the year in conformance with agricultural irrigation and drainage practices and to maintain the Lake and WCA's within their appropriate regulation schedules.

2) The coastal canal network of Dade County provides primary drainage for the intensely-developed urban and agricultural areas of the southeast coast. Stages in these canals are maintained at levels that vary with the season. During the wet season, canal stages are generally kept at a low level to provide additional storage capacity for retention of stormwater runoff. During the dry season, canal stages are usually kept at higher levels to provide additional groundwater recharge and to prevent saltwater intrusion. An exception occurs in South Dade County, where groundwater levels are maintained lower during the winter growing season, and allowed to return to more normal wet season levels during the summer, when most fields are fallow. Releases are made from the canals whenever local rainfall conditions raise the canals above maintenance levels, or in anticipation of major storm events.

3) The coastal canals allow transfer of water from the Water Conservation Areas to coastal communities during times of drought. This water recharges major wellfields that are located near the canals and raises the groundwater levels in coastal areas to provide additional water to self-supplied water systems.

The primary drainage system that is operated by the SFWMD also supports smaller, secondary drainage systems that are maintained by private interests or local drainage districts. Canals of the SFWMD system generally drain east to the Atlantic Ocean. Water stages in the eastern reach of these canals are controlled by a series of coastal water control structures, most of which are set to automatically open or close in response to canal stages. Canal gates can also be operated manually or by remote control during times of emergency. Water stages are set by the U.S. Army Corps of Engineers (USCOE) and maintained by the water management district (SFWMD) through various agreements. In some basins, such as the Tamiami Basin, the District is considering plans that could allow excess water from coastal areas to be pumped back into the Water Conservation Areas as a means to place additional water in the regional storage system.

Major tributaries that discharge into Biscayne Bay are Arch Creek, Snake Creek, Little River, Miami River, Coral Gables Waterway, Snapper Creek Canal, Black Creek, Goulds Canal, North Canal, the Model Land Canal and C-111 Canal. Snake Creek has the largest volume of discharge and the Miami River has the second largest discharge. Freshwater discharges from the Miami River generally have little influence on other areas of the Bay because these discharges are generally contained within the region between Rickenbacker Causeway and the Government Cut ship channel. In addition, freshwater from the River is rapidly exchanged with oceanic water through the channel. Low rates of flow from the Miami River are associated with stratification, so that bottom salinities remain high (on the order of 20 ppt) and surface salinities are low (5 ppt) (Metro-Dade County DERM, 1985). Minimum flow is needed in the Miami River to hold back saltwater intrusion in the aquifer. Adjustments in the operation of canals and control structures to meet changing needs have altered the amount, timing and distribution of seasonal discharges from the Miami Canal. Reduction in flow to the ocean began with completion of the levee system east of the Water Conservation Areas in 1953. Discharge to the ocean through the Miami Canal since 1953, as the result of flood control and water control measures, has been reduced by about 20% relative to flows what would have occurred otherwise (Leach, 1972).

Releases of water from coastal canals occasionally create localized problems due to transfer of freshwater and polluted runoff from urban and agricultural lands

into the coastal waters and estuaries. Problems with this type of introduction are especially apparent where water is discharged into an enclosed or semi-enclosed estuary, such as occurs in Biscayne Bay. These problems are directly related to the introduction of large volumes of freshwater into a marine system as point sources at unnatural times of the year. The primary design of the water control works in South Florida has been to facilitate the flow of freshwater out of the Everglades by means of the canal system, thereby changing the spatial and temporal distribution of runoff to Biscayne Bay and associated coastal areas. Unfortunately, at the time of their design, the effect on groundwater and coastal saltwater communities of canal discharges was unknown. Freshwater discharge now occurs as channelized flow to local areas of the Bay at the outlets of coastal canals, rather than to broader areas of the Bay as diffuse groundwater seepage or sheet flow through coastal marshes.

Freshwater has a direct influence on salinity conditions in the Bay. Most of Biscayne Bay adjacent to the mainland has low salinities during the wet season due to canal discharges and groundwater seepage. When large volumes of water are discharged from the canals, this water tends to move into the marine system of the Bay as discrete masses of low-salinty water that do not readily mix with surrounding high salinity water (Wang *et al.*, 1978; Chinn Fatt and Wang, 1987). During the dry season, saltwater moves inland and the western shore of South Bay frequently experiences high salinities (Wang *et al.*, 1978; Lee, 1975). A region of relatively constant salinity exists in the vicinity of the Safety Valve, where water from the Bay exchanges freely with adjacent coastal waters (Lee, 1975).

The timing and duration of freshwater flow to the Bay have also been altered. Studies by the USGS (Klein and Hull, 1978) indicate that construction of canals has had three primary impacts on groundwater conditions in South Dade County a) peak groundwater stages that occur in response to a rainfall event have been reduced, b) the recession rate of groundwater has increased, and c) the rate of groundwater movement into the Bay through the canals has increased.

The interaction of the canals with the Bay ecosystem is complex. Biscayne Bay, as an estuary, provides a variety of habitats that are necessary to support offshore, near shore, and Bay-wide fisheries (Zieman *et al.*, 1984; Colby *et al.*, 1985; Haunert and Startzman, 1985; Thayer *et al.*, 1987). The survival of many of these organisms depends upon the seasonal availability of low-salinity habitats. Freshwater inflow from canals and surface runoff transports nutrients and detritus from adjacent marshes and uplands into the Bay. These materials are needed to sustain biological productivity. However, the timing and location of freshwater deliveries must provide conditions that can be tolerated by aquatic communities.

Thorhaug (1976) observed that species diversity and numbers of fish, mollusks, crustaceans and algae decreased in the vicinity of a canal in Biscayne Bay during periods of freshwater discharge. Colby *et al.* (1985) attribute a decrease in abundance of fish in a southwestern Florida bay (Faka Union) to the change in freshwater delivery from overland flow to channelized flow. Channelized flow in these areas has produced periods of unusually high salinity ($>$ 40ppt) in inshore areas when no water is released from the canals, followed by periods of very low salinity when large volumes of freshwater are discharged from the canals. During dry periods, salinities near the shore increase, and these areas are colonized by marine species. Rapid reduction in salinities occurs when freshwater is discharged from the canals and destroys the marine communities, and yet these discharges are not constant or extended long enough to provide an estuarine habitat.

Restoration of natural hydroperiods in the coastal areas could be used to establish conditions that reflect the natural salinity structure and hydroperiod of the system. A more natural hydroperiod would provide for a seasonal reduction in salinity during the wet season to support brackish or freshwater habitats that are necessary for the early life stages of marine and estuarine organisms and a seasonal rise in salinity during the dry season that would favor the growth and development of juvenile and adult marine organisms.

Management of freshwater inflows could be improved if efforts were made to a) minimize the impacts of freshwater discharges into North Bay, and b) redistribute the canal discharges into adjacent marshlands in South Bay to improve flushing and restore natural salinity gradients in the coastal marshes. Impacts of freshwater discharges in North Bay could be minimized by reducing the amount of water released through the canals, diverting more flow into the Miami River, and improving the flushing characteristics of the Bay (or preventing further restrictions to flushing), in the area where canal discharges occur, when possible. Due to the complex needs of water supply and flood control in Dade County there is not much capability to reduce freshwater flows to the Bay by storing additional water in the coastal canal system. However, a project has been proposed, in cooperation with Biscayne National Park, to redistribute canal discharges into South Bay. This project provides for diversion of water into a canal that runs parallel to the Bay and allowing water to overflow from the canal into coastal marshes and mangroves.

Habitat and Living Resources. The resource inventory section of this report identifies and describes the major communities within the Biscayne Bay watershed. These include submerged aquatic, coastal wetland and coastal upland communities.

Submerged Aquatic Habitats. The most productive submerged aquatic habitats in Biscayne Bay include seagrass, algal, and hard bottom communities. Seagrasses are the most abundant benthic habitats in Biscayne Bay and are often considered as the most productive environments. Macroalgal and hard bottom communities, however, may have species diversity values that are equal to or greater than diversity values of seagrass communities.

Hard bottom habitats are dominant in the central portion of south Biscayne Bay and thus are not directly affected by shoreline activities. The distribution of these habitats has generally been somewhat reduced in recent years as seagrasses have expanded to colonize areas that have shallow sediments. Seagrasses have also invaded areas that historically were primarily hard bottom areas to form mixed seagrass-hard bottom communities.

Algal communities dominate in some parts of the Bay. Red algae such as *Laurencia, Hypnea, Gracilaria* and *Acanthophora* occasionally form extensive mats and may compete with seagrasses in some areas. In other areas, brown algae such as *Dictyota,* green algae such as *Caulerpa* and the calcareous green algae, *Halimeda,* cover extensive areas of the Bay bottom (Metro-Dade County DERM, 1983). Numerous species of red, green and bluegreen algae colonize seagrass blades as epiphytes. Macroalgal communities appear to be relatively unstable and change seasonally in density and species composition. Shifts from seagrasses to macroalgae have been attributed to environmental stresses, such as the influx of nutrients and freshwater (Thorhaug, 1976).

Primary factors that limit the distribution of submerged aquatic habitats in Biscayne Bay are light penetration and substrate. Adequate light levels must reach bottom communities to support photosynthesis of seagrasses, macroalgae, and or the microalgae (zooxanthellae) that live in corals. Seagrass communities colonize areas with sufficient sediment depth, whereas hard bottom communities occur where the bottom has shallow sediment or exposed rock (Metro-Dade County Planning Department, 1986).

The effect of severe storms and hurricanes has been identified as a major threat to seagrasses. Studies of historical photographs of Biscayne Bay have shown that major hurricanes destroyed vast areas of seagrasses in the shallow waters of the Bay (Harlem, 1979; Wanless *et al.*, 1984). In many cases, seagrasses returned to the areas that were destroyed. In other cases, seagrasses that were lost during storms never returned. Biscayne Bay has had a large increase in the amount of seagrasses in recent years and this has been primarily attributed to the lack of major hurricanes.

Forces that impact submerged aquatic communities are primarily related to water quality and physical disturbance. The greatest persistent threat to survival of these communities is turbidity. Viable seagrass and hard bottom communities help to control turbidity by removing suspended materials from the water column. High levels of turbidity reduce light penetration and hence restrict photosynthesis. In addition, suspended particles clog the feeding and respiratory mechanisms of animals that comprise hard bottom communities.

Land development activities destroy submerged aquatic communities by the direct impacts of dredge and fill and by the indirect effects of polluted runoff and increased turbidity. In general, seagrasses will tend to colonize any areas that are suitable for their survival and will not survive, even if they are transplanted, in areas that are unsuitable. For this reason great care should be taken before seagrasses are removed under the pretext that they will be reestablished in another location. The best policy is to require that any proposed mitigation activities be successfully conducted prior to the removal of the original community.

Coastal Wetland Habitats. Coastal wetland habitats include mangroves and marshlands. Coastal wetland communities play important roles within the Bay ecosystem in shoreline stabilization, nutrient cycling, removal of suspended materials, as habitat, and as major components of the aquatic food chain.

Mangroves. An understanding of the composition and structure of mangrove communities will help to understand the variety of threats that are posed to these important and sensitive components of the Biscayne Bay ecosystem. Mangroves are widely distributed along the shoreline of Biscayne Bay. The major species of mangroves in Biscayne Bay and adjacent sounds are red (*Rhizophora mangle*), white (*Laguncularia racemosa*), black (*Avicennia germinans*), and buttonwood (*Conocarpus erecta*). Five forest types have been identified for south Florida by Snedaker and Pool (1973) and Lugo and Snedaker (1974) as follows:

Basin Forests are strand-like formations that occur along inland terrestrial drainages. Basin forests are often exposed to fresh or brackish waters for long periods during the year but are occasionally flushed with high salinity waters. These forests are characterized by the presence of epiphytic flora and are often associated with other trees.

Riverine Forests occur on flood plains of major river drainages. Salinity may fluctuate widely depending on rainfall. These forests are flushed by the rise and fall

of the tide. Velocity of flow is low with little apparent redistribution of litter and organic export consists primarily of the dissolved products of decomposition.

Fringe Forests occur along the shorelines of the terrestrial mainland and the larger islands. Tidal water movement follows an "in-out" pattern which is with the rise and fall in water level. Flow velocities are small so that only small particulate matter and dissolved organic materials are exported from inside the fringe forests.

Overwash Forests occur on small islands and finger-like projections of the mainland. These forests are washed with every high tide. Velocities are high so that detritus, leaf litter and loose debris are moved into adjacent open waters and do not accumulate.

Dwarf Forests, are comprised of mature individual trees and occur primarily in Dade and Monroe counties as scattered stunted individuals. Mangroves are dominants or may be associated with other plant types. Upland drainage is not readily discernible. These forests occur in low areas and are inundated by tides and so possess a relatively low dissolved nutrient load.

Mangroves play a major role in nutrient cycling within the Bay as one portion of the ecosystem and food web that also includes upland communities, marshes, seagrass and algal communities, benthic infaunal assemblages, water column communities and nearshore and offshore reefs (Snedaker and Brook, 1976; Roman *et al.*, 1983). Burns (1976) gives a general definition of primary productivity as "The rate of storage of radiant energy in organic materials . . ." Together, communities of the Biscayne Bay ecosystem "fix" or capture radiant energy (sunlight) in the form of organic compounds and provide this energy throughout the system via diverse and complex interconnections (Snedaker and Brook, 1976; Roman *et al.*, 1983; Incze and Roman, 1983; Thayer *et al.*, 1987; Odum and Heald, 1972).

Mangrove productivity reaches the Bay in various forms, such as macro (nitrogen and phosphorus compounds) and micro (trace element) nutrients, dissolved organic matter, and particulate organic matter (Alongi, 1988; Camilleri and Ribi, 1986; Heald, 1971; Twilley *et al.*, 1986). These compounds are primarily transported into the Bay by one or more of the following mechanisms: a) overland runoff (rainfall and flushing); b) occasional storm or frontal system tides (in fringing and coastal areas); c) normal tidal flushing; and d) various mechanical processes such as wind or biotic transport (Twilley *et al.*, 1986; Snedaker, 1982; Odum and Heald, 1972; Teas, 1976; Robertson, 1988; Camilleri and Ribi, 1986; Roman *et al*, 1983).

In most areas of the Bay, much of the productivity that would normally be available from the mangrove communities has been lost or diverted. Removal of back or non-fringing forests, primarily black (*A. germinans*) and white (*L. racemosa*) mangroves, decouples and/or eliminates the productivity from these portions of the ecosystem. In addition, impoundment of the mangroves as a means of mosquito control and diversion of overland runoff into channelized flow, eliminates or reduces the remaining productivity, that would otherwise be available to the Bay.

Red mangrove fringe forests serve as habitat for invertebrates, juvenile fishes, and small fish that serve as food for larger species (Thayer *et al.*, 1987). Upland areas of black and white mangroves provide a source of dissolved nutrients, provide a filter for upland runoff, and maintain the diversity necessary for the continued integrity of the system. In Biscayne Bay, mangrove habitat serves as breeding, feeding, and nursery grounds for wading and fishing birds, commercial and sport fishes, various invertebrates that are important in the food chain and to commercial fishing interests, and the American crocodile (Burns, 1976; Thayer *et al.*, 1987; Colby *et al.*, 1985; Snedaker and Brook, 1976; Smith *et al.*, 1950; P. Molar, personal

communication). In addition, mangroves protect the coast from the effects of hurricanes. Thayer *et al.* (1987) found that mangrove prop root habitats in Florida Bay were important to the life history of the grey snapper (*Lutjanus griseus*) and other species, and that 68% of the wet weight biomass of grey snappers was obtained from mangrove habitat.

Mangrove communities are affected by physical disturbances such as dredge and fill, pruning, and hurricanes. Most species of mangroves require some or most of the root system to be exposed to the air. Filling of mangrove areas above the root system with high BOD soils, or maintenance of high water levels that cover the entire root system are techniques that have been used by developers to kill mangroves (Teas *et al.*, 1976). Mangroves are temperature sensitive and are limited in their distribution by this factor (Teas, 1976). White mangroves are the most sensitive to cold temperatures, followed by red mangroves which are less cold sensitive, and then by black mangroves which are the most widely distributed mangrove species in Florida (Teas, 1976). This factor limits the northern range of the red mangrove along the east coast of Florida but does not affect this species within Biscayne Bay (Teas, 1976).

The most direct threat to mangrove communities of Biscayne Bay is land development activities along the shoreline and adjacent uplands.

> "The central issues in the loss of non-fringing coastal wetlands are water quality and biological diversity. In this southeast region of Florida, red mangrove fringe forests constitute maybe 10-20% of the total coastal wetland area. The other 80-90% consists of a large diversity of vegetated wetlands which perform most of the water quality maintenance functions and generate most of the dissolved organic matter of benefit to nearshore marine life. Under the present regulatory climate, however, all of these non-fringe forest mangrove wetland types are potentially subject to development with a concomitant loss of biological (i.e., functional) diversity." (S. Snedaker personal communication.)

Dade and Monroe counties contain areas of both mixed and dominant mangrove forests. Mangrove communities are necessary for the integrity of the coastal wetland system but are not adequately protected from development. It is much more cost effective for state and local governments to preserve these areas and their natural functions, rather than to institute costly treatment procedures such as retrofitting, water delivery, restoration of previously impacted or removed wetlands, flood control, and hurricane protection, to replace the functions of these natural systems.

Currently Dade County codes and FDER rules regulate trimming and some destruction of red, white and black mangroves. However destruction and removal of these communities still occur, due primarily to heavy development pressure. In addition, water tables have been lowered by development and sheet flow of freshwater from the uplands has been converted to channelized flows and the timing of these flows has been altered by the construction of canals and levees parallel to the coast. These changes have resulted in decreased integrity of mangrove ecosystems, decreased ability of these systems to filter pollutants, loss of nutrients to the Bay, loss of habitat, and the reduced ability of mangrove communities to further assimilate changes.

Marshlands. Prior to construction of the coastal canal system, marshes along the shore of Biscayne Bay were dominated by freshwater species. Fringe forests, currently dominated by mangroves, contained freshwater species prior to the artificial reduction of freshwater flow (Teas, 1976). The area westward of the mangrove fringe was dominated by juncus-distichlis (*Juncus roemerianus* and *Distichlis spicata*) and then sawgrass (*Cladium jamaicensis*) marshes (Teas, 1976). Many freshwater plants still persist in coastal marshes, due perhaps to seepage of groundwater from the Biscayne Aquifer. In other areas, however, the coastal canals and levees have cut off the flow of freshwater and saline vegetation has replaced the freshwater plants (Teas, 1976). In some areas, especially in South Bay and Card Sound, the flow of freshwater, combined with poor tidal exchange has created hypersaline soils that can maintain little vegetation with the exception of stunted mangroves. Saltmarshes are not abundant in Biscayne Bay, probably because these communities tend to be invaded by mangroves. Growth of mangroves eventually shades out and eliminates the understory of marsh vegetation.

