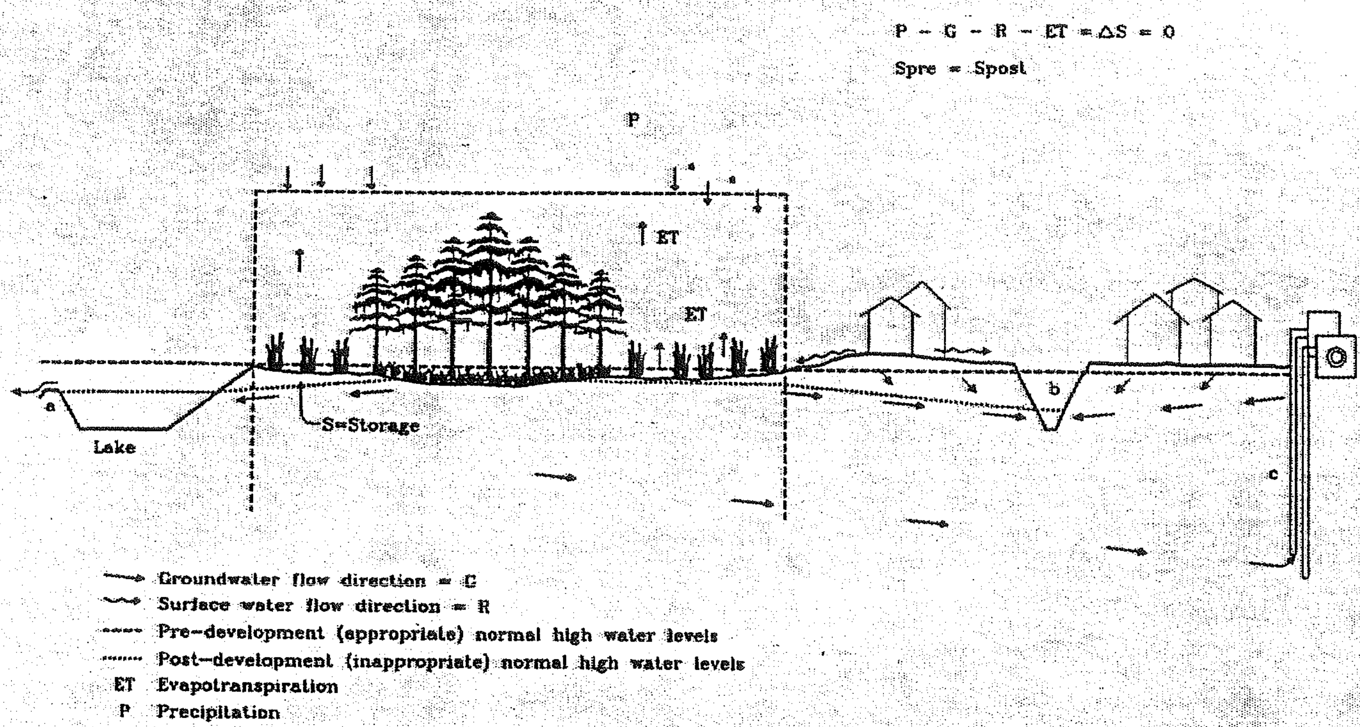
# AN EVALUATION OF WETLAND MITIGATION WITHIN THE SOUTH FLORIDA WATER MANAGEMENT DISTRICT

# VOLUME I





By:

Kevin L. Erwin
Kevin L. Erwin Consulting Ecologist, Inc.
2077 Bayside Parkway
Fort Myers, Florida 33901


For:

South Florida Water Management District
3301 Gun Club Road
West Palm Beach, Florida 33416-4680

JULY 1991

# AN EVALUATION OF WETLAND MITIGATION IN THE SOUTH FLORIDA WATER MANAGEMENT DISTRICT

## VOLUME I

Contract # C89-0082-A1

*date*

*July 1991*

*by*

*Kevin L. Erwin*
*Kevin L. Erwin Consulting Ecologist, Inc.*
*2077 Bayside Parkway*
*Fort Myers, Florida 33901*

*for*

*South Florida Water Management District*
*P.O. Box 24680*
*3301 Gun Club Road*
*West Palm Beach, Florida 33416-4680*

# TABLE OF CONTENTS

# LIST OF TABLES

# LIST OF FIGURES

## LIST OF APPENDICES

# EXECUTIVE SUMMARY

# I. EXECUTIVE SUMMARY

## Introduction

This study is a thorough evaluation of the effectiveness of the wetland mitigation efforts and needs of the District. Wetland restoration, creation, and preservation has been required as compensatory mitigation for wetland impacts since the District adopted the Isolated Wetlands Rule in 1987. Since 1987 when the rule was incorporated into Appendix 7 of the Basis of Review for Surface Water Management Permit Applications, the District has permitted approximately 4,439 acres of wetland impacts. Currently over 570 projects have been permitted with wetland mitigation requirements.

This study was designed as a programmatic review to evaluate the effectiveness of existing design and operational technology for the maintenance, creation, and restoration of wetlands permitted by the District. Secondly, the study provides information and recommendations for improvements to the District's wetland mitigation program by highlighting critical design features and a framework for recommended changes.

Volume I presents the methodology, findings, discussion, and recommendations for the evaluation of wetland mitigation projects. Volume II contains the data collected for each project in a characterization form. A bibliography of pertinent wetland mitigation literature, including gray and refereed publications, is contained in Volume III.

## Scope of Work

Forty completed wetland mitigation projects were identified in 13 counties following a comprehensive survey of 195 projects. The selected projects contained various combinations of created, restored, and preserved forested and non-forested freshwater wetlands in agricultural, residential, commercial, and public developments. Each site was inspected and characterized to evaluate the project's features. Surface hydrology and vegetation were evaluated for each site. Observations were also made pertaining to project goals, success criteria, design, location, adjacent land uses, water source, management, functional values, and persistence. Water quality and macroinvertebrate sampling was conducted at each project where conditions allowed.

## Results

Out of more than 100 permitted projects requiring wetland mitigation only 40 had undertaken any mitigation activity. The average age of the completed mitigation projects was less than three years. The oldest was three and one half years. Twenty-one of the projects required the creation, restoration, and preservation of non-forested wetlands only. Seventeen projects dealt with both forested and non-forested wetlands. The size of the individual wetlands required to be created, restored, and preserved ranged from; 0.2 to 207.2 acres, 0.8 to 131.9 acres and 1.2 to 865 acres, respectively. All 15 residential and ten commercial projects were located in the urbanized areas along the coasts and in the upper Kissimmee Valley area. The 12 agricultural and two of the three public projects were located in the rural interior.

The mitigation project goals were rarely stated in the permits. Only three of the projects had a full set of environmental goals, six had no goals at all and 27 projects had goals limited to acreage and type of habitat targeted. Only four of the 40 projects studied met all of the stated goals established in the permit. Twenty-four of the projects contained success criteria. However, for 23 of the projects the success criteria were not appropriate.

Of the 1,058 acres of wetlands required by permit to be created for all 40 projects, approximately 530.6 had actually been constructed leaving a shortfall of 527.4 acres. Wetlands actually restored, although not always successfully, total 695.3 acres netting a surplus of approximately 88 acres over the permitted amount. None of the required 3,095 acres of wetland preserves had been directly impacted (dredged or filled) by development. These acreages were estimated since "as built surveys" or "record drawings" were not required or provided to the District by the applicant for any project.

Each of the projects were evaluated with regard to its location in the surrounding landscape. Location and persistence are not in the District's criteria and did not appear to be considered when these projects were permitted. Twenty-three of the 40 mitigation projects studied were located where surrounding existing or future land uses may prevent the wetlands from providing the intended functional values. Only three of the projects included a long-term management plan.

The most significant project design problem identified was improper water levels and hydroperiod. Twenty-five or 62.5 percent of the projects studied exhibited hydrological problems within the created, restored or preserved wetlands. Seventeen of the 31 projects that contain wetland creation exhibited hydrological problems related to design and/or construction deficiencies. Six of the 15 projects containing wetland restoration and five of the 21 projects with wetland preserves were adequately designed.

Colonization of wetlands by undesirable plant species such as cattail and melaleuca were common in 32 of the 40 projects. Permits for 22 of the projects required removal of problematic plants, however, no activity attempting control was undertaken in 13 of these projects. Post-construction monitoring was required by permit for 39 of the 40 projects. Adequate monitoring had been undertaken for 15 projects and no monitoring reported at all for 15 projects.

The water quality and macroinvertebrate sampling of the projects studied established baseline conditions for these relatively young mitigation projects. Violations of Chapter 17-3. F.A.C. water quality standards were restricted to alkalinity which was not significant. However, 30 of the wetland mitigation projects receive stormwater discharges from parking lots, industrial sites, residential areas, and citrus groves without pretreatment. Long-term water quality problems may develop within these wetlands without corrective action.

Not directly stated as a goal in any of the project's permits, "no net loss" was generally inferred. For those projects that undertook mitigation as far as acreage only, not type, quality, or function, the projects studied have not yet achieved "no net loss" given the shortfall of acreage.

## Recommendations

The District Governing Board should define, adopt and implement "no net loss" of wetland functional values as an agency wide goal and conservation of biological diversity as a regional policy. The District staff should make the following modifications in the wetland mitigation process;

- Success Criteria. Measurable and specific success criteria that directly pertains to the project goals must be incorporated into each project.

- Project Design and Location. Require that appropriately skilled professionals prepare the mitigation plans; identify the process to develop appropriate hydrological designs; evaluate the cost effectiveness of construction techniques; require the applicant to provide adequate documentation of project water level and hydroperiod; emphasize "stand alone", low energy, self maintained systems; develop a method for assessing upland and wetland values and determining the type and amount of compensation; maximize habitat diversity by incorporating native upland habitat into wetland mitigation projects; incorporate elements of a water budget evaluation in the surface water management engineering analyses and reduce the cumulative impacts on wetlands.

Compliance. Create and adequately staff a wetland resource compliance section to; conduct regular compliance inspections, reporting, and accounting; implement procedures so that noncompliance will not be cost effective for the project sponsor; initiate timely enforcement action; require performance guarantees and improve project construction drawing specifications.

Water Quality. Require reasonable assurance from the applicant that the quality of the source of water for the wetlands is compatible with long-term maintenance of the project goals; investigate the effects of restored, created, and preserved wetlands receiving treated and untreated stormwater runoff.

Management. Require the incorporation of long-term management plans with all projects and include details on operations, responsibility and funding.

Biological Integrity. The District should investigate the measures of a wetland system's biological integrity that could be used as a criterion for evaluating wetland systems including wetland creation, restoration, preservation projects.

Monitoring. Develop monitoring plans and criteria with goal evaluation and compliance as the priority; expand the baseline monitoring requirements and require submittal with the permit application; require regular inspections and reports during construction; require "time zero reports" to be prepared by the applicant; require regular, comprehensive post-construction monitoring until the project goals and success criteria are met and less intensive long-term qualitative monitoring for successful projects.

Finally, this study recommends that the District soon undertake a regional resource protection and compensation planning effort. This project would locate and quantify the natural resources by watershed including uplands, wetlands, surface and groundwater characteristics (including quality, quantity, discharge, etc.). A resource management plan could be developed for each basin or region that would identify and rank all systems and habitats according to importance to maintain biodiversity. The basin plans will enable the District to quantify the direct and indirect (cumulative) impacts on wetlands, and properly locate and implement acquisition, conservation, mitigation, and development.

# INTRODUCTION

## II. INTRODUCTION

Historically, the importance of our wetlands has been overlooked. As recently as 20 years ago they were considered expendable. Wetland ecosystems are very productive areas biologically. Their importance lies in both the traditional values of biological diversity of fish and wildlife, as well as the more recently discovered value as natural water treatment systems and buffers that attenuate peak flows of surface water.

At the time of colonial America, approximately 221 million acres of wetlands were located in the lower 48 states. Over a period of approximately 200 years this area lost an estimated 54 percent of the original wetlands or 60 acres of wetlands lost for every hour between the 1780's and 1980's. Twenty-two states have lost 50 percent or more of their wetlands. California has lost the largest percentage of wetlands within one state (91 percent). Florida has lost the most acreage, 9.3 million acres, (Dahl 1990). It has been estimated that Florida once had approximately 20.3 million acres of wetlands which covered 54.2 percent of the State's surface area. By the 1980's Florida's wetland acreage had been reduced by 46 percent to approximately 11 million acres (FDNR 1988, Shaw and Fredine 1956, and Tschinkel 1984). Based on current U.S. Fish and Wildlife Service (USF&WS) National Wetlands Inventory estimates of past wetland losses, an estimated 400,000 acres of wetlands are lost nationally while only about 25,000 acres are gained on an annual basis.

In the last decade interest has increased in wetland creation and restoration to compensate for wetland impacts at all levels of government, in the scientific community and in the private sector. Restoration and creation of wetlands has been advocated to: reduce the impacts of activities in or near wetlands, compensate for additional losses, restore or replace wetlands already degraded or restored, and serve a variety of new functions such as waste water treatment, aquaculture, and waterfowl habitat. Wetland restoration and particularly wetland creation is a very new science with attempts to implement such activities as policy on a large scale only occurring since the mid 1980's.

In Florida, as throughout the United States, concern about the status of the wetland resource and interest in enhancing it through wetland restoration and creation continues to be strong. Recently, at the request of the U.S. Environmental Protection Agency (EPA), the Conservation Foundation convened the National Wetlands Policy Forum to address major policy concerns. The goal was to develop sound broadly supported guidance on how federal, state, and local wetlands policy could be improved. In its final report, (the Conservation Foundation 1988) the Forum specifically recommended that: "the nation establish a national wetlands protection policy to achieve no overall net loss of the nation's remaining wetlands base as defined by acreage and function, and to restore and create wetlands, where feasible, to increase the quality and quantity of the nation's wetlands resource base".

The Forum also emphasized that the goal of "no net loss" does not imply that the individual wetlands will be untouchable. Therefore, a substantial increase in efforts to restore and create wetlands is inherent to attaining the Forum's objective.

Within the State of Florida a wide variety of agencies including the five water management districts, the Florida Department of Environmental Regulation, Florida Department of Natural Resources, U.S. Army Corps of Engineers, U.S. Fish and Wildlife Service, U.S. Environmental Protection Agency, National Marine Fisheries Service, and local municipal governments have some degree of wetland regulatory authority. Even with the recently increased legislative intent and regulatory protection since the early 1970's, Florida's wetlands continue to be lost, often as a result of impacts resulting from agricultural conversion, residential development, mining, and highway projects. Compensation for these losses and related wetland functional values is absolutely necessary. In a state where more than 11 million acres of wetlands have already been lost there is a critical need to restore and create wetlands to rehabilitate our remaining functional ecosystems.

In 1987, the EPA selected a group of scientists to prepare a status report on wetland creation and restoration in the U.S. This preliminary evaluation of the status of the science of wetland creation and restoration in the U.S. (Kusler and Kentula 1990) identifies what has and has not been learned, and recommends research priorities. The report also covers a wide range of topics of general application to wetland creation and restoration such as hydrology, management techniques, and planning. This work was commissioned by the EPA to identify the adequacy of available information, help establish priorities for EPA's research program and provide agency personnel with an analytical framework for making wetland permit decisions based on the status of the science of wetland creation and restoration. This study is intended to build upon this earlier effort, focusing on south Florida.

The creation and restoration of wetlands is a complex and often difficult task and as such there is a great need for setting clear, common, ecologically sound goals for projects and developing quantitative methods for determining if they are being met. To date, wetland mitigation studies within the state of Florida have been limited to in-house agency evaluations such as DER's Report on the Effectiveness of Permitted Mitigation 1991, and the Office of the Auditor General's (OAG) Report on Wetland Mitigation Practices of the Southwest Florida Water Management District (SWFWMD), 1990. While these reports contain valuable information, they mainly focused on degree of compliance with the permit. These studies were not undertaken to comprehensively assess the degree of success or failure of existing wetland mitigation practices in providing compensation for lost or reduced wetland functional values nor do they address the needs for operational or policy changes to achieve this goal.

This report on the status of wetland mitigation in the South Florida Water Management District (District) is perhaps the first, comprehensive quantitative evaluation of restored and created wetlands as compensation for permitted wetland losses within the United States. This study focuses on identifying the areas where improvements can be made in wetland resource protection.

Since the District began keeping records in 1984 some 4,439 acres of wetlands have been permitted by the District to be altered through the surface water management regulatory program. Currently, over 570 projects have been permitted with wetland mitigation requirements (REEP 1991). As mitigation for those losses, 4,393 acres of wetlands were to be created and 708 acres of wetlands were to be restored.

Prior to this study, a thorough evaluation of the effectiveness of the wetland mitigation efforts and future needs of the District had not been undertaken. The District's Regulatory Evaluation and Effectiveness Program (REEP), established in 1989, was the Regulatory Department's first attempt to evaluate the results of the Department's efforts to manage and protect the water related resources of South Florida. The 1991 REEP report contains the results of four categories covering surface water and water use permitting processes; Engineer Certified General Permit, Wetland Protection and Mitigation, Industrial Stormwater Quality, and Long-Term Operation and Maintenance. As with the DER and OAG-SFWMD studies, the REEP program focuses on project compliance with permitting criteria.

The creation and restoration of wetlands remains a relatively new field. Wetland mitigation programs in general are complicated by the fact that individual mitigation projects are evaluated on a case by case basis with only partial knowledge of how well the plan will actually replace lost wetland functions and values or fit into a regional scheme for the preservation and enhancement of ecological values. Due to the relatively new and rapidly evolving nature of the District's regulatory program, necessary regional policy setting mechanisms to improve integration of mitigation, planning, and regulatory programs have not previously been adequately established.

When the District enacted the "Isolated Wetlands Rule" in 1987 (codified in the Basis of Review for Surface Water Management Permit Applications, Appendix 7 in 1987) the opportunity was provided to protect thousands of acres of wetlands that were previously unprotected by the State and Federal regulatory agencies. At that time the District officially joined other agencies across the nation in using mitigation as a tool to compensate for wetland impacts. These agencies had little scientific information on this process then and even now are questioning the ability of compensatory mitigation to adequately replace lost wetland functions and values. Wetland mitigation practices have been evolving with recognized improvement over the last decade, however, with a relatively poor database nationally, we are still at an early stage on the learning curve.

Of the completed wetland mitigation projects evaluated in this study, only one project was three and one half years old and the remainder were three years old or less. This situation exists nationwide. For example, research and experience in the creation and rehabilitation of wetlands in the Pacific Northwest is a relatively new endeavor, with most projects less than five years old; the median age is two or three years (Kentula, et al. In Press).

The amount of information on wetland restoration and creation varies by region and topic. The most quantitative and best documented information available is for tidal marshes along the Atlantic Coast, while information on creation and restoration of inland freshwater wetlands is far less extensive (Kusler and Kentula 1990). Most of the studies of wetland mitigation projects have been qualitative case studies (Baker 1984, Reinold and Cobler 1986, Fishman et al., 1987, Good 1987, Mason and Slocum 1987, and Reiner 1989).

The timing of this study was appropriate in as much as, wetland mitigation as a permit condition had been undertaken as standard procedure since 1987 (REEP 1991) and a sufficient number of completed projects should by now exist, providing the opportunity for evaluation. Finally, there was and still is an increasing amount of permitted wetland alteration where mitigation in the form of restoration, creation or preservation is required as compensation for estimated lost wetland functional values. It is now critical that the District evaluate its wetland restoration and creation projects to determine what operational goals and policy changes should be implemented to better protect and manage the resource.

There were a number of limitations associated with this study: the process of gathering the information presented in this report was very labor intensive; there was difficulty in identifying 40 projects with wetland mitigation reasonably complete; there were prevailing drought conditions during a portion of the evaluation period; there were incomplete project files with conflicting information and low similarity of content from one project to another; there was a lack of baseline data surveys, inadequate or non-existent monitoring reports, poor access to some sites, illegible permit drawings, and poorly stated goals and success criteria. Similar limitations were also reported by (Gwin and Kentula 1990), during their work in Oregon and Washington. These problems will no doubt challenge other investigators at this early stage of wetland program implementation.

Prior to initiating this study, a detailed work scope was drafted. First, a literature synthesis was prepared. This bibliography of wetland restoration and creation related literature is contained in Volume III. Second, wetland mitigation projects were selected for evaluation that would represent a cross section of those types of projects typically permitted by the District, i.e., agricultural, commercial, public, and residential. An adequate distribution of projects throughout the region from the upper Kissimmee Valley to South Florida as well as different wetland types, i.e., forested (swamp) and non-forested (marsh) was also desired. Finally, wetland mitigation for the purposes of this study was to include all means of intended compensation for lost wetland functions and values resulting from project impacts including wetland creation, restoration, and preservation. The focus of this study is to answer operational questions and determine the policy implications derived from the analysis at the operations level.

Initially 195 project files containing some form of wetland mitigation covering 15 counties were made available for review. Those projects that had not yet been built or that were the subject of enforcement action were not selected for further evaluation. The review process yielded a representative sample of 44 wetland mitigation projects in 13 counties. However, an additional four sites were dropped during the actual field evaluation process when it was determined that those sites did not meet the selection criteria (i.e., no mitigation constructed).

This study was designed as a programmatic review to evaluate the effectiveness of existing design and operational technology for the maintenance, creation, and restoration of wetlands permitted by the District. Secondly, this study provides information and recommendations for improvements to the District's wetland mitigation program by highlighting critical design features and a framework for recommended changes.

The study results are intended to be used in improving wetland related permit guidelines, compliance monitoring and enforcement. The results provide baseline information that will assist the District in clarifying wetland system goals and objectives from an ecosystem and regional resource management perspective. This study will also be used as a baseline for future District evaluations of wetland mitigation. While the report recommends planning action that should be undertaken to improve the effectiveness of mitigation in protecting the resource, no attempt was made to evaluate cost effectiveness of mitigation. Particular attention is given to the operational nature of the goals and objectives, including quantifiable measures and parameters and reasonable observations to the extent possible.

# MATERIALS AND METHODS

## III. MATERIALS AND METHODS

### Project Selection Criteria.

Approximately 195 projects were initially evaluated utilizing criteria that would provide a list of projects whose status of completion could be determined by the District's Field Engineering inspectors. Information in the project files included staff reports, applications, drawings, narratives (memos, letters), aerial photographs, surface water data, proposed mitigation and monitoring plans and monitoring reports. Unfortunately, much of this information was often missing, illegible, incomplete, or inaccurately stated in the project files and required a constant and lengthy labor intensive process of verification throughout the entirety of this study. Comparative analysis of projects was difficult due to the varied amounts and reliability of information available.