Coastal Upland Habitats. The role of coastal upland communities in protection of the resources of Biscayne Bay is generally not appreciated. The pinelands, oak hammocks and tropical hammocks of South Florida are unique natural resources in their own right that support a wide variety of rare and unusual plant and animal species. Coastal upland communities provide protection to the wetland marshes and forests by filtering and reducing the velocity of runoff water before it enters the wetlands and the Bay. Many of these areas also recharge the shallow aquifer system that provides groundwater flow into the Bay.

Because coastal upland habitats occupy upland environments that are deemed most suitable for development, they comprise what is probably the most endangered natural habitats in South Florida. Few, if any, attempts are made to mitigate the loss of upland coastal communities. The functions that are provided by these communities are replaced, often at substantial cost, by properly-designed and maintained stormwater management systems that allow adequate on-site retention or the use of swales and ponds to improve water quality and provide recharge.

Restoration and Mitigation. Proposed restoration or mitigation sites should be carefully selected in advance for suitability based on substrate characteristics, water quality and other factors, including reasons why that plant community does not occur naturally at the proposed mitigation site. Because restoration or mitigation efforts are expensive, will often not be entirely successful, and because the newly created habitats will probably not be as productive as the habitats that are destroyed, mitigation should only be used as a last resort, when all other remedies have failed. The mitigation project should be established, monitored for 1-2 years, and shown to be effective before the original habitat is altered. Although this "up-front" mitigation is recommended due to the inadequacy of replacing healthy natural vegetation with with plantings, it is not currently required under established mitigation procedures.

Restoration efforts should be limited to areas and methods where success is most likely. Planting of mangroves in properly prepared and stabilized substrate and planting of marsh vegetation has been proven to be effective when the planting and maintenance are properly designed and supervised. Areas that are best suited to freshwater or saltwater marsh replanting or to mangrove planting should be identified within the watershed and efforts made to initiate these projects.

Seagrass Restoration. Planting of seagrasses is not generally effective as indicated by the following information from the Biscayne Bay Aquatic Preserve Management Plan report (Metro-Dade County Planning Department, 1986). "In October 1980, the Corps of Engineers issued a dredge and fill permit for expansion of the Port of Miami facilities. As a special permit condition the Seaport was required to plant 251 acres of bay bottom with seagrasses to mitigate for damages to 81 acres of grass beds. About $2,000,000 was allocated for the seagrass planting and monitoring. Between January and October 1982, 25 acres near Mercy Hospital and 13 one-acre test plots were planted. Survival rates were measured about a year after the initial plantings. In 43% of the subplots, the degree of survival was rated as a total loss (Connell and Associates, 1983). Of those that survived, *Thalassia* shoots had the highest rate of survival (63%), followed by *Halodule* shoots (46%) and *Syringodium* (9%). *Halodule* plugs which were planted in six subplots had a 24% survival rate. The highest rates of survival were observed in Units III and VI. Poor rates of survival were observed in Units II, VII and VIII. The rate of survival in the 25 acre planting off Mercy Hospital was extremely low. The overall survival rate for Phase I was about 12%."

"A second phase of planting was done, primarily at a location in Unit IV, which had shown good survival rates in Phase I. At this location 15 acres of *Halodule* shoots and 5 acres of *Thalassia* shoots were planted during the summer of 1984. An additional 1.6 acres were planted in the same general vicinity to mitigate for seagrass beds that were eliminated by construction of the Rickenbacker Causeway and the Homestead Bayfront Marina. About a year later, a 70-80% survival was noted for the *Thalassia* and 30-50% survival was observed for the *Halodule*."

"In the summer of 1985, seagrasses that would have been destroyed by the Key Biscayne Beach Restoration project were planted in 73 acres at the Mercy hospital site, using six-inch 'plugs' of uprooted seagrasses. The following spring the survival rate was observed to be about 50%. Monitoring during the late summer revealed that the survival rate had actually declined to 10% after one year" (Metro-Dade County Planning Department, 1986).

A better strategy to improve bottom communities in the Bay may be to improve turbidity and other water quality conditions, if these are determined to be limiting factors. If appropriate bottom conditions exist or can be established, and a vegetative source is available, these communities should naturally colonize the area. This approach has been effective with hard bottom communities. Communities of corals, sponges and a large variety of fishes and invertebrates colonize areas where hard substrate is provided in the form of artificial reefs.

Wetland Restoration. Dade County DERM has had success with planting saltmarsh vegetation, especially *Spartina*, as a means to stabilize shorelines. This vegetation tends to become invaded by mangroves which provide additional shoreline stability. Some restoration techniques for freshwater wetlands have been successful in other areas of the state.

Mangrove Restoration. The value of mangroves in estuarine systems has been well documented. Therefore, since 1980, mangrove planting has generally been required whenever mangroves have been destroyed as a result of coastal construction activities. Between June, 1980 and October, 1985 mangrove planting was required as a condition of a number of coastal construction permits. A study of past mangrove planting projects revealed that most such efforts were unsuccessful due to

improper substrate, inadequate protection, and failure to plant at proper elevations (Metro-Dade County DERM, 1983). More recently, mangroves have been successfully planted along the Sunny Isles and 79th Street Causeways with a first year survival rate of better than 75 percent. Recent experiences with pruning of mangrove forests have resulted in County ordinances regulating cutting or trimming of coastal red mangroves. In one instance, over 100 mangroves were killed as a result of improper techniques and inadequate monitoring during an experimental pruning study (Metro-Dade County Planning Department, 1986). DERM has successfully used *Spartina* in combination with mangrove planting and in areas where there is a mangrove seed source as a successful method of stabilizing sediments for mangrove colonization.

2. Preservation.

Preservation is discussed in this section as a Bay-wide strategy. In addition, preservation of certain resources of the Bay is also discussed in the endangered species section of this report and in the sections that deal with individual management areas within the Bay.

Preservation is required in areas of Biscayne Bay that have unique water quality and environmental values, and is recommended for most remaining natural habitats within the ecosystem as a means to protect the quality of Bay resources. Many of these areas are partially protected within one or more state and federal facilities or programs, such as national parks, state parks, aquatic preserves, Outstanding Florida Waters, etc. Some of these areas may benefit by additional protection. Other areas that are not currently protected by these means should become candidates to receive protection or preservation.

Management of the natural communities of Biscayne Bay should focus primarily on protection and preservation efforts. Preservation of threatened habitats should not be limited to seagrasses and red mangroves but should include all types of submerged and coastal plant and animal communities. Shoreline and submerged communities are perhaps the most fragile of the communities considered, but natural upland plant communities are the most threatened. Successful protection of these resource requires first an inventory of the distribution and condition of existing natural communities. DERM has prepared such an inventory of bottom communities in the Bay and an inventory of most shoreline and upland communities based on aerial photography and ground truthing. Existing land use data for Dade County provides another good basis to begin such an inventory. The best areas for preservation, as well as areas suitable for restoration have been identified. These areas should now be prioritized for acquisition and for restoration projects, based on the results of this inventory. All maps and related data should be computerized, interfaced with existing inventories such as the natural heritage program and Florida Game and Freshwater Fish Commission inventories of animals and other biotic resources. Maps and other data should be continually updated as part of a state wide effort to provide a data base of biotic resources.

Various resource preservation projects may be initiated within Biscayne Bay, once appropriate areas have been identified. Many of these areas are currently in good condition but are threatened by encroaching development or by water quality degradation from surrounding areas. Preservation strategies should not only consider the identification and management of areas that are of most critical importance, but also the delineation and identification of appropriate management

practices for protective buffer zones. High priority for preservation should be placed on the following areas:

1. The Dade County Comprehensive plan coastal element identified a number of mangrove areas within the Bay that are suitable for preservation as follows: 1) Oleta River State Recreation Area; 2) Haulover Park; 3) Bird Key; 4) Near shore islands and northwestern shoreline of Virginia Key; 5) The western shore of Key Biscayne; 6) Bear Cut shoreline; 7) The Cocoplum Mangrove Preserve; 8) Matheson Hammock Park; 9) Snapper Creek Preserve (former ITT property); 10) Chapman Field Park; 11) The Deering Estate and Chicken Key; 12) Paradise Point south shoreline; 13) Coastal mangrove and scrub forests within and adjacent to Biscayne National Park; and 14) Coastal Mangrove and scrub forest adjacent to Card Sound.

2. Natural areas adjacent to Barnes Sound and Card Sound that provide habitat for threatened and endangered species

3 Upland areas adjacent to Biscayne National Park that are necessary to protect the Park from the effects of groundwater seepage and runoff from upland land use practices.

4. The West Indian Hammock area of North Key Largo; remaining unpurchased areas should receive high priority for state and Federal purchase and this area should be preserved as a natural hammock area with a buffer zone recommend to prevent natural habitat degradation due to encroaching heavy development.

3. Public Awareness.

Some public information and awareness programs concerning Biscayne Bay that are currently underway include the following:

- Dade County has undertaken many programs, over the years, to provide the public with information concerning Biscayne Bay resources and Management., including special publications, brochures, reports, seminars, public meetings and sponsored events such as "Baynanza."

- The Dade County Public School system has incorporated studies concerning Biscayne Bay into the public school curriculum for elementary and secondary education.

- Biscayne National Park has an active program of public awareness and information in cooperation with school systems and produces and distributes a number of publications concerning resources and management of the Park.

- The University Of Miami Rosenstiel School of Marine and Atmospheric Sciences also has numerous reports and publications concerning the Bay and related public information and awareness programs.

- A number of private attractions and facilities such as Planet Ocean and the Miami Seaquarium emphasize the resources and features of Biscayne Bay and help public understanding of Bay resources and management.

Most of these efforts, however do not place emphasis on water quality problems in the Bay and the role of the public in managing these problems. A public awareness program is needed to specifically address SWIM plans and management concerns. This program should provide multi-lingual materials in an effort to reach the large population of non english-speaking residents.

4. Commercial and Recreational Resources and Activities.

Marina Siting and Operating Criteria. The design and construction of marinas, boat yards and other water-dependent facilities are regulated by various federal, state and local entities such as DERM, FDER, SFWMD, USCOE and FDNR to ensure that the potential for contamination of the environment is minimized. Construction activities at these facilities are also occasionally monitored to ensure that they are built according to design specifications and that these activities do not cause environmental degradation. Currently some monitoring can be instituted by allowing construction in phases and requiring monitoring during this time. However, once the construction phase is completed, no provisions have been made for continued monitoring to determine whether these facilities are operated and maintained according to design specifications or whether that the original design criteria were adequate or appropriate for long-term management.

Metro-Dade county DERM information indicates that marinas, boat yards and other water-dependent facilities are persistent sources of pollutants to Biscayne Bay, including metals, hydrocarbons and raw sewage contamination. It is not clear from the available data whether these problems are entirely due to improper operation and maintenance procedures or whether they are due to improper design that could be improved in future construction. The integrity of the aquatic resources of the Bay can best be maintained and protected by instituting operating permits for many of these facilities.

Codes and rules associated with the permitting of these types of facilities should be revised to institute operating standards and require water quality monitoring to assure that the specified design conditions are met and that the facility does not have adverse effects on water quality. These monitoring provisions should also apply to currently operating facilities to characterize their contaminant contribution and find acceptable methods to abate these identified problems. The Deep Ports Rule FC 17.45 may be a possible method to address part of this problem and/or this rule may be revised to consider this issue.

Monitoring of facilities should include water quality and sediment sampling, and on site inspection of upland surface water management facilities, pump-out facilities, fuel handling procedures and equipment and solid waste disposal. Data indicates that liveaboards in various areas of Biscayne Bay may be responsible for elevated levels of sewage in parts of the Bay (McCorquodale, 1986), but even marinas with no liveaboards occasionally have high levels of these contaminants.

B. Problems and Resources Specific to Defined Areas

Analysis of the problems and issues that are specific to defined areas should also consider the general need to restore, or improve conditions that are currently undesirable and the need to preserve and protect features that are still in good condition. These considerations are addressed in the following section of the report for each of the major segments of Biscayne Bay.

1. Dumfoundling Bay.

Dumfoundling Bay was historically a brackish to freshwater system, bordered by mangrove wetlands, and subject to those processes that act on Lagoonal-Barrier Island complexes (Harlem, 1979). In 1925, the local population decided to open a connection with ocean in this area to relieve stagnant conditions resulting from raw sewage contamination (Harlem, 1979). This opening is now known as Bakers Haulover Inlet. Creation of this inlet drastically altered the freshwater-brackish water system that occurred prior to that time.

Condition and Problems. Currently, salinities are lower in this area than in most other portions of the Bay, but are much higher than salinities that occurred prior to opening the inlet. Backflow from Bakers Haulover inlet occurs during certain tides and acts to hold freshwater and any associated contaminants in this area (Metro-Dade County Department of Environmental Resources Management [DERM] unpublished data). Turbidity is low in this section however this water is naturally colored and so is perceived as not clean. Dumfoundling Bay is subjected to runoff from heavily urbanized and industrialized areas. Old landfills, particularly the Munisport Landfill that is currently on the EPA superfund list, are located in this drainage basin. Dumfoundling Bay is in need of restoration and requires intensive study. This area should receive attention under the revised monitoring program.

Tributaries. Snake Creek, Maule Lake and the Oleta River form a complex of tributaries that empties into the Dumfoundling Bay unit. Snake Creek carries freshwater flow from the water management system and associated urban stormwater runoff. This complex has problems that are just being defined by the Dade County DERM, including stagnant areas in blind finger canals, sewage contamination, low dissolved oxygen values, and anthropogenic contamination. In 1985, a study that was funded by the U.S. Army, Corps of Engineers (USACOE), examined oysters in this area for organic pollutants, pesticides and metals. This study found levels of PCB's, DDT metabolites and various metals that indicated that this area was significantly contaminated (Metro-Dade County Planning Department, 1986). In addition, sediments from the junction of Snake Creek Canal and the Oleta River had 242.85 ppm of total aromatic hydrocarbons, which included 0.29 ppm naphthalene, 7.68 ppm phenanthrene, 47.92 ppm dibenzothiophene, and 22.91 ppm pyrene (Corcoran *et al.*, 1983). Dibenzothiophene is usually derived from petrogenic contamination. These observed levels indicate that a direct source of this material probably occurs in the immediate area (Corcoran *et al.*, 1983; Hale, personal communication). An evaluation of sediments in this area to determine the extent of this contamination should include mass spectral verification and quantification of dibenzothiophene, since this compound has a similar gas chromatographic retention time to fluoranthene, a more common PAH that is generally found with the rest of the suite of compounds that have been identified from this area (Hale, personal communication). These tributaries have not been

intensively studied and should be examined in more detail under the revised monitoring program.

2. North Bay

North Bay extends from the south end of Dumfoundling Bay to the North side of Rickenbacker Causeway and includes four tributary sub-basins as follows: Arch Creek, Little River, Biscayne/C-8 Canal and the Miami River. Arch Creek, Little River, and C-8 Canal will be discussed in this section of the report. The Miami River is included as a separate section. This discussion provides more detail on areas that have not been specifically identified in other evaluations of water quality and the health of the Bay. More detailed discussions of the general problems of North Bay and other areas are provided in reports by Dade County (1986; 1988); and DERM (1985; 1987). With the exception of a few remaining tracts of natural shoreline, North Bay is in need of restoration rather than preservation.

Conditions and Problems. The Aquatic Preserve Management Plan divided North Bay into seven management units as follows:

Unit I	Sunny Isles to just south of the Oleta River (excluding the Oleta River)
Unit II	Broad Causeway to 79th St. Causeway
Unit III	79th St. Causeway to Julia Tuttle Causeway
Unit IV	Julia Tuttle Causeway to Venetian Causeway
Unit V	Venetian Causeway to MacArthur Causeway
Unit VI	MacArthur Causeway to the Port of Miami
Unit VII	Port of Miami to Rickenbacker Causeway

Turbidity has been identified as a major problem in North Bay. High levels of turbidity limit light transmission to benthic communities and severely restrict the growth of seagrasses which are an important community for the health of the Bay. Three primary sources of turbidity have been identified in North Bay as follows: a) the scouring of unstabilized shorelines by wave action, b) transport of fine sediment into the Bay through the inlets from ocean beach renourishment projects, and c) deep holes and dredged areas that become repositories for sediment fines and high organic content muds. Unstabilized shorelines are created when spoil islands are constructed during maintenance dredging operations of the navigational channels. Heavy boat traffic in North Bay contributes to this problem due to the effects of wake action. Vertically bulkheaded shorelines that have no wave attenuating characteristics and so act to reflect and maintain wave energy. Increased wave energy erodes the unstable shorelines by wave action and increases resuspension of bottom sediments.

Although results of monitoring studies have shown that 96% of all samples showed phthalate acid ester (PAE) contamination, selected samples of sediments in North Bay have much greater than background amounts of PAE's. The significance of this contamination is unknown. However, in most areas of the Bay the distribution of contaminated samples suggests a wide-spread, non-point source. These compounds have various degrees of toxicity and they are known to be mutagenic. The source and consequences of increases in PAE levels above background should be examined. In addition, sediments from various portions of North Bay contain chemical compounds that may reflect input from marine repair/storage facilities, marinas or ports, leachate from landfills, and runoff from unknown sources. Efforts will be made, in conjunction with DERM, to identify these sources in finer detail during the coming year.

A major feature of North Bay, and a potential source of water quality and environmental problems, is the Port of Miami. Commercial shipping activities pose a threat due the possibilities of chemical and fuel spills. Use of antifouling paints on ships pose additional problems. The area around the Port of Miami should continue to be monitored for various chemicals in sediments and in the water column, including trace metals, organotin compounds, petrogenic and pyrogenic organic compounds, and various other organic and inorganic chemicals that may be associated with shipping activities.

The proposed dredging of the Miami River by the USACOE may have severe adverse effects on North Biscayne Bay. However, the Corps has not finished evaluation of this project. Dredged spoil material from the Miami River may contain toxic materials that cannot be safely disposed of in the Bay or offshore. The dredging process mixes sediments and water. Toxic materials are released from the sediments, dispersed into the water and change chemically to forms that can readily be absorbed by living organisms. The dewatering process would thus release highly toxic materials into the water column, including metals and organic pollutants, that are currently bound in the sediments. These materials can be distributed by organisms and by circulation throughout North Bay. Dewatering was not adequately addressed in the USACOE study.

Although the passage of large ships through the River resuspends some portion of the channel sediments on a daily basis, large scale dredging will disturb many areas of the River that otherwise would not have been affected by the passage of ships. This may release chemicals into the water column that otherwise would have remained in the sediments. Any dredging of the River must use adequate methods to contain, treat and dispose of both the sediments and dewatering waste. A small scale demonstration project on a small portion of the River may be advisable to provide preliminary indication of problems that may occur.

The USACOE has proposed ocean disposal of dredged material from the Miami River as one alternative. This is the least expensive option, but offshore disposal of contaminated sediments may be environmentally unacceptable, since this only moves the problem into offshore environments. Land disposal or incineration were other alternatives. Land disposal could be very expensive and will depend on locating a safe site where chemicals and saltwater will not affect the shallow aquifer. Incineration would be a more environmentally sound option depending on requirements for air quality prior to atmospheric release. Currently, methods are being evaluated by the National Research Council of the National Science Foundation to determine the most acceptable methods for dealing with contaminated marine sediments (C. Chien, National Research Council, personal communication). The outcome of this evaluation is expected to provide direction to aid in the proper assessment of the Miami River dredging problem.