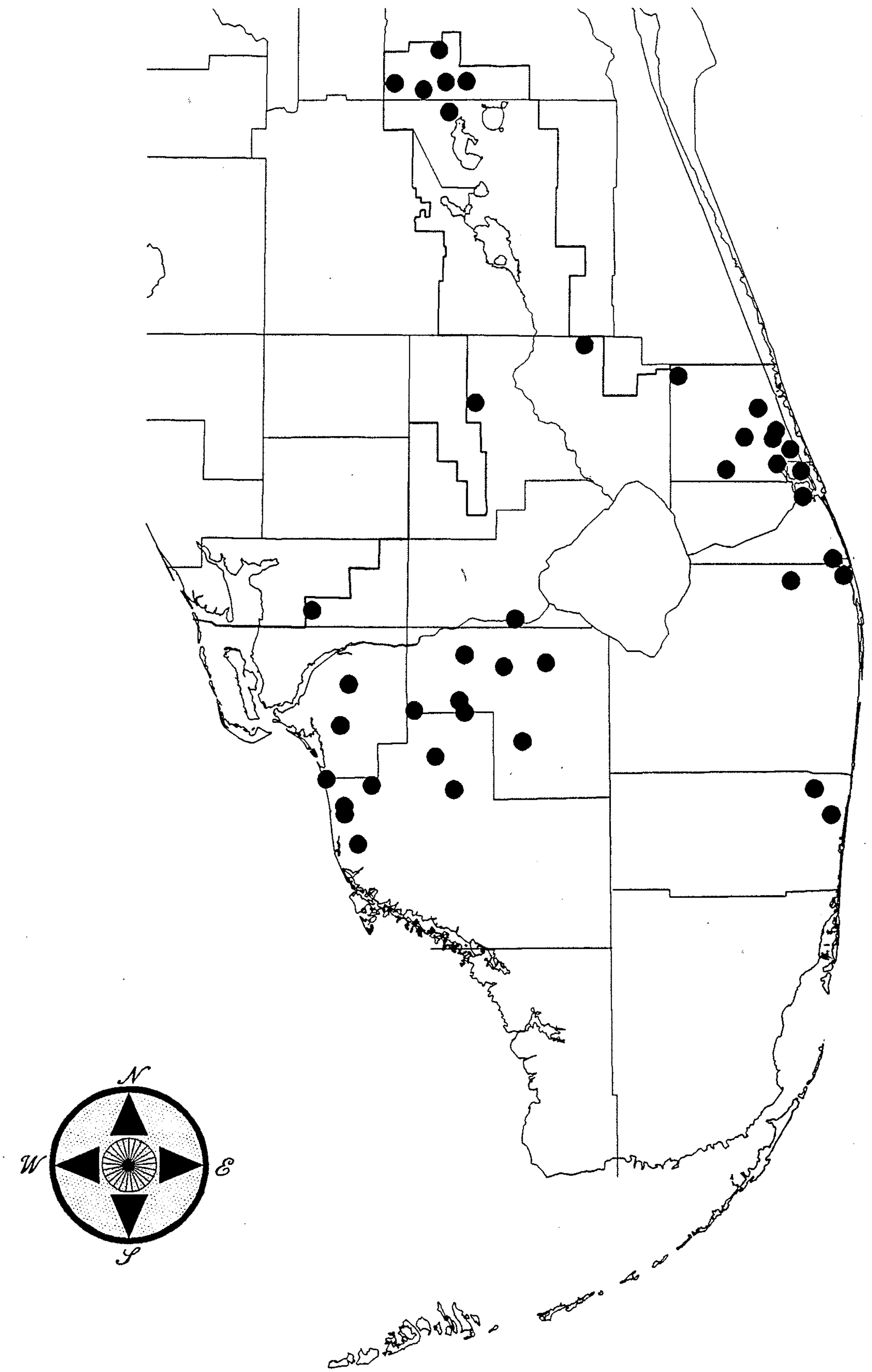
The lack of baseline data and information for impacted wetlands resulted in a modicum of subjectivity being applied to the evaluation of project success where the compensation for lost or reduced wetland functional values was the implied goal. Usually, it was not possible to discern from the District's files the condition of the wetlands proposed for development (that eventually required mitigation) nor their role in the landscape in providing certain functional values.

Upon review of the project files, a list was prepared of potential study sites (permitted projects where some type of wetland mitigation was or appeared to be completed). This list of over 100 projects was provided to the District's Natural Resource Management and Field Engineering staff. Field Engineering conducted site inspections to determine the completion status of wetland mitigation where inadequate information was contained in the file. Through a lengthy process of field verification, 40 study sites were selected in 13 counties (Figure 1).

The single most limiting factor of the number of study sites that were eventually evaluated was that the wetland creation or restoration activity required by the permit was incomplete or not undertaken. Most of the wetland mitigation projects in the District where construction was completed, except those under enforcement action, were evaluated.

The 40 wetland mitigation projects were segregated into four basic categories: agricultural (12), residential (15), public (3), and commercial (10). These projects contained a wide variety of habitats, i.e., wet prairie, marsh, swamp, and lake littoral zone. The methods of compensation included wetland creation, restoration, and preservation utilizing a variety of designs. (A restored wetland was a pre-existing natural wetland to which additional water was added and/or from which exotic plants were removed). The term enhancement was often improperly used for restoration by the District and applicants. Using the correct definitions of restoration and enhancement (Appendix I), all references to enhancement in the project files were

FIGURE 1. Location of 40 Wetland Mitigation Projects Studied within the SFWMD



actually for restoration. Upon selection of the study sites for evaluation, the respective permittee or land owner was contacted by the District via certified mail and informed of the study, its goals and the impending project evaluation (Appendix II).

## Field And Laboratory Methods

Each mitigation project was inspected and evaluated in the late summer and early fall of 1990 by a team of ecologists and biologists and accompanied by a representative from the District. Field evaluations averaged (15-25 man hours per site). A detailed project characterization form was used in the field and later completed in the office to comprehensively evaluate the project's features, including but not limited to surface hydrology, vegetation, water quality, benthic macroinvertebrate populations, surrounding land uses and landscapes, and wildlife utilization. A sample characterization form is contained in Appendix III.

Each project characterization provides the following information:

a). a description of the permitted project,
b). a chronology of events,
c). a description of type, size, and location of mitigation,
d). stated goals and success criteria,
e). appropriate success criteria,
f). observed and/or anticipated design problems,
g). an evaluation of hydrology, vegetation, macroinvertebrates, and wildlife utilization,
h). a description of surrounding and future land uses,
i). an evaluation of persistence of the wetland,
j). type of management plan,
k). adequacy of monitoring reports,
l). a discussion of wetland functional values provided,
m). degree of goal attainment.

Each project form was reviewed with pertinent data extracted and used to create the tables and figures using individual categories or a combination of related categories. Individual project characterization forms are contained in Volume II of this report.

## Vegetation Analysis

A combination of qualitative and quantitative sampling methods were used to characterize the vegetation within created, restored, and preserved wetlands. These methods were selected in order to facilitate the rapid and cost effective assessment of the 40 projects within the study.

Within each project, the number and location of major macrophyte communities were determined. This determination was made by visual reconnaissance, by previous vegetation mapping, and/or by aerial photography. Typical areas of each major macrophyte community were identified and subsequently sampled. This process of identifying repeating community types and sampling a subset of each community is similar to the Releve Method as described by Barbour et al., 1987. This methodology was selected in order to provide the maximum amount of information on the major macrophyte communities within the wetland and to insure that all significant plant communities were included.

Quantitative Sampling: Replicate $1m^2$ quadrats were used for the quantitative sampling of 55 herbaceous communities in 24 projects. The vegetation was divided into three strata (0-6" in height, 6-18" in height, and >18" in height) based on vertical height. The percent cover of each species within each strata was visually estimated. Water depth and percent of non-vegetated areas (bareground) was also recorded. Species occurring outside of the $1m^2$ sampling quadrats were also noted. Due to structural stratification, the sum of percent cover for all taxon in all strata often exceeded 100 percent. The amount of total percent cover greater than 100 percent is indicative of the degree of structural complexity. Given the study's limitation on time (i.e., limiting the number of replicates) this methodology does not provide an exhaustive species list for the sampled community.

Qualitative Sampling: Sixty-six non-forested communities in 26 projects were qualitatively sampled. Representative portions of the macrophyte community were traversed and all observed plants were listed. Plants were identified in the field to the lowest taxon possible, usually genus or species. Based on these observations, the relative abundance of each taxon was estimated and the taxon assigned to one of three abundance categories: D - dominant; C - common; P - present in low quantities. Those species listed as dominant were plants which were readily encountered throughout the community. Species listed as common were typically found in lesser quantities throughout the community or in isolated patches. Species listed as present were those plants which occurred infrequently within the macrophyte community. This qualitative method provides a good general description of the vegetative community. However, it does not provide detailed information on characteristics such as structural diversity, extent of bareground, etc.

Eighteen restored or preserved forested wetlands in 12 projects were qualitatively sampled. Representative portions of the forested community were traversed and all observed plants were listed. Plants were identified to the lowest taxon possible, usually genus or species. Based on their relative height, each taxon was assigned to a stratum; canopy, midstory, or groundcover. Canopy species consisted of the largest trees. Midstory species consisted of smaller trees, saplings, and shrubs. Ground cover consisted of all non-woody (i.e., herbaceous) vegetation. The relative abundance of each taxon in each strata was estimated and the taxon was assigned to one of the three abundance categories described for qualitative non-forested wetland sampling. This qualitative method provides an accurate description and species list for the sampled community. However, providing detailed information such as canopy structure, basal area, etc. is beyond the scope of this method.

Only one created forested wetland was included in this study. Given the young age of these projects typical forested wetland canopy, midstory, and ground cover conditions have not been attained in these wetlands. Therefore, these wetlands more closely resembled non-forested wetlands and were sampled accordingly. The average size (height and crown diameter) and condition (good, stressed, dead, etc.) of all tree species were recorded. The description of average size and condition of each tree species provides valuable information on the structure and potential future success of the developing forested system. In the absence of detailed quantitative annual or semi-annual data sets, parameters such as growth rate (crown and height) and survival cannot be determined. Therefore, one time quantitative sampling for this project was judged inappropriate.

## Hydrology

Project hydrology was reviewed in order to accurately assess the current status and long-term fate of the created, restored, and preserved wetlands. This review included analysis of project hydrologic design and "as built" hydrologic conditions. The surface water management system was included within this review to determine how the overall system interrelated with the wetland mitigation areas. The goal of this process was to determine if the designed and/or built system would facilitate existence of a persistent functional wetland.

The review of each project consisted of two primary components. The District permit file and application drawings were examined to determine pertinent design characteristics of the project. These included control structure design, control elevation, wetland floor elevation, slopes, potential water sources, level of pre-treatment of stormwater prior to discharge into the wetland, etc. When possible the rationale for the proposed design was reviewed.

The second primary component was the review of actual hydrologic conditions in the field. In order to fully evaluate "as built" conditions District Field Engineering staff were asked to provide specific elevations at various locations in the field. These locations included historic/recent water levels determined by cypress buttress morphology, current water levels, wetland floor, littoral shelf side slopes, and control structures. This elevation data was utilized to estimate the depth of inundation which should occur within the wetland and to determine if desired hydrologic conditions would be provided for the wetlands by the surface water management system.

Based on this information the potential long-term viability of the project's wetland mitigation plan was evaluated. The data was also utilized to ascertain if projects with inappropriate hydrologic design/construction (e.g., control structure produced inadequate depth of inundation) could practically be redesigned or modified to produce more favorable conditions.

The analysis of hydrology for 40 District mitigation projects contains several inherent limiting factors. For the vast majority of the projects reviewed baseline wetland hydrologic studies had not been conducted. "As built" surveys and/or "record drawings" submittals of control structure elevations, wetland floor elevations, and littoral zone side slopes are not specifically required under current District rules and were rarely available in the permit files. The extremely poor quality (i.e., photocopies of photocopies), lack of full size drawings together with the extremely small scale (8½" x 11" format) of a majority of the permit drawings made the analysis of the permitted design difficult.

## Aquatic Macroinvertebrates (Biological Integrity)

Benthic macroinvertebrates are frequently used as environmental indicators of biological integrity, a fundamental building block of biological diversity, because they are found in most aquatic habitats. They are of a size that makes them easily collected. They can be used to describe the water quality conditions or health of the ecosystem components and to identify causes of impaired conditions.

Qualitative sampling of aquatic macroinvertebrates was conducted using a standard D-frame aquatic dip net. Sampling was done preferentially in emergent vegetation habitat, but some samples were taken in open water, floating plant, and submersed plant habitats. At each sampling location, the collector worked the net vigorously within the vegetation and associated bottom sediments. Net contents were placed in a white pan and sorted through with forceps and eyedroppers until no new species were found. If present, larger substrate components (e.g., branches, rocks, algae clumps) were examined individually. Organisms were preserved in 90% ethanol. This was repeated during a period of 20 minutes which was sufficient time to record observations on relative abundance and reach asymptote of the species accumulation curve. Collection and observations of fish were also made at this time. Organisms were returned to the laboratory where they were identified to the lowest possible level, usually genus or species, using the taxonomic literature listed in the "Literature Cited" section of this report.

For data presentation and analysis, three categories of mitigation wetlands were recognized; created, preserved, and restored. A master species list was prepared indicating what aquatic macroinvertebrates were collected, what species were relatively abundant, and the frequency of occurrence of species in samples from the three wetland types: agricultural, commercial, public, and residential. Also analyzed was the species-richness of samples collected from the different wetland types, as well as samples collected from the different project types: agricultural, commercial, public and residential. The lack of pre-development data collection limits the present comparative value of this information. However, as with water quality the data collected and evaluated for this study provides a baseline for future comparative analysis as these projects mature and the surrounding landscapes develop. The results of the macroinvertebrate sampling is found in Appendix IV.

## Water Quality

The quality of water affects the biological integrity and functional values in freshwater wetlands. Water quality is dependent on a diverse set of chemical (e.g. nitrates, phosphates) and physical (e.g. temperature, transparency) properties, and deviations from the normal range of these properties can adversely affect the biota (flora and fauna) of the ecosystem. Interactions between organisms and their environment are critical to the vitality of the wetland.

Some of the more commonly measured water quality parameters include transparency, specific conductance (conductivity), pH, temperature, dissolved oxygen, turbidity, color, alkalinity, hardness, nutrients (nitrogen and phosphorus compounds), fecal coliform bacteria, chlorophyll a (as a measure of the amount of microscopic algae in the water column), and various heavy metals.

During this study, several mitigation projects were evaluated on any one day. Because of this, we did not include the measurement of water quality parameters that typically vary over a 24-hour period; for example, dissolved oxygen, pH, and temperature. Due to time constraints imposed on the survey, the minimum seven-parameter package selected by the District was routinely measured to generally characterize the water quality of created, restored or preserved wetlands. These parameters were total kjeldahl nitrogen (TKN), total phosphorus, alkalinity, hardness (calcium and magnesium), specific conductance, and chlorophyll a.

In almost all cases, water quality sampling was conducted in the same location as macroinvertebrate sampling. Water samples were collected at the surface using a 5-liter plastic bucket. Aliquots for all parameters were taken from this 5-liter sample. Sample bottles, syringes, and filters were received clean from the District's Water Quality and Chemistry Laboratory Divisions. For every ten samples collected, a series of QA/QC (quality assurance/quality control) samples were taken (replicate sample, field blank, equipment blank). All analyses were conducted by District staff in accordance with their standard methods described in the Generic Quality Assurance Plan dated 1 February 1990.

Our interpretation of the significance of the measured values was based on several considerations. One was our own experience with the range of values normally encountered in ambient water quality monitoring in south Florida. For example, TKN (which is a measure of dissolved nitrogen compounds) commonly ranges between 0.5 and 1.5 mg/l; higher values could indicate large amounts of decaying vegetation or stormwater input from heavy rains. Total phosphorus has a three-order-of-magnitude range, 0.03-1.00 mg/l. Concentrations of calcium and magnesium commonly range from 2-44 mg/l and 1-16 mg/l, respectively.

Chlorophyll a values above 10 $mg/m^3$ were considered to be elevated. The District considers chlorophyll a concentrations of 40-90 $mg/m^3$ to represent distinct algal bloom conditions, and concentrations greater than 90 $mg/m^3$ having the potential to cause adverse ecological impact (i.e., reduced dissolved oxygen, release of algal toxins).

Values were also interpreted in relation to the Florida Department of Environmental Regulation (FDER) Class III Water Quality Standards (F.A.C. 17-302). Class III standards were chosen because those are the standards that would have to be met if a mitigation wetland were ever to be connected to waters of the State. Only two parameters had a Class III standard, alkalinity (NLT 20 mg/l) and specific conductance (not to exceed 1275 µmhos/cm *or* not greater than 50% above background). It should be noted that agricultural projects fall under Class IV standards; the specific conductance criterion is the same, the alkalinity criterion is $\leq$ 600 mg/l.

Additional water quality parameters such as herbicides, pesticides, hydrocarbons, heavy metals, etc. which may be problematic, particularly in urban wetlands, were not analyzed for during this study. Accordingly, the water quality data collected in this survey and reported in Volume III should be viewed as a baseline with which future measurements can be compared.

## Functions and Values

Wetland functions were not measured, however, they were considered for each project and are discussed in each project characterization (Volume III). The type, size, condition, and location of each wetland system differed to some degree as do the expected wetland functions and values. The functions considered include groundwater recharge, groundwater discharge, flood storage, shoreline anchoring, sediment trapping, food chain support, wildlife habitat, recreation heritage and education, and fishery habitat. All discussion of functional compensation is based on limited information. However, the data collected on project hydrology, vegetation, biological integrity, water quality, location, management, etc. was utilized to provide a general evaluation of estimated functional values for discussion purposes only.

In summary, the evaluation of these parameters is important in addressing the operational goals of the study. The inconsistencies of the database from one project to the next contained in the District files, the lack of comparative baseline evaluation or characterizations of the wetlands permitted to be impacted (those that necessitated the requirement for compensation), failure to provide "as built" surveys

# TABLE OF CONTENTS

Page

Page

# LIST OF TABLES

Page

# LIST OF FIGURES

## ACKNOWLEDGEMENT

The research described in this report has been funded by the South Florida Water Management District, Contract # C89-0082-A1 to Kevin L. Erwin Consulting Ecologist, Inc. It has been subjected to the District's peer review procedures and approved for publication.

This effort would have been impossible without the enthusiastic cooperation of many people. Steve Light, Director of Special Projects for the District was supportive of the effort and provided valuable advice. Robert Rutter, Park Lewis, Ed Emmons, Craig Smith, and the staff of the District's Division of Field Engineering assisted in data collection by serving as members of the field crew. Bill Lauzon and Julie Horr, used their computer skills to provide the statistics and graphics.

Special thanks to Craig Smith who spent many hours providing editorial and quality assurance reviews and Linda Gonsalves whose dedication to detail through numerous drafts crafted the text. Angela Lawrence, and Susan Fenimore for their assistance in the wordprocessing.

Finally, there were several people who improved this report through their review of the draft document, including Terrie Bates, Stuart Bradow, Ria Brown, Jeff Gronborg, Garth Redfield, Craig Smith, David Unsell, and David Watt.

# LIST OF APPENDICES

of the mitigation areas and lack of baseline and post-construction monitoring increases the difficulty in evaluating certain parameters for each study site. However, despite the inadequacies and problems, the data and information collected for each project enabled the reviewer to appropriately respond to the operational goal questions and discuss future policy implications as a result of these findings.

# RESULTS

## IV. RESULTS

### Type, Condition, Size, and Location

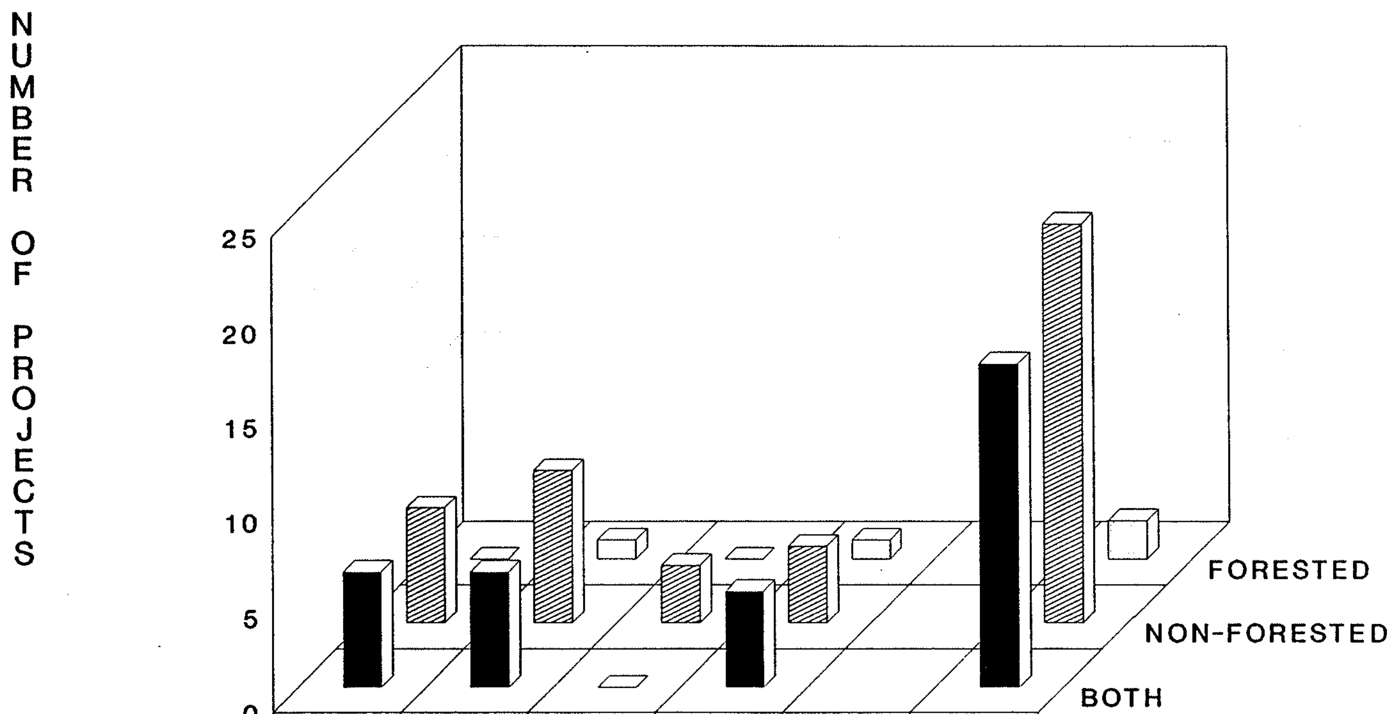
Type. Those types of wetlands created, restored, preserved or allowed by permit to be impacted within the District differ in the type of habitat, condition, size, location, and functional values. The wetlands evaluated in this study included interior freshwater systems only. The most common wetland habitats encountered in this study were hydric hammock, wet flatwoods, wet prairie, basin marsh, basin swamp, depressional marsh, and dome swamp. For the purpose of this study these wetland habitats were placed in two categories; forested (swamps) and non-forested wetlands (marshes). Twenty-one permitted projects required the creation, restoration, or preservation of non-forested wetlands only, two projects dealt with forested wetlands only, and 17 projects dealt with both forested and non-forested (Figure 2). Other than the public projects (which contained only non-forested wetlands), agricultural, residential, and commercial projects each contained forested and non-forested wetlands (Figure 2).