The District supports the continued evaluation of the feasibility of environmentally sound removal and disposal of the sediments and dewatering from the Miami River. However, the District agrees with the USACOE assessment that all inputs of contaminants to the River, including point and non-point discharges as well as non-point sewage contamination, must be removed for dredging to cause any significant long-term improvement in water or sediment quality.

The Miami River and Little River have been identified as sources of sewage contamination to North Bay. Coliform counts indicate that this pollution is

generally localized near river mouths and tributary outlets. Sewage contamination from Miami River, Little River and other sources may prove to be more widespread in North Bay as better methods are developed to detect such pollution in salt water. Contamination of the Bay by raw sewage has severe human health implications. The degree of contamination and potential human health impacts from pathogenic organisms in the Bay could be evaluated using serological methods to detect specific pathogens. Such data, documenting the severity of the problem, would lend additional support for local efforts to obtain state or federal funding to upgrade the sanitary sewer system.

Increased amounts of phytoplankton occur near the mouths of canals and Rivers in North Bay due to the influx of nutrients from upland areas. Studies indicate that phosphorus is apparently the limiting nutrient (Brand, 1988). These canals also contribute colored water to the Bay due to the presence of organic materials. Colored water is a natural phenomenon associated with the input of organic nutrient materials, and should not be mistaken for "bad" water quality. Color affects the wavelengths of light that penetrate the water column. Localized effects of colored water should be evaluated on a site-specific basis to determine impacts on the composition of benthic communities.

Management Unit II is the section of the Bay that extends from Broad Causeway south to the 79th St. Causeway. This section is the nodal point between the Government Cut and Bakers Haulover Inlets and has generally poor circulation, flushing and exchange characteristics (van de Kreeke and Wang, 1984). Water quality in this section of the Bay is generally worse than other areas with relatively high persistent levels of turbidity, low levels of dissolved oxygen, and occasional high levels of nitrogen (Alleman, 1987). Only 8% of the bottom in this section of the Bay is covered with vegetation (Metro-Dade County Planning Department, 1986).

The section of the Bay (Unit III) that lies between the 79th St Causeway and the Julia Tuttle Causeway contains several unique environmental resources.. Although ninety percent of the 23.3 linear miles of shoreline in this section of the Bay is vertically bulkheaded, water quality in the majority of this unit is extremely good. This area contains the largest and healthiest grassbed in North Bay and Bird Key (Metro-Dade County DERM, 1986). Bird Key supports one of the largest pelican rookeries found along the southeastern coast of Florida (Wattendorf, personal communication). The grassbed found in this area is primarily composed of *Syringodium* and covers most of the submerged portion of this unit and rivals pristine areas of South Bay for productivity and numbers of organisms (Metro-Dade County DERM, 1986). This area represents an important healthy and diverse habitat for the entire Bay and is particularly important to North Bay. It is extremely important that the habitats found within this unit be protected. Activities in this section of the Bay should be closely reviewed to restrict or prevent any construction, dredging, or development that may impact this grassbed community, the rookery, or adjacent healthy habitats .

Tributaries. Tributaries that flow into North Bay are Arch Creek, Little River and Biscayne (C-8) Canal. The Miami River also discharges into North Bay, but is discussed in a separate section of this report.

Arch Creek. North and South Arch Creek are tributaries to North Biscayne Bay that empty into Unit I. Arch Creek, North and South tributaries have higher than background levels of various phthalates, and may also receive leachate from landfills and input from industrial and marine repair sources (Metro-Dade

County DERM, 1985; Florida Department of Environmental Regulation, 1985). Arch Creek and Black Creek had the highest mean concentrations of ammonia for the years 1984-85 (Metro-Dade County DERM, 1987). Surface sediments in North Arch Creek had 19 ppb chromium, 45 ppb copper, 0.9 ppb mercury and 36 ppb zinc (Metro-Dade County Planning Department, 1986). In the Biscayne Bay system, higher levels of these compounds are only known to occur in the Miami River.

Little River. The Little River has a history of poor water quality and shows high levels of various metals, nutrients, and coliform bacteria (Corcoran et al., 1983; McCorquodale, 1986; Pierce and Brown, 1986; and Ryan, 1986). The Little River may exhibit the effects of previous land uses in the basin. Contaminants from these unknown sites may still be leaching into the river. In Dade County, the highly permeable nature of the shallow aquifer results in free exchange between surface and ground water so that contaminants in either system are more mobile than would otherwise be expected (Klein and Hull, 1978).

The Little River showed higher than average monthly concentrations of nitrate/nitrite nitrogen for the years 1984-85 (Metro-Dade County DERM, 1987). Little River also had the second highest levels of lead (just below levels in the Miami River) during the period 1984-85 with concentrations of 6 ppb (Metro-Dade County DERM, 1987). The poorest water quality for all years sampled (1979-83) occurred at the mouth of the Little River. This area had high nutrients, low water clarity, and trace metals were consistently detected in the water column (Metro-Dade County DERM, 1985). This area also had persistent sewage contamination problems (McCorquodale, 1986), which are believed to originate, in part, from liveaboard boats, leaky sewer lines, and unknown sources (Alleman, personal communication). Turbidity levels are elevated in this area and in the portion of the Bay that is influenced by river water (Metro-Dade County DERM, 1985), perhaps due to resuspension of sediments from boat wakes or the presence of phytoplankton.

The Little River contained measurable pyrogenic and petrogenic contamination in sediments (Corcoran *et al.*, 1983). These samples contained the aromatic hydrocarbons dibenzothiophene and phenanthrene at levels of 0.08 and 0.04 ppm, respectively, at one station and pyrene at levels of 0.08 ppm and 0.01 ppm from two different stations (Corcoran *et al.*, 1983). All surface sediments from the Little River contained measurable concentrations of aromatic hydrocarbons that ranged from 2.13 ppm to 16.2 ppm (Corcoran *et al.*, 1983). Sediments from the north fork of the Little River contained petroleum contaminants. However, coring at this site showed that contamination only occurred in surface sediments (Corcoran *et al.*, 1983). By comparison, background levels for the total aromatic hydrocarbon fraction in Chesapeake Bay sediments is thought to be 1-2 ppm (Hale, personal communication). Higher levels, in combination with ppm concentrations of individual compounds, may indicate a nearby, persistent source of contamination. Two samples in the Little River show this pattern. Sample 223 had a total aromatic fraction of 16.2 ppm and a pyrene concentration of 2.5 ppm. Sample 229, located upstream, had a total aromatic fraction of 8.44 ppm and 480 ppb dibenzothiophene (Corcoran *et al.*, 1983). Sample 223, from the mouth of the river is more indicative of pyrogenic contamination, while sample 229 is more indicative of petrogenic contamination. Concentrations in the Little River of the pesticides Endosulfan and DDT were 1014.3 ppb and 52.7 ppb, respectively (Metro-Dade County Planning Department, 1986).

Biscayne (C-8) Canal. Biscayne Canal has not been well studied and is currently being included as part of the tributary sampling program that is being

initiated for the SFWMD by DERM. Data for this area will be examined as it becomes available. The nature of land uses in the drainage area indicates that it likely falls under the same pressures that impact the Little River, Arch Creek and Dumfoundling Bay. Preliminary studies indicate that this canal occasionally has high levels of coliform bacteria

3. South Bay

South Bay includes the area from the Rickenbacker Causeway south to the Arsenicker Keys. This section of the Bay is divided into two units. Central Bay extends from Rickenbacker Causeway south to a line that extends across the Bay between Goulds Canal and Sands Key. "South Bay Proper" includes the area from the Goulds Canal south to the Arsenicker Keys.

Condition and Problems. South Bay is generally better flushed and has less input of runoff from urban and industrial land uses than North Bay. South Bay has healthy seagrasses and other bottom communities, is generally considered to be in good condition, and needs protection rather than restoration. Tidal volumes are high and tidal flushing helps maintain the health of the system. Salinities are generally 32-35 ppt but are mediated by canal input along the western banks. Canals provide a source of nutrient enrichment and pesticide contamination from agricultural runoff; contribute unnatural, localized inflows of freshwater at various times during the year in response to storm events and water management practices; and transport organic and trace metal pollutants from inland urban, industrial, military, and agricultural sites into this portion of the Bay. Problems that have been identified in South Bay include the following:

a) Interruption of sheet flow of fresh water to the wetland fringe that serves as nursery habitat for organisms that live in Bay and offshore communities.
b) Impacts of propeller scouring on bottom communities in shallow areas .
c) Monitoring has shown that toxic metals are present in various portions of the area. New (1987) monitoring data indicates that high concentrations of Arsenic occur in and around Key Biscayne and in areas of South Bay that would otherwise be considered pristine. This contamination may have resulted from a variety of historic sources including past use of this metal in agriculture, or the use of sodium arsenate to control aquatic weeds.
d) The adverse effects of further development on the healthy biotic communities of Central and South Bay that may result from the removal of wetland or upland communities from behind the red mangrove fringe (S. Snedaker, personal communication).
e) Impacts of nutrient enrichment from agricultural runoff and impacts of unnatural amounts and timing of freshwater releases from canals.

South Bay has vast seagrass beds and healthy marine and estuarine communities. These communities are fragile and depend on good water quality, adequate light penetration into the water column, and inputs from healthy upland systems to maintain their integrity. Management of South Bay should attempt to avoid the damage and mistakes that have occurred in North Biscayne Bay and to preserve as much of this area as possible in a pristine condition. In addition, the function of this area as a nursery for estuarine and marine organisms should be preserved and enhanced. Redirection of freshwater flow, when possible, through mangrove and wetland fringe will enhance this function and restore part of the natural action of the coastal communities and their links with the marine portions of the Biscayne Bay ecosystem.

Future management activities in South Bay should consider the preservation and restoration of the coastal tree communities and wetlands that are integrally tied to the estuarine/marine environment. Preservation and restoration of these resources may, in turn, require such actions as a) limiting development in the southern regions of the Bay, b) restoring or protecting mangroves and other communities that function together to form a healthy wetland fringe, and c) providing adequate freshwater flow that is timed and distributed in a natural manner. Other preservation methods for this area may involve the establishment of no wake zones, restricted access areas, or other measures to limit the damages to seagrass beds that occur from boat propellers.

Tributaries. The major tributaries that discharge into Central Biscayne Bay include the Coral Gables Waterway, Lago Minore, Snapper Creek Canal, C-100, and Black Creek-Goulds Canal. Major tributaries that discharge into South Bay proper are North Canal, Military Canal, Mowry Canal, Florida City Canal and C-102.

Some of the problems that have been attributed to these tributary basins are the unknown quantity and quality of runoff and other input from Homestead Air Force Base into Military Canal, and the possibility of leachate into the Bay from Black Point landfill and from the Black Point/Goulds Canal basin in general.

The U.S. Geological Survey has documented groundwater movement above the Q_3 unconformity of leachate from an unknown source in the area of Black Point (Shinn and Corcoran, 1987; Waller,1987). The Q_3 unconformity is a shallow geologic formation that prevents downward movement of groundwater flow (Shinn and Corcoran, 1987). Previous monitoring for leachate from Black Point used wells that extended below this zone and showed no leachate effects. Leachate may be moving from a variety of sources including older unlined landfills or older cells of the main landfill. Future evaluation of this problem should include placement of monitoring wells to determine the direction of the source and more detailed monitoring of contaminants to indicate the nature of the source. Support should be given to permitting of properly lined and treated new sections of the landfill at Black Point as well as the use of alternative processing facilities such as those found in Palm Beach County.

The existence, extent and types of problems that occur within South Bay and Central Bay will first be documented through the monitoring program and will later be addressed through special studies within target basins.

4. Extreme South Bay - Card Sound and Barnes Sound

Description. Card Sound and Barnes Sound are marine lagoons in the southernmost portion of Biscayne Bay that are threatened by a number of human activities. This area requires additional research to define management strategies and special efforts to protect their unique natural resources. Card Sound and Barnes Sound are bordered on the east by north Key Largo and old Rhodes Key and on the west by the southern portion of Dade County and northern Monroe County. Fresh water historically entered this system as overland sheet flow, aquifer outflow around tree islands and upwellings of fresh water from the aquifer (Harlem, 1979). Currently, freshwater inflow occurs primarily through the C-111 canal. Sheet flow occurred in this part of the Everglades in a southeasterly direction. The roadbed for

US Route 1 has no provisions to allow sheet flow and so serves as a levee that prevents overland flow into Barnes Sound.

The primary physical problems that occur in this area are due to reduced circulation and flushing which, in turn, result in periodic development of hypersaline conditions and water quality problems that alternate with extreme salinity decreases due to regulatory releases of freshwater. Card Sound and Barnes Sound also contain important and critical habitats for the survival of Florida populations of a number of threatened and endangered species. The C-111 basin has been identified as being utilized by the Cape sable seaside sparrow and Roseate spoonbills. The integrity of these habitats is threatened by land development, water flow changes and various activities in adjacent areas.

Reduced Circulation. Circulation and flushing in Card Sound and Barnes Sound are often severely reduced due to artificial diversion of freshwater sheet flow, artificial impoundments created by the system of bridges and causeways, and naturally reduced tidal flushing from the ocean. Tidal fluctuation in Card Sound is 22 cm (0.74 ft) and in Barnes sound is 12 cm (0.40ft) (Lee, 1975). Residence times for water are 2.3 months for Card Sound and 3.4 months for Barnes Sound (Lee, 1975).

Circulation and flushing characteristics of this area could be improved by removal or alteration of the causeway at the south end of Barnes Sound and the addition of culverts in the US 1 roadbed to facilitate sheet flow. Proposals have been made to construct channels across the north end of Key Largo from the Atlantic Ocean into Card Sound. Although, such channels may improve flushing, they would likely alter the natural circulation and adversely impact both the sounds and John Pennekamp State Park due to nutrients, pollutants, increased turbidity, and detritus that could potentially move through the system.

Hypersalinity and Altered Timing of Flow. Due to restricted circulation and freshwater flow, portions of these areas become hypersaline and may have salinities above 46 ppt during the dry season (Lee, 1975; Lee and Rooth, 1972). Hypersalinity occurs in the wetland fringe bordering these areas during the dry months of the year (Lee, 1975). Historically, this area was a nursery for many fish species and invertebrates (Bader and Roessler, 1972; Smith *et al.*, 1950; Roman *et al.*, 1983). Hypersaline conditions alternate with severe reductions in salinity due to high volume freshwater releases. Salinity levels may fluctuate from 35- 40 ppt during the dry season to 5-20 ppt during wet periods, depending on canal releases and rainfall, are not well tolerated by either marine or low salinity organisms. Hypersalinity and drastic salinity changes reduce the potential of this area to serve as a nursery and breeding habitat for coastal organisms (Zillioux, 1978). These rapid reductions in salinity, which may occur due to freshwater discharges, are destructive to marine communities, and yet do not occur frequently enough to support estuarine communities.

Methods that may be used to address salinity problems in this portion of the Bay include the review and possible alteration of structural features of the C-111 basin to reestablish sheet flow. In addition, the water delivery schedule for this canal should be reviewed to determine the feasibility of providing residual freshwater flow through the structure or adjacent wetland areas into Barnes Sound. Large volume, pulsed releases of freshwater have extremely detrimental impacts. To preserve this system, regulation of water levels in upland agricultural basins should not be the only factor that dictates the schedule for water deliveries into Barnes Sound. The environmental needs of his lagoon must also be considered. The SFWMD is currently conducting studies in Barnes Sound to review the water delivery schedule for the C-111 canal.

Water Quality. Long term water quality data are not available for Card Sound and Barnes Sound. Such data could indicate current conditions and provide a baseline for evaluating changes that may occur in the system. Results of preliminary water quality sampling by Dade County DERM in Card Sound indicate that fecal pollution may occur in this area (Metro-Dade County DERM, 1985; 1987). Sampling of organic contaminants showed that sediments in Card Sound contained one of the highest phthalate acid ester levels in the Bay (Corcoran *et al.*, 1984). These results should be further examined to determine the extents and sources of contamination.

Reduced circulation aggravates any natural or man-made water quality problems that may occur in Card Sound and Barnes Sound. Marina or shoreline development in this area potentially represent sources of severe water quality problems. Any contaminants that enter the system will have a high residence time. Nutrient enrichment of these naturally oligotrophic waters may also cause adverse shifts in biological communities. Currently, there are no pump out facilities for liveaboard boats in Key Largo. The presence of sewage contamination from this source is likely. However, assessment of this problem is hampered by the lack of effective monitoring methods for fecal contamination in saltwater.

Routine water quality monitoring should be initiated as soon as possible in Barnes Sound and Card Sound. This sampling program should include parameters such as total and fecal coliforms, biological oxygen demand, turbidity, salinity, dissolved oxygen, metals, pesticides, pyrogenic hydrocarbons and petrogenic hydrocarbons. Preliminary screening for organic contaminants should concentrate on sediments. Previous sampling efforts in Biscayne Bay, Chesapeake Bay and other areas have shown that these compounds are not generally found in the water column unless they are associated with a persistent point source of contamination (Corcoran *et al.*, 1983; Bieri *et al.*, 1986; Hale, personal communication). Metal sampling schedules should be determined after the results of an initial sampling set have been examined.

Environmental Resources. Areas bordering Card Sound and Barnes Sound and portions of southern Dade County have been designated by the federal government as critical habitat for the American crocodile, the West Indian manatee and the Everglades snail kite (Florida Natural Areas Inventory). Card and Barnes Sounds represent one third of all American crocodile nesting in the continental United States and thus contain an important portion of habitat for this endangered species in the Caribbean. The wetland and tropical hammock areas bordering these sounds contain the Schaus swallowtail butterfly, Key Largo wood rat, Key Largo cotton mouse, the Monroe County population of ospreys, and the eastern indigo snake, as well as endangered species of orchids and tree snails. This area also serves as habitat for wading birds that are listed as species of special concern on the state threatened and endangered species list.

The Conservation and Recreational Lands (CARL) fund report for this area lists the primary threats as dumping, poaching of native species, and planned development for multi-family housing communities. A significant tract of land on the Key Largo side of Card Sound is in private ownership and may eventually be developed by the Anglers Club, adjacent communities, or the Ocean Reef Resort (Conservation and Recreational Lands, 1987).

Card Sound is currently a lobster sanctuary and is, in part, protected as an area associated with the Biscayne Bay Aquatic Preserve and Biscayne National Park. The Biscayne Bay Aquatic Preserve includes Card Sound, but the current plan does

not address management needs for this area. Barnes Sound is located adjacent to Everglades National Park but is not included in any formal management plan. Most of the eastern shore of Barnes Sound is within the Crocodile Lake National Wildlife Refuge. Barnes Sound also abuts portions of the western edge of Pennekamp State Park and thus represents a buffer for the sensitive coral communities in that park.