Condition. None of the preserved wetlands within the projects studied could be classified as pristine. All wetlands had some prior impact, most commonly; fragmentation, melaleuca (*Melaleuca quinquenervia)* infestation, and hydroperiod alteration. The average age for 33 completed wetland mitigation projects by type is 1.3 years agriculture, 2.2 years residential, 2.3 years public, and 2.2 years commercial. Only one wetland mitigation project was three and one half years old and the remainder were three years old or less (Figure 3).

Size. The estimated size of the created wetlands studied ranged from: 0.6 to 195.2 acres for agricultural projects; 0.1 to 24.0 acres for commercial projects; 0.9 to 19.7 acres for residential projects; and 0.4 to 49.7 acres for public projects. The size of restored wetlands studied ranged from: 25.7 to 131.9 acres for agricultural projects; 1.1 to 34.0 acres for commercial projects; and 0.8 to 24.0 acres for residential projects. Restoration was not undertaken in any public projects. The size of preserved wetlands studied ranged from 2.75 to 865.0 acres for agricultural projects; 2.0 to 146.0 acres for commercial projects; 1.2 to 255.0 acres for residential projects; and 1.55 to 41.3 acres for public projects. These figures are provided in Table 1. None of these "as built" acreages were verified by "record drawings" or survey. Table 2 provides the range and mean of acreage permitted by project type.

Location. The landscape settings of the wetland systems evaluated included both urban and rural settings. The 15 residential and ten commercial projects were predominantly located in urbanized areas along the east and west coasts and in the upper Kissimmee Valley area. The 12 agricultural and two of the three public projects were located in the rural interior.

FIGURE 2. Types of Wetland Mitigation Undertaken in 40 Projects Studied by Project Type Within the SFWMD



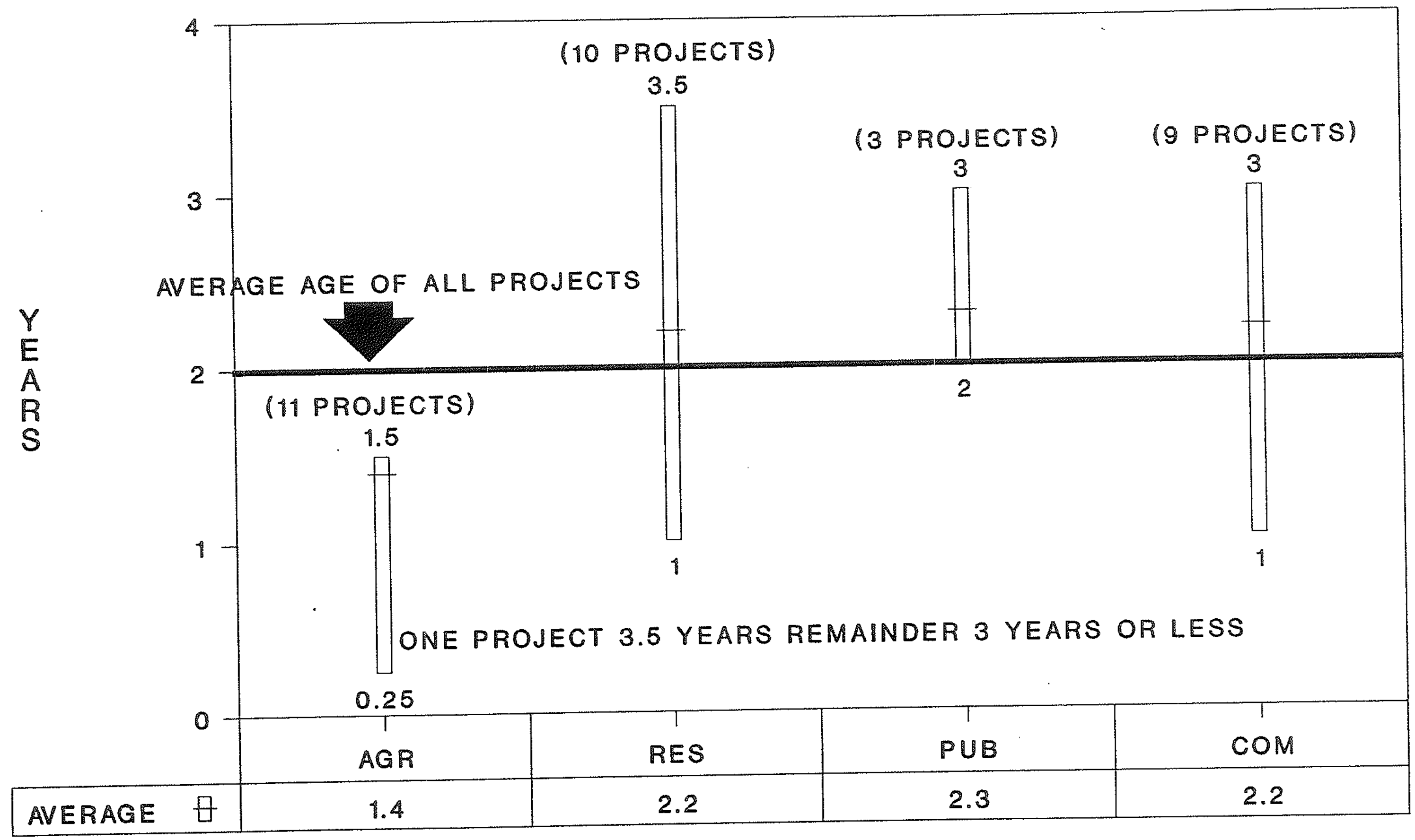

| | AGR | RES | PUB | COM | | TOTAL |
|---|---|---|---|---|---|---|
| FORESTED | 0 | 1 | 0 | 1 | | 2 |
| NON-FORESTED | 6 | 8 | 3 | 4 | | 21 |
| BOTH | 6 | 6 | 0 | 5 | | 17 |

Kevin L. Erwin Consulting Ecologist Inc.
2077 Bayside Pkwy.
Ft. Myers, FL 33901

NOTE: •ALL TYPES DETERMINED FROM DISTRICT FILES
•INCLUDES CREATED AND RESTORED WETLANDS UNLESS ONLY PRESERVATION REQUIRED

FIGURE 3.

## Age Distribution of 33 Completed Wetland Mitigation Projects by Project Type Within the SFWMD




Kevin L. Erwin Consulting Ecologist Inc.
2077 Bayside Pkwy.
Ft. Myers, FL 33901

NOTE: ALL INFORMATION OBTAINED FROM DISTRICT FILES IN ADDITION IT WAS NOT POSSIBLE TO DETERMINE THE AGE OF 4 PROJECTS, MITIGATION NOT COMPLETED ON THREE PROJECTS

TABLE 1. Mean and Range of Acreage for Created, Restored, and Preserved Wetlands "As Built" by Project Type

| | | CREATED | | RESTORED | | PRESERVED | |
|---|---|---|---|---|---|---|---|
| TYPE OF PROJECT | TOTAL #OF PROJECTS | RANGE | MEAN | RANGE | MEAN | RANGE | MEAN |
| AGRICULTURAL | 12 | 0.6 - 195.2 | 91.5 | 25.7 -131.9 | 101.5 | 2.75 - 865 | 227 |
| RESIDENTIAL | 15 | 0.9 - 19.7 | 5.42 | 0.8 - 42.0 | 14.9 | 1.2 - 255 | 79.0 |
| PUBLIC | 3 | 0.4 - 49.7 | 17.2 | - | - | 1.55 - 41.3 | 19.8 |
| COMMERCIAL | 10 | 0.1 - 24.0 | 8.9 | 1.09 - 34.0 | 7.6 | 2.0 - 146 | 93.9 |

NOTE: ALL.DATA OBTAINED FROM DISTRICT FILES

TABLE 2. Mean and Range of Acreage for Created, Restored, and Preserved Wetlands as Specified in the Permit by Project Type

| | | CREATED | | RESTORED | | PRESERVED | |
|---|---|---|---|---|---|---|---|
| TYPE OF PROJECT | TOTAL #OF PROJECTS | RANGE | MEAN | RANGE | MEAN | RANGE | MEAN |
| AGRICULTURAL | 12 | 1.5 - 207.2 | 101 | 25.7 - 131.9 | 95.4 | 2.75 - 865 | 227 |
| RESIDENTIAL | 15 | 0.2 - 109.8 | 16.0 | 0.8 - 42.0 | 17.8 | 1.2 - 255 | 79.0 |
| PUBLIC | 3 | 1.6 - 49.7 | 17.9 | - | - | 1.55 - 41.1 | 19.8 |
| COMMERCIAL | 10 | 2.2 - 151 | 34.5 | 1.09 - 34.0 | 16.7 | 2.0 - 146 | 93.9 |

NOTE: ALL DATA OBTAINED FROM DISTRICT FILES

## Goals

The ability to estimate the success of a project is possible only by establishing specific goals that can be targeted in an evaluation. Project goals were rarely specified even in cases where wetlands have been initially restored or created. This fact complicates efforts to evaluate "success". "No net loss" of wetlands, although not defined by acreage or function, was generally inferred as a goal throughout the projects files. Of the projects studied, three or 7.5 percent had a complete set of goals where the type, acreage, and function of the wetland was stated in the permit conditions. Twenty-seven projects or 67.5 percent of all the projects studied had goals limited to acreage and type of habitat targeted. Three projects or 7.5 percent contained acreage related goals only. One project contained habitat type goals only and six projects or 15 percent of all projects studied did not contain any goals (Table 3 and Figure 4).

Only four of the 40 projects studied have met all of the stated goals (Figure 5). Limited success was achieved in 12 projects, 14 projects were failures, and ten projects were still under development (incomplete). An estimated 16 of the 22 failed and incomplete projects could meet an inferred "no net loss" goal if appropriate corrective action is undertaken, i.e., manipulations of water delivery schedules, re-contouring, redesign of water control structures, additional wetland acreage, problematic plant removal and control, etc. Corrective action is probably not feasible for six of the 22 failed and incomplete projects due to the problems that would be caused on surrounding developed lands as a result of increasing the project's surface water levels (possibly causing flooding problems) or the existing intense urbanization of surrounding landscapes. The remaining 14 projects would require further study to determine the type and suitability of possible corrective action (Table 4).

## Success Criteria

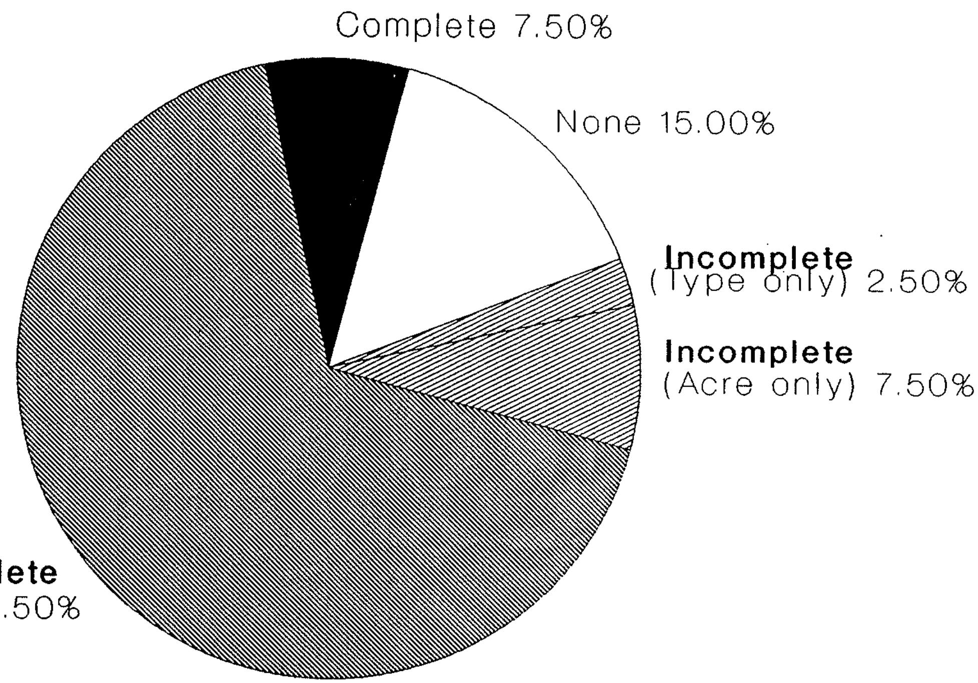
A measurable goal is the required acreage of restoration, creation or preservation. The total amount of permitted wetland impacts for all projects was 676.1 acres and two projects accounted for 485 acres of after-the-fact permitted wetland impacts. All projects studied required a sum total of 607.7 acres of wetlands to be restored, 1,058 acres of wetlands to be created, and 3,095 acres of wetlands to be preserved. The estimated required acreage of wetland creation, restoration, and preservation is based on the permitted acreage.

The acreages of wetlands actually created restored and preserved was estimated since "as built" surveys "record drawings" were not provided to the District for any project. Typically, a project staff report would state the acreage of wetlands that were to be created at designated locations onsite. However, our inspections often revealed some wetland areas not yet created, with some wetlands of an unknown size in place.

TABLE 3. Adequacy of Goals as Stated in the Permit for 40 Wetland Mitigation Study Sites in the SFWMD by Project Type

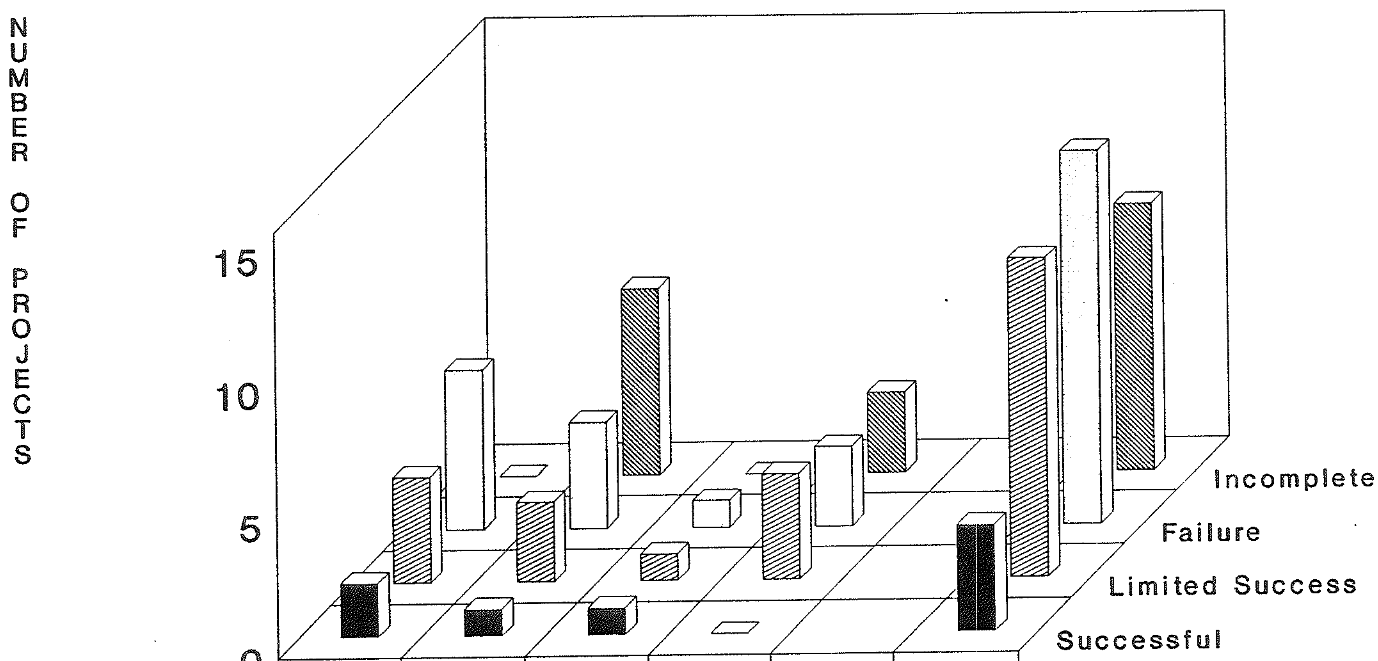
| STATED GOALS | RESIDENTIAL | AGRICULTURAL | COMMERCIAL | PUBLIC | TOTAL |
|---|---|---|---|---|---|
| | | | | | |
| COMPLETE (ACREAGE, TYPE, FUNCTION) | 2 | 0 | 1 | 0 | 3 |
| ACREAGE/TYPE ONLY | 11 | 5 | 8 | 3 | 27 |
| ACREAGE ONLY | 0 | 3 | 0 | 0 | 3 |
| TYPE ONLY | 0 | 0 | 1 | 0 | 1 |
| NO GOALS | 2 | 4 | 0 | 0 | 6 |
| | | | | | |
| TOTALS | 15 | 12 | 10 | 3 | 40 |

FIGURE 4. Adequacy of Permit Goals for 40 Wetland Mitigation Projects Studied Within the SFWMD




Kevin L. Erwin Consulting Ecologist Inc.
2077 Bayside Pkwy.
Ft. Myers, FL 33901

FIGURE 5. Goal Attainment Status for 40 Wetland Mitigation Projects Studied by Project Type in the SFWMD




| | AGR | RES | PUB | COM | | TOTAL |
|---|---|---|---|---|---|---|
| Incomplete | 0 | 7 | 0 | 3 | | 10 |
| Failure | 6 | 4 | 1 | 3 | | 14 |
| Limited Success | 4 | 3 | 1 | 4 | | 12 |
| Successful | 2 | 1 | 1 | 0 | | 4 |

Kevin L. Erwin Consulting Ecologist Inc.
2077 Bayside Pkwy.
Ft. Myers, FL 33901

TABLE 4. The Potential for the 36 Unsuccessful Wetland Mitigation Projects to Attain All Stated Goals by Undertaking Corrective Action

| | SUCCESS CRITERIA | | | | CAN GOALS BE MET WITH CORRECTIVE ACTION | | |
|---|---|---|---|---|---|---|---|
| TYPE OF PROJECT | TOTAL PROJECTS EVALUATED | # OF PROJECTS WHERE GOALS WERE STATED | # OF PROJECTS WHERE GOALS HAVE BEEN MET | WILL MEET* | YES | NO | UNKNOWN ** |
| | | | | | | | |
| AGRICULTURAL | 12 | 3 | 0 | 0 | 2 | 1 | 7 |
| RESIDENTIAL | 15 | 10 | 2 | 2 | 5 | 4 | 5 |
| PUBLIC | 3 | 2 | 1 | 0 | 2 | 0 | 0 |
| COMMERCIAL | 10 | 9 | 1 | 2 | 7 | 1 | 2 |
| | | | | | | | |
| TOTALS | 40 | 24 | 4 | 4 | 16 | 6 | 14 |

NOTE: FOUR PROJECTS SUCCESSFULLY ATTAINED GOALS
* WILL MEET WITHOUT CORRECTIVE ACTION AS PROJECT MATURES
** MORE INFORMATION REQUIRED

**Wetland Restoration.** Wetlands actually restored totaled approximately 695.3 acres (Figure 6) therefore, netting a surplus of approximately 88 acres over the permitted requirement. Restoration was not a factor in the public projects. The total restoration provided by all commercial projects was 83.7 acres. There was a 28.4 acre shortfall of restored wetlands found for residential projects and an estimated surplus of 126 acres for agricultural projects (Figure 6).

**Wetland Creation.** The estimated amount of wetlands created for all 40 projects is 530.7 acres yielding a shortfall of 527.4 acres (Figure 7). All types of projects, except public, exhibited significant shortages in the amount of wetlands created: shortfalls of 138.9, 164.3, and 222.2 acres for agricultural, residential, and commercial projects, respectively (Figure 7).

**Wetland Preserves.** Again, while "as built" surveys or "record drawings" were not provided for the studied wetland mitigation projects it was estimated that the required 3,095 acres of wetland preserves had not been directly impacted by development activities (i.e., dredging or filling) (Figure 8).