Card Sound and Barnes Sound are extremely important areas within Biscayne Bay that require a through evaluation of resources and additional protection. Both Card and Barnes Sounds should be listed as Outstanding Florida Waters and designated as Aquatic Preserves or included within existing Aquatic Preserves. These areas could also be considered for inclusion in Everglades National Park or Biscayne National Park. Management plans should be developed to protect the resources of these sensitive areas.

5. Miami River

Historically, the Miami River originated in the Everglades, east of the Atlantic Coastal Ridge (Harlem, 1979). The Miami River is the largest of two major natural tributaries into North Biscayne Bay and was historically used as a waterway for commercial and marine commerce. Currently it has a SFWMD salinity control structure (S-26), at 36th Street, and water flow is partially regulated by SFWMD release schedules for the area. The upper portion of the River, now the Miami Canal, continues upstream from the salinity structure at 36th St. and enters the Water Conservation Areas. This western portion of the Canal drains highly urban areas, light industrial areas, and some areas that are primarily agricultural. The lower portion of the River (from 36th St. south to the river mouth) is characterized by low levels of dissolved oxygen, high levels of turbidity, and the presence of a salt wedge at the bottom of the canal that is overlaid by a freshwater lens. This section of the River drains the intensely urban/industrial area of downtown Miami.

The Miami River has a history of water quality problems due to the urbanization of Miami and the discharges of raw sewage that occurred into the River for many years (McNulty, 1970). The River was dredged to a depth of 15 feet (4.6 meters) under flood conditions. In 1909 the falls north (approximately 4 miles or 6.4 kilometers) of the river mouth were dynamited to allow for channelization and draining of the southeastern Everglades (Harlem, 1979; Metro-Dade County Planning Department, 1986).

Monitoring Programs and Results. Water quality monitoring by DERM has been in practice in Biscayne Bay since 1979, and stations have been sampled in the Miami River since 1984. The Miami River is consistently in violation of Dade County water quality standards for coliform bacteria (Metro-Dade County DERM, 1985). In addition, the water is turbid and has a low concentration of dissolved oxygen. Ambient turbidity ranges from 4.0 to 4.7 NTU at the mouth and is approximately 3 NTU in the rest of the River's surface waters (Metro-Dade County DERM, 1985). The bottom of the River receives no measurable light.

The Miami River has both chronic and acute management problems. Acute problems present immediate human health hazards, immediate impacts upon the receiving ecosystem, or occur as discrete events. Chronic problems do not present immediate human health hazards, but cause long term cumulative ecosystem damage, or occur constantly and act cumulatively or synergistically with other factors in the system and may cause major or extensive damage to the receiving system. Examples of acute problems are fecal coliform and associated viral or

pathogen contamination; freshwater pulses that have high levels of turbidity and nutrients and low levels of dissolved oxygen; and periodic phytoplankton blooms. Chronic problems include contamination with metals, polycyclic aromatic hydrocarbons (PAH), organic materials, petroleum products and byproducts, tributyltin (TBT), and high levels of biochemical oxygen demand (BOD).

Acute Problems. Acute problems in the Miami River are primarily related to continued high levels of sewage pollution and stormwater runoff (Metro-Dade County DERM, 1985). The Metro-Dade Water and Sewer Authority (WASA) and DERM have ongoing programs to assess these conditions. Stormwater runoff occurs from the drainage system that serves the highly urbanized area of downtown Miami. High levels of raw sewage pollution are attributed to the following causes: 1) interconnections of sanitary and stormwater sewers and overflows allow sewage to be carried directly into the river; 2) failed and aging sanitary sewer pipes allow waste to flow directly into stormwater sewers and into groundwater that ultimately moves into the River and the Bay; and 3) illegal flushing and dumping occurs from shipping interests and liveaboard boats.

Methods that have been suggested to rectify these problems include retrofitting of stormwater outfalls and upgrading the sewer system. The SFWMD as part of the SWIM program has initiated efforts in cooperation with the City of Miami to retrofit stormwater outfalls along the Miami River. Upgrade of the aging sanitary sewer system is a major public works project that should be funded by a regional bond issue, perhaps with state or federal assistance. This problem is beyond the scope of the SWIM plan except for the ability of this plan to point out potential effects on the population and the environment that can occur from continued contamination of marine and estuarine waters with raw sewage.

Problems resulting from this continued input of raw sewage into the Miami River include 1) health hazards from contact with the water; 2) hazards due to eating contaminated finfish and shellfish; and 3) environmental damage. Environmental damage can result from the effects of increased levels of nutrients and pollutants on species diversity, phytoplankton and turbidity. Increased nutrients also increase the biochemical oxygen demand (BOD) and lower the amount of dissolved oxygen in the water column that is available to fish and other living organisms. Pollutants include such chemicals as solvents, detergents, oil and grease, trace metals and organic compounds.

Significant health hazards are associated with the high level of sewage pollution in the Miami River. Sewage pollution has the potential to carry pathogenic bacterial and viral disease organisms. These organisms may survive better in the receiving waters of the River or the Bay than fecal coliform indicator organisms. For example, Schaiberger *et al.* (1982) assessed enterovirus movement from the offshore sewage outfall at Miami Beach and traced polio and echo viruses from this site, 2.25 miles (3.6 kilometers) back to Miami Beach.

To address these problems, HRS and Dade County health services should initiate studies to a) run serological tests on water from the river, determine the types of pathogens present and determine the relative concentration of potential pathogens that originate from sanitary sewer input; b) If pathogens are present, then methods should be designed to determine their residence time, survival, and ultimate fate in the system; and c) Examine the potential for human health hazards from fish that are caught in and around the Miami River and consider a possible ban on fishing in the River depending on the outcome of this work. DERM is continuing

to investigate the use of alternative, more reliable methods for determination of fecal wastes in salt water. The outcome of such studies may lend support for local government efforts to seek federal and state aid to refit the aging sanitary system.

Chronic Problems. Chronic problems in the Miami River include turbidity, metals, tributyltin, polycyclic aromatic hydrocarbons and other organic materials, the lack of adequate state water quality standards, illegal dumping of fish wastes and waste water that contains solvents, detergents, oil and grease, and turbidity.

Metal Pollution. Metal contamination occurs in both the sediments and water column of the Miami River. Sediments currently have no state standards for allowable metal concentrations. Metal concentrations in Miami River sediments are higher than occur in similar areas throughout the state and are higher than ambient Bay background concentrations for mercury (Hg), lead (Pb), chromium (Cr), copper (Cu), and silver (Ag). Potential impacts may include toxic effects on humans as the result of bioaccumulation in the food chain, direct effects on animal reproduction, and mortality within the ecosystem. Sources of these contaminants should be determined and the potential for human health and ecosystem impacts should be assessed. Standards for concentrations of metals in Biscayne Bay sediments should be developed, perhaps based on background levels that occur in both contaminated and uncontaminated areas of the Bay.

Tributyltin. Preliminary screening of the Miami River shows levels of tributyltin (TBT), in parts per trillion (pptr) of 29 pptr at N.W. 24th Avenue; 27 pptr at 11th Street; and 19 pptr at N.W. 21st Street. These levels are above the maximum USEPA recommended saltwater concentration of 10 pptr but fluctuate around the maximum recommended level of 26 pptr for fresh water (Hoehn, personal communication). The USEPA issued a paper entitled, "Ambient Aquatic Life Water Quality Advisories for Tributyltin," to provide necessary information on this subject quickly, because time did not allow the development of national water quality criteria. The effects of TBT on marine life are well documented and the threat that this chemical poses to Biscayne Bay should be recognized (Rexrode, 1987; Thain *et al.*, 1987; Wolniakowski *et al.*, 1987). Efforts should be made to develop a monitoring program and determine the presence of any known ecosystem effects of TBT.

Polycyclic Aromatic Hydrocarbons (PAH) and Other Organic Materials. Marine hydrocarbons are derived from three major sources: biogenic compounds are derived naturally, i.e. from organisms; pyrogenic compounds are generated by combustion; and petrogenic compounds occur due to uncombusted petroleum contamination (Corcoran *et al.*, 1983; La Flamme and Hites, 1978). The type of organic compound generally indicates the origin of contamination. Organic compounds that have been found in the Miami River sediments are listed in Table 8 and include a compilation of hydrocarbon work on sediments by Corcoran *et al.*, (1983) and Ryan *et al.* (1987). Organic contaminants were mostly found in the Port of Miami, but were also present in the sediments of the Miami River. Runoff may be the principal source for these contaminants. Runoff from different types of land uses has different contaminants. Higher nutrient loads tend to be associated with residential use, mixed commercial and urban, and roadways. Metal contamination is more closely related to commercial use or roadways. Limited information suggests that PAH loadings may occur from all land uses. Whalen and Cullum (1988) noted higher levels of PAH's at a heavy industrial site.

One way to control organic contamination of sediments is through stormwater retrofitting. Another method may be to regulate land use adjacent to the River. A

Table 8. Anthropogenic Organic Chemicals in Sediments and Water Column of the Miami River.

	SEDIMENTS	WATER COLUMN	REFERENCE
Naphthalene	X		1,2
Dibenzothiophene	X	X	1
Phenanthrene	X	X	1,2
1-Methylphenanthrene	X	X	1
Pyrene	X	X	1,2
Chrysene + Benzo(a)Anthracene	X	*	2
Benzo(bk) Fluoranthene	X	*	2
Fluoranthene	X	*	2
Dibenze(al)Anthracene	X		2
Acenaphthalene	X		2
Acenaphthylene	X		2
Aldrin	X		2
Chlordane	X		2
PCB's	X		2
DDT & DDE	X		2

1. Corcoran et al., 1983; 2. USACOE,1986; *Not Examined in USACOE Study

study conducted by the USACOE (1986), as the basis for a river sediment clean up project, concluded that certain land uses may be more compatible than others with the goals of clean water. Successful cleanup may require removing the sources of contamination or modifying these sources. Increased enforcement on the River and more stringent fines would aid in preventing impacts from marine docking, container shipping and marine repair facilities (USACOE, 1986).

In addition to long term sediment contamination, a series of events occurred at the Miami International Airport that have resulted in extensive local contamination of groundwater (Florida Department of Environmental Regulation, 1985; Baddour, 1983). The mobile nature of groundwater around Biscayne Bay means that these chemicals may be moving or leaching into surface waters of the River or the Bay. A description of the problem at the Miami International Airport and the status as of 1985 are found in Appendix I. Origins and probable fates of these materials should be determined in the Biscayne Bay system.

State Water Quality Requirements. The Miami River is currently listed as a Class IV water body and so falls under the agricultural/industrial water use category. Class IV water bodies have much less stringent state water quality standards than Class III water bodies, which is the classification that has been assigned to the remainder of Biscayne Bay. This discrepancy is inconsistent with the designation of the Miami River as part of the Aquatic Preserve Management Area (APMA). The APMA is, in turn listed as Outstanding Florida Waters. The state, Metro-Dade County, the City of Miami and perhaps the federal government are spending large sums of money to improve the water quality of the Miami River. However, if the standards that apply to the River are inadequate, the state will have no legal basis to protect water quality, even if cleanup efforts are successful. This inconsistency should be rectified by an FDER rule change. Currently, Metro-Dade DERM standards for water quality are higher than state standards for Class IV and Class III water bodies. The State should consider adoption of better water quality and sediment standards, for the River and for Biscayne Bay as a whole, that are more closely tied to the requirements of the living ecosystems that such standards are intended to protect. This is a critical issue in the Miami River and an important issue for the Bay area and the rest of the state.

Illegal Dumping of Fish Wastes. This practice by local businesses and fishermen should be discontinued because it contributes biochemical oxygen demand and increases microbial and nutrient problems in an already bad area. One focus of

the public information and awareness program should be to educate the public concerning the adverse impacts of this practice on the River and the Bay.

Chronic Turbidity Problems. The Miami River has highly turbid water that generally does not allow light to penetrate to the bottom of the River. Turbidity results, in part, from the resuspension of bottom sediments by container ships in the River. This condition severely stresses bottom communities in the River and is a major threat to adjacent areas of the Bay. The basis and management of turbidity problems are discussed in detail in other sections of this report.

C. Specific Requirements of the SWIM Legislation and DER Rule.

The SWIM Legislation (Ch 87-97. F.S.) and the FDER rule (Rule 17-43 F.A.C.) require that the water management districts consider specific types of information in the development of SWIM plans, including adjacent land uses and a review and listing of certain types of point and non-point sources of pollution. In addition, the SWIM plan must include schedules and timetables to achieve compliance, restoration and management.

1. Description of Adjacent Land Uses.

The SFWMD has developed an extensive land use/land cover data base for most of the 16-county region of south Florida. This mapped information has been digitized and entered into a Computervision Computer Assisted Design (CAD) system. The District has research efforts currently underway to relate the graphic information in the CAD system to other data bases with the goal of creating a comprehensive, District-wide geographic information system. Land use data for Dade County were initially acquired during the period from 1979 through 1981 by District staff. Portions of that land use data base were updated in 1981 and 1985 in response to special project needs. In addition, in 1986, the SFWMD initiated a contract with the South Florida Regional Planning Council (SFRPC) to update land use throughout the eastern part of Dade County. The SFRPC has largely completed that effort and is in the process of providing the District with the final maps.

The District uses a three-level land use classification scheme that is similar to that used by the Florida Department of Transportation (FDOT). This classification system is described in detail in the SFWMD Technical Publication by Isern and Brown (1980). Level I represents the general level of detail and includes seven categories that represent both natural vegetation systems and various types of human use. Level II is more specific and presents several subgroupings under each of the level I categories. At level II, land uses are divided into 26 categories. The 75 categories at the most detailed level, Level III, were developed by the Water Management District and reflect characteristics that are applicable to water resources and management within the District. A complete listing of the land use/land cover categories within the three levels of the SFWMD classification system and the relationship of these categories to those used by the FDOT is presented in Appendix E of this report. Samples of urban land use classification, to show the three levels of detail follow:

Level I	Level II	Level III
(U) Urban & Built Up	(UR) Residential	(URSL) Single-Family, Low Density (under 2 D.U./gross acre)
		(URSM) Single Family, Medium Density (2 to 5 D.U./gross acre)
		(URSH) Single-Family, High Density (Over 5 D.U./gross acre)
		(URMF) Multi-Family Building
		(URMH) Mobile Homes

As the example shows, the code consists of four letters. The first letter indicates the Level I category, the second letter represents the Level II category, and last two letters represent the Level III category.

Land use data for Dade County are available on a series of 1:24,000 scale maps that are of the same scale and are designed to be overlaid on standard United States Geological Survey (USGS), 7.5 minute quadrangle sheets and Mark Hurd aerial photographs. The quad sheets contain data on land surface features, topography, vegetation, and man-made improvements that provide a framework for the land use/land cover data. The various land use designations appear as polygons. Each polygon has a code that corresponds to one of the District's land use categories. The nominal accuracy of land use designations for large tracts of land is ten acres. At the scale of these quad sheets, it is possible to designate land use for areas of three acres.

Appendix E provides a map that shows the current status of District land use data mapping efforts for Dade County. Land use data for 1981 are available throughout the county, 1985 data are available for some basins in the central part of the county, and 1986 data are currently available in the south coastal basins, the western C-9 Basin and western portion of Area B and the coastal areas of Miami Beach. Current (1986) land use data are expected to be available for most of the Biscayne Bay Watershed by September, 1988. Appendix E also provides a sample map of a portion of Dade County that shows the level of detail that is provided on SFWMD land use maps.

2. Point and Non-Point Sources of Pollution.

Ch 87-97 F.S. and Rule 17-43 F.A.C. request that the SWIM planning effort should include the identification of point and non-point sources of pollution. The Rule specifically requests that the Districts develop

> " a list of the owners of point and non-point sources of pollution that are discharged into each water body and tributary thereto and that adversely affect the public interest (by causing or significantly contributing to violations of water quality standards), including separate lists of those sources that are operating without a permit, operating with a temporary permit, and those presently violating effluent limits or water quality standards, and including a timetable for bringing all sources into compliance with state standards."[Ch 17-43.035(2)(a)4.]

To meet this objective, the SFWMD has initiated a three-step process. The first step is to identify those areas within the Bay that currently experience violations in water quality standards. The second step is to take a more detailed look

at activities near those areas that may be responsible for the observed violations. The third step is the recognition that the existing standards are inadequate to protect the Bay and to support local efforts to develop better standards.

Areas within the Bay that Violate Existing Water Quality Standards. The SFWMD has relied on information from the water quality monitoring program of Dade County DERM to indicate areas within the Bay that are experiencing water quality violations. These data indicate that water quality throughout most of Biscayne Bay does not violate existing state standards, with a only a very few exceptions. Primary problem areas are the Little River and the Miami River. The Miami River consistently violates DERM water quality standards for coliform bacteria and state standards for coliform bacteria in Class III water bodies. Water from this river causes violations of state standards as soon as it leaves the River (which is currently a Class IV water body) and enters the Bay (which is currently Class III and an Outstanding Florida Water body). Another area where state water quality standards for coliform bacteria are violated is the Little River.

In both of these cases, the violations are attributed to non-point sources of pollution. The primary suspected source of this material is stormwater drainage that has been contaminated with sewage. Such contamination occurs from interconnections between stormwater and sewage systems, or emergency overflows from the sanitary disposal system to the stormwater disposal system. Another possible source of this material is waste from boats that serve as residential facilities (so-called "liveaboards") and/or boats that do not use proper pumpout facilities for sanitary waste disposal. The third possible source is illegal and non-permitted sewage disposal facilities that discharge directly to the rivers.

Permits for Point and Non-Point Sources of Pollution. In spite of the fact that water quality in Biscayne Bay does not generally violate existing state water quality standards, the Bay has substantial water quality problems. The SFWMD has thus initiated efforts to compile information concerning point and non-point sources that discharge to Biscayne Bay.

Maps showing locations of marinas and stormwater outfalls in the vicinity of the Miami River and the Little River (as well as throughout the rest of the northern portion of the Bay) have been developed and were included in the Aquatic Preserve Management Plan (Metro-Dade County Planning Department, 1986). These maps, in conjunction with intensified monitoring efforts, can be used to identify specific sources of contamination that can be addressed through enforcement actions, repairs or retrofitting.

The SFWMD has compiled data for this SWIM plan from various agencies that issue permits for point and non-point sources. Acquisition of permit data was a three step process. The first step was to decide which permits were needed. A listing of permit types was obtained from various regulatory agencies. Domestic waste, industrial waste, construction, outfall, surface water management and underground storage tank permits were selected. In addition, a list of enforcement actions was requested. The second step was to decide what information was needed concerning each specific facility/site. The information that was requested included the facility name, location, permit status and specifications. The third step was to identify and contact the agency that could provide this information. DERM had the most extensive permitting authority in the Bay basin. The wastewater, storage tank, code enforcement, hazardous waste and the hazardous facilities sections of DERM provided the bulk of the information for this report. Some additional data were also

obtained from the Resource Control Department at the SFWMD and the local office of the FDER. Table 11 provides a summary of permit information that was obtained from the various sources. Table 12 summarizes information from domestic wastewater and Industrial point sources that discharge into Biscayne Bay.

The third step will include meetings between the SFWMD and enforcement personnel from DERM and DER to review the data on enforcement actions and to identify which of the permittees are violating the criteria of their permit and/or are currently under enforcement action in those areas that have water quality problems. Any known violators that do not have a permit will also be identified. Initial listings of recent enforcement actions by DER and Dade County were obtained from DERM and are provided in Appendix J. The majority of these cases appear to involve problems with solid waste disposal, oil, grease and chemical spills and represent sediment and groundwater contamination rather than the direct contamination of surface waters. DER provided two lists of enforcement actions--one list of active enforcement proceedings and one list with with both active and deactivated enforcement cases. The lists were very similar to the one provided by DERM. Violations included unpaid permit fees, uncontained garbage, oil and grease spills, and soil contamination with pesticides.

Development of Appropriate Standards. Although the information that was compiled for this SWIM plan meets the requirements of the legislation, this information may not be adequate to protect the resources of Biscayne Bay. The Miami River, Little River, several of the tributary canals and a number of areas within Biscayne Bay have additional problems, especially turbidity levels in the water column and chemical contamination of sediments, that do not involve violation of existing standards, but are felt to pose a significant threat. State standards for turbidity are very high relative to conditions that normally occur in Biscayne Bay. Violation of state standards is seldom observed in the Bay, except perhaps temporarily from boat wakes or in the effluent plume of construction or dredging activities. In spite of this, the Bay has experienced losses of seagrass communities in many areas that are attributed primarily to turbidity. The existing state standard is not adequate to protect seagrass communities in Biscayne Bay. A local standard should therefore be developed and implemented that will provide such protection. Similarly, chemical contamination of sediments with metals, pesticides, PCB's, PAH's, PAE's and various other materials is documented in many areas of the Bay. The state currently has no standards for sediments so that, technically, none of these areas violate existing standards.

Identifying and Controlling Sources of Water Quality Degradation. In spite of the fact that relatively few problem areas have been identified in the Bay, based on existing standards, efforts are continuing to identify suspected sources of contamination and to mitigate or eliminate these sources. The primary sources of turbidity have been identified as the effects of wave action and erosion from unconsolidated shorelines. Various projects are underway to stabilize shorelines and mitigate the reflection of wave action by vertical seawalls. The following ongoing activities are directed toward identification and control of chemical contamination in the Bay: a) retrofitting of high-priority stormwater outfalls, especially in the Miami River Basin; b) identification of industrial waste permits, underground storage tanks and surface water management systems that may be point or non-point sources of chemical contamination in the sediments and c) an enhanced monitoring program to identify sources of chemical pollution in problem areas of the Bay.

Table 11. Summary of Permit Data Concerning Point and Non-Point Sources in the Biscayne Bay Watershed

PERMIT TYPE	PERMIT AGENCY	PERMITTED ACTIVITY	DESCRIPTION OF PERMIT INFORMATION COLLECTED	INFORMATION GIVEN ON THE LISTINGS	Types	TOTAL NUMBER
POINT SOURCE PERMITS						
Industrial Waste	DERM	Industrial Treatment Systems	Listing of IW5 permits county wide Listing of IW5 permits in Miami River Basin Listing of IW 2-4 permits county wide Listing of IW 2-4 permits in Miami River Basin Listing of Enforcement Activities	Permittee* Location* Date of Permit* Amt of Discharge** Design Capacity** Type of Permit**	2 3 4 5	97 170 66 541** 2670*
Domestic Waste	DERM DER	Regional Waste Water Facilities Municipal Waste Water Facilities Private Waste Water Facitities	Wastewater/Utility Engineering Status Report	Facility Name Location Permit Date System Type Design Capacity Operating History '87		50 1
NON-POINT SOURCE PERMITS						
Surface Water Management	SFWMD	Storm Water Management Systems	Listing of SFWMD SWM permits	Permit number Permittee Location Recieving body Type of facilities Rate of discharge Project size		44
Landfill Permits	DER	Landfills Sludge Disposal Sludge Disposal Incineration Thermal Treatment	Listing of waste disposal sites within the bay basin	Site Name Location DER Permit # Status Class		66
Tank Operating Permits	DERM	Underground Gas Station Tanks	Listing of underground storagetanks **	Permittee Location		454
Construction (Class 1)	DERM	Docks(&repair) Bulkheading(&repair) Piers Seawalls(&repair) Boat Ramps Sand Dredging Mangrove Trimming/Destruction Fill Marinas Rip Rap	Listing of Class 1 construction permits county wide	Permittee Location Proposed work Issue Date		1795
Outfall (Class 2)	DERM	Storm Drainage Systems Water Management Systems Storm Sewer Systems	Listing of permitted outfalls discharging to sfc waters	Permit number Permittee Location Job description		123

*County-wide
** Permits concerning Miami River Basin

Table 12. Summary of Industrial and Domestic Point Source Discharges into Biscayne Bay and Industrial Sources in the Biscayne Bay Watershed that are Operating with a Temporary Operating Permit.

Industrial Point Source Discharges to Biscayne Bay

1. Belcher Oil. DER #IO 13-140252. Located on Fischer island has an operating permit to treat water accumulated in petroleum product storage tanks. The system separates oil from water returns oil to storage tanks and the water is discharged to Biscayne Bay. Oil and Grease violations were noted in May, 1987. Violation was caused by equipment malfunction. Problem was rectified permittee is in compliance with permit specifications. Average monthly discharge is 2000 gallons with a peak discharge of 5000 gallons.
2. Citgo Petroleum Corp.(MIA) DER #IO 1013-69928. Applied for operating permit for industrial wastewater treatment disposal system. 1986 Permit renewal denied and referred to enforcement section. Discharge to surface water (unnamed ditch to Tamiami canal) was found to be acutely toxic.
3. University of Miami fish hatchery. Currently under review. May be exempt.
4. FPL Turkey Point DER #IO 13-138992. Industrial wastewater treatment facility that includes Neutralizing, Ash collection, oily water collection, and stormwater systems. A cease and desist order was levied when oily wastewater was found to be escaping the oil and water separator to the ground/ground water over a period of several years. A ground water monitoring program was initiated and lead and zinc levels were in violation of ground-water standards. Soil samples were taken and elevated levels of lead, copper, zinc, and oil and grease, were found. Negotiations between DERM and FPL are currently underway.
5. Miami Herald NPDES # FL0662861. Discharges 0.36MGD cooling water into Biscayne Bay.
6. Homestead Power Plant DER # IO 13-00067. Industrial wastewater and treatment and disposal system discharges 7.248MGD cooling water to a ditch and then to C-103S.
7. Cutler Ridge Power Plant DERM # 1582 Has been recently been reactivated. Discharges to surface waters are stormwater drainage and cooling water. Discharges in 1984 ranged from 10 to 15 MGD and were in compliance. The facility is currently under review by DERM.

Domestic Point Source Discharge to Biscayne Bay

8. Atomic Sewage DERM #DWO-0033. Only domestic wastewater treatment discharge to surface water (FEC canal) Average daily flow .0173 MGD and is operating within standards.

Temporary Operating Permit in the Biscayne Bay Watershed

9. US Asphalt DER # TO 13-113660. Industrial treatment and disposal system for max 90,000 GPD of wastewater from a wet scrubber. Water is discharged to a 121 acre class III lake. The TOP expired Aug,1987. If the permittee has not come under compliance it is likely operating without a permit. DER says this operation has little impact on Bay water quality.

3. Timetables and Schedules.

The Swim legislation requires that the plan include a timetables and schedules to bring point and non-point sources into compliance and for restoration and management of the water body. Details of schedules and timing will become more evident as monitoring of the system is refined, sources of discharges are identified and the best possible technologies are identified and implemented to correct these conditions.

SWIM goals need to be realistic. These timetables reflect conservative estimates for compliance, restoration and management, based on the current level of understanding of the system. The schedules for achieving compliance, restoration and management of Biscayne Bay depend directly on the amount of funding that can be provided each year from local, state, regional or other sources, and also depend on the (currently unknown) speed with which the Bay recovers, once pollution loadings into the system or other sources of degradation have been stopped. If funding is available and the various restoration and management projects that have been proposed in this plan are implemented, then conditions in the Bay will improve.

Compliance. The first milestone in the schedule is to achieve compliance. It is assumed that the legislation intended this to mean compliance with state water quality standards. Two areas--the Miami River and Little River--are the primary locations where state water quality criteria for Class III waters are violated (the Miami River is currently a Class IV water body, but efforts will be initiated during the coming years to upgrade the River to Class III). Levels of coliform bacteria and dissolved oxygen occasionally fall outside the acceptable ranges of these parameters for Class III waters in parts of these Rivers and adjacent waters of the Bay. Projects that are being initiated this year to retrofit stormwater systems in the Miami River basin should result in significant improvements in water quality within five years. However, the solutions to problems of sewage contamination in Biscayne Bay are expected to be very expensive.

The following activities toward achieving compliance should be underway or completed in Biscayne Bay within 5-years:

1) The entire Biscayne Bay Management Area should be designated as Class III and an Outstanding Florida Water body by the state
2) Effects of the current retrofitting and increased enforcement activities should result in significantly improved water quality in the Miami River.
3) The trend for declining dissolved oxygen levels in the Bay should have been stabilized or reversed due to the reduction of non-point pollution.
4) Coliform levels in the Little River and Miami River should have improved significantly.
5) Any remaining point sources of domestic wastewater contamination (legal or illegal) should have been eliminated.
6) Programs should be in place and a schedule should be developed to eliminate all remaining major industrial point sources that are impacting the Bay.

Within 10-years,

7) The Bay should consistently be in compliance with state and local standards as coliform and oxygen levels will be within acceptable limits. Further improvement of the system will then depend on application of more stringent local standards as discussed in the following section.

Success Criteria. The SWIM 5-year and 10-year goals were selected on the basis that they represent measurable factors or objective criteria such that success in achieving a goal or progress toward the goals can be measurably assessed on an annual basis. For example for the first set of compliance goals.

Goal	Success Criteria
1) Class III designation	achieved or not
2) improved retrofitting and enforcement	improved water quality
3) reverse D,.O. Trend	D.O. levels begin to rise
4) Little River Coliform levels	fewer violations, lower average nos.
5) eliminate point sources	number of point sources removed
6) eliminate industrial sources	number of industrial sources removed
7) compliance with standards	achieved or not

Restoration. Achieving compliance with state standards will be a major step toward restoration of the Bay. However, efforts to further improve conditions in the Bay and for long-term management will depend upon the development,

implementation and enforcement of local standards for water and sediment quality that are more stringent than state standards. Other major steps toward restoration of the Bay must include a) the effective retrofitting of stormwater systems, b) the elimination or mitigation of the impacts of point and non-point sources of pollution or contamination, and c) control of freshwater discharges into the Bay as a means to to improve salinity conditions and the transport of nutrients into the system; and d) the reestablishment of suitable upland, shoreline and submerged habitats and viable natural plant and animal communities, within areas that currently do not support such habitats and communities.

Restoration of Biscayne Bay will be successfully completed when water and sediment quality remain within optimal ranges for the growth and survival of estuarine and marine organisms, discharges from major point sources of pollution have been eliminated, stormwater systems that are significantly degrading the Bay have been retrofitted, turbidity levels in the Bay have been controlled to the point that significant revegetation of seagrasses can occur in areas that are otherwise suitable for their growth, and when the integrity of the natural Bay ecosystem based on upland, shoreline and submergent communities, has been reestablished to successfully sustain the long-term survival and growth of marine and estuarine organisms.

The following restoration activities should be underway or completed in Biscayne Bay (depending on availability of funding and resources) within 5-years:

1) Major water quality and environmental problems within the Bay should be identified and the magnitude of these problems should be known.
2) Major point and non-point sources of contamination or pollution should be identified and efforts to correct these problems should be underway.
3) Efforts to develop meaningful local water and sediment quality standards for Biscayne Bay should be underway--improved standards for turbidity and some improved water and sediment quality standards for toxic materials should be in place.
4) Turbidity should improve in North Bay due to shoreline stabilization .
5) Freshwater sheet flow should have been restored into major tracts of mangroves adjacent to South Bay. Some wetland and upland restoration projects should be underway

Within ten years,

6) A number of major stormwater systems should have been retrofitted, resulting in a significant decline in nutrient and coliform levels in the Miami River, Little River and North Bay, improved water clarity, and higher levels of dissolved oxygen.
7) A schedule should be in place for retrofitting many of the remaining major stormwater systems.
8) Turbidity levels should improve noticeably in North Bay with seagrass recovery in some areas where these communities do not currently exist.
9) The condition of benthic and shoreline communities of the Bay, as measured by species diversity and other indexes should have improved significantly.

Management. Management of the Bay will be achieved when restoration efforts are underway to the extent that major sources of degradation have been controlled or eliminated, management mechanisms are in place for Card Sound and

Barnes Sound, preservation efforts have identified and purchased or authorized for purchase major tracts of land, and the BNP and ENP and other sensitive areas have been protected through the purchase of adjoining lands or protective easements to act as effective buffer areas. Funds may come from state programs such as CARL funding, federal purchase, or private conservation foundations.

The following management-related activities should be underway or completed in Biscayne Bay within 5-years:

1) Major problems within the Bay should be identified and the magnitude of these problems should be known and documented in management plans.
2) Major point and non-point sources of contamination or pollution and management strategies should be identified. Efforts to correct these problems should be underway.
3) Management issues concerning Card Sound and Barnes Sound should be resolved through incorporation of these areas in the Aquatic Preserve program, federal or state purchase, or development of special management plans.
4) Efforts will have been initiated at the federal level to expand the areas of Everglades national Park and/or Biscayne National Park to include more sensitive lands within the Bay and some adjacent upland areas.
5) Major tracts of land should have been identified for purchase as preservation areas within the Bay ecosystem.
6) Interagency efforts will be largely completed to develop an integrated, centralized data base for Biscayne Bay, including fine-scale land use and public ownership maps

Within 10-years,

7) Large tracts of land will have been preserved adjacent to South Bay and Card Sound/ Barnes Sound.

IV. CONCLUSIONS AND RECOMMENDATIONS--

A..Strategies to Address Bay Management Problems

The conclusions and recommendations that are presented in this section of the plan represent an initial attempt to develop management strategies for Biscayne Bay. During the past year, the SFWMD developed and implemented several activities that are intended to set the stage for influencing District and other agency actions during the years to come. These strategies and activities will be continually updated as programs and projects continue to be developed and implemented.

Existing Committees and Programs. The District is committed to work with existing coordination mechanisms such as the Biscayne Bay Management Committee and the Miami River Coordinating Committee to improve management of the Bay. Both of these committees have been suggested as a forum and a means to improve regulation enforcement activities on the Bay. The District is a member of the Biscayne Bay Management Committee and is providing financial support for the Miami River Coordination Committee this year. In addition, the SFWMD is in the process of developing a Technical Advisory Committee (TAC) to support the SWIM program in Biscayne Bay. Other committees or subcommittees may be established as issues or problems are identified. The interaction of these committees will form the basis for the initiation of action items suggested in the SWIM plan, such as revision of water quality standards.

Increased Commitment to Enforcement. The SFWMD as part of the SWIM program recently completed a review of its rules and regulations. As the result of this review, a number of changes have been suggested to improve the ability of the District to develop and implement management plans and strategies for surface water bodies. The review suggests the need for revised criteria for the design of wetlands and on-site lakes, and improved water management practices, especially for industrial land uses, landfills, and agricultural Best Management Practices. This report identified the need to review and improve water management requirements of estuaries and methods to provide increased protection of regional water resources. The SFWMD also recognizes the need to improve enforcement activities by other agencies and local governments. A portion of the SWIM money is being used to subsidize and enhance existing enforcement programs, while trying to develop a continuing commitment to these activities at the local level. Although the SFWMD has delegated much of its water management regulatory authority for projects under 320 acres in size to Dade County, District staff continues to work with county staff on special regulatory issues, primarily to develop and refine criteria for wetlands and wellfields.

Increased Technical Coordination. The District has worked extensively during the past year to develop close interaction with the technical staff of local governments and other agencies concerning Biscayne Bay and related Bay management issues. The District has developed working relationships with technical experts of the University of Miami, Rosenstiel School of Marine and Atmospheric Sciences, Florida International University, the National Marine Fisheries Service and the National Park Service, who provided much of the background material that provided the basis for the SWIM plan. District staff worked extensively with local governments, especially Dade County Department of Environmental Resources Management (DERM), Dade County Planning Department and the City of Miami concerning local issues and projects. Staffs of

Regional, state and federal agencies including the South Florida Regional Planning Council, the Florida Department of Environmental Regulation, the Florida Department of Natural Resources, Florida Department of Transportation, Florida Game and Freshwater Fish Commission, Biscayne National Park, Everglades National Park, United States Fish and Wildlife Service and the United States Army, Corps of Engineers provided technical assistance and comments.

Increased SFWMD Staff Support. Several District staff members have been assigned to provide full time technical and administrative support to SWIM programs including Biscayne Bay. SFWMD technical staff time will be assigned during the coming year to provide review and analysis of the technical data, including water quality data, that has been collected from all sources for Biscayne Bay to better direct future technical programs and projects to be funded. The staff will provide support for the development and implementation of SWIM projects, programs and contracts for the Biscayne Bay SWIM effort. A major objective during the coming year will be to tighten the fiscal accountability of the plan through more detailed planning, design and budgeting during earlier stages of the budget process. Toward this end, the District added a project to the Biscayne Bay SWIM program to provide for advanced planning of SWIM projects. This project will attempt to develop scopes of work, and generate requests for proposals and obtain necessary permits for future projects during the fiscal years prior to the time that funding is requested from the legislature. These detailed analyses and cost estimates can then be incorporated into the SWIM budget requests.

Encourage Cost Sharing on SWIM Programs. The SFWMD recognizes that the amount of money that will be provided for the SWIM program in Biscayne Bay will probably not be sufficient to address all of the current management needs. The District will therefore try to improve the cost-effectiveness of state expenditures recognizing that money provided by local governments cannot be used in lieu of the District's share of the cost of a program. SWIM projects will be implemented primarily through contractual services, interagency and interlocal agreements, emphasizing cooperative and participative programs using state money to initiate programs and working with local entities to develop additional sources of funding. This year the SFWMD is providing support of local government efforts through support of the MRCC, a cooperative agreement with the City of Miami concerning retrofitting of stormwater systems and cooperative agreements with Dade County DERM concerning monitoring and enforcement programs.

Local Government Assistance Program. The SFWMD has developed and implemented an intensive local government assistance and coordination program in Dade County that is also directed toward development and implementation of SWIM programs and projects. This program administers SWIM projects and programs and provides coordination between the District and local governments on SWIM and other issues of mutual concern.

Local Office in Miami. The SFWMD has opened a local administrative office in Miami to provide improved coordination and technical support for local government programs and greater public visibility and access in Dade County.

Public Information Program. the SFWMD is implementing a public information program that is not only directed toward providing information concerning the Bay to non-technical audiences and school programs, but is also directed toward building support for SWIM programs and projects among local

governments and special interest groups. The District has also developed an extensive mailing list of local special interests groups and concerned citizens.