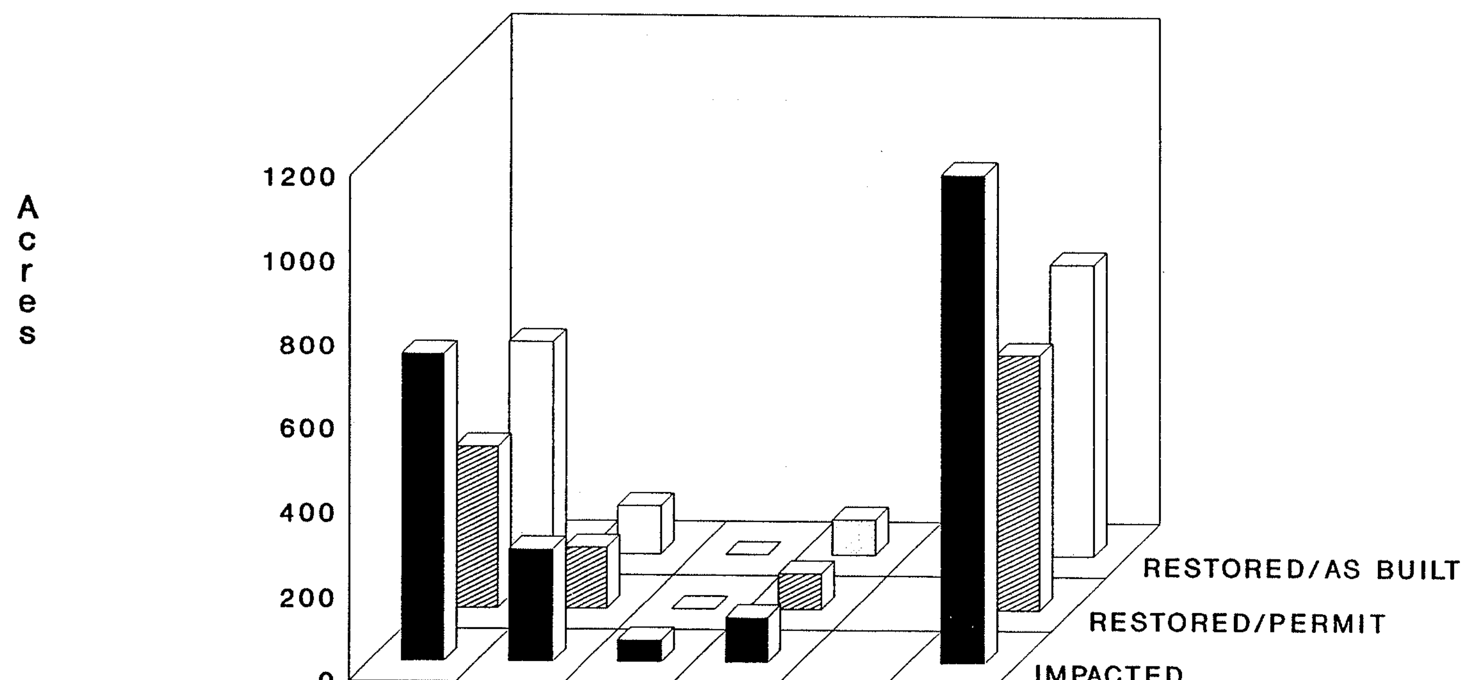
**Upland Preservation.** Since the adoption of the District's Isolated Wetlands Rule in 1987, upland habitat has often been preserved with some credit applied toward compensation toward lost wetland functional values. An unknown amount of mitigation credit was applied for upland preservation in 21 of the 40 projects studied (Table 5). Fifteen of the 21 projects allowing upland compensation actually specified the amount of acreage to be preserved (Table 5). Five agricultural projects accounted for 388.5 acres, five residential projects accounted for 235.2 acres, one public projects account for 3.8 acres, and four commercial project accounted for 44.7 acres for a total of 672.2 acres (Table 5).

## Viability of the Wetland Mitigation Project and Persistence as a Function of Location and Design.

### Viability/Persistence

The long-term viability of each restored, created or preserved wetland was considered. The objective is to create, restore, or preserve a viable persistent system which will exhibit a variety of functional roles. Each of the wetland mitigation projects studied was evaluated with regard to its location in the surrounding landscape (Volume III). Location and persistence are not in the District's criteria and did not appear to be a factor of consideration as these projects were permitted. Twenty-three of the 40 mitigation projects studied were located where surrounding existing or future anticipated land uses may prevent the created, restored or preserved wetlands from providing the intended wetland functional values (Table 6).

FIGURE 6. A Comparison of Permitted and "As Built" Acreages for Restored Wetlands in 17 Wetland Mitigation Projects in the SFWMD

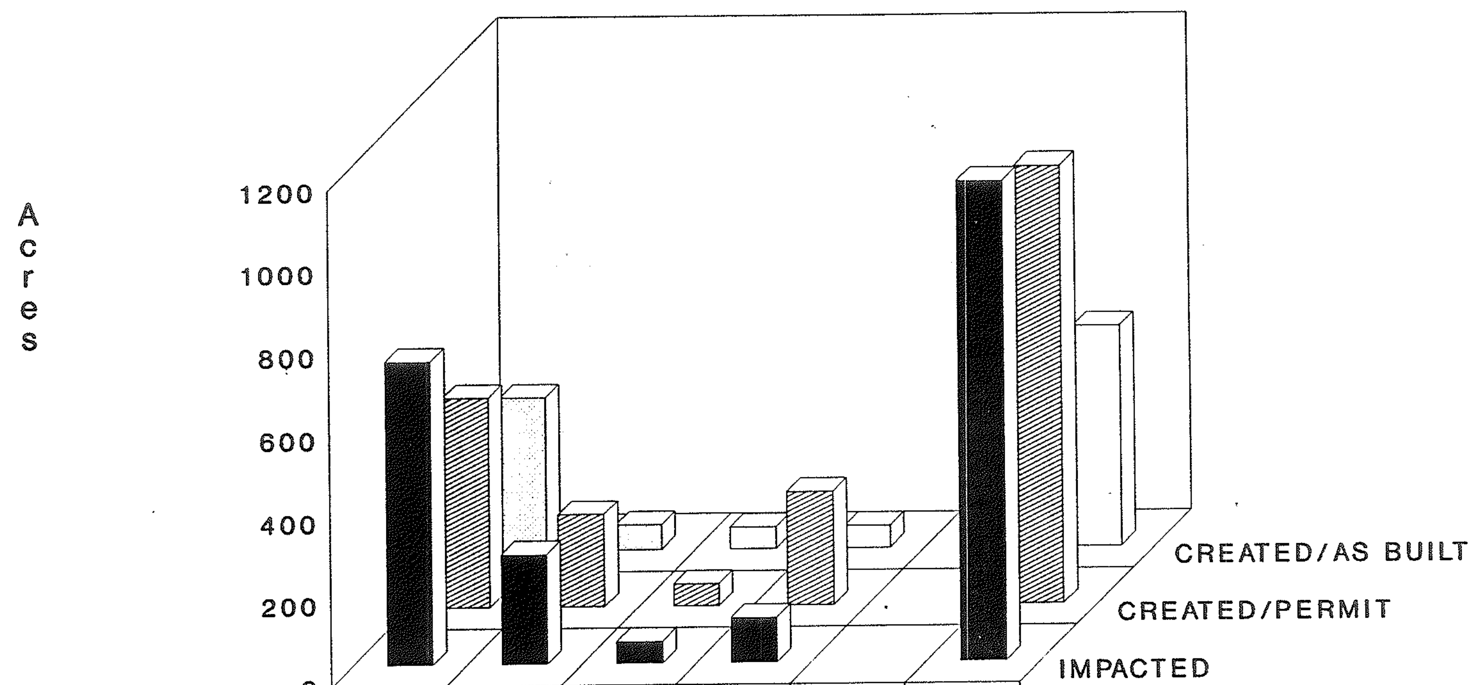



| | AGR | RES | PUB | COM | | TOTAL |
|---|---|---|---|---|---|---|
| RESTORED/AS BUILT | 507.6 | 114.02 | 0 | 83.69 | | 695.31 |
| RESTORED/PERMIT | 381.6 | 142.42 | 0 | 83.69 | | 607.71 |
| IMPACTED | 733 | 266.35 | 53.68 | 108.28 | | 1161.31 |

Kevin L. Erwin Consulting Ecologist Inc.
2077 Bayside Pkwy.
Ft. Myers, FL 33901

NOTE:
- ALL ACREAGES ARE APPROXIMATE
- NO AS BUILT SURVEYS AVAILABLE
- DATA OBTAINED FROM DISTRICT FILES

FIGURE 7. A Comparison of Permitted and "As Built" Acreages for Creted Wetlands in 28 Wetland Mitigation Projects in the SFWMD



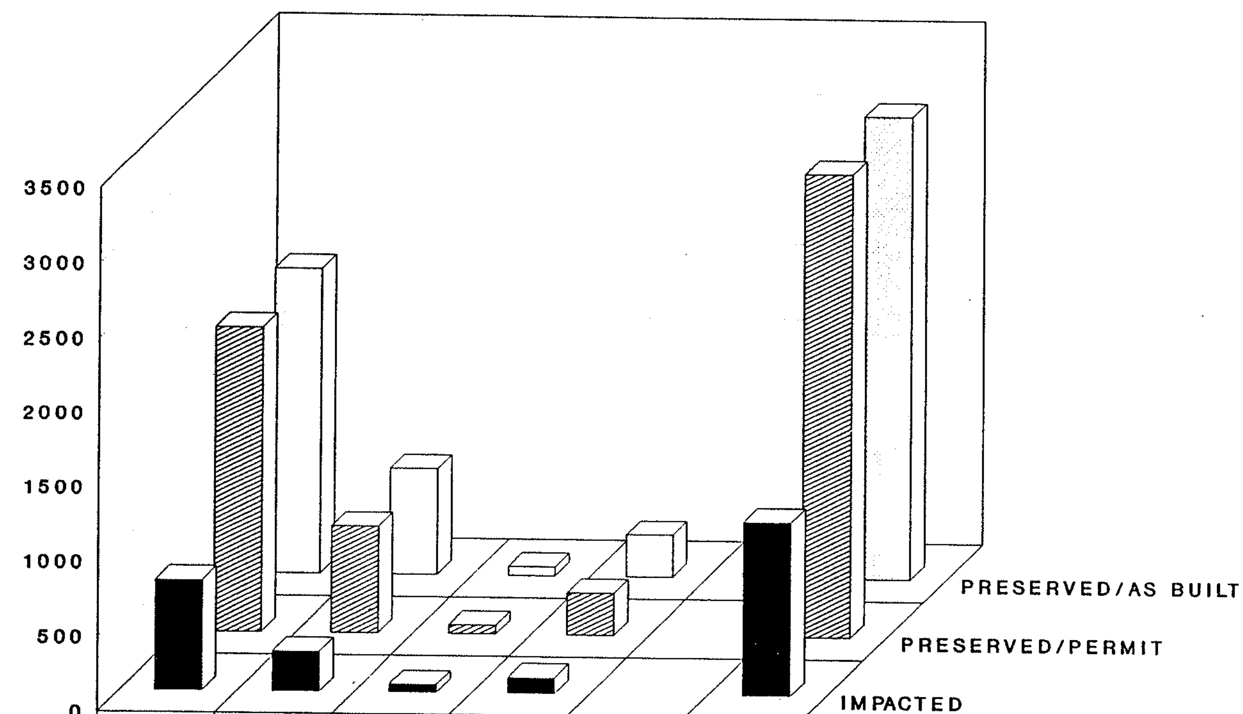

| | AGR | RES | PUB | COM | | TOTAL |
|---|---|---|---|---|---|---|
| CREATED/AS BUILT | 365.8 | 59.63 | 51.72 | 53.5 | | 530.65 |
| CREATED/PERMIT | 504.7 | 223.87 | 53.75 | 275.65 | | 1057.97 |
| IMPACTED | 733 | 266.35 | 53.68 | 108.28 | | 1161.31 |

Kevin L. Erwin Consulting Ecologist Inc.
2077 Bayside Pkwy.
Ft. Myers, FL 33950

NOTE:
- ALL ACREAGES ARE APPROXIMATE
- NO AS BUILT SURVEYS AVAILABLE
- DATA OBTAINED FROM DISTRICT FILES

FIGURE 8.

## A Comparison of Permitted and "As Built" Acreages for Preserved Wetlands in 24 Wetland Mitigation Projects in the SFWMD




| | AGR | RES | PUB | COM | | TOTAL |
|---|---|---|---|---|---|---|
| PRESERVED/AS BUILT | 2041.85 | 711.35 | 59.45 | 281.7 | | 3094.35 |
| PRESERVED/PERMIT | 2042.55 | 711.35 | 59.25 | 281.7 | | 3094.85 |
| IMPACTED | 733 | 266.35 | 53.68 | 108.28 | | 1161.31 |

Kevin L. Erwin Consulting Ecologist Inc.
2077 Bayside Pkwy.
Ft. Myers, FL 33901

NOTE:
- ALL ACREAGES ARE APPROXIMATE
- NO AS BUILT SURVEYS AVAILABLE
- DATA OBTAINED FROM DISTRICT FILES

TABLE 5. The Extent of Upland Preservation Receiving Credit as Wetland Mitigation for 40 Projects Studied within the SFWMD

| TYPE OF PROJECT | TOTAL #OF PROJECTS EVALUATED | NUMBER OF PROJECTS CONTAINING UPLAND PRESERVATION | NUMBER OF PROJECTS NOT CONTAINING UPLAND PRESERVATION | UNKNOWN ** | NUMBER OF PROJECTS WHERE THE ACREAGE* WAS SPECIFIED | TOTAL PERMITTED ACREAGE OF PRESERVED UPLANDS |
|---|---|---|---|---|---|---|
| | | | | | | |
| AGRICULTURAL | 12 | 7 | 2 | 3 | 5 | 388.5 |
| RESIDENTIAL | 15 | 7 | 5 | 3 | 5 | 235.2 |
| PUBLIC | 3 | 2 | 1 | 0 | 1 | 3.8 |
| COMMERCIAL | 10 | 5 | 4 | 1 | 4 | 44.7 |
| | | | | | | |
| TOTALS | 40 | 21 | 12 | 7 | 15 | 672.2 |

NOTE: ALL DATA OBTAINED FROM DISTRICT FILES
* BASED ON THE PROJECTS THAT HAVE UPLAND ASSOCIATIONS
** NOT CLEARLY STATED IN PERMIT OR STAFF REPORT

TABLE 6. The Number and Types of Mitigation Projects Studied where the Surrounding Land Uses May Eventually Prevent the Wetlands from Providing the Intended Functional Values

| TYPES OF PROJECT | TOTAL #OF PROJECTS EVALUATED | MITIGATION APPROPRIATELY LOCATED | MITIGATION INAPPROPRIATELY LOCATED |
|---|---|---|---|
| AGRICULTURAL | 12 | 7 | 5 |
| RESIDENTIAL | 15 | 5 | 10 |
| PUBLIC | 3 | 3 | 0 |
| COMMERCIAL | 10 | 2 | 8 |
| | | | |
| TOTALS | 40 | 17 | 23 |

## Design

**Hydrology**. Twenty-five or 62.5 percent of the mitigation projects studied exhibited water level or hydroperiod problems within the created, restored or preserved wetland areas (Table 7). Of the 35 projects that contain wetland restoration and preservation areas, 19 or 54 percent exhibited hydroperiod problems (Table 8). Of the 15 projects containing wetland restoration, water levels were excessive (water too deep to maintain the desired wetland plant community) in one project, too low (water level too shallow or soils too dry to maintain the desired wetland plant community) in eight projects, and satisfactory in six projects (Table 8). Of the 21 wetland mitigation projects containing preservation, three projects contained excessively high water levels, nine projects exhibited excessively low water levels and five projects were adequately designed. It was not possible to determine water levels within four of the preserve areas due to the absence of reliable survey data. Thirty-one of the 40 mitigation projects contain some form of wetland creation. Seventeen of those projects exhibited hydrological problems related to design or construction deficiencies (Table 9). Water levels were excessive in 11 projects, too low in six projects, adequate in 12 projects, and undetermined in two projects (Table 9).

TABLE 7. Observed Water Level Problems in Created, Restored or Preserved Wetlands in 40 Wetland Mitigation Projects in the SFWMD

| TYPE OF PROJECT | TOTAL #OF PROJECTS EVALUATED | PROJECTS WITH A HYDROLOGICAL PROBLEM | PERCENT OF TOTAL |
|---|---|---|---|
| | | | |
| AGRICULTURAL | 12 | 8 | 66.7% |
| RESIDENTIAL | 15 | 9 | 60.0% |
| PUBLIC | 3 | 2 | 66.7% |
| COMMERCIAL | 10 | 6 | 60.0% |
| | | | |
| TOTALS | 40 | 25 | 62.5% |

**Problematic Plant Species.** One of the observed symptoms of improper project hydrology and management was colonization of the wetland by undesirable plant species. Thirty-two of the 40 wetland mitigation projects exhibited problems with excessive cover of problematic plant species. District files indicate that 22 of the 40 mitigation projects permits require removal of problematic plant species (Table 10). Problematic plant removal was undertaken for 13 projects (four of which were not required to by the permit). No activity was observed in 13 projects where control was required by the permit (Table 10).

**Planting Technique.** Specific details on planting techniques and other project construction details were usually lacking in the project files. Wetland vegetation is usually introduced into created and restored wetland systems via planting nursery stock, sprigging relocated native stock, inoculation of mulch from a wetland donor site, direct seeding, and natural colonization. It is estimated that the following planting methods were used on the mitigation projects: mulch from a wetland donor site (6), sprigging (1), planting nursery stock (9), natural colonization (7), and a combination of techniques (13). Planting techniques were not specified in some permits and the absence of "time zero" reports for all projects made it difficult to determine what techniques were used and what was put in the ground (i.e., species, numbers of plants or tree seedlings, location and density of plantings, etc.).

TABLE 8. Types of Water Level Problems Observed in Restored and Preserved Wetland Areas in 40 Wetland Mitigation Projects in the SFWMD

| TYPE OF PROJECT | TOTAL # OF PROJECTS EVALUATED | PROJECTS WITH RESTORED& PRESERVED AREAS | PROJECTS WITH RESTORED &PRESERVED PROBLEMS | DESIGNED/ CONSTRUCTED WATER LEVELS TOO HIGH | | DESIGNED/ CONSTRUCTED WATER LEVELS TOO LOW | | DESIGNED WATER LEVELS | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | SATISFACTORY | | UNKNOWN | |
| | | | | RESTORED | PRESERVED | RESTORED | PRESERVED | RESTORED | PRESERVED | RESTORED | PRESERVED |
| AGRICULTURAL* | 12 | 12 | 8 | - | 3 | 3 | 3 | 1 | 3 | - | - |
| RESIDENTIAL** | 15 | 13 | 6 | - | - | 3 | 3 | 2 | 2 | - | 4 |
| PUBLIC* | 3 | 3 | 2 | 1 | - | 2 | - | - | - | - | - |
| COMMERCIAL*** | 10 | 7 | 3 | - | - | - | 3 | 3 | - | - | - |
| | | | | | | | | | | | |
| TOTALS | 40 | 35 | 19 | 1 | 3 | 8 | 9 | 6 | 5 | 0 | 4 |

* ONE PROJECT HAD TWO PRESERVE AREA PROBLEMS
** ONE RESIDENTIAL PROJECT HAD BOTH TYPES
*** THREE COMMERCIAL PROJECTS DID NOT HAVE ANY RESTORED OR PRESERVED AREAS AND ONE PROJECT HAS NOT YET CONSTRUCTED THE RESTORED AREA

TABLE 9. Types of Water Level Problems Observed in 31 Created Wetlands Studied in the SFWMD

| TYPE OF PROJECT | TOTAL #OF PROJECTS EVALUATED | PROJECTS WITH CREATED WETLAND AREAS | TOTAL #OF PROJECTS WITH WATER LEVEL PROBLEMS | DESIGNED/CONSTRUCTED WATER LEVELS | | | |
|---|---|---|---|---|---|---|---|
| | | | | HIGH | LOW | APPROPRIATE | UNKNOWN * |
| AGRICULTURAL | 12 | 6 | 3 | 2 | 1 | 3 | - |
| RESIDENTIAL | 15 | 14 | 7 | 3 | 4 | 5 | 2 |
| PUBLIC | 3 | 3 | 1 | - | 1 | 2 | - |
| COMMERCIAL | 10 | 8 | 6 | 6 | - | 2 | - |
| TOTALS | 40 | 31 | 17 | 11 | 6 | 12 | 2 |

* MORE INFORMATION REQUIRED

TABLE 10. Incidence of Colonization by Problematic Plant Species and Management in 40 Wetland Mitigation Projects Within the SFWMD

| TYPE OF PROJECT | TOTAL # OF PROJECTS EVALUATED | PROJECTS WITH PROBLEMATIC SPECIES PRESENT | PROJECTS WHERE REMOVAL WAS REQUIRED BY PERMIT | PROJECTS WHERE REMOVAL WAS UNDERTAKEN | PROJECTS WHERE REMOVAL WAS EFFECTIVE |
|---|---|---|---|---|---|
| | | | | | |
| AGRICULTURAL | 12 | 8 | 1 | 1 | 0 |
| RESIDENTIAL | 15 | 13 | 12 | 7 | 1 |
| PUBLIC | 3 | 2 | 1 | 1 | 1 |
| COMMERCIAL | 10 | 9 | 8 | 4 | 0 |
| | | | | | |
| TOTALS | 40 | 32 | 22 | 13 * | 2 |

* REMOVAL WAS UNDERTAKEN AND NOT REQUIRED BY THE PERMIT ON FOUR OF THESE PROJECTS

## Management

The wetlands within 18 of the 40 wetland mitigation projects were afforded some degree of long-term protection (i.e., for the life of the wetland) such as incorporation within the surface water management system or providing a conservation easement to the District, local government, or a home owner's association (Table 11). One unconfirmed case of transfer of title of a wetland preserve was noted. Only three of the projects included a long-term management plan (Table 11).

TABLE 11. Incidence of Created, Restored, and Preserved Wetlands with Long-term Management and Protection from 40 Study Sites within the SFWMD

| TYPE OF PROJECT | TOTAL #OF PROJECTS EVALUATED | PROJECTS WHERE PROTECTION IS AFFORDED | | PROJECTS WHERE LONG TERM MANAGEMENT IS INCLUDED | |
|---|---|---|---|---|---|
| | | YES | NO | YES | NO |
| | | | | | |
| AGRICULTURAL | 12 | 4 | 8 | 1 | 11 |
| RESIDENTIAL | 15 | 9 | 6 | 0 | 15 |
| PUBLIC | 3 | 0 | 3 | 0 | 3 |
| COMMERCIAL | 10 | 5 | 5 | 2 | 8 |
| | | | | | |
| TOTALS | 40 | 18 | 22 | 3 | 37 |

NOTE: ALL DATA OBTAINED FROM DISTRICT FILES

## Water Quality

The water quality sampling undertaken within the created preserved and <u>restored</u> wetland systems did not exhibit any significant existing problems. Violations of Chapter 17-3, F.A.C. Class III and IV water quality standards were restricted to alkalinity which was not significant (Table 12). Due to the relative newness of the projects and the surrounding developed landscape it is probably too early to observe water quality problems that would be anticipated to develop in some projects within the next one or two decades or more.

TABLE 12. Wetland Mitigation Projects where Violations of Chapter 17-3 F.A.C. Water Quality Standards were Observed from 40 Sites Studied within the SFWMD

| TYPES OF PROJECT | TOTAL #OF PROJECTS EVALUATED | #OF SAMPLES TAKEN | INCIDENCE OF VIOLATION OF MEASURED PARAMETERS | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | TKN | TP04 | CACO3 | CA | MG | CHLA | SPEC COND |
| AGRICULTURAL | 12 | 20 | 0 | 0 | 1 | 0 | 0 | 1 | 0 |
| RESIDENTIAL | 15 | 19 | 0 | 0 | 6 | 0 | 0 | 1 | 0 |
| PUBLIC | 3 | 6 | 0 | 0 | 3 | 0 | 0 | 0 | 0 |
| COMMERCIAL | 10 | 16 | 0 | 0 | 5 | 0 | 0 | 0 | 0 |
| | | | | | | | | | |
| TOTALS | 40 | 61 | 0 | 0 | 15 | 0 | 0 | 2 | 0 |

Thirty of the wetland mitigation projects studied receive stormwater discharges from parking lots, industrial sites, residential areas, and citrus groves without pretreatment. Current District policy allows multi-uses of wetlands (e.g., storage and treatment of surface water). Of the remaining discharges the majority received some degree of pretreatment via wet detention or dry storage areas. There is the potential for water quality problems to develop in 33 of the 40 wetland mitigation projects.

## Aquatic Macroinvertebrates - Biological Integrity

Thirty-eight mitigation projects were sampled qualitatively for aquatic macroinvertebrates: 14 residential, 11 agricultural, 10 commercial, and 3 public. Table 13 summarizes information pertaining to the number and type of samples collected from these projects. Altogether, 77 samples were collected; 28 from agricultural, 22 from residential, 20 from commercial, and 7 from public projects. Three categories of mitigation wetlands were recognized; created, preserved, and restored. Fifty-one, 23 and 3 samples, respectively, were collected from the three types.

Several wetland systems were encountered, *viz.*, lakes, marshes, flow-ways, flooded pastures, cypress heads, and a hardwood swamp. Flow-ways comprised a broad range of water conveyance channels, from narrow/shallow ditches to wide/deep canals. During the evaluation period (late July - late October), water flow in some of these channels was barely perceptible or stagnant. The littoral zone habitat of lakes and deep flow-ways was referred to as "terraced" when constructed as a broad, shallow shelf rather than sloped. The purpose of terracing is to increase the area covered by emergent vegetation.

Sixty-five aquatic macroinvertebrate samples were collected within emergent vegetation habitats, two samples from the open water area of cypress heads, and ten samples from floating/submersed plant habitats (usually some combination of *Eichhornia*, *Hydrilla*, *Lyngbya*, *Lemna*, *Salvinia*, *Chara*, and *Nymphaea*). The average number of species recorded for these samples was 19.8 (range 7-35), 18.5 (range 14-23), and 15.4 (range 4-37), respectively. Individual sample data tables are included in each project characterization (Volume II).

**TABLE 13. Created, Preserved and Restored Wetland Systems and Habitats Sampled for Aquatic Macroinvertebrates**

| WETLAND SYSTEM: HABITAT TYPE | NUMBER OF SAMPLES COLLECTED PER PROJECT TYPE | | | | |
|---|---|---|---|---|---|
| | AGRICULTURAL | COMMERCIAL | PUBLIC | RESIDENTIAL | TOTAL |
| <u>Created Wetlands</u> | | | | | |
| Lake: Littoral | -- | 1 | -- | 7 | 8 |
| Lake: Littoral outfall | -- | 2 | -- | -- | 2 |
| Lake: Terraced littoral marsh | -- | 2 | 1 | 1 | 4 |
| Marsh | 1 | 9 | 2 | 8 | 20 |
| Flooded pasture | 4 | -- | -- | -- | 4 |
| Flow-way | 2 | -- | -- | 2 | 4 |
| Flow-way: Outfall | 5 | 1 | -- | -- | 6 |
| Flow-way: Outfall spillway | 1 | 1 | -- | -- | 2 |
| Flow-way: Terraced littoral marsh | -- | 1 | -- | -- | 1 |
| **TOTAL** | **13** | **17** | **3** | **18** | **51** |

**TABLE 13. (Cont.)**

| WETLAND SYSTEM: HABITAT TYPE | NUMBER OF SAMPLES COLLECTED PER PROJECT TYPE | | | | |
|---|---|---|---|---|---|
| | AGRICULTURAL | COMMERCIAL | PUBLIC | RESIDENTIAL | TOTAL |
| **Preserved Wetlands** | | | | | |
| Marsh | 7 | 1 | 4 | 3 | 15 |
| Cypress Head | 7 | -- | -- | -- | 7 |
| Hardwood Swamp | -- | 1 | -- | -- | 1 |
| **TOTAL** | **14** | **2** | **4** | **3** | **23** |
| **Restored Wetlands** | | | | | |
| Marsh | 1 | 1 | -- | 1 | 3 |
| **TOTAL** | **1** | **1** | **0** | **1** | **3** |

* Number of projects included in this study were: Agricultural = 11, Commercial = 10, Public = 3, Residential = 14.

Considering only those samples collected in created wetlands, lake littoral samples (n = 14) averaged 17.1 taxa (range 4-24), marsh samples (n = 20) averaged 19.3 taxa (range 7-34), flooded pasture samples (n = 4) averaged 22.2 taxa (range 15-28), and flow-way samples (n = 13) averaged 21.2 taxa (range 5-37). For comparison, marsh samples collected in preserved wetlands (n = 14) averaged 20.4 taxa (range 12-32), and restored marsh samples (n = 3) averaged 14.0 taxa (range 7-26).

A comparison of created lake littoral samples suggests that the biological integrity of this habitat is enhanced when the area is terraced. Non-terraced littoral samples (n = 10) averaged 15.1 taxa (range 4-22) whereas terraced littoral samples (n = 4) averaged 22.0 taxa (range 20-24).

## Wildlife Utilization

While not specifically addressed as a goal or success criteria in any of the wetland mitigation projects, wildlife utilization of the wetlands was inferred by the permit. Actual monitoring or observations of wildlife utilization in these projects by the permittee was very limited. The short period of time spent on each project site by this investigator did not afford the opportunity to collect meaningful data or observations pertaining to wildlife utilization. However, the potential wildlife utilization for each project was discussed based upon the type of each wetland system, its location in the landscape, biological integrity, and the long-term management plan. Generally, 15 of the wetland mitigation projects studied presently provide good wildlife habitat (Table 14). Within the next 20 years as few as five of these projects may continue to provide good wildlife habitat, with 17 providing poor habitat and 18 projects with undetermined value due to adjacent development activity and a current lack of long-term management plans (Table 14).

TABLE 14. Observed and Potential Wildlife Utilization from 40 Wetland Study Sites within the SFWMD

| TYPE OF PROJECT | TOTAL #OF PROJECTS EVALUATED | OBSERVED CURRENT POTENTIAL WILDLIFE UTILIZATION | | ESTIMATED FUTURE LONG-TERM POTENTIAL WILDLIFE UTILIZATION | | |
|---|---|---|---|---|---|---|
| | | GOOD | POOR | GOOD | POOR | UNKNOWN |
| AGRICULTURAL | 12 | 9 | 3 | 2 | 1 | 9 |
| RESIDENTIAL | 15 | 3 | 12 | 0 | 9 | 6 |
| PUBLIC | 3 | 2 | 1 | 2 | 0 | 1 |
| COMMERCIAL | 10 | 1 | 9 | 1 | 7 | 2 |
| | | | | | | |
| TOTALS | 40 | 15 | 25 | 5 | 17 | 18 |

# DISCUSSION

## V. DISCUSSION

### Operational Goals

### Type and Condition of the Wetlands Studied.

Types of Wetlands Studied. Types of wetlands created restored, or preserved by the District's regulatory programs do not usually include coastal tidal wetland systems such as mangroves and salt marshes which more often are under the purview of the Florida Department of Environmental Regulation, Florida Department of Natural Resources; federal agencies such as the U.S. Army Corps of Engineers and U.S. Environmental Protection Agency and local governments. All of the wetlands within each study site evaluated in this report are contained within four categories: wet flatlands, seepage wetlands, floodplain wetlands, and basin wetlands.

Within the District wet flatlands would include hydric hammocks, marl prairies, wet flatwoods, and wet prairie. Seepage wetlands would include baygalls or bayheads and seepage slopes. Floodplain wetlands include bottomland forest, floodplain forest, floodplain marsh, floodplain swamp, freshwater tidal swamp, sloughs, strand swamps, and swales. Basin wetlands would include basin marshes, basin swamps, bogs, depressional marshes, and dome swamps. Comprehensive definitions of these wetland types can be found in the "Guide to Natural Communities of Florida" prepared by the Florida Natural Areas Inventory and the Florida Department of Natural Resources 1990.

Conditions of Wetlands Studied. Those wetlands permitted to be impacted for which compensation was required differed not only in type but in condition as well. Few natural systems in this region, including wetlands, have escaped man induced alterations resulting from a number of influences including drainage, stormwater runoff, logging, fire, infestation by problematic exotics, dredging, and fragmentation.

**Project Goals.** The major initial short-coming of the wetland creation and restoration project process is a failure to identify realistic goals (Erwin 1990). Evaluating whether an attempt to create or restore a wetland has been successful is always controversial, largely because criteria for success differ (Zedler and Weller, 1990). Most of the projects studied contained some combination of wetland creation, restoration and preservation as compensation for an unquantified permitted reduction or loss in wetland functional values. The District does not attempt to determine the functional values of the wetlands to be lost and the type of compensation required for those values in the mitigation project review process. Occasionally, this information is supplied by the applicant.

"No net loss" of wetland functional values was not a stated goal in any of the projects. However, wetland creation was generally type for type in most permits and all remaining undeveloped wetland habitats on a site were required to be restored and preserved. Therefore, while not specifically stated, project by project "no net loss" of wetlands, primarily acreage and type, was probably the intended goal.

**Success Criteria.** Ideally, the success criteria for the wetland mitigation project should relate directly to the type, nature, and function of the desired wetland compensation. These success criteria must be measurable in order to eventually determine the degree of success or failure and attainment of goals.

Appropriately stated success criteria would at a minimum include: the type of wetland desired; a specified acreage; a list of desirable and for undesirable plant species, and the percent cover acceptable; specific hydroperiod; depth of inundation; and biological diversity of macroinvertebrates. The criteria selected must be attainable within a reasonable time frame and continue to provide the desired compensation in perpetuity.

**Wetland Viability - Persistence.** Observations were made of the landscapes surrounding the projects studied. Twenty-three of the 40 mitigation projects studied appear to be located where adjacent existing or future land uses may prevent the mitigation area from providing the intended wetland functional values (Table 6). For example, one of the commercial projects studied contained a ± 2.2 acre herbaceous wetland created in the midst of a 19.5 acre warehouse facility. This wetland is isolated from native habitats by adjacent structures, roads, and parking lots. The wetland that is restored, created or preserved should be a persisting, self perpetuating system which will exhibit a variety of functional roles.

The idea of persistence is particularly relevant to wetland ecology. Over many decades or even centuries one may expect changes in the vegetation structure and composition of the wetland system. Some changes will be small, others significant or even catastrophic, but the wetland system will persist (Niering 1990). Therefore, the goal in wetland creation and restoration should not always be to exactly duplicate a specific vegetation type but to create a wetland system that is hydrologically sound (Carter 1986) and incorporates the potential for all those future biotic variations that might be expressed under different hydrologic regimes in that particular site.

In considering the persistence or long-term viability of these wetland systems, we must understand the relationship between adjoining "patches" of land such as forests, fields, agricultural lands, roads, river corridors, and urban areas. In general, larger adjoining patches of habitat support more species than smaller isolated areas. Larger patches are more likely to have a complex structure and thus provide habitats for a greater diversity of species. Also, the larger area makes possible colonization by species with large range requirements, particularly the predators, usually missing in smaller areas (Smith 1980).

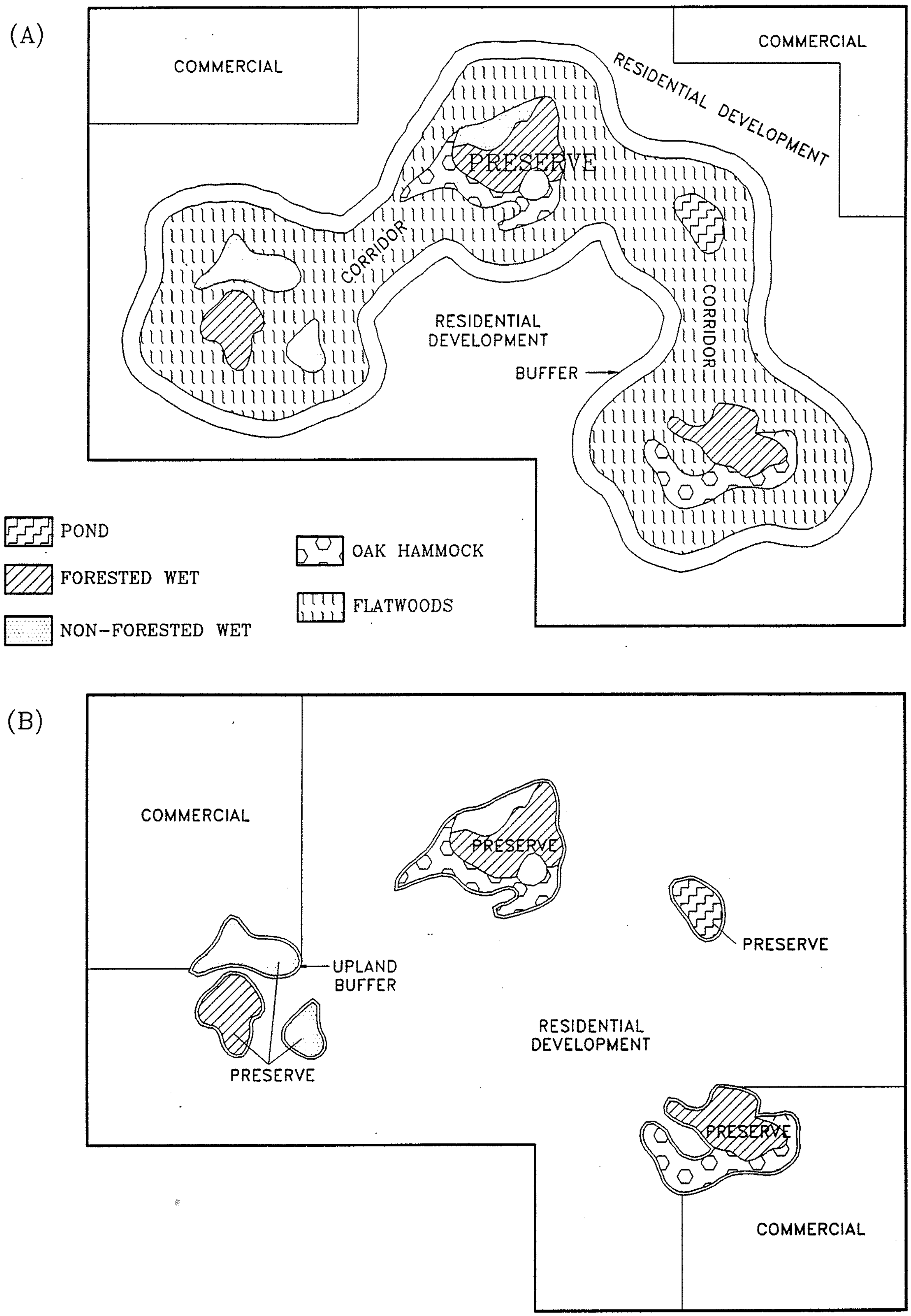
Future studies of resource management and compensation should take the comprehensive approach of a landscape ecologist which differs from a more traditional approach focusing on individual habitat units or a single species. This latter approach has inadvertently allowed habitat fragmentation to occur in the past. Fragmentation occurs when a large expanse of habitat is transformed into a number of smaller patches of total area, isolated from each other by a matrix of habitats unlike the original (Wilcove, et al. 1986). Is it naive for example to create, restore or preserve a relatively small isolated wetland surrounded by intense urbanization and expect it to remain static and viable over time? One must consider whether the values for which the area is sought can realistically be maintained once the area is removed from the existing landscape by future development of surrounding lands. These projects were proposed to compensate for wetlands originally often located in a natural to semi-natural landscape i.e., surrounded by pine flatwoods and other wetlands. Within the isolated patches of native habitat we often observed vegetative composition changes and problematic exotic species such as melaleuca *(Melaleuca quinquenervia)* and Brazilian pepper (*Schinus terebinthifolius*) dominating the endemic plant communities.

Many conservation and wetland mitigation areas as currently permitted may simply be too small to afford adequate protection from neighboring development, sustain healthy populations of wildlife, maintain acceptable water quality, and provide other important wetland functions at the desired values. One conservation approach is to plan for large, connecting areas or corridors, which include zones that have special environmental importance because of their species distributions, as well as buffer areas where varying degrees of human activity are permitted (Figure 9).

Analyses of the effect of fragmentation and conservation guidelines have generally been based on the conceptual framework of island biogeography (Preston 1962; MacArthur and Wilson 1967, Soule and Wilcox 1980, Burgess and Sharpe 1981). Island biogeography is of considerable potential importance for an enlightened approach to nature conservation (Begon et al. 1986). Not all islands are oceanic. Ecologically any patch of habitat isolated from similar habitats by different, relatively inhospitable terrain (i.e., a grid pattern of residential or commercial development) traversed only with difficulty by organisms of the habitat patch may be considered an island. A number of investigators have studied the application of the island biogeography theory to terrestrial habitat "islands or patches" (Simberloff 1974). Most research in this area has dealt with documenting species-area relationships, and little work has addressed the more difficult task of quantifying immigration and extinction rates.

A recurring observation by conservation biologists is that habitat area or size and structural diversity (heterogeneity) is a major factor accounting for differences in species diversity. The majority of the wetland mitigation projects studied were

FIGURE 9. A Conceptual Approach to Maintaining Biodiversity using Corridors and Buffers (a) as an Alternative to Habitat Fragmentation (B)



located in areas of existing or eventual urbanization. This process of urbanization often results in greater habitat fragmentation and disturbances, and increases the isolation of habitat patches from one another and from the surrounding rural or undeveloped landscape, which typically brings about a reduction in the species richness of a community area or biodiversity. The District's intent to protect small isolated wetlands and their values remains important. However, great effort must be made to counteract excessive fragmentation by incorporating native upland habitats and linking these areas.

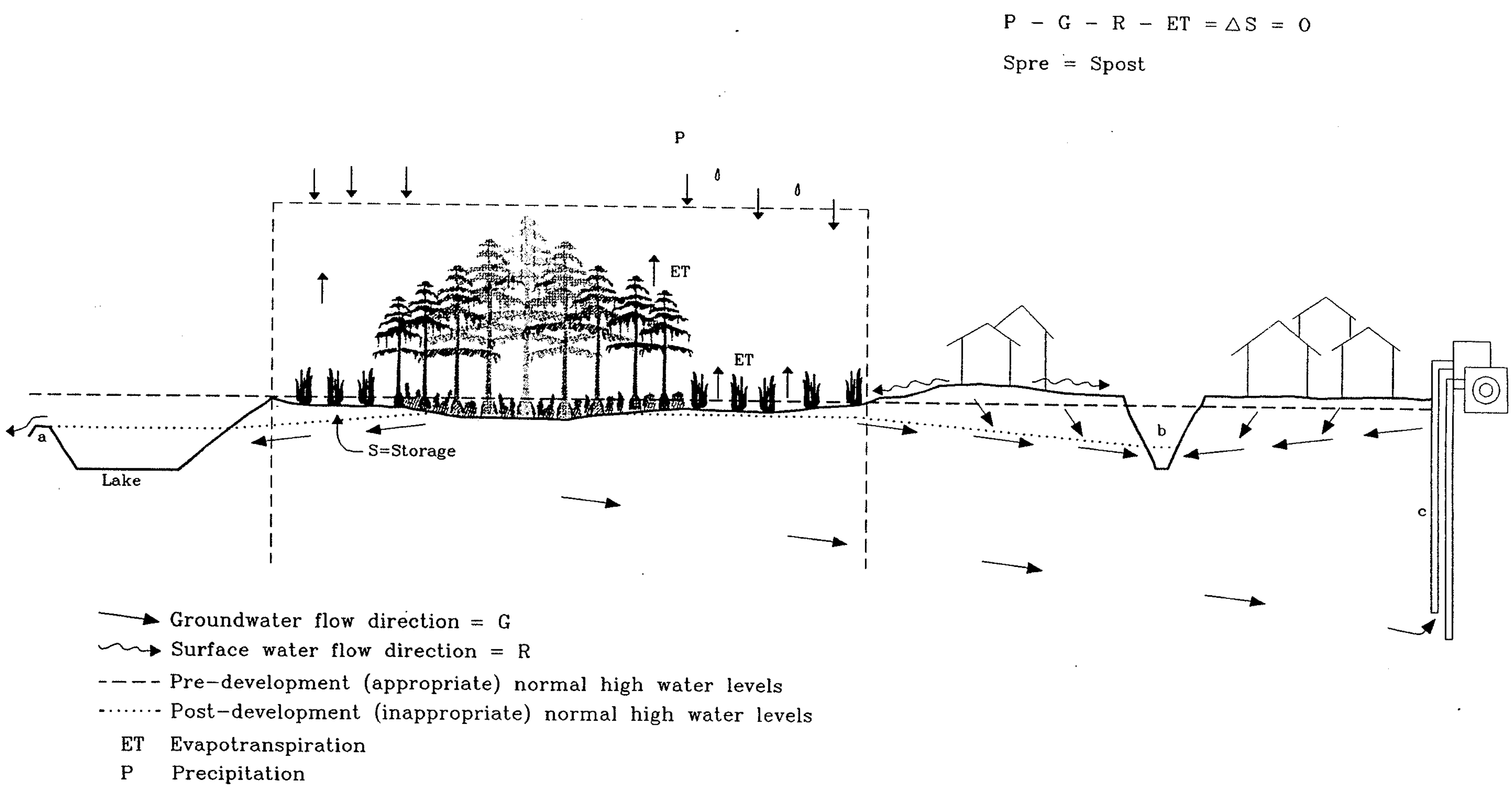
**Design - Hydrology.** The ultimate success of wetland restoration and creation projects depends upon the appropriate project design as well as location within the landscape. Wetland design should consider relationships of the wetland to the resources within the watershed and their proximity to the project. The project should be constructed in an area of suitable land use with an adequate watershed to provide the proper hydroperiod time and degree of inundation required to meet the established goals. Hydrology and location are therefore, the most important factors to consider in designing and implementing restoration, creation and preservation projects for specific wetland systems and their related functions (Erwin 1990).