B. Conclusions and Recommendations

(The following Conclusions and Recommendations are not necessarily listed in order of priority. Priorities are discussed in the SCHEDULE AND FUNDING section of this report)

Need For Consistent State Water Quality Classifications within the Biscayne Bay Aquatic Preserve

Conclusions:

The Miami River is currently classified by the FDER as a Class IV water body, suitable for agricultural and industrial water supply. The River thus has a lower water quality classification and lower water quality standards than the remainder of Biscayne Bay, which is designated as a Class III water body--suitable for recreation and propagation of fish and wildlife. The classification of the Miami River should be changed to Class III to provide additional protection to Biscayne Bay for three primary reasons:

1) All of northern Biscayne Bay, including the Miami River, lies within the Biscayne Bay Aquatic Preserve and hence is designated as an Outstanding Florida Water (OFW) by the state. The OFW designation protects the Bay by not allowing further degradation relative to ambient water quality conditions. The existence of the Class IV water body (the River) discharging into the Class III water Body (Biscayne Bay) is inconsistent with the OFW designation of the Aquatic Preserve.

2) The current classification of the Miami River is perceived as a problem for management of the Bay. Class IV includes no standards for bacteria and few standards for pesticides and metals. Currently water quality in the River does not violate any of the Class III standards with the exception of coliform bacteria and occasionally dissolved oxygen. However, the potential does exist for the River to become degraded with metals, pesticides, etc. and, under the current classification, no regulatory authority exists to deal with this contamination. Changing the classification of the River would provide the county and the state with additional regulatory authority to prevent further degradation of existing water quality conditions in the River and to deal more effectively with sewage contamination problems that are impacting the River and the remainder of Bay.

3) Federal, state and local governments are spending millions of dollars to "clean up" the Miami River. Unless the classification is changed to establish meaningful water quality standards, the state will not have adequate means to maintain and protect the River once cleanup is accomplished.

Recommendation:

1) **Reclassify the Miami River.** Support efforts by Dade County and the FDER to have the classification of the Miami River upgraded from its existing Class IV to a Class III water body.

Sanitary Waste and Stormwater.

Conclusions:

Sewage contamination has been a problem in Biscayne Bay since the early growth of the Miami area. Dade County records indicate that, although fecal coliform levels have declined for many areas throughout Biscayne Bay, they have increased or remained at high levels in localized areas such as the Miami River, the Little River, Maule Lake, Biscayne Canal, and particularly in marinas with 'liveaboard' facilities. Sewage pollution originates from both point and non-point sources, including ruptured sewage lines, dysfunctional lift stations, degraded sewer pipes, septic tank leachate, and discharges from ships and boats. A major suspected source of sewage contamination is the cross-connection of sanitary and storm sewer systems, degraded sanitary sewer pipes, and the emergency overflows from sanitary sewer lines to stormwater drainage lines that occur when capacity of the sanitary system is exceeded.

Assessment of the extent and magnitude of sewage contamination problems is hampered by the standard methods available for measurement of sewage pollution. Coliform bacteria are found in human and mammalian fecal waste and are used to indicate the presence of human waste contamination. The fecal coliform standard was developed for use in freshwater and is not directly applicable in marine systems. The survival of coliform bacteria is dependent upon a variety of factors including light intensity, temperature, and salinity. The limited survival time of these bacteria in marine and estuarine environments of Biscayne Bay and tributaries hampers the usefulness of this standard as a means to detect sewage pollution. Coliform survival time in this system should be calibrated and better methods sought to detect human fecal contamination in marine systems.

Stormwater drainage has been identified as a major source of pollution to the Bay. Numerous stormwater outfalls discharge into Biscayne Bay and virtually all of this discharge is untreated. Retrofitting of stormwater systems was identified as a high priority in previous Bay management plans and in the SWIM legislation. This area of South Florida has high ground water levels and readily interchangeable surface water-ground water movement, and a small soil matrix with a low percentage of organic materials. As such, this area may not be suited to the use of exfiltration trenches, particularly for water quality treatment. Synoptic storm-event and dry period sampling are necessary to determine the effectiveness of retrofitting currently being done in this geological formation prior to recommending use of specific systems to meet regulatory requirements.

The SWIM legislation recognizes the importance of both point and non-point sources of pollution in Biscayne Bay. However, although the legislation allocates specific funds for retrofitting of stormwater outfalls discharging into Biscayne Bay, the legislation states that SWIM funds shall not be spent to upgrade existing sewage treatment facilities. Hence, separate recommendations are proposed to deal with stormwater and sewage problems. An important recommendation is to support local government efforts to develop alternative funding sources for this work. The City of Miami has recently developed one such source of revenue through the implementation of a Stormwater Management System Fee, established as part of the City of Miami's Stormwater Utility Ordinance.

Recommendations:

2) **Separate Sanitary from Stormwater Sewers.** Assess the extent of interconnections between stormwater and sewage systems and upgrade, repair or replace facilities as necessary to eliminate these interconnections.

3) **Stormwater.** Continue to support local government efforts to retrofit (including the addition of treatment processes) existing stormwater systems that discharge into Biscayne Bay or tributary rivers and canals. Encourage long term maintenance programs (greater than 10 years) on older stormwater retrofits and require that new retrofit projects include provisions for long term maintenance (greater than 10 years) of the systems. Priorities for retrofitting of facilities should be based on consideration of monitoring data concerning present water quality conditions in the Bay or tributary, residence times in receiving waters of the Bay, and land uses within the basin. Require synoptic storm event and dry period sampling programs to determine the effectiveness of retrofitting methods and projects that are implemented in this area.

4) **Sanitary Sewers.** Support ongoing programs to evaluate the sanitary sewer system of Dade County and define problems or conditions that result in the release of inadequately treated or untreated wastewater to the Bay through overflows, surface water discharges or groundwater seepage. The purpose of this study shall be to define the nature and extent of the impacts of this problem on Biscayne Bay and assist the county to obtain funding for actions that will improve water quality in the Bay.

5) **Improved Marine Sewage Contamination Standards.** Conduct basic research necessary to improve methods for evaluating sewage contamination in salt water areas, so that appropriate standards can be developed.

Specific Water Quality Problems and Areas of Contamination

Conclusion:

Analyses of existing water quality data for Biscayne Bay that have been collected by DERM since 1979, and results of special studies that have been conducted periodically during the past ten years, have shown that a number of specific areas within the Bay have chronic resource management problems that are related to the input of toxic chemicals. In addition, a number of toxic chemicals have widespread distribution in the Bay and the effects of these chemicals are largely unknown. Studies are therefore needed within specific basins to identify sources of toxic material contamination and develop methods to control or eliminate these sources. Additional research is needed to assess the impacts that specific toxic materials have on Biscayne Bay ecosystems and to determine safe levels of exposure.

Recommendation:

6) **Specific Water Quality Problems and Areas of Contamination.** Develop methods to assess known problems of contamination with toxic substances within the Bay. This program should include projects to address specific problems such as the following:

A. Target Areas
1. Miami River and tributaries such as Wagner Creek and Laurence Canal;
2. Military Canal;
3. Goulds Canal and Black Point Canal basins;
4. Little River and Biscayne Canal;
5. Munisport Landfill Site
6. Virginia Key Sewage Facility
7. Snake Creek/Maule Lake
8. Arch Creek

B. Target Contaminants
1. Phthalate acid ester (PAE) contamination;
2. Localized high levels of Arsenic and other heavy metals in sediments and biota;
3. High levels of petrochemicals in various tributary basins; and
4. Levels and environmental effects of Tributyltin compounds
5. PCB's
6. Polycyclic Aromatic Hydrocarbons
7. Pesticides/Herbicides
8. Anthropogenic organic contaminants

Monitoring

Conclusions:

Monitoring is necessary to assess water quality, evaluate ongoing problems, and identify new problems within the system. It provides a basis for the understanding the Bay and is required for the continued preservation and maintenance of water quality, habitat, and system integrity. The continuation of ongoing monitoring efforts provides background data to be used in restoration, preservation, and enforcement activities. The water quality monitoring effort should build upon historical data bases that have been established by DER, DERM Biscayne National Park, the USGS and SFWMD, with continuation of many of the same sampling locations and parameters. These existing networks should also be expanded and diversified to include new areas within the Bay, more intensive sampling of suspected problem areas, and sampling of tributaries above the salinity control structures.

Data from the monitoring program can be used to support restoration programs such as turbidity abatement and shoreline stabilization projects; stormwater system retrofitting; and enforcement programs. These data are also essential to preservation efforts to ensure that appropriate water quality conditions are maintained within designated areas. Five types of monitoring programs have been suggested--water quality, sediments, biological, microbiological and ecological systems.

Water Quality. DERM and Biscayne National Park have ongoing water quality sampling programs within the Bay. The SFWMD will work in cooperation with these agencies and other interested entities during the coming year to review existing water quality sampling stations and parameters. Recommendations will be developed to add more stations and/or more parameters in areas of concern and yet continue to collect data from stations that can provide the most useful historical

baseline information as determined from in-depth analysis of previously collected data.

Tributary Criteria. Implement a cooperative program among SFWMD, DERM and DER, with DER as lead agency, to develop water quality criteria for incoming quantities of freshwater, BOD, suspended solids, nutrients, pollutants and contaminants that are currently being received from canal discharges, sewage, stormwater, groundwater, and rainfall. FDER and Dade County standards may be revised to more sensitive levels, based on considerations of residence times, flushing characteristics and resources that need to be restored or preserved. Results of this analysis could be used as the basis for assessment of cumulative impacts. Tributary monitoring will 1) give an indication of the magnitude of the problems associated with non-point and point source inflows of contaminants 2) will help to identify sources of contaminants, 3) help to quantify the amount of these compounds coming into the system, and 4) aid in assessment of the efficiency and effectiveness of stormwater retrofitting, retrofit maintenance and enforcement activities.

Sediments. Sediment samples have been collected from the Bay occasionally in the past, primarily to document historical and long-term contamination problems. This program should be expanded and implemented on an annual basis as a means to survey the types of anthropogenic compounds found within the sediments, document changes in concentration of these compounds, and identify loading sources within tributary sub-basins.

Biological Materials. Samples of living organisms have been occasionally taken in the past to monitor levels of metals, pesticides, synthetic organic compounds, and petrochemicals and their breakdown products that are often selectively concentrated by certain aquatic species. A biological materials monitoring program should be established on a regular basis to survey concentrations of toxic chemicals, and metals within biota of the Bay.

Microbiological. Microbiological samples have been taken within the Bay in the past as a means to document human health hazards. Coliform bacteria, an indicator of fecal contamination, are monitored routinely. Levels of these bacteria are consistently above recommended safe standards (although not above state standards) in certain areas, especially near the Miami River and Little River, suggesting that sewage contamination is occurring continually. Coliform bacteria are not an adequate indicator of sewage contamination in saltwater. Many other bacteria and viruses, including some that pose human health hazards, survive longer in sea water than coliform bacteria. A calibration of survival time of coliform bacteria should be made within the Biscayne Bay system. Coliform counts, calibrated for this area, should then be examined in conjunction with alternate methods for detection of fecal contamination in marine waters. Methods should be evaluated to develop a potential suite of parameters to indicate current human fecal contamination in marine waters. This work should be done in conjunction with a current literature search and in coordination with state and Federal programs addressing this topic.

Ecological. Numerous ecological studies have been conducted in the Bay in the past and DERM has established an ecological monitoring program for benthic communities. A survey of species abundance and distribution should be conducted to provide comparison with past work and to document long term trends in biotic resources within the Bay. Various components of the ecosystem including benthos,

plankton and fish should also be monitored to document temporal and spatial changes in ecosystem dynamics.

Monitoring Network Review and Analysis. The final component of the monitoring program should be periodic review and analysis of the data for the purpose of improving the monitoring network and identifying water quality trends. The distribution of sampling stations and sampling frequency should be analyzed to eliminate stations or parameters that are redundant or not producing useful information and to add stations or parameters in suspected problems areas. Parameters and methods should be reviewed to take advantage of the latest technology.

Recommendations:

7) **Monitoring.** Continue, extend and improve existing water, sediment, biological, and ecological quality monitoring efforts in the Bay to provide a historical data base and identify problem areas. Consider the addition of a microbiological sampling program to better identify human health hazards. Expand the current Dade County and Biscayne National Park networks to include Card Sound and Barnes Sound. Analyze the existing data and network to eliminate redundant or inefficient sampling stations and add stations or new parameters in areas where data are inadequate or known problems exist, including upstream areas of tributary basins.

Need For Revised (Local) Water Quality and Other Standards

Conclusions:

Preservation of the resources of Biscayne Bay depends on the maintenance of appropriate levels of environmental protection, including water quality and other standards that will ensure survival and continued health of the the ecosystem. If water quality, sediment or other conditions continue to deteriorate within Biscayne Bay, some species will die, diversity will be lost and the Bay ecosystem will degrade. Levels of contaminants and conditions that can be safely tolerated by the receiving systems should be defined in terms of levels naturally present, the response of the most sensitive portions of the systems, and the length of time that exposure can be tolerated without damage to the system. The levels that are defined as standards must allow the system to function continuously without loss of biological diversity and must be legally and technically defensible and enforceable.

In Biscayne Bay, and other areas of south Florida, water quality standards that are more stringent than standards that exist statewide are required to protect the sensitive systems that occur in these areas. Stringent local standards are necessary to provide a realistic basis for restoration of the system. New standards must consider both acute and chronic exposure levels. Currently, state standards allow much greater levels of some contaminants than occur locally as background levels in Biscayne Bay. One method to address the problem of local standards is to use natural background levels that have been observed in the system over time. DERM has approximately nine years of data on which to base such standards. Another part of this approach is to define levels that are necessary to protect certain sensitive organisms (e.g., seagrasses) that are considered to be of vital importance to the ecosystem. Levels of pollutants in which these organisms are known to occur

naturally could be used as a basis for the development of a standard. Proposed standards should be verified by toxicity tests using local organisms and ecosystems.

Once appropriate local standards or safe exposure levels have been established, this information can be combined with hydrologic, hydrodynamic and monitoring data to develop management criteria such as the following: a) an environmental quality index for various areas within the Bay depending on how well these areas conform with local standards, and b) water quality budgets for freshwater, biochemical oxygen demand, suspended solids, nutrients, pollutants and contaminants within various areas of the Bay. These criteria, in turn, could provide a basis for regulation and enforcement actions.

Recommendations:

8) **Local Standards.** Encourage funding for the technical research efforts that are needed to develop water, sediment, and/or biological standards that are appropriate to protect the resources of Biscayne Bay. Two standards that should be reviewed immediately are the coliform standard as it applies to salt water and turbidity standards. Support interagency, legal and legislative efforts that are required to adopt, implement and enforce these standards.

Compliance Monitoring.

Conclusions:

Federal, state agencies and local governments issue permits for numerous water-dependent and water-related activities and facilities within the Biscayne Bay watershed. Many of these permits only regulate the construction and design of marina facilities, and do not adequately consider or monitor impacts that may occur during long-term operation and maintenance. Once a marina facility is constructed, generally no permit is required for operation and maintenance (DNR leases and some recently-constructed public marinas are an exception). Hence, there is no formal process by which the state, county or other permitting authority can be assured that these facilities, which are known sources of *in situ* pollution, are maintained and operated according to design specifications or that design specifications are adequate to protect the resources of the Bay over the life of the facility.

Data collected by Metro-Dade county indicate that marinas, boat yards, marine repair shops, etc. may be persistent sources of pollutants including metals, hydrocarbons, and raw sewage contamination in Biscayne Bay. The codes and rules associated with these types of facilities, particularly marinas, should be revised to institute appropriate operating standards and require monitoring to assure that these standards are met. Such operational monitoring and standards should apply to both new and existing facilities.

Long-term monitoring of such activities is desirable as a means to document impacts on Biscayne Bay, to develop and implement mitigation methods, and to improve design, construction and operational criteria for future facilities. One means to implement a monitoring, mitigation and design review program is to require operating permits for water-dependent and/or water-related facilities.

Recommendation:

9) **Permitting Requirements for Marina Facilities.** Recommend and encourage the FDER and DERM to develop rules requiring operating permits and associated monitoring, beyond those requirements for construction, of new and existing marina facilities. Marinas have uniformly been identified as an extreme problem and source of continued pollution by all regulatory agencies involved.

10) **Compliance Monitoring of Existing Permitted and Operating Systems.** Encourage regulatory authorities within Biscayne Bay to develop and implement a compliance monitoring process to ensure that marinas, boat building/repair operations, outfalls, dredging, etc. are operated and maintained in a manner that is consistent with their design specifications. Lack of compliance may be due to either operational or design problems. Operational problems shall be subject to enforcement action. Design problems should be addressed either through enforcement or review of the existing design criteria.

Enforcement

Conclusions:

Many agencies have regulatory authority within Biscayne Bay, but there is little coordination among agencies with regard to enforcement activities. There is consensus that these agencies have insufficient personnel to adequately enforce local, state and federal laws and regulations. At the same time, each agency or authority is only empowered to enforce certain laws.

Recommendations:

11) **Funding for Additional Enforcement.** Provide for additional personnel to enforce current regulations in Biscayne Bay, including stormwater management, wastewater treatment, marina operations, coastal construction and shipping. SWIM monies will be used to fund additional enforcement activities within Biscayne Bay and its watershed. Local governments are encouraged to provide additional support as a means to increase the level of enforcement possible. Local governments are encouraged to provide monies, manpower or document related expenditures to help support these enforcement activities.

12) **Enforcement Responsibilities.** Develop a multi-agency task force for enforcement, including local, state and federal enforcement entities, to meet on a quarterly or biannual basis. The purpose of this group would be to coordinate efforts of the diverse regulatory interests, prioritize, and review enforcement needs in Biscayne Bay. The Biscayne Bay Management Committee (BBMC) or the Miami River Coordinating Committee (MRCC) would provide an appropriate forum to coordinate the regulatory interests of these agencies. Perhaps a task force could be formed to address this issue.

Freshwater Inflow

Conclusions:

Prior to construction of major drainage projects in the greater Miami area that occurred during 1900-1925, Biscayne Bay received freshwater primarily as groundwater seepage and sheet flow of surface waters across the adjacent marshlands. Before completion of Bakers Haulover Inlet, much of north Biscayne Bay was a freshwater or brackish embayment.

The major canals now form a primary water supply and drainage system that serves four main functions--a) as a drainage outlet for excess water from the Everglades, b) to provide primary drainage for the intensely-developed urban and agricultural areas of the southeast coast; and c) to allow transfer of water from the Everglades Water Conservation Areas to provide groundwater recharge for coastal communities during droughts.

The primary effect of the water control works in South Florida has been to facilitate the flow out of the Everglades by means of the canal system, thereby changing the spatial and temporal distribution of runoff to Biscayne Bay and adjacent wetlands. Freshwater discharge now occurs primarily to localized areas of the Bay, near the coastal canals, rather than to broader areas of the Bay as diffuse groundwater seepage or sheet flow across coastal wetlands. Releases of water from canals occasionally create local problems due to the introduction of large pulses of freshwater and runoff from urban and agricultural lands into coastal waters.