The failure to provide the proper wetland hydroperiod (both water levels and period of inundation) was related to the improper design and elevation of water control structures, creation of inappropriate substrate contours and elevations, and excessive flooding or drainage. Cumulative impacts may affect the wetland's hydrological regime where wetland areas are located adjacent to drainage canals, surface water management systems and well fields (Figure 10). For example, water use permits for a farm well field allowed a reduction of shallow groundwater levels over a large area. This draw down had an apparent adverse effect on permitted wetland preserves evaluated during this study that were located on an adjacent property. The cumulative effects of water use on adjacent habitats must always be considered.

In most instances, proper determination of the historical water levels for wetland preserves and restoration areas is a well established procedure including the collection of topographic data from the edge of the wetland or benchmarks on vegetation within the wetland systems. Determining the proper hydroperiod within created wetland systems is a function of modeling the watershed and balancing the elevation of a proposed or existing control structure and the contours within the created wetland area.

Appropriate water level depths for most species of emergent freshwater plants and planted wetland tree seedlings range from 0.0 (saturated soils) to $\pm$ 2.5 feet with targeted elevations measured in fractions of a foot. Improper placement of a control structure or creation of substrate contours is a major cause of plant mortality and project failure.

FIGURE 10. Typical Impacts on Wetland Hydrology Resulting in Reduced Hydroperiod and Water Levels; A) Improper Control Structure Elevation (too low); B) Drainage Canal; C) Well Field.



A typical example of design failure involved a large mixed use development where enforcement action associated with unauthorized wetland impacts required mitigation by restoring and creating 19.0 acres of cypress, 5.8 acres of marsh and preserving 2.0 acres of remaining cypress. The control structure was built to permit specifications, however, the created wetland floor (contour) was built lower than the permitted criteria. The control elevation now maintains water depths exceeding 2.5 feet in the planted cypress during the wet season thus insuring that portions of the forested wetland creation/restoration will probably fail. In addition, the control elevation for the project is below the existing floor elevation of the preserved cypress. Therefore, the cypress preserve will not be regularly inundated. Many wetland functions may not be provided or will be lost to the system if it is too dry. These dry sites typically become colonized by upland weedy species and often dominated by problematic plant species such as melaleuca, Brazilian pepper, and torpedo grass.

Restoration of a previously drained wetland cannot be facilitated when water levels are not properly established. Since maintenance of the cypress preserve in the example above was a priority, the surface water management system should have been designed to provide the required water levels and hydroperiod for the wetland preserve. All created and restored wetlands would then be designed using this control elevation.

Significant water level problems were observed in eight of the 12 agricultural mitigation projects studied (Table 8). In addition to the structural designs wetland hydroperiods within many of these projects are dictated as a function of pumpage from a farm or citrus grove into the reservoir. The reservoir usually consists of a mosaic of upland and wetland habitats surrounded by a dike and ditch system designed to store excess surface and groundwater from the farm. Wetland hydroperiods within these reservoirs are dependant solely upon the drainage and irrigation schedules of the adjacent farm land, often receiving excess quantities of water for prolonged periods of time resulting in significant changes in plant community structure (i.e., dominance by problematic species such as cattail and mortalities of the desirable species such as oaks and pines within the upland preserves).

One 253 acre agricultural reservoir evaluated contained a large area of oak and pine forest. Evidence of excessively high water levels were observed; ± 4.0 feet in the pasture where creation of herbaceous wetlands is the stated goal and ± 1.0 feet in the upland preserve. During these high water events an additional ± 2.0 feet of water would have been required for the structure to discharge.

Inappropriate hydroperiods also cause mortalities of planted nursery stock, including both herbaceous plants and tree seedlings. This extends the time necessary for a site to successfully attain cover by desirable species and when replanting is necessary generates additional financial expenses to the project sponsor.

**Design - Vegetation.** Many species of problematic plants are exotics and are ideally suited to south and central Florida's warm climate and extended growing season. Exotic species such as melaleuca, hydrilla (*Hydrilla verticillate)*, Brazilian pepper, and natives including cattail (*Typha spp.),* primrose-willow (*Ludwigia peruviana*), and torpedo grass (*Panicum repens*) easily adapt to disturbed wetland systems, often becoming dominant and displacing the more desirable native species of plants. As a result of these infestations wetland functions such as fishery habitat, wildlife habitat, food chain support, recreation heritage and education values are often significantly diminished. There appears to be a correlation between wetland mitigation projects with improper hydrology and colonization by problematic vegetation species.

**Management.** Long-term management deficiencies for the wetland mitigation projects is particularly significant given the degree of colonization by problematic plant species. Problems where observed in 32 of the 40 study sites (Table 10), the majority of which were located within the urban corridor or within the irrigation/detention system of the citrus groves where the elimination of adjacent undesirable seed sources is difficult therefore, creating a long-term project maintenance requirement. These projects will require regular intensive monitoring and management, often for the life of the wetland.

Management must be reflected in the designs so that a low maintenance approach to managing a persistent system is possible. The wetland project should be owned by an entity which will have the finances available to implement future management practices such as control of undesirable plant species (Erwin 1990).

**Wildlife Utilization.** Wildlife managers and some fishery managers have been involved in wetland enhancement and restoration for many years. Most of the habitat management techniques are based on natural processes in wetland systems, and thus influence other wetland values and functions. However, few of these practices have been subjected to long-term experimental testing and evaluation. Much of this material has been published but it is not available in a single document that covers all wetland types and their regional variations (Weller 1990).A decline in wildlife habitat value is anticipated for the majority of the mitigation projects. This decline would follow the decrease of wetland functional values resulting from degradation of water quality, domination by problematic plant species, lack of management, and the development of surrounding natural or rural landscape "patches".

**Pre and Post-project Wetland Functional Values.** The capacity for each wetland mitigation project to provide compensation for specific wetland functions was generally evaluated (Volume III) for discussion purposes. This necessitated a comparative analysis of those known or estimated baseline wetland functional values and the post-development functional values provided by the created, preserved, and restored wetlands. While baseline data for those wetlands permitted to be developed was lacking, an effort was made to assign wetland functional values based upon the available information in the files. Although this type of evaluation is subjective, broad ranges of categories (good, fair, poor, none) allow flexibility in the assessment while still providing a reasonable determination to be made. We believe that at this early stage of the science and the regulatory program it is important to at least have a reasonable perspective relative to the current status of wetland compensation.

Of the ten basic functional values, five have the greatest relevance to the projects studied. Those wetland functional values are food chain support, wildlife habitat, recreation heritage and education, fishery habitat, and water quality. The limitations of this study did not permit wetlands to be assessed for groundwater recharge, groundwater discharge, and flood. Shoreline anchoring was not particularly relevant to the types of wetlands evaluated.

## Policy Implications

**The majority of the wetland mitigation projects studied have not been successful in achieving "no net loss" of wetland functional values.** As a concept "no net loss" is a relatively new and was not a stated goal in any of the permits. Only four of the 40 projects studied have met all of the stated goals (Figure 5). "No net loss" of wetland functional values was often inferred in the permit conditions but not directly stated. Approximately 82.5 percent of all projects contained acreage requirements as a stated goal of the project (Figure 4). Therefore, as far as acreage only is concerned (not type, quality or function) those currently permitted wetland mitigation projects studied have failed to achieve "no net loss" given the short fall of created and restored wetland acreage.

**The District, through its regulatory programs, cannot avoid the degradation of natural systems.** The sum of all regulatory actions does not achieve a non-degradation standard. Degradation will probably continue as a result of existing and future alterations of the surrounding and regional landscapes resulting in fragmentation of habitat and a reduction of species richness and diversity. Every natural system and compliment has previously, and will continue to be influenced by man induced actions. Therefore, we cannot assume that by preserving wetland systems we will maintain all functions at static levels. The District should focus on managing and planning a reduction of systems degradation and provide an integrated plan of acquisition, regulation, and natural resource management.

**It is not likely that the District can avoid loss of wetlands and their related functional values under the existing regulatory program.** However, the District can significantly reduce the current trend of wetland impacts and work toward "no net loss" through resource management and restoration programs. The District should focus on the protection, restoration, and maintenance of natural systems where wetlands are a key component and the surrounding upland landscape ensures and contributes to functional integrity.

**A wetland mitigation program undertaken by the District, or any regulatory agency in of itself is not sufficient to achieve "no net loss" of wetland functional values.** Wetland functions are integrated with the surrounding regional landscape. There are losses of wetland functions and values derived as a result of changes in adjacent landscapes. Wetland structure, species diversity, wildlife utilization, water quality, etc. undergo significant alterations as a result of direct project impacts, surrounding development, and natural as well as man induced catastrophic events. Therefore, compensation of wetland functions by mitigation should include consideration of the regional context in order to achieve "no net loss" of wetland functional values and conservation of biological diversity.

**There are inherent deficiencies in any regulatory program and strategy such as the District's, that focuses on wetland protection on a project basis.** The most significant problem with the regulatory paradigm is that it deals with the regulation of parts of systems, or "islands", such as wetlands, instead of integrating a mosaic of diverse habitats (uplands and wetlands) that comprise the ecosystem. Habitat area or size is a major factor accounting for differences in species richness. The process of urbanization results in greater habitat fragmentation in disturbances, and increases the isolation of wetland "islands" from one another and from the surrounding rural landscape, which typically brings about a reduction in species richness. The current regulatory strategy of focusing on wetland preservation and mitigation at the project level may eventually result in a loss of wetland functions and cumulative degradation of the system.

# SUMMARY OF FINDINGS

## VI. SUMMARY OF FINDINGS

a). Out of more than 100 projects requiring wetland mitigation evaluated, only 40 had undertaken any mitigation activity.

b). For the projects studied, wetland mitigation and preservation has not insured the future maintenance of the desired wetland functional values due primarily to a combination of poor location, design inadequacies, and inappropriate long-term management.

c). Only one wetland mitigation project was three and one half years old. The remainder were three years or less. The average age of 30 completed wetland mitigation projects by types is: 1.4 years agriculture, 2.2 years residential, 2.3 years public, and 2.2 years commercial.

d). The mitigation project goals were rarely specified in the permits. Of the 40 projects evaluated, three had a full set of environmental goals, six had no goals at all, and 27 projects had goals limited to acreage and type of habitat targeted.

e). Only four of the 40 projects studied met all of the stated goals established in the permit. Sixteen of the failed or incompleted projects were correctable and potentially successful. It was determined that six projects could not have succeeded under any circumstances and 14 projects would have required more study to determine the type and suitability of possible corrective action.

f). Twenty-four of the 40 projects evaluated contained success criteria. However, for 23 of the projects the success criteria were either not appropriate to the type of mitigation (i.e., percent survival of planted species for two years) or unmeasurable (no specific acreage required).

g). Of the 1,058 acres that were to be created under permit for all 40 projects, the evaluation found 530.6 acres had actually been created leaving a shortfall of 527.4 acres. The shortfall was distributed as follows:

| | |
|---|---|
| agriculture | 138.9 acres |
| residential | 164.3 acres |
| commercial | 222.2 acres |
| public | 2.0 acres |

Wetlands actually restored (acreage only - not quality) totalled approximately 695 acres, netting a surplus of approximately 88 acres over the permitted requirement. The 3,095 acres of wetlands required to be preserved had not been directly impacted (dredged or filled) by development.

h). In our judgement, some degree of offsite regional resource compensation would have been appropriate for at least 21 of the 40 study sites. Ten of the 15 residential and seven of the ten commercial projects were located among intensively developed areas.

i). The most significant wetland mitigation project design problem is improper water levels and hydroperiod. Twenty-five of the mitigation projects studied exhibited hydrological problems within the created, restored and preserved wetland areas. Thirty-one of the 40 mitigation projects contained some form of wetland creation. Seventeen of these projects exhibited hydroperiod problems related to design and/or construction deficiencies. Water levels were excessive in 11 projects, too low in six projects, adequate in 12 projects and undetermined in two projects. Of the 15 projects containing wetland restoration, water levels were excessive in one project, too low in eight projects and satisfactory in six projects. Of the 21 wetland projects containing preservation, three projects had excessively high water levels, nine projects exhibited low water levels and five projects were adequately designed.

k). One of the symptoms of improper project hydrology and management is colonization of the wetland by problematic plant species. Thirty-two of the 40 wetland mitigation projects exhibited problems with colonization by problematic plant species. Twenty-two of the 40 mitigation projects required removal of problematic plant species. Removal had been undertaken in 13 (four of which were not required by the permit) of the 22. No activity attempting control was observed in 13 projects where control was required by the permit.

l). Only three of the 40 wetland mitigation projects included a long-term management plan.

m). The water quality sampling undertaken within the created, preserved, and restored wetland systems, did not exhibit any significant existing problems. However, 30 of the wetland mitigation projects studied were observed to receive direct discharges from parking lots, industrial sites, residential areas and citrus groves without any pretreatment prior to discharge. Consequently, long-term water quality problems may develop in many of these wetland mitigation projects.

n). Only five of the 40 wetland mitigation project files contained details of construction and planting methods.

o). Post-construction monitoring was required by permit for 39 of the 40 projects studied. Adequate monitoring had been undertaken by the applicant for 15 of the 39 projects. Monitoring had not been undertaken for 15 projects.

p). Since the adoption of the District's Isolated Wetlands Rule in 1987 upland habitat has often been preserved with some credit applied toward compensation toward permitted wetland impacts. An unspecified amount of wetland mitigation credit (acreage) was applied for upland preservation in 21 of the 40 projects studied.

# RECOMMENDATIONS

# VII. RECOMMENDATIONS

This study was a programmatic evaluation to determine the performance of an success of existing technology and wetland mitigation and not an evaluation of the District's criteria. However, the study does provide indications of how well the criteria are being applied in practice.

**"No net loss" of wetland functional values should be adopted and implemented by the District as an agency wide goal and conservation of biological diversity as a policy. The following actions supporting this goal are recommended for consideration and implementation:**

## Avoidance of Wetland Impacts

The avoidance of direct impacts to wetlands should be the first priority of the regulatory program. However, this avoidance in and of itself is usually not successful in providing long-term protection of the wetlands functional values, insuring persistence of the wetland system, or maintaining biological diversity when the surrounding landscape becomes fragmented by development. The degree of avoidance should be balanced with the estimated success of the preservation management plan in maintaining or enhancing those wetland functional values that are identified as important.

One must consider whether the value for which the land to be preserved or restored can realistically be maintained once the area is removed from the landscape as a result of the encroachment of surrounding development. One way to determine the answer to this question is to conduct a gap analysis. This involves the analysis of species composition and distribution relative to the size and distribution of the proposed created, restored or preserved wetland system and the opportunities for movement to other habitat areas by wildlife. If this analysis shows that declines in species diversity can be expected, the next step is to attempt to fill in the gap by expanding the size of the wetland system and its mosaic of surrounding native landscapes and when this is not possible consider offsite compensation for those wetland functional values lost even when the wetland is preserved.

## Type of Wetland and Location in the Landscape.

Only when project impacts have been reduced to the greatest extent possible should compensation be considered. This compensation should provide those functional values lost or reduced as a direct result of the proposed development activity as well as the functional values expected to be lost through time in the wetland preserves or conservation areas as a result of the cumulative adverse impacts of the surrounding developed landscapes adjacent to the wetland system. The type of wetland specified for restoration or creation should have a bearing on the types of wetland functions and related values provided if the compensation is successful.

There are three basic types of compensatory mitigation which are available as options to replace wetland functional values lost as a result of development activity; restoration, creation and enhancement. Restoration of an existing degraded wetland is often preferable to wetland creation or enhancement.

A relatively high degree of success has been achieved with the restoration and creation of tidal wetlands (i.e., mangroves and salt marshes) and freshwater marsh systems (Kusler and Kentula 1990) as compared to forested and shrub dominated freshwater wetland systems which are sensitive to slight changes in hydroperiod and water depths. This element of design is particularly important during the first few years of forested wetland development when planted tree seedlings are not only sensitive to specific water level and hydroperiod requirements but are also subject to planting shock and a wide variety of environmental stresses. In later stages of forest development, trees are less sensitive to seasonal and annual variations in hydroperiod.

While significant advances have been made with forested wetland creation and restoration over the last decade it may be another decade or two before investigators can substantiate some of the current positive trends that indicate possible success of some existing projects. Many years are required to produce a mature forest and develop the desired structure (i.e., understory, species diversity) and functions. The major reasons for lack of success for the projects evaluated in this study were improper application of known technology, inappropriate location, and absence of management.

The majority of mitigation projects including preserves evaluated in this study will have difficulty maintaining the desired functional values as a result of poor location and the synergistic cumulative effects of the adjacent land uses. Some degree of offsite regional resource compensation would have been appropriate for at least 21 of the 40 study sites. Ten of the 15 residential and seven of the ten commercial projects were located among intensely developed single and multiple land use areas, industrial parks and shopping centers (Table 15). These results are predictable given the fact that onsite wetland mitigation is encouraged by the District and most, if not all other, regulatory agencies. The District should develop a procedure for determining the type and degree of compensation to be undertaken onsite and those instances where regional compensation (offsite) is appropriate.

TABLE 15. The Number and Type of Wetland Mitigation Projects where some Degree of Offsite Regional Resource Compensation would Serve to Better Protect the Resource and Offset the Impact to Functional Values

| TYPE OF PROJECT | TOTAL #OF PROJECTS EVALUATED | YES | NO |
|---|---|---|---|
| | | | |
| AGRICULTURAL | 12 | 3 | 9 |
| RESIDENTIAL | 15 | 10 | 5 |
| PUBLIC | 3 | 1 | 2 |
| COMMERCIAL | 10 | 7 | 3 |
| | | | |
| TOTALS | 40 | 21 | 19 |

## Design

**Design of the wetland restoration, creation, and preservation.** The results of this study identified the following critical design features that must be properly incorporated into the project plan to insure goal attainment.

**Goals.** Clear, site specific project goals must be established for each wetland restoration, creation, and preservation project. The mitigation process should begin with a thorough evaluation of the functions that will be lost or diminished when the wetland is modified or destroyed. These goals should be used to assist project design, monitoring, and development of success criteria. These goals may relate to the ultimate size of the wetland system, functions and values, species of vegetation, location and density of vegetation, targeted species of fauna (i.e., endangered species), management activities and recreational values for the wetland system to be created, restored, or preserved. The major resources conservation goal should be to design and implement mitigation as resource compensation and natural resource conservation strategies to reduce the loss of biological diversity.

**Success Criteria.** Success criteria that directly pertain to the project goals must be drafted for each project. The success criteria must be measurable and specific enough to determine the degree of success or failure in attaining the established goals. Twenty-four of the 40 projects evaluated contained success criteria. However, these success criteria were not appropriate (i.e., percent survival of planted species for two years) or immeasurable (no acreage stated) for 23 of the projects (Table 4).

Success criteria should at a minimum include the following:

a). hydrological standards (i.e., water levels, hydroperiod, and water quality),
b). specific acreages of habitat types,
c). topography and specific contours,
d). vegetation criteria: percent cover and diversity of herbaceous species, percent cover of problematic species, density, height and canopy development of forested areas,
e). utilization by targeted species of wildlife,
f). water quality, and
g). biological integrity (i.e., diversity and richness of aquatic macroinvertebrates).

The project reviewer should consider the inherent difficulty in attaining success for the type of wetland project proposed including the expertise of the consultant for similar projects. The State should require licensing standards for environmental professionals that prepare wetland mitigation plans and supervise the construction and monitoring of wetland mitigation projects.

**Hydrology.** The most significant wetland mitigation project design problem relates to project hydrology. Fourteen projects contained wetland systems with excessively high water levels and 15 projects contained wetland systems with water levels too low to facilitate successful attainment of goals.

Wetland restoration, creation, and preservation projects with inappropriate hydrological designs are certain to fail. The application drawings and narrative must contain sufficient detail to support the surface water management design or hydrological model for the subject wetland system.

Project water levels must be established very early in the preliminary design stage. The water level elevations, design of structures, etc. within a project will dictate the design and development of water management features, roads, house pads, etc. In many of the instances where the observed water levels are too low, corrective action that would raise water levels to satisfactory elevations in the wetland system would create conflict (i.e., flooding) with the surrounding development. Therefore, it is important that appropriate water levels for the wetlands systems be established early in the design stage of the project before the elevations of roads and building pads are set.

The District should develop guidelines to be used by the project designer to determine the appropriate wetland water levels and hydroperiods to be incorporated into the design of surface water management systems. It is necessary to require the development of a water budget or model to assure that the watershed and structure(s) is adequate to create the proper hydroperiods and depths of inundation to attain the goals for the selected habitat type (including uplands). Hydrological modeling and water budgeting, even with quantitative analysis, is often inaccurate to some degree. Due to this fact and also because it is often difficult to maintain exact control during construction, some flexibility should be allowed to make "mid-course" adjustments such as changing the elevation of the control structure inlet or outlet mechanisms. This fine tuning of the system is often desirable and necessary in order to achieve the preferred results (Erwin 1990).

Project hydrological designs should be required to function as a "stand alone" or self-maintained systems. The water should be supplied via low energy means such as ground or surface water flow from an adjacent natural area or a properly designed man made system (i.e., reservoir). Except in very restricted cases, such as some agricultural projects, should high energy "demand" systems (i.e., pumping) be allowed. In agricultural reservoir situations where pumping is necessary, the reservoir should be of sufficient size and the pumping schedule regulated with a proper outfall structure design to insure the appropriate hydroperiods are maintained. Attention must also be directed to preventing excess draw down of shallow groundwater levels. Pumped systems are expensive, energy intensive, difficult to maintain and regulate. The District and all other regulatory agencies also need to consider the long-term viability of the water source for decades rather than the life of the permit.

**Uplands.** All wetland restoration, creation, and preservation projects undertaken by the District should, to the greatest extent possible, incorporate native upland habitat in order to provide and maintain the desired wetland functional values. The continued process of fractionalization or removal of wetlands from the surrounding landscape results in greater habitat fragmentation and disturbance. Increasing the isolation of wetlands from one another and from the surrounding rural landscape typically brings about a reduction in species richness. A method should be developed for assessing the values of uplands and wetlands that can be applied in all District programs so that impacts to wetlands as a result of direct and indirect processes can be identified, evaluated, proper compensation determined, appropriate designs and management plans developed.

**Drawings.** Project drawings must be of sufficient detail, clarity, and scale to allow a reviewer to conduct thorough and fair evaluation of the constructed project. The District's ability to conduct compliance inspections or to successfully implement enforcement action as a result of lack of project compliance is significantly reduced if design details are vague or absent.

The construction plans and specifications should be sufficiently detailed for construction purposes, engineering and environmental review, and verification of the "as built" conditions for compliance purposes. At a minimum, these drawings should include:

a). Overall plan view drawings of the entire site clearly stating the acreages of all parts of the created, restored and preserved wetland, and upland habitats.
b). Specific plan view drawings showing details of planted, restored, or preserved vegetation.
c). Location of all structures.
e). 0.5' contours with spot elevations (to 0.1') at the appropriate spacing.
f). The location of all upland buffers.
g). The location of all proposed and existing land uses adjacent to the project and within the project watershed.
h). Hydrological features such as seasonal high and low surface water levels and groundwater levels.
i). A verification of "as built" design features such as design contours in elevations.
j). Structure locations and elevations, location of all benchmarks on the site.
k). A detailed construction schedule explaining the coordination of earthwork with planting or mulching with flooding or irrigation of the area.
l). Landscape notes including the list of species planted or source of mulch, planting or mulching areas.
m). Densities of plants.
n). Types of plant materials (i.e., tubling, containerized nursery stock, sprigs, seeds).
o). Size of plants.
p). Aerial photographs at a scale of 1" = 100' to 1" = 400' (depending upon project size) upon which the project design has been overlayed.
q). A post-project construction schedule for irrigation or drainage.
r). Any geographical constraints regarding the origin of the plant materials.
s). Details on removal and control of problematic native and exotic species of vegetation (i.e., cutting and/or herbiciding regularly on an annual basis for the term of the project).
t). Special maintenance or protective features such as fences, fire lanes, signage, and conservation easement boundaries.
u). The monitoring and reporting time table.
v). Monitoring program design and locations of sampling stations.
w). Certification by an expert practitioner in wetland restoration, creation, and management.

**Soils Analysis.** While soils were not found to be a significant factor in the success or failure of the wetland mitigation projects studied, early evaluation of the soil types and conditions on the proposed mitigation site is recommended. Conducting appropriate hydrological analyses of a subject area will identify soil types and address the characteristics of these soils, but often will not identify problematic features such as the existence of cap rock on a site.

On project sites where excavation and contouring for wetland restoration or creation is implied, data should be collected to insure that cap rock is not present at elevations or quantities that would conflict with the project design. A sufficient number of soil borings on a site will easily determine the location and extent of underlying rock. Excessive quantities of rock are expensive to excavate, resulting in re-contouring problems following the removal of the rock to the exact elevations in contour required, and if left in place at or near the surface do not provide suitable substrate for desirable trees and herbaceous species of wetland plants. The project files did not confirm if these evaluations were conducted for the project sites evaluated.

**Water Quality.** Many wetland values are related to the quality of wetlands with respect to contaminants in wetlands and their associated biota. Wetland values can be compromised by the impacts of contaminants that originate from a variety of sources. Although one of the values of wetlands is their ability to assimilate contaminants, excessive amounts of contaminants impair the functions of wetlands and diminishes all of their values.

The District should require the applicant to provide assurance that the quality of water to be discharged into the wetland system will be compatible with the targeted wetland functions and values in perpetuity. This means that the applicant should provide an evaluation of existing and future land uses within the basin that are expected to contribute directly or indirectly to water quality within the project site.

Whenever possible, the applicant should provide the District with ambient water quality, vegetation, and macroinvertebrate data from the wetlands proposed for disturbance, and a reference wetland which is typical of the system which the applicant has agreed to create, restore, and preserve. The reference wetland could in certain situations be the wetland proposed for impact. This water quality and macroinvertebrate data is not only important to ascertain the degree of goal attainment or meeting success criteria, but will also function as baseline information to assess the cause and effect relationship of future development in the project's drainage basin and the effects on the subject wetland system. Parameters that should be monitored, the number and location of sample stations and the frequency of sampling should be selected on a site specific basis.

The District should evaluate the results of restored, created, and preserved wetlands receiving direct discharges of stormwater to determine if treatment in wetlands is viable. Adequate levels of pretreatment may be required to prevent degradation of water quality within the wetland system. Those wetlands created, restored, or preserved in order to provide specific water quality treatment functions may not require this pretreatment or at a reduced level. The short and long-term quality of the surface and groundwater discharged into these wetland systems must be compatible with those functions and values of the wetland identified in the project goals.

**Construction Methods.** Only five of the 40 wetland mitigation project files contained details of construction methods (Table 16). Adequate planning and design of any wetland creation, restoration, or preservation projects can easily be defeated by problems during the construction process. Two ways to reduce the construction problems are:

TABLE 16. Incidence of Known Construction Methods form 40 Wetland Mitigation Projects Studied in the SFWMD

| TYPE OF PROJECT | TOTAL #OF PROJECTS EVALUATED | CONSTRUCTION METHOD STATED IN PROJECT FILE | CONSTRUCTION METHOD NOT STATED IN PROJECT FILE |
|---|---|---|---|
| AGRICULTURAL | 12 | 1 | 11 |
| RESIDENTIAL | 15 | 2 | 13 |
| PUBLIC | 3 | 1 | 2 |
| COMMERCIAL | 10 | 1 | 9 |
| | | | |
| TOTALS | 40 | 5 | 35 |

NOTE: ALL DATA OBTAINED FROM DISTRICT FILES AND INTERVIEWS

1. Advise and educate the contractor on the design specifications and other requirements such as logistics (i.e., removal, stockpiling, and transport of wetland mulch material). This usually can be facilitated by one or more pre-construction meetings both in the office and on the project site. Where the bid process is involved, the project sponsor/developer should provide the contractors with the detailed construction drawings specified above and ascertain the experience of those contractors bidding on the project and the extent to which they have successfully completed projects of a similar nature.

2. Provide adequate supervision by a qualified wetland expert during the critical phases of construction. An open line of communication between the contractor, developer, wetland consultant, engineer, and the District will usually prevent most problems. When mid-course corrections are required or remedial action necessary, these changes then can be facilitated quickly with minimal interruption of the site

work process. If the consultant is forwarding regular construction reports to the District staff, evaluation of the project status and compliance will allow rapid determination of problems and implementation of acceptable solutions.

The majority of the projects studied would have benefitted greatly if these construction considerations were followed.

**Monitoring.** The reasons for instituting a comprehensive monitoring program are many but may be classified into three general categories;

a). assessing the effectiveness of policy or legislation,
b). regulatory (performance or audit functions), and
c). detecting change (early warning, trends).

**Monitoring of the wetland systems should be required at four different levels in the permitting process:**

a). *baseline monitoring* or evaluation of the wetlands and related habitats to be impacted as a result of permit issuance;
b). *construction monitoring* to frequently check compliance and project status;
c). *time zero report* to evaluate the "as built" conditions of the mitigation project immediately following the completion of construction;
d). and *post-construction project monitoring* conducted at regular and periodic intervals.

Of the 40 wetland mitigation projects studied, some form of monitoring and reporting (generally post-construction) was required for 39 projects (Table 17). Some type of monitoring had been done for 24 projects, however, monitoring was determined adequate (to evaluate compliance and degree of success) for only 15. Monitoring was not undertaken for 15 projects (Table 17). Only two residential and three commercial projects had submitted baseline and post-construction monitoring reports to the District at the time the site evaluations were conducted.

TABLE 17. Adequacy of Monitoring and Reporting for 40 Wetland Mitigation Projects Studied in the SFWMD

| TYPE OF PROJECT | TOTAL #OF PROJECTS EVALUATED | PROJECTS WHERE MONITORING REQUIRED* WAS PERMIT | PROJECTS WHERE SOME TYPE OF MONITORING WAS DONE | PROJECTS WHERE MONITORING WAS ADEQUATE | PROJECTS WHERE NO MONITORING WAS DONE |
|---|---|---|---|---|---|
| AGRICULTURAL | 12 | 12 | 8 | 5 | 4 |
| RESIDENTIAL** | 15 | 15 | 9 | 5 | 6 |
| PUBLIC** | 3 | 3 | 3 | 3 | 0 |
| COMMERCIAL*** | 10 | 9 | 4 | 2 | 5 |
| | | | | | |
| TOTALS | 40 | 39 | 24 | 15 | 15 |

NOTE: ALL MONITORING DATA OBTAINED FROM DISTRICT FILES
* NOT REQUIRED ON 1 COMMERCIAL PROJECT
** TWO PROJECTS HAD BASELINE AND POST CONSTRUCTION MONITORING
*** ONE PROJECT HAD BASELINE AND POST CONSTRUCTION MONITORING

The lack of attention given to providing adequate monitoring of wetland mitigation projects (Table 17) compounds a serious compliance problem. Without monitoring reports, the actual status of the project cannot readily be determined. The District's compliance efforts, discussed later in this report, must be tied directly to the timely submittal of monitoring reports to the District and evaluation by District staff.

All monitoring programs should include data requirements, evaluation criteria, and methods for reporting with goal evaluation in mind. The key items to be monitored are the site's size and configuration, hydrology, water quality, flora, and macroinvertebrate fauna. Achieving satisfactory hydrology and vegetation of the proper site location will usually lead to accomplishment of additional goals such as wildlife utilization.

Baseline Monitoring. Wetland evaluation is needed prior to a project to set goals and develop a plan, as a component of the monitoring program, and as a means for ultimately determining compliance. Although the timing differs for each of these evaluations, the factors to be considered and the general needs and approaches are the same (Erwin 1990). There is the difficulty of knowing how representative the functional status of the system was when the evaluation was conducted. All wetlands and most upland habitats exhibit cyclical or stochastic changes. A period of surveillance is therefore, desirable to insure that when a baseline is established it does represent a base.

Since 1989, the District has required the submittal of baseline data for agricultural projects (where wetlands are incorporated into reservoirs) prior to permit issuance. Most of the projects evaluated in this study were permitted prior to this requirement. Eight project files contained various amounts of baseline data on those wetlands and the surrounding landscapes that were proposed and eventually permitted to be impacted. This lack of baseline information complicates the agency's ability to determine the functions that will be lost when the wetland is modified or destroyed and the degree of compensation that is required.

The District should expand its wetland baseline monitoring requirements to involve measuring plant species diversity, richness, cover, water quality sampling, benthic macroinvertebrate sampling, and wildlife surveys. This baseline monitoring should be taken for an appropriate representative sample of all types of wetlands and adjacent uplands onsite. This baseline data should then be submitted to the District with the permit application.

The baseline data should be utilized by the applicant and the District to:

1. Determine the viability of the wetlands and role of the uplands (as related to wetland functions) onsite at the present time.

2. Direct the preferred avoidance of any wetlands and associated uplands providing functional values where compensation would be difficult or impossible.
3. Determine the degree of compensation required for those wetlands to be directly impacted by dredging or filling, and indirectly as a result of the development of the adjacent landscape.

This data, which is related to the type, nature, and functions of the wetlands onsite, may then be used to establish goals and success criteria to be met by the wetland compensation project. Wetland evaluation may be required of systems located off the project site when the desired reference wetland (system model) is not located onsite.

Construction Monitoring. The construction of wetland compensation projects may occur over a few weeks or extend over many months. Regular, often daily inspection of the project by the applicant's environmental professional is crucial to the successful outcome of the project. Coordination with the project's contractor, sponsor, and engineer is necessary as with any other construction project. Frequent inspections by the applicant's environmental professional are required to review construction methods, check design details in the field, evaluate the accomplishment of certain milestones such as "as built" surveys, installation of structures, and the necessity for adding or removing surface water from a site.

The District should require brief regular and periodic narrative reports from the applicant's environmental professional routed through the Field Engineering staff, thus enabling proper overview of activities and coordination of District compliance inspections.

Currently, District compliance inspections are too infrequent. An increase in staff inspections is required until monitoring and reporting by the permittee is in order. However, frequent reliable construction monitoring and reporting could eventually reduce District related compliance inspections in the future. A reporting format should be developed by the NRM and Field Engineering staff so that the required information is reported at the desired frequency, properly routed through the District and compiled. As problems develop on a project after construction, this chronological record of events can be most useful in answering the "how" and "why" questions that often arise.

Time Zero Report. This report is an evaluation of the onsite conditions at the time of project completion and should be submitted to the District within 30 days of project completion. This report should contain an "as built" survey or "record drawing" of the created, restored, and preserved wetland systems, buffers, and upland associations. "As built" contours and topography at specified detail and intervals, along with a planting plan locating the major macrophyte communities, densities, species, and photographs taken at a sufficient number of permanent photo stations to adequately cover the project should also be provided in this report.

Post-construction Monitoring. This monitoring should be undertaken at least once per year during the growing season (May - October). Certain types of restoration and creation with an identified higher risk of probable goal attainment (i.e., some freshwater forested systems) should be monitored more frequently and extensively. Monitoring should continue until success criteria are met and goals are accomplished. The monitoring and reporting should be conducted by an experienced wetland scientist with the reports supplied to the District within a reasonable time frame (i.e., 60 - 90 days) to enable corrective action as identified by monitoring results to be undertaken prior to the next growing season.

The plans for monitoring the wetland preservation, creation, and restoration areas should be approved by District staff and given as much attention as the permit application itself. Monitoring reports should contain:

- A complete description of project and goals, a statement of success criteria.
- The methods of construction.
- A complete chronology of events commencing with the date of the application being filed.
- A results and discussion section that reports and evaluates the data collected and observations made.
- A conclusion section where goal attainment status is discussed and corrective action (if needed) recommended.

Monitoring of the wetland system should be applied according to its structure and vegetation communities (e.g. modified Releve Method, Barbour et al., 1987). Each major macrophyte community and points of surface water recharge and discharge should be thoroughly described and a permanent sampling station established. The parameters evaluated at each permanent sampling station would include water level and qualitative macroinvertebrate evaluation. Vegetation sampling should be undertaken within each plant community by establishing a sufficient number (at least six) of random $1m^2$ plots. Data should be reported individually for each plot and then summarized for all plots for each macrophyte zone. Data collected would include species richness, diversity, and percent cover including bareground by stratum.

The report should also contain; water level data collected from permanent constant recording stations located within the project, photographs at each sample station, weekly rainfall data collected at the site, detailed drawings, and wildlife observations. When wildlife utilization is a specific goal of the project, more frequent site evaluations or sampling should be required specifically designed to record the degree of utilization by the targeted species of wildlife.

The wetland scientist monitoring the project and District staff are encouraged to evaluate trends, both positive and negative, as the wetland system matures. Problems such as inappropriate hydroperiod, stormwater pollution, problematic exotic infestation, and management related problems will be evidenced in monitoring reports and can then be given prompt attention. This immediate corrective action can often place a project back on course. Treating problems early can also save the project sponsor financial expenditures which will usually increase significantly if problems are allowed to develop unnoticed and untreated.

Adequate monitoring of wetland systems is necessary, but is a significant expense to the project sponsor. The design and management of a compensatory wetland mitigation directly influences the length of time required for a project to meet success criteria and attain its goals. The longer a project requires to attain success and meet its goals, the longer monitoring will be required, at greater cost.

The District should institute long-term monitoring of wetland mitigation projects, including wetland and upland preserves, for projects that have been deemed successful. In these cases the intensive annual monitoring and reporting would be discontinued and periodic (2 - 5 years), low intensity, qualitative reports with photographs would be submitted for District review. This long-term "post success" monitoring will allow District staff to keep track of projects over time. Should any problems be identified (i.e., lack of maintenance, exotic plant infestations, etc.) then corrective action can be directed and more intensive monitoring required, if necessary, until the problem has been corrected.

**Economics.** The successful compensation of lost or impaired wetland functional values is usually an expensive proposition. Expenses related to permitting, engineering and environmental consulting fees, materials, land and heavy equipment costs typically range from five thousand ($5,000.00) to thirty-five thousand ($35,000.00) dollars per acre or more depending upon the type of project. This estimate does not include the cost of land, which in the developing urban corridor often exceeds all other costs combined on a per acre basis. Higher wetland and overall natural resource values and lower land costs in rural areas dictate that some degree of offsite regional resource compensation may often serve to better protect the resource and offset the impacts realized in the developing urban corridor when all wetland impacts cannot be avoided, both directly or indirectly.

These financial costs of properly undertaking wetland mitigation may be an underlying cause of the high number of projects not constructed, not within compliance, improperly designed and maintained. Proper evaluation, design, construction, monitoring, and management of compensatory wetland mitigation generates expense. In addition, there are direct and indirect economic values associated with our natural resources and those wetland functional values provided by the wetland systems. Improper management of these resources results in a decline of economic values related to a loss of functional values. Both private and public decisions regarding wetland protection too often ignore the substantial goods and services generated by wetland systems. The substantial number of wetland mitigation project failures and number of projects not even constructed are in part economic decisions resulting in losses of wetland values.

Performance bonding of wetland mitigation projects should be considered as a means of insuring project compliance and ultimate attainment of the projects goals. The bonding should adequately address all anticipated costs of construction, monitoring, maintenance, management, and corrective action. A scheduled reduction in the bond amount is possible as certain milestones are reached such as construction, monitoring, and maintenance phases. The District must implement procedures that will cause non-compliance and project failure not to be cost effective for the project sponsor.

**Compliance.** The District should undertake the following actions to reduce costs and improve compliance with a "no net loss" of wetland functional values goal:

a). The District should now reassess all of the permitted wetland mitigation not yet constructed and determine if these projects should be redesigned to provide better results.

b). Identify appropriate measurable goals and success criteria in each permit.

c). The District should require performance guarantees, i.e., performance bonds, letters of credit or agreements as a means of insuring project compliance and ultimate attainment of the project's goals.

d). Initiate enforcement action if compensation activity is not commenced on time as required per the permit or monitoring is not performed.

e). Require legal and enforceable conservation easements on all restored, created, and preserved wetland systems and associated upland habitats.

f). Create and adequately staff a compliance section.

g). Undertake regular compliance inspections and enforce District rules and policies.

h). Develop a "bio-accounting system" that will provide regular and periodic (at least annual) updates of the District's wetland compensation project status.

i). Require conservation easements on all restored, created, and preserved wetland systems and associated upland habitats.

j). The entire process of project design and implementation (construction) should be documented in detail by the applicant and District.

**Project Documentation.** The entire process of project design and implementation (construction) should be documented in detail by the applicant and District. The absence of this information in the project files made project evaluation difficult and creates confusion between the regulatory agency, applicant, and permittee. It is important to understand the basis for a proposal supporting a particular design criteria or modification.

**Expertise.** The success of the wetland system proposed for restoration, creation, and preservation will depend on the correctness of the plans and specifications as well as the execution of construction according to these plans and specifications. Therefore, it is important that the appropriate skilled professionals prepare the project plans and supervise the construction and monitoring of the project.

# RESEARCH NEEDS

## VIII. RESEARCH NEEDS

Information gaps and research needs related to wetland creation, restoration, and preservation can be divided into the following categories:

a). Site selection and design.
b). Project construction techniques.
c). Comparative studies of the biological communities and processes in natural, created, and restored wetland systems.
d). The role of surrounding landscapes in maintaining wetland functional values.
e). Evaluation of success.

### Site Selection and Design

There is great need for information related to the suitability of wetland restoration, creation, and preservation in urbanized landscapes. The subject of landscape ecology needs to be evaluated with regard to the impact of surrounding land uses on natural and created wetland systems (Erwin 1990). Given the fact that we have lost over 116 million acres of an original estimated total of 215 million acres of wetlands in the United States (Tyner 1984), the understanding of feasibility and success of wetland creation, restoration, and preservation projects in developed and undeveloped landscapes should be a high priority and not automatically considered for compensatory mitigation only. The development of cost effective designs and construction methods is needed to insure a higher degree of successful wetland compensation projects.

The District should undertake an effort that will identify the process to be used by the project planner to determine the appropriate wetland water levels and hydroperiod and the design of the surface water management systems including structure (weirs, culverts, etc.) required to provide the desired results.

The District should evaluate the effectiveness of the 200 foot setback criteria in Appendix 7 of the Basis of Review (5.1.6.b) to protect adjacent wetland systems from adverse hydrological impacts.

The District should evaluate the cumulative effects of water use and surface water management. The District should develop a procedure for determining what the type and degree of compensation that will be undertaken onsite and where regional (offsite) compensation is appropriate. Research should be conducted to determine thresholds for the type and degree of compensation to be undertaken onsite.

The District should investigate alternative stormwater and wetland mitigation designs that would improve upland and wetland resource values and reduce fragmentation.

Finally, the District should now reassess all of the permitted wetland mitigation not yet constructed and determine if they can be redesigned to provide better results. This process must be undertaken if a goal of "no net loss" of wetland functions and values is to be attained. The re-assessment could be cost effective for project sponsors who could avoid the construction of poorly designed projects that as currently planned may never accomplish their permitted compensation goals.

## Project Construction and Maintenance Techniques

The District should evaluate the cost effectiveness of construction techniques related to wetland creation, restoration, and preservation. Cost is usually driven by the size and condition of the wetland system and construction techniques applied. Since long-term management capability is critical to the continued functioning of a system, management techniques including acquisition, easements, and restrictive covenants should be evaluated to determine the appropriate application for different situations. Management activities including prescribed burning, control of problematic species, and water level manipulation which are necessary to maintain the desired wetland functions should be evaluated.

## Comparative Studies

Comparative studies of created or restored wetlands and comparable natural systems.The scientific community questioned how created and restored wetlands, as well as preserved wetlands in certain landscape settings, compare in structure, function, and value to comparable natural systems (Race and Christie 1982). The high degree of variability among different types of wetland systems and their associated upland habitats discourages generalizations and raises the need for comparative studies which have only recently been initiated. Comparative studies would assist in developing a system or technique of measuring wetland functional values to assist in permit application evaluation and the evaluation of mitigation project design and success post-construction compensation.

## The Role of Surrounding Landscapes

The processes of urbanization and agricultural conversion result in greater habitat fragmentation and disturbance, creating an increased number of isolated patches or islands of habitat. This process typically brings about a reduction in biological diversity and functional values of wetlands. A method should be developed for assessing the values of adjacent upland habitats in project review so that proposed impacts to wetlands (direct and indirect) can be evaluated, proper design, and compensation determined.

The current goal of the District's regulatory process seeks to reduce wetland related impacts to the greatest extent possible. However, as this study points out, the goal of "no net loss" of wetland functional values is not currently being attained as a result of a significant number of poorly located and improperly designed wetland compensation projects. The major question that one should ask in evaluating the degree of success of this or any regulatory process is, what will be the state of our natural resource base, both upland and wetland systems, when the vast majority of the south Florida area is at "build out", perhaps in 100 years.

Evaluation of Success

Scientifically defensible standards are needed, based on research to develop appropriate sampling protocols and identify suitable reference (comparison) data sets.

A Comprehensive Regional Resource Plan

**The systems that we create, restore, or preserve today must be persistent over many decades or centuries. The District must undertake planning action that fully identifies these system objectives and uses the regulatory process to implement those policies. Therefore, the District should identify, as a primary goal, resource protection through implementation of a comprehensive regional plan that involves acquisition, wetland restoration, preservation, and where required creation that will conserve biological diversity.**

This regional resource protection and compensation planning effort for the District could be undertaken in the following manner.

A synthesis of natural communities consisting of a comprehensive inventory and mapping effort that will produce:

a). Basin delineations of all watersheds within the District and their hydrological characteristics (i.e., flow characteristics, water quality, point and non-point discharges).

b). Florida Land Use, Cover and Forms Classification System mapping to Level III and IV, thus precisely describing the mosaic of landscapes.

c). An identification of the biological components of the natural and man made landscapes according to functional values.

The District would then develop a resource management plan for each basin or region.

a). Indexing the systems by type, location, and function, and b). prioritize (rank) all habitats and systems according to importance to maintaining biodiversity.

This effort will identify those areas where;

a). acquisition should be undertaken,
b). conservation easements should be obtained,
c). various levels of regulation should be applied, and
d). where regional resource compensation projects including wetland mitigation can best be located.

The problems raised by cumulative impact assessment and regulation require radical re-thinking and modification of the District's and other wetland regulatory agencies present approach to regulation. Specifically, cumulative impact assessment requires a change in focus from a specific, detailed analysis of structure and function at a permit application site to a broad analysis of the landscape within which a individual permit is reviewed. These broad, regional analyses should include concern for structural and functional properties that "emerge" at this scale resulting in successful "regional resource management". Hydrological and water quality properties, landscape patterns, and home range requirements for wildlife species that greatly exceed individual permit sites are a few such properties. The degree of success in attaining this kind of regulation will require the implementation of these ecologically based resource protection methods. Failure to adopt this approach will in the long-term effectively reduce the region's remaining biological resources to fragmented, non-functional remnants of an irreplaceable ecosystem, south Florida.

# SUMMARY OF RECOMMENDATIONS

# IX. SUMMARY OF RECOMMENDATIONS

This study was a programmatic evaluation to determine the performance of an success of existing technology and wetland mitigation and not an evaluation of the District's criteria. However, the study does provide indications of how well the criteria are being applied in practice.

## Goals

a). The Governing Board should define, adopt, and implement "no net loss" of wetland functional values as an agency wide goal and conservation of biological diversity as a regional policy.

b). Mitigation of wetland impacts should follow these sequential steps; avoidance, minimization, restoration, reduction or elimination over time and compensation. Wetland restoration should be the preferred form of compensatory mitigation, followed by wetland creation.

c). The District's conservation policy should be to compensate for all resource losses, and with mitigation and other natural resource conservation strategies reduce the loss of biological diversity.

d). All wetland restoration, creation, and preservation projects undertaken by the District should, to the greatest extent possible, incorporate native upland habitats in order to provide and maintain the desired wetland functional values and biodiversity.

e). Measurable and specific success criteria that directly pertain to the project goals must be incorporated into each project.

## Project Design and Location

a). The State should require licensing standards for environmental professionals that prepare wetland mitigation plans and supervise the construction and monitoring of wetland mitigation projects.

b). The District should develop guidelines to be used by the project designer to determine the appropriate wetland water levels and hydroperiods to be incorporated into the design of surface water management systems.

c). The District should evaluate the cost effectiveness of all forms of mitigation (i.e., construction techniques and practices related to wetland creation, restoration, and preservation) to determine that reasonable assurance is provided.

d). Project hydrological designs should be required to function as "stand alone" or self-maintained systems. When agricultural reservoirs are proposed the reservoir should be of sufficient size and the pumping schedule adequately regulated with an acceptable outfall structure design to insure the maintenance of proper hydroperiods and water levels to support the natural habitats within the reservoir.

e). A method should be developed for assessing the values of uplands and wetlands that can be applied in all District programs so that impacts to wetlands as a result of direct and indirect processes can be evaluated, proper compensation determined, appropriate designs developed, and management plans developed.

f). The District should develop a framework for determining the type and degree of compensation to be undertaken onsite and those instances where regional compensation (offsite) is appropriate.

g). All wetland restoration, creation, and preservation projects undertaken by the District should, to the greatest extent possible, incorporate native upland habitats in order to provide and maintain the desired wetland functional values and biodiversity.

h). Surface water management engineering analyses should incorporate elements of a water budget evaluation in its review because of impacts on wetlands. Methods should be selected to determine the depth and duration criteria on a seasonal or annual basis.

**Compliance**

a). The District should now reassess all of the significant permitted wetland mitigation not yet constructed and determine if these projects should be redesigned to provide better results.

b). Create and adequately staff a compliance section to undertake regular compliance inspections and enforce District rules and policies. A threshold for evaluation, such as projects containing a specific type or acreage of wetlands, could be used to identify the significant projects.

c). Develop a "bio-accounting system" that will provide regular and periodic updates of the District's wetland compensation projects status.

d). The District must implement procedures so that non-compliance and/or project failure will not be cost effective for the project sponsor.

e). Identify appropriate, measurable goals and success criteria in each permit.

f). Initiate enforcement action if compensation activity is not commenced on time as required per the permit or when monitoring is not performed.

g). The District should require performance guarantees, i.e., performance bonds, letters of credit or agreements as a means of insuring project compliance and ultimate attainment of the project's goals.

h). Require legal and enforceable conservation easements on all restored, created, and preserved wetland systems and associated upland habitats.

i). Project drawings must be of sufficient detail, clarity, and scale to allow a reviewer, who is unfamiliar with the project, to conduct a thorough and fair evaluation of the constructed project. The District's ability to conduct compliance inspections or to successfully implement enforcement action as a result of lack of project compliance is significantly reduced if design details are lacking.

## Water Quality

a). The short and long-term quality of the surface and groundwater discharged into these wetland systems must be compatible with those functions and values of the wetland identified in the project goals.

b). The District should evaluate the results of restored, created, and preserved wetlands receiving direct discharges of stormwater runoff to determine if treatment in wetlands is viable.

## Management

a). Long-term management should be incorporated in all plans to preserve, restore or create wetland systems. These plans should identify specific details on operations, responsibility, and funding.

**Biological Integrity**

a). The District should investigate the measures of a wetland system's biological integrity that could be used as a criterion for evaluating wetland systems including wetland creation, restoration, preservation projects.

**Monitoring**

a). All monitoring programs should include data requirements, evaluation criteria, and methods for reporting with goal evaluation and compliance in mind.

b). The District should develop criteria and standards monitoring the wetland preservation, creation, and restoration projects. Monitoring plans should be approved by District staff and given as much attention as the permit application itself.

c). Baseline wetland evaluation is needed prior to a project to set goals and develop a plan, as a component of the monitoring program, and as a means for ultimately determining compliance.

d). The District should expand its wetland baseline monitoring requirements to involve measuring plant species diversity, richness, cover, water quality sampling, benthic macroinvertebrate sampling, and wildlife surveys to adequately assess wetland functions and values.

e). The District should develop a comprehensive schedule for compliance inspections.

f). The District should require regular and periodic narrative reports from the applicant's supervising professional routed through the Field Engineering staff, thus enabling proper documentation of activities and progress onsite during construction so that sufficient compliance inspections can be conducted.

g). Time zero reports, evaluating the site conditions at the time of project completion should be submitted to the District within 30 days of project completion.

h). Post-construction monitoring should be undertaken at least once per year during the growing season (May - October) until the mitigation is found to meet the established goals and success criteria.

i). The District should institute low intensity, qualitative long-term monitoring of wetland mitigation projects, including wetland and upland preserves, for projects that have been deemed successful. Should any problems be identified (i.e., lack of management, exotic plant infestations, etc.) corrective action can be directed and more intensive monitoring required, if necessary, until the problem has been corrected.

# REFERENCES

## X. REFERENCES


Baker, G.F. 1984. An analysis of wetland losses and compensation under the Clean Water Act, Section 404 Program: Managing natural resources through mitigation. M.S. Thesis, University of San Francisco, San Francisco, California.

Barbour, M.G., J.H. Burk, and W.D. Pitts. Terrestrial Plant Ecology. The Benjamin/Cummings Publishing Company, Inc. Menlo Park, California.

Beck, W.M., Jr. 1954. Studies in stream pollution biology. 1. A simplified ecological classification of organisms. Quarterly Journal of the Florida Academy of Sciences 17(4):211-227.

Beck, W.M., Jr. 1955. Suggested method for reporting biotic data. Sewage and Industrial Wastes 27(10):1193-1197.

Begon, M., J.L. Harper, and C.R. Townsend. 1986. Ecology: individuals, populations, and communities. Sinauer Associates, Inc. Sunderland, Mass.

Burgess, R.C. and D.M. Sharp (editors.). 1981. Forest island dynamics in non-dominated landscapes. Springer Verlay, New York.

Carter, V. 1986. An overview of the hydrologic concerns related to wetlands in the United States. Canadian Journal of Botany. 64:364-374.

Dahl, T.E. 1990. Wetlands losses in the United States 1970's to 1980's. U.S. Department of the Interior, Fish and Wildlife Service, Wash. D.C. 21 pp.

Erwin, K.L. 1990. Wetland evaluation for restoration and creation. *In* Wetland Creation and Restoration: The Status of the Science. J.A. Kusler and M.E. Kentula (editors). Island Press. Wash. D.C.

Fishman, P.A., N.S. Geiger, L. Sharp, J.W. Buell, and L. Wilson. 1987. Estuarine Mitigation Evaluation Project - Mitigation site evaluation notebook. Submitted to the Department of Land Conservation and Development and the Division of State Lands. Fishman Environmental Services, Portland, Oregon.

FDNR Florida Department of Natural Resources. 1988. Wetlands in Florida. An addendum to Florida's comprehensive outdoor recreation plan. Division of Recreation and Parks. 91 pp.

Good, J.W. 1987. Mitigating Estuarine Development in the Pacific Northwest: from concept to practice. Northwest Env. Jour. 3(1):93-111.

Gwin, S.E. and M.E. Kentula. 1990. Evaluating design and verifying compliance of wetlands created under Section 404 of the Clean Water Act in Oregon. EPA/600/3-90/061. U.S. Environmental Protection Agency, Environmental Research Laboratory, Corvallis, Oregon.

Kentula, M.E., J.C. Sifneos, J.W. Good, M. Rylko, and K. Kunz. Trends and patterns in Section 404 permitting in Oregon and Washington. In Press.

Kentula, M. 1986. Wetland creation and rehabilitation in the Pacific Northwest, p. 119-150. *In* R. Strickland, (editor) The State of Our Understanding. Washington State Department of Ecology, Olympia, Washington. P. 119-150.

Klemm, D.J., P.A. Lewis, F.Fulk, and J.M. Lazorchak. 1990. Macroinvertebrate field and laboratory methods for evaluating the biological integrity of surface waters. EPA/600/4-90/030. United States Environmental Protection Agency, Cincinnati, Ohio.

Kusler, J.A. and M.E. Kentula (editors). 1990. Wetland Creation and Restoration: The Status of the Science. Island Press. Wash. D.C.

Lenat, D.R., L.A. Smock, and D.L. Penrose. 1980. Use of benthic macroinvertebrates as indicators of environmental quality. *In* Biological Monitoring for Environmental Effects. D.L. Worf (editor). Lexington Books, D.C. Heath and Company, Lexington, Massachusetts. P. 97-112.

MacArthur, R.H. and E.O. Wilson. 1967. The theory of island biogeography. Princeton University Press, Princeton, N.J.

Mason, C.O. and D.A. Slocum. 1987. Wetland replication - does it work? *In* Proceedings of the 5th Symposium on Coastal and Ocean Management, May 1987, Volume 1. American Society of Civil Engineering, New York, New York. P. 1183-1197.

Niering, W.A. 1990. Vegetation Dynamics in Relation to Wetland Creation. *In* Wetland Creation and Restoration: The Status of the Science. J.A. Kusler and M.E. Kentula (editors). Island Press. Wash. D.C.

Preston, F.W. 1962. The canonical distribution of commonness and rarity (2 parts). Ecology 43, 185-215; 410-432.

Race, M.S. and D.R. Christie. 1982. Coastal zone development: mitigation, marsh creation, and decision making. Environmental Management 6:317-328.

Reiner, E.L. 1989. The biological and regulatory aspects of salt marsh protection, restoration and creation in Massachusetts. M.S. Thesis, Department of Biology, Northeastern University, Boston, Mass.

Reinold, R.J. and S.A. Cobler. 1986. Wetlands mitigation effectiveness. USEPA Contract No. 68-04-0015. Metoaft and Eddy, Inc. Wakefield, Mass.

Ross, L.T. 1990. Methods for aquatic biology. Florida Department of Environmental Regulation Technical Series 10(1):1-47.

Shaw, S.P. and C.G. Fredine. 1956. Wetlands of the United States. U.S. Department of the Interior, Fish and Wildlife Service. Wash. D.C. Circular 39. 67 pp.

Simberloff, D.S. 1974. Equilibrium theory of island biogeography and ecology. Ann. Rev. Ecol. Sys., 5:161-182.

Smith, C.L. and J.T. Polhemus. 1978. The Veliidae (Heteroptera) of America north of Mexico - keys and check list. Proceedings of the Entomological Society of Washington 80:56-68.

Soule', M.E. and B.A. Wilcox. 1980. Conservation Biology: An Evolutionary - Ecological Approach. Sinauer Associates, Sunderland, Mass.

Tyner, R.W. Jr. 1984. Wetlands of the United States: Current status and recent trends. U.S. Fish and Wildlife Service. National Wetlands Inventory. Washington, D.C.

Toth, L. A. 1991. Environmental responses to the Kissimmee River Demonstration Project. South Florida Water Management District, Technical Publication 91-02. West Palm Beach, Florida.

Tschinkel, V.J. 1984. Ecosystems of surface waters. *In* Water Resources Atlas of Florida. E.A. Fernald and D.J. Patton (editors). Florida Resources and Environmental Analysis Center, Institute of Science and Public Affairs, Florida State University. Tallahassee. 291 pp.

Weller, M.W. 1990. Waterfowl Management Techniques of wetland enhancement, restoration, and creation useful in mitigation procedures. *In* Wetland Creation and Restoration: The Status of the Science. J.A. Kusler and M.E. Kentula (editors). Island Press. Wash. D.C.

Wilcove, D.S., C.H. McLillan & A.P. Dobson. 1986. Habitat Fragmentation in the Temperate Zone. In Conservation Biology: The Science of Scarcity and Diversity. Ed. M.E. Soule'. Sinauer Associates, Inc. Sunderland, Mass.

Zedler, J.B., and M.W. Weller. 1990. Overview and Future Directions, In Wetland Creation and Restoration: The Status of the Science. J.A. Kusler and M.E. Kentula (editors). Island Press, Wash.D.C.

## APPENDIX I

## DEFINITIONS

**CREATION** - The conversion of a persistent non-wetland area into a wetland through some activity of man. This definition presumes the site has not been a wetland within recent times (100-200 years) and thus restoration is not occurring. Created wetlands are subdivided into two types: artificial and man-induced. An artificial created wetland exists only as long as some continuous or persistent activity of man (i.e., irrigation, weeding) continues. Without attention from man, artificial wetlands revert to their original habitat type. Man-induced created wetlands generally result from a one-time action of man and persist on their own. The one-time action might be intentional (i.e., earthmoving to lower elevations) or unintentional (i.e., dam building). Wetlands created as a result of dredged material deposition may have subsequent periods during which additional deposits occur. Man-initiated is an acceptable synonym.

**ENHANCEMENT** - The increase in one or more values of all or a portion of an existing wetland by man's activities, often with the accompanying decline in other wetland values. Enhancement and restoration are often confused. For our purposes, the intentional alteration of an existing wetland to provide conditions which previously did not exist and which by consensus increase one or more values is enhancement. The diking of emergent wetlands to create persistent open water duck habitat is an example; the creation of a littoral shelf from open water habitat is another example.

**MITIGATION** - For the purposes of this document, the actual restoration, creation, or enhancement of wetlands to compensate for permitted wetland losses. The use of the word mitigation here is limited to the above cases and is not used in the general manner as outlined in the President's Council on Environmental Quality National Environmental Policy Act Regulations (40 CFR 1508.20).

**MITIGATION BANKING** - Wetland restoration, creation, or enhancement undertaken expressly for the purpose of providing compensation for wetland losses from future development activities. It includes only actual wetland restoration, creation, or enhancement occurring prior to elimination of another wetland as part of a credit program. Credits may then be withdrawn from the bank to compensate for an individual wetland destruction. Each bank will probably have its own unique credit system based upon the functional values of the wetlands unique to the area. As defined here, mitigation banking does not involve any exchange of money for permits. However, some mitigation programs, such as those in California, do accept money in lieu of actual wetland restoration, creation or enhancement.

**MONITORING** - Intermittent (regular or irregular) surveillance carried out in order to ascertain the extent of compliance with a predetermined standard or the degree of deviation from an expected norm.

**OPERATIONAL HEALTH** - The ability of the system's hydrology to provide the appropriate hydroperiod, water levels, and water quality.

**RESTORATION** - Returned from a disturbed or totally altered condition to a previously existing natural, or altered condition by some action of man. Restoration refers to the return to a pre-existing condition. It is not necessary to have complete knowledge of what those pre-existing conditions were; it is enough to know a wetland of whatever type was there and have as a goal the return to that same wetland type. Restoration also occurs if an altered wetland is further damaged and is then returned to its previous, though altered condition. That is, for restoration to occur it is not necessary that a system be returned to a pristine condition. It is, therefore, important to define the goals of a restoration project in order to properly measure the success.

In contrast with restoration, creation (defined below) involves the conversion of a non-wetland habitat type into wetlands where wetlands never existed (at least within the recent past, 100-200 years). The term recreation is not recommended here due to confusion over its meanings. Schaller and Sutton (1978) define restoration as a return to the exact pre-existing conditions, as does Zedler (1984). Both believe restoration is therefore seldom, if ever, possible. Schaller and Sutton (1978) use the term rehabilitation equivalent to our restoration. For our purposes, "rehabilitation" refers to the conversion of uplands to wetlands where wetlands previously existed. It differs from restoration in that the goal is not a return to previously existing conditions but conversion to a new or altered wetland that has been determined to be "better" for the system as a whole. Reclamation is also used to mean the same thing by some, but "wetland reclamation" often means filling and conversion to uplands, therefore its use is not recommended.

**SUCCESS** - Achieving established goals. Unlike the dictionary definition, success in wetlands restoration, creation, and enhancement ideally requires that criteria, preferably measurable as quantitative values, be established prior to commencement of these activities. However, it is important to note that a project may not succeed in achieving its goals yet provide some other values deemed acceptable when evaluated. In other words, the project failed but the wetland was a "success". This may result in changing the success criteria for future projects. It is important, however, to acknowledge the non-attainment of previously established goals (the unsuccessful project) in order to improve goal setting. In situations where poor or nonexistent goal setting occurred, functional equivalency may be determined by comparison with a reference wetland, and success defined by this comparison. In reality, this is easier said than done.

**GOALS** - The goal of compensatory mitigation should be consistent with the goal of the Clean Water Act which is "to restore and maintain the chemical, physical, and biological integrity of our Nation's Waters". Created and restored wetlands should be designed to replace the ecological functions and values provided by the destroyed wetlands.

**BIODIVERSITY OR BIOLOGICAL DIVERSITY** - The state or fact of life being diverse; difference; unlikeness.

# APPENDIX II

Draft Letter to Wetland Mitigation Study Project Site Sponsors

Re: South Florida Water Management District
Wetland Mitigation Study
Project Number / Permit Number

Dear________:

Since the District began keeping records three years ago, some 4,439 acres of wetlands have been permitted to be altered through the surface water management regulatory program. As mitigation for those losses, 4,393 acres of wetlands were to be created and 708 acres of wetlands were to be restored. To date a thorough evaluation of the effectiveness of the mitigation efforts and future needs of the District's program has not been undertaken.

The creation and restoration of wetlands is a relatively new field. Wetland mitigation programs in general are complicated by the fact that individual mitigation plans are evaluated on a case by case basis with only partial knowledge of how well the plan will actually replace lost wetland functions and values, or fit into a regional scheme for the preservation and enhancement of environmental values. Due to the relatively new and rapidly evolving nature of the program, necessary regional policy - setting mechanisms to improve integration of mitigation programs have not been adequately established.

The District has initiated a Wetland Mitigation Study to evaluate the effectiveness of existing modern design and operation technology for the maintenance, creation, and restoration of wetlands in the South Florida region. This study will provide information and recommendations for the improvement of the District's wetland mitigation program. The results of this study will be used in improving wetland related permit guidelines, compliance monitoring, enforcement, and will provide baseline information to assist the District in clarifying wetland goals and objectives from a regional and ecosystem perspective.

This study will be undertaken by the District's contractor, Kevin L. Erwin Consulting Ecologist, Inc. (KLECE). KLECE will be conducting ecological assessments of wetland creation and restoration projects permitted by the District including the project name project.

It is important that the attached postcard be filled out and mailed by June 11, 1990 to facilitate our inspection schedule. The project contact person as indicated will be notified by telephone of the inspection date window.

The results of this study will enhance the District's wetland resource protection and management capabilities and improve in improved wetland permitting guidelines.

Thank you for your cooperation.

Sincerely,

Enclosure

cc: Appropriate Governing Bd. Member
Appropriate DER District Manager
Appropriate WMD Staff
KLECE

# APPENDIX III

## WETLAND MITIGATION PROJECT CHARACTERIZATION FORM

---

1. PROJECT NAME/SFWMD Permit #:
2. LOCATION:
3. DATE OF SITE EVALUATION:
4. PROJECT DESCRIPTION:
5. TYPE OF DEVELOPMENT:
6. ARE GOALS STATED (i.e., type of wetland, acreage, specific functions, etc.)?
7. TOTAL MITIGATION ACREAGE:
8. WETLAND TYPE (i.e., forested