Recommendation:

13) **Freshwater Inflow.** Continue efforts to analyze the impacts of freshwater discharges from canals on Biscayne Bay and to mitigate adverse impacts of these discharges. This includes evaluation of a) methods to alter the amount and timing of freshwater releases from canals that discharge into North Bay; b) methods to restore sheet flow of freshwater into South Bay and extreme South Bay to alleviate periodic hypersaline conditions, help decrease the need for unnatural heavy pulses of freshwater, and to help restore transport of mangrove detritus into the Bay; and c) methods to mitigate or eliminate impacts of maintaining abnormal water levels in the South Dade County canal system.

Circulation and Flushing

Conclusions:

Biscayne Bay is a shallow, well mixed estuary, which receives fresh water from surface runoff and a series of drainage canals along the western shore. Exchange with the Atlantic Ocean occurs via a number of tidal inlets along the eastern barrier islands. The dominant forcing mechanisms for mixing and transport within the Bay are tide and wind.

Biscayne Bay has several areas where circulation and flushing are reduced due to artificial alterations to the system. Circulation and flushing in North Bay are generally good, due to the presence of adequately-sized and placed openings between

the units. However, problems occur in localized areas where tidal exchange is reduced or semi-enclosed basins have been constructed.

South Biscayne Bay is generally well mixed, with salinity contours that run in a north-south direction, parallel to the western shoreline. However, short-term vertical stratification has been observed along the western shore after periods of large freshwater inflow from drainage canals.

Extreme South Bay, Card Sound and Barnes Sound have poor circulation and long residence times (up to one year). Tidal flushing, which occurs via Angelfish Creek and Broad Creek, is limited because of the small tidal range. Circulation is primarily driven by wind. Due to the small tidal range, water tends to remain in this section of the Bay for long periods, which may result in hypersaline conditions during the dry season.

Recommendation:

14) **Circulation and Flushing.** Ensure that all existing inter-unit connections remain unobstructed. Evaluate methods to improve circulation and flushing characteristics in localized problem areas, near stagnation points, finger canals, or in semi-enclosed basins, and ensure that such enclosed basins and blind canals are not constructed in the future. Circulation and flushing considerations should be incorporated into FDOT repairs and improvements to existing causeways, roads and structures.

Shoreline and Bottom Stabilization to Reduce Turbidity

Conclusions:

Historically, Biscayne Bay was a clear, shallow coastal estuary. Today, turbidity is a major problem that is a continued source of water quality degradation. Major sources for continued turbidity are sedimentary input associated with the erosion of the margins of non-stabilized spoil, transport of beach nourishment materials back into the Bay by tides, and the resuspension of fine and flocculent materials from dredged areas and deep holes. Increased wave action resuspends fine sediments and flocculent materials and increases erosion of spoil margins.

The following is a summary of the process by which fine materials create turbidity problems within Biscayne Bay:

1) Deep holes and dredged areas serve as sinks and sources for these materials.
2) Unconsolidated spoil islands and margins are sources of sedimentary input as these shorelines are continually eroded by wave action.
3) Vertically bulkheaded shorelines aggravate turbidity conditions. Bulkheads reflect wave energy with little or no attenuation. Wave action resuspends sediment fines from deep holes and unconsolidated or eroding spoil margins. Wave action may be due to natural causes such as winds or tidal currents or it may be due to unnatural causes such as boat wakes.
4) Increases in the number of marinas and boats and an increase in the linear feet of vertically bulkheaded shoreline are believed to be responsible for increased wave action, bottom scour, and high turbidity levels in North Bay.
5) Input of fine sediments occurs from overland runoff and storm water drainage.

Various restoration actions may be used to reduce turbidity levels in the Bay, such as the modification or elimination of vertically bulkheaded shorelines, and the stabilization of unconsolidated spoil and other eroding shorelines, and possibly the filling of deep holes. Vertically bulkheaded shorelines tend to reflect wave energy back and forth across the basin rather than dissipate this energy, as would occur on a sloping shoreline. Wave action resuspends fine materials from the bottom, increases erosion of unprotected shorelines, and hence contributes to the turbidity problems of the Bay. DERM and Dade County have already developed ordinances that require the modification of vertically bulkheaded areas to attenuate wave activity. The common practice of spoil disposal on islands provides sources of turbidity by erosion from the unprotected margins of these islands and by runoff from the island's surface. Alternative methods for spoil disposal should be considered, including upland disposal sites and the use of spoil to fill deep holes.

Dade County DERM has proposed that artificial reefs may be constructed, using waste construction materials, as a means to stabilize the substrate in deep holes and provide additional habitat for hard bottom communities. Use of artificial reefs has been shown by DERM to provide effective habitat for fish and invertebrates. However, the effects of these structures on overall fish populations, water quality and substrate are not clear. This method deserves further investigation and consideration as a possible means to improve turbidity conditions within the Bay.

Recommendation:

15) **Shoreline and Bottom Stabilization.** Support efforts of county and municipal governments and other agencies and interests to develop and implement alternative methods for shoreline and bottom stabilization that use emergent vegetation and avoid or mitigate the construction of vertical bulkheads. Consider alternative methods for disposal of spoil materials from maintenance dredging that would avoid the deposition of unconsolidated materials on islands or other shoreline areas adjacent to the Bay. Consider the use of these spoil materials or perhaps artificial reef materials to fill deep holes that have been identified as persistent sources of turbidity.

Land Use and the Protection and Restoration of Natural Habitats

Conclusions:

The natural relationships among coastal upland vegetation such as pine flatwoods, tropical hammocks and beach dunes; shoreline vegetation such as mangroves and saltmarshes; and submerged plant and animal communities should be protected throughout the watershed as a means to protect water quality and other natural resources of Biscayne Bay. These natural communities are rapidly disappearing throughout Dade County. The best (and least expensive to state citizens) means to maintain the resource benefits that are provided by these communities is to purchase and preserve these lands. Another (more expensive for state citizens) approach is to purchase vacant land for use as retention and/or recharge areas and restore natural plant communities to these areas. The third (and most expensive for all concerned) approach is to allow the land to be developed and

use technology to add on the protection that was formerly provided by the natural environment (i.e. retention, removal and/or treatment of groundwater and surface water contaminants) before water is allowed to leave the site.

Certain land use practices are not compatible with protection of water quality within the Bay. Such development and land uses should be located in areas that do not directly impact the Bay. Due to the highly permeable nature of the Biscayne Aquifer and the interconnecting network of surface water drainage canals, there are few safe places within the basin where such incompatible land uses can be located, unless appropriate additional methods are employed to prevent surface water and groundwater contamination.

Dade County DERM, the National Park Service, the SFWMD, FDNR, FDOT and perhaps other entities have together compiled extensive land use/ land cover data for Biscayne Bay. This information needs to consolidated, compiled and updated to create a consistent computerized data base and entered into digital format.

Recommendations:

16) **Restoration and Preservation of Natural Habitats.** Explore, develop and implement alternative methods for purchasing, protecting, and restoring the integrity of wetlands and upland habitats and communities that provide water quality benefits to surface water and shallow groundwater systems. Appropriate techniques may include restoring water flow through previously-drained coastal wetlands, restoring natural topography and vegetation to filled or cleared areas, filling of deep holes in the Bay bottom, placement of artificial reefs, repair of propeller-scarred grassbeds, and restoration of abandoned agricultural lands to natural plant communities.

17) **Land Use.** Protect water quality and environmental resources within Biscayne Bay through careful regulation, primarily at the local government level, of land use and use of lower density zoning. Critical areas that have been identified near the Bay or its tributaries should have special restrictions on land uses and/or land and water management practices to protect the resources of Biscayne Bay. Remaining natural areas within the watershed, or sites that are suitable for restoration, should be protected, to the extent possible, through purchase of the property, protective easements or the placement of land use restrictions. .Local governments efforts in this area should be supported.

18) **Manage Restoration Areas.** Initiate a cooperative effort among the SFWMD, counties, municipalities, Biscayne National Park, DER, DNR, FGFWFC, other agencies and other public or private interest groups to develop restoration and continuing management plans for individual tracts of land that have been identified as suitable for restoration. Determine priorities and sources of funding for purchase and/or management of these areas and implement appropriate restoration activities.

19) **Manage Preservation Areas.** Initiate a cooperative effort among the SFWMD, counties, municipalities, Biscayne National Park, DER, DNR, FGFWFC other agencies and other public or private interest groups to develop preservation and continuing management plans for individual tracts of land that have been identified as suitable for preservation. Determine priorities and obtain funding from appropriate state programs such as CARL and Save

Our Rivers, federal monies, or private conservation foundations for the purchase and/or permanent protection of these lands.

Submerged Land Ownership

Conclusions:

The Aquatic Preserve Management Plan for Biscayne Bay made initial attempts to identify ownership of submerged lands within Biscayne Bay. The maps that were developed for this plan have never been approved by the FDNR. Ownership is determined by the DNR on a case-by-case basis as sites are proposed for development.

The purpose of a land ownership survey would be to identify those lands that are owned by the state, lands that are owned by the Federal government (primarily within Biscayne National Park), lands that are owned by other governmental entities and lands that are in private ownership. Land ownership is an important issue for the protection of the resources of Biscayne Bay, because ownership generally determines the type of use and development that can occur in a particular area. In general, submerged lands that are owned by the federal government as part of the park are protected from any form of development. Development of submerged lands that are in state ownership requires a lease from the DNR. In the past, development of such lands, especially within an aquatic preserve, has generally been restricted by the need to meet DER requirements. The use of submerged lands that are in public ownership by local governments is determined by that jurisdiction. Local governments are often more amenable to development that may have a beneficial economic impact. Submerged lands in private ownership can often be developed as the owner sees fit, subject to local government land use restrictions.

Recommendation:

20) **Submerged Land Ownership.** The lack of adequate ownership data severely handicaps efforts to restore and preserve the Bay. This inventory will require cooperative efforts among local, state and federal entities and should identify submerged land use patterns, areas that are privately owned, areas that are publicly owned, and areas that are leased to private interests. The SFWMD, DERM, BNP, FGFWFC and FDER should work together with FDNR as lead agency to complete an inventory of the ownership and use of submerged lands and emergent marshlands in Biscayne Bay. The SFWMD, DERM, and FDER should provide their existing land use, land cover, and ownership data and technical assistance to help FDNR complete this inventory in a timely manner.

Card Sound and Barnes Sound Management.

Conclusions:

Card Sound and Barnes Sound are marine lagoons in the southernmost portion of Biscayne Bay that are sensitive to a number of man's activities. These areas require additional research to define management strategies and special efforts to protect their unique natural resources.

This area is bordered on the east by north Key Largo and old Rhodes Key and on the west by southern Dade County and northern Monroe County. Freshwater flow historically entered this area as overland sheet flow, aquifer outflow and estuarine upwellings of groundwater. Currently, freshwater inflow occurs primarily through the C -111 canal.

Card Sound and Barnes Sounds are areas of restricted circulation and freshwater flow due to artificial diversion of freshwater sheet flow, impoundment created by bridges and causeways, and naturally reduced tidal flushing from the ocean. During the dry season, hypersaline conditions reduce the potential of this area to support estuarine animals. Reduced circulation aggravates water quality problems.

Card and Barnes Sounds and the land associated with the C-111 are important habitats for the Roseate spoonbill, the Cape Sable seaside sparrow, the American crocodile and the Schaus' swallowtail butterfly. Wetland and hammock areas bordering these two Sounds contain numerous other threatened and endangered species. The major threats to this area are dumping, poaching of native species, artificial timing and volume of freshwater inflow, marina siting, and planned development.

Although some of the lands surrounding both lagoons are protected under a variety of state and federal programs, large tracts of land remain in private ownership. Due to poor circulation and flushing, and lack of nutrients, even minor development may have potentially serious impacts on critical wildlife habitats. These extremely important areas require a thorough evaluation of resources and additional protection. The SFWMD is currently conducting studies in this area to review the water delivery schedule for the C-111 canal. A water quality monitoring program for Barnes Sound and Card Sound is being considered in cooperation with Dade County DERM and Biscayne National Park. An Aquatic Preserve Management Plan should be completed for Card Sound. In addition, Barnes Sound should be considered for inclusion as an Outstanding Florida Water, in the state Aquatic Preserve program, or as a water body in one of the adjacent State or National Parks.

Recommendation:

21) **Card Sound and Barnes Sound Management.** Initiate management efforts to protect Card Sound and Barnes Sound, recognizing the unique resources and management problems of these areas and the need for cooperation among the SFWMD, FDER, FDNR, FDOT, USFWS, NPS, FGFWFC and local government entities in Monroe and Dade Counties. The DNR should review aquatic preserve status of this system and include Barnes Sound in the existing Biscayne Bay/Card Sound Aquatic Preserve area.

Centralized Data Bases

Conclusions:

Many entities throughout South Florida collect information that is relevant to management of Biscayne Bay. The various agencies and local governments that are responsible for management of the Bay need to be able to access a common, consistent source of information as a basis for management decisions and resource evaluation. The various agencies and local governments should pool their resources

to develop centralized data bases or a centralized index for available information concerning Biscayne Bay.

The research efforts that were associated with preparation of the SWIM plan and other cooperative programs with local governments, state and federal agencies, have identified extensive information concerning the Biscayne Bay watershed. Sources of information include the various regional, state and federal agencies; local governments and entities; and private interests such as utility companies and conservation groups. Much of the existing information has not been updated and/or is not in a consistent form or computerized format. Efforts need to be initiated to identify and update information and make it accessible by computer.

A number of projects are currently underway to exchange information between the SFWMD and Dade County. The SFWMD already compiles regional water resource data from a number of state federal and local sources. Efforts are underway to provide Dade County with access to this computerized hydrologic data base. Dade County has more detailed information concerning water management and other permits than is available at the SFWMD. Listings of these permits have been provided to the SFWMD. The SFWMD is also arranging for DERM to store water quality data on a SFWMD computer system and to have access to these data.

Analysis of information for the SWIM plan has also identified the need for additional information concerning features and resources of Biscayne Bay. A major deficiency is the lack of adequate information concerning the distribution of ecological resources within the Biscayne Bay watershed. DERM has prepared, and is updating, a map of benthic communities. However, although Dade county has a similar map for shoreline vegetation, mangroves and saltmarshes, and for coastal freshwater wetlands, beaches and dunes, tropical hammocks and pine forests. This information is not readily available in a quantitative, digitized form. This information is necessary to provide quantitative assessments by the regulatory community of the impacts of development proposals on a case by case basis. The work should be accomplished in conjunction or coordination with the Florida Natural Areas Inventory program.

Recommendation:

22) **Develop Centralized Data Bases.** Develop a centralized resource data base for Biscayne Bay and its drainage basins, incorporating existing land use/land cover data, water quality, hydrologic and fine scale ecological data from the District, other agencies and local governments. Location and species composition of natural communities of the Biscayne Bay watershed and the Bay bottom, including benthic communities, mangroves, freshwater and tidal wetlands, and coastal uplands, should be thoroughly mapped and the maps digitized. This work should be coordinated with the efforts of the Florida Natural Areas Inventory. These data would provide a basis for restoration and preservation projects and for evaluation of the cumulative impacts of future development.

Public Education/Awareness

Conclusions:

A number of public information and awareness programs concerning Biscayne Bay are currently underway. Most of these efforts, however, do not emphasize water quality problems in the Bay and the role of the public in managing these problems. A public awareness program is needed to specifically address SWIM plans and management concerns. This program should provide multi-lingual materials in an effort to reach the large resident population of non-english speaking residents.

Recommendation:

23) **Public Education/Awareness.** Support efforts by local governments, state agencies, the National Park Service and other interests to develop and implement multi-lingual and other educational programs to increase public awareness of, interest, and participation in addressing water quality related issues and problems in Biscayne Bay and aid existing interpretive efforts by local authorities and state agencies.

Identify Areas of Probable Historical Contamination

Conclusions:

Land adjacent to Biscayne Bay has been developed since the late 1800's. During this period, various activities have occurred within the watershed that may have resulted in contamination of surface or ground water resources. Due to the extensive network of drainage canals and the high permeability of the Biscayne aquifer underlying the Biscayne Bay watershed, groundwater and surface water are interchangeable. Sources of contamination anywhere in the basin may potentially impact Biscayne Bay. Research is needed to identify areas that due to past land use practices may currently be releasing toxic materials or other contaminants. Closed or inactive landfills have been mapped and many of these sites are actively leaching contaminants into the environment. In addition, many land use practices such as agricultural spraying, that used organic compounds and heavy metals, were conducted in the Biscayne Bay watershed until use of these materials was banned.

Currently, Key Biscayne and its surrounding waters contain high levels of arsenic that may have resulted from a variety of sources including an old landfill and agricultural practices. The Little River and Arch Creek areas currently have no significant heavy industrial or commercial land use. However, these basins have unusual levels of contaminants that result from unknown sources. Miami International Airport has extensive groundwater contamination problems and the impact of these contaminants is unknown. The airport is located near the Miami River and may be impacting its waters or adjacent canal systems. This work should result in a concise document containing information that currently is scattered through a number of publications and agencies. A publication of this type could then be used as a guide to future contaminant work where analyses of compounds are very expensive and it is desirable to have some idea of the type of contamination to be expected. It would also serve as a reference to determine possible sources of aberrant compounds that have no apparent source.

Recommendation:

24) **Historical Contamination.** Commission a research investigation by a local historian to summarize existing information, examine historical records, and interview residents in Dade County to identify prior land uses that may continue to contribute to current water quality problems, such as historical agricultural sites and practices and industrial sites. This would result in a concise document that can then be used as a guide to designing future contaminant studies in the basin.

V. PROGRAMS AND PROJECTS

A. Management Strategies.

Strategies and potential strategies for the management of Biscayne Bay have been outlined in the final recommendations of this plan. These recommendations provide a framework to support future restoration and preservation efforts in Biscayne Bay. In conjunction with the recommendations, during the past year the District has implemented specific programs to address the major management concerns in the Bay that fall within the scope of SWIM. The programs and a schedule to address the management concerns of the Bay are, in turn, based on the assumption that the legislature, District and local government will provide continuing support for these programs. Contingent on the availability of funding, SFWMD SWIM programs will:

1. continue funding of enforcement activities while encouraging local governments to develop alternate funding sources for these activities. Consider support of research or special projects that may be needed to enhance enforcement efforts
2. continue support for shoreline stabilization projects to address the areas of immediate major concern.
3. continue funding of stormwater retrofit projects with future emphasis in other areas of the Bay besides the Miami River. SWIM will continue to provide seed money for these projects but will expect more of the costs to be borne by local government.
4. conduct periodic review of status, condition, maintenance and success of previously-funded projects especially those concerning stabilization, flow diversion, stormwater retrofit and sanitary systems
5. continue to fund the monitoring program with periodic review, possible reorganization for more effective coverage, and expansion to consider new areas and new parameters
6. continue multi-agency efforts to collect land use and other data, and to develop and implement data bases, data management and access procedures
7. continue support of management projects in Card Sound and Barnes Sound,
8. develop support for studies of special problem areas
9. continue to support selected research efforts that address management issues
10. assist the county and other local entities to obtain funding from local, state and federal sources.
11. continue support for demonstration projects that use innovative technological approaches and solutions to address management issues

The scope of ongoing and proposed programs for Biscayne Bay is outlined in the following section.

B. Programs and Projects.

A variety of monitoring, implementation and research projects have been recommended for funding in Biscayne Bay by the SFWMD as part of the SWIM plan. Projects for FY 87-88 are currently underway. Additional projects have been proposed for FY 88-89, and these projects will be initiated, pending final approval and appropriation. Funds to support the FY 88-89 projects in Biscayne Bay were requested from the recently completed (June, 1988) legislative session. In addition, continuing funding for ongoing projects and funds for additional projects are requested in the FY 89-90 budget that is outlined in this report and will be submitted to the legislature in March, 1989.

Programs, projects, priorities and funding for FY 89-90 and FY 90-91 may change, depending on the outcome of current work, or as additional problems are defined within the system based on research, monitoring or other concerns. Programs for FY 87-88 and 88-89 are extensions of ongoing work by other agencies and local government entities that have previously been identified as necessary activities for Bay management.

All projects that are funded for implementation by SWIM money must address serious problems in the system that relate to water quality, must be consistent with the SWIM plan and recommendations, and must have been defined or described by past research or monitoring efforts. In addition, continued monitoring and research are required in Biscayne Bay to gather information in new areas where little or no data currently exist, obtain data on currently healthy areas, and examine known problem areas in more detail to define the scope of remedial procedures that are necessary to address problems. Basic research is also needed to develop appropriate analytical methods, local standards, and management techniques.

1. Programs and Projects for FY 87-88.

Projects that are being funded in Biscayne Bay for the current fiscal year are grouped according to programs and include continued retrofitting of stormwater basins, increased enforcement, water quality and habitat monitoring, shoreline stabilization, and support for the Miami River Coordinating Council. Of these projects, enforcement, monitoring and shoreline stabilization are being directly funded to Metro-Dade County DERM. Stormwater system retrofitting is being conducted in cooperation with the City of Miami. In addition, funds were provided this year to match a city grant for staffing and operations of the Miami River Coordinating Committee.

Water Quality and Habitat Monitoring Program. The monitoring program includes sampling networks and analyses for water quality, sediments, toxic materials, chemical contamination, storm event monitoring, contaminants in biological materials, and long-term monitoring of epibenthic communities. The monitoring program is designed to provide baseline data on water quality and Bay habitats, detect and describe water quality and environmental trends, complement and support other research and management studies in the Bay, assess the impact of stormwater drainage on the water body, and provide support data for regulatory decision making. Monitoring is intended as a continuing program. However, the emphasis of this program may shift periodically--to examine existing or new problem areas in more detail, consider new sources and types of pollution, or to complement other work--by adding or removing stations and/or parameters.

Metro-Dade County DERM has an ongoing, state-funded, monitoring effort that began in 1979 for stations in Biscayne Bay and Card Sound. These data have been used successfully to identify problem areas and point sources of pollution and as the basis for enforcement actions to reduce pollution inputs to the Bay. Continued acquisition of such data is essential to support management actions, enforcement, and identification of new problems. Water and sediment samples are collected in the Bay, the Miami River and at stations in the canals and tributaries.

The project for FY 87-88 will involve expansion of the existing monitoring network. Water samples will be collected at 74 stations each month and will be analyzed for color, total non-filterable residue (TNR), turbidity, NO_x-N, NO_3-N, PO_4 total, chlorophyll *a*, phaeophytin, cadmium, copper, lead, and zinc. Chlorophyll *a*,

phaeophytin, and metals will be analyzed less frequently. Sediments will be analyzed periodically for metals and various physical characteristics.

Long-term, epibenthic habitat monitoring is another ongoing effort that evaluates the health and condition of selected stations and various bottom types. These benthic data are used in conjunction with changes in water quality, in an attempt to determine negative or positive impacts that changes in water quality may have on these important communities. This activity is necessary to evaluate the success of water clean-up and pollution abatement activities in the Bay.

Turbidity Abatement Program. Turbidity has been identified as a major problem and has been implicated with the destruction of grass beds in certain areas of Biscayne Bay. The purpose of this program is to undertake projects and research that will help to reduce turbidity levels in the Bay. One method to reduce turbidity is by shoreline stabilization. The purpose of shoreline stabilization projects is to develop and construct or install various alternative methods for stabilizing unconsolidated shorelines and/or mitigating the adverse impacts of vertically bulkheaded shorelines. These funds can only be used on public lands. The current project includes a contract with Metro-Dade County DERM that provides funding to stabilize an eroding red mangrove shoreline at the Oleta River state recreational area. The first phase involves the design and permitting of a stabilization structure. Construction will commence, once the design is approved and permitted. Shoreline stabilization is an ongoing project that may include other areas as funding permits.

Enforcement Program. This program provides funding to local government for enforcement-related expenses and activities such as additional personnel, equipment, monitoring and research. The current project provides funding to Metro-Dade County DERM to support two new and one existing enforcement personnel, two vehicles and the costs of water quality sample analyses. The purpose of this project is to provide additional assistance to Dade County efforts to identify and control point and non-point sources of pollution within the basin that are subject to enforcement action under county codes. The funding of these positions should eventually be taken over by the county.

Stormwater Outfall Retrofitting Program. This program provides financial and technical assistance for local government efforts to design and retrofit stormwater systems. The current stormwater basin retrofitting project is being initiated with the City of Miami. The contract for this effort has been signed. Cross-connections between stormwater and sanitary systems will be eliminated in all basins that are retrofitted under this program. Cross-connections between the sanitary and stormwater sewers, sewer line breaks and illegal discharges are viewed as the major sources of fecal pollution in the Miami River and Biscayne Bay.

The scope of this project is to retrofit stormwater systems of four basins in downtown Miami that were previously ranked as important sources of contaminants, and one additional system in Little River New systems will be designed to contain the runoff from the first inch of rainfall. Runoff will be treated by a grease and oil interceptor before discharge to surface waters. The City of Miami is responsible for design, permitting, construction, and quality control of this project. Design and construction must be sufficient to meet all applicable regulatory requirements and codes of practice. Construction drawings will be provided to the SFWMD for each basin prior to construction. The City of Miami will cooperate with DERM during installation of these facilities and will provide continuing access to the outfalls for monitoring. The city will provide a maintenance record of all basins

covered under this contract for a period of not less than five years. Funding for this project is scheduled to continue through FY 90-91.

Bay Management Program. The purpose of this program is to provide financial and technical assistance to support efforts by local governments and other state agencies to develop plans and other methods to improve management of the Biscayne Bay watershed. This program also includes efforts to collect additional data and organize this information into a Bay-wide data base. Funding is provided this year to the Miami River Coordinating Committee, in conjunction with matching city money and services from the county, to support staffing and operations of the Miami River Coordinating Committee. This committee is comprised of a cross section of business, civic, environmental, and governmental representatives and was created to address the environmental and socioeconomic issues and concerns related to the health and utility of the Miami River. In the past, this committee has been severely hampered by the lack of staff support.

2. Proposed Programs and Projects for FY 88-89.

Proposed projects for the FY 88-89 Biscayne Bay SWIM programs include continued funding for shoreline stabilization, stormwater basin retrofitting, water quality and sediment monitoring and the Miami River Coordinating Committee. The detailed scope of work for these programs will be determined as funding for SWIM programs is allocated by the Legislature and SFWMD Governing Board.

Water Quality and Habitat Monitoring. The water quality monitoring effort will be increased in Biscayne Bay, but epibenthic habitat monitoring will continue at the same level. The water quality monitoring project will be expanded to include organic compounds, tributyltin and pesticides. Organics, pesticides, and tributyltin will be surveyed to determine the ambient concentrations in sediments, on a one time basis. Future sampling will depend upon the outcome of these analyses. Tributyltin will be added to all sampling areas as a new parameter that will be examined yearly as a sediment parameter and monthly in water column samples at selected stations.

Stations in Barnes Sound will be added to DERM's routine water quality and biological sampling network. Barnes Sound is a sensitive system that is in need of preservation. Very little water quality data are currently available for Barnes Sound. Monitoring data are required to obtain baseline values for this area

Improved Circulation and Flushing Program. This program will address problems related to inadequate circulation or flushing in the bay and problems related to the impacts of freshwater discharges from the canal system. Examples of some such problems include the following: a) areas in the Bay where inadequate circulation and flushing are cause degradation of water quality or natural communities, b) areas where unnatural distribution of fresh water causes localized salinity stratification, and c) areas where lack of freshwater flow through the adjacent marshes causes high salinity conditions during the dry season or where productivity of these marshes is lost to the Biscayne Bay ecosystem because detrital material is not adequately flushed from the floor of the mangrove forest.

Two projects are proposed in FY 88-89 within this program. The purpose of the first project is to examine the feasibility of redistributing flow through the fringing wetlands adjacent to Biscayne National Park and the effectiveness of these techniques toward reducing the impacts of freshwater discharges from the canals

and facilitating the transfer of mangrove detritus into the Bay. The second project will help correct a circulation and flushing problem that has been identified in the vicinity of Homestead Bayfront Park and Biscayne National Park headquarters at the Mouth of Mowry Canal. A dead-end basin has been created by the construction of marina facilities. This basin tends to have poor water quality, especially low levels of dissolved oxygen. The purpose of this project is to improve water quality by the placement of appropriate culverts connecting the back of the basin with the adjacent Mowry canal and allowing tide-induced flushing of the system. This includes two projects Biscayne National Park-Bayfront Park Flow culverts and L-31E Flow Redistribution to restore flow through the mangrove wetland fringe.

Bay Management Program. The scope of this program will be expanded to include a new project to provide support for the design and permitting of future Bay management projects. This projects will provide necessary background information, budgeting, planning and permit acquisition for future Bay Management projects. This will facilitate actual execution of these projects in the same fiscal year.

Tributary Sediment Monitoring Program. The tributary sediment monitoring program is to be focused on canals in South Bay where known contaminant sources include extensive agricultural usage, Homestead Air Force Base, and older landfills known to be leaching into adjacent canals. Sampling will include two to three stations downstream and one station upstream of the control structures. in the six canals from Black Creek to the Florida City Canal.

3. Proposed FY 89-90 Programs and Projects.

Specific work has not yet been defined for FY 89-90 projects, since the amount of funding that may be available for these efforts is uncertain. The shoreline stabilization, Miami River Committee and stormwater outfall retrofitting projects will be continued, with a slight reduction in funding. The canal flow redistribution, and educational materials projects will continue at about the same level of funding. Monitoring will be expanded to consider stormwater events and assessment of toxic substances and microorganisms in biological materials. New projects are proposed to address data needs, circulation, non-point pollution from prior land uses and management concerns in the Card Sound/Barnes Sound area. These projects will be further defined as data are obtained from other projects and funding issues are resolved.

Monitoring Program. Storm event monitoring is a new project that will be instituted to evaluate the success of outfall retrofitting. Samples will be collected with an automatic water sampling device that will be triggered by a rapid increase water levels, such as occurs in a storm event. Samples will be analyzed for pH, conductivity, inorganic nutrients, suspended solids, color, BOD, COD, selected trace metals, and various hydrocarbon fractions as determined necessary. Samples will also be collected during dry periods to determine the water quality in these systems under non-storm conditions. Samples collected during the dry periods will be analyzed for coliform bacteria, fecal coliform bacteria, temperature, salinity, and turbidity in addition to the other parameters that are measured during storm events.

The monitoring effort will also be expanded to consider toxic substances and microorganisms in biological materials. Certain marine and estuarine organisms tend to accumulate toxic metals, organic materials and microorganisms and concentrate these materials in their tissues to levels that are substantially higher

than may be found in water or sediments. These living materials thus may be useful as sensitive indicators of low levels of pollution in the ecosystem. The purpose of this project will be to conduct a survey of potential indicator organisms that reside in Biscayne Bay select appropriate organisms and contaminants, and design a monitoring study based on this information. Actual implementation of such a monitoring network will depend on the results of this initial study.

Research Program. The purpose of the research program is to provide financial and technical support for basic and applied research that is directed toward improved monitoring, enforcement or management of Biscayne Bay. The project that is initially proposed under this program is to collect and refine local historical knowledge from residents, historical records, and other planning efforts, to define and describe historical practices and land uses that may have resulted in current contamination problems, and to prepare a report and recommendations.

Public Awareness/Public Education Program. This program would provide educational materials that could be used to educate children and adults concerning SWIM activities, the Biscayne Bay ecosystem, diversity of biological communities, the dependence of this system on water quality, and methods to prevent damage to these resources. Currently no such educational materials exist that address this range of concerns. This program will interface with other county, state, and federal programs as well as non-profit educational programs of various conservation groups. This work will also use facilities, programs and assistance provided by state parks and the National Park Service.

The Miami area has an extensive population of citizens that do not speak or read English. The District feels that multi-lingual educational materials should be provided for the diverse groups of these people that use the Bay. This project would assist in the development of multi-lingual educational materials concerning Biscayne Bay. The intended audience would be primary and secondary school children and teachers, but the project may also be expanded to include adult groups. This project is proposed again for FY 89-90.

Bay Management Program. Four projects are proposed for FY 89-90 under this program. They are Miami River Coordinating Committee support, planning for future Bay management projects, design and implementation of restoration and preservation projects, and initiation of a management effort in Card Sound and Barnes Sound. The purpose of the restoration/preservation project is to a) computerize available land use, ecosystem and biotic information to provide detailed information concerning species, communities and habitats; b) identify and prioritize areas for preservation or restoration; and c) initiate purchase of lands, planning, design and permitting as necessary to implement preservation or restoration of the high priority areas. This study must interface with ongoing projects by DERM, FDNR, BNP, USFWS, FGFWFC and the Natural Areas Inventory Programs. Planners, regulatory agencies and statewide planning interests would benefit greatly through access to such a system. These data would be valuable as a basis to evaluate permitting requests where the survival of small parcels of important natural plant communities is at stake.

The Card Sound/Barnes Sound Management effort will begin the development of a management plan for this area of the Bay. Card Sound and Barnes Sound contain healthy natural systems. This part of the system should be protected from any further development. Currently, no management plans exist for these systems. Barnes Sound is not included under any special state designation, however due to its

healthy state It should perhaps be designated as an Aquatic Preserve and efforts should be initiated to acquire this area for inclusion in the National Park System or Crocodile Lake National Wildlife Refuge.

Card Sound and Barnes Sound have been specifically identified as target areas that have extremely restricted circulation and flushing and so are sensitive to contaminants and unnatural salinity changes. Steps need to be taken to ensure that properly timed and regulated flow are provided to Barnes sound to prevent large volume pulse releases of freshwater and the extensive development of hypersaline conditions. This area has extremely reduced flushing and is partially impounded by the fill that was used to construct highway A1A. Any further construction of causeways in this area would cause potentially strong damage to the system. Replacement of existing causeways with bridges and/or the installation of culverts should be considered as means to alleviate these problems. Construction of Marinas in this area would provide known sources of pollutants to systems with extreme residence times. Management programs are necessary to define needs for additional study and modifications necessary to address known problems in this area.

Circulation and Flushing. The new projects that have been are proposed within this program for FY 89-90 are modification of canal getaway channels in South Bay and examination of circulation and flushing conditions in Card Sound and Barnes Sound. Water management canals in South Bay were dug with deep getaway channels, downstream of the coastal salinity structures to facilitate heavy flows during storm events. This design has been identified as a possible source of poor quality water. Water in these deep channels is removed from normal circulation patterns by stratification and physical separation and becomes stagnant. When strong discharges occur, due to a heavy rain event or regulatory discharge, these stagnant waters can become turbulently mixed and flushed into the adjoining Bay. The District is considering the feasibility of a study to examine the design of getaway canals, downstream of the coastal control structures in South Bay, to determine if an alternative design can be used that will avoid stagnant bottom conditions and still allow sufficient flow of floodwaters.

Studies of Special Problem Areas and Problem Contaminants. This program will consider alternative methods to analyze and resolve special problem conditions within the Biscayne Bay ecosystem, including the target areas and target contaminants that were identified in the Recommendations section of this report. The project that is proposed for FY 89-90 is a study of leachate movement from the Black Point Landfill area. Groundwater contamination may have occurred at the the site of the Black Point Landfill, potentially from a variety of sources. Due to the geological formations underlying this area it may be moving into the Bay. The source of this leachate and its ultimate fate in the system should be determined.

VI. SCHEDULE, FUNDING, AND PRIORITIES

Schedule and Funding. The general schedule for compliance, restoration and management of Biscayne Bay is discussed in the section of this report that deals with specific requirements of the SWIM legislation. The above programs and schedule depend on an estimated funding support of approximately $2 million per year from the legislature or other outside sources in addition to the support of the SFWMD, DER, DERM, the City of Miami, Biscayne National Park , etc. The general schedule for completion of SWIM projects funding requirements of projects in Biscayne Bay are summarized in Table 13.

Priorities. Priorities for FY 89-90 funding are divided into three groups--very high, high and medium. Very High priority efforts include the following:

1) Retrofitting of stormwater systems and development of local funding sources for continuation of these efforts in north Bay and the Miami River.
2) Continuation, expansion, and reevaluation of monitoring programs.
3) Protection of existing resources of South Bay, especially Biscayne National Park, Card Sound and Barnes Sound, including restoration of marshlands and development of a management plan for Card Sound and Barnes Sound.

Table 13. Biscayne Bay SWIM Programs, Projects and Budget

Item No.	Project Title/Description	Funding (000's)			Recommendation No.
		87-88	88-89*	89-90*	
1	Stormwater Outfall Retrofit Program a. Miami River Stormwater systems	1,190	919	1,130	1,2
2	Enforcement Program Local Government Enforcement	150			9,10,11
3	Monitoring Program a. Water Quality/Biological Monitoring b. Tributary Sediment Monitoring c. Stormwater d. Biological Materials	300	300 50	300 150 100	2,5,6, 7,21
4	Turbidity Abatement Program a. Oleta River Stabilization	735		300	14
5	Bay Management Program a. Miami River Committee b. Preservation/Restoration Project Planning c. Card Sound/Barnes Sound Management. d.Planning and Permitting for Future Projects	25	 50	20 25 50 50	15,16,17, 20,21
6	Circulation and Flushing Program a. Canal Discharge Redistribution b. Flow Culverts at Mowry Canal c. Canal Getaway Channel Modification d. Circulation Maintenance		200 30	200 30 50	12,13
7	Research Program a. Historical Contamination			20	23
8	Public Education/Awareness Program a. Educational Materials (multi-lingual)			50	22
9	Special Problem Areas and Contaminants a. Black Point Canal Basin Water Quality			30	24
	TOTALS	2,400	1,549	2,505	

*Proposed

4) Development of a central, computerized database for land use and other needed to support future monitoring, restoration and preservation efforts

High priority efforts include

5) Turbidity Abatement projects
6) Studies of special problem areas such as Black Point

Medium priority efforts include

7) Educational materials
8) Historical contamination
9) Miami River Committee

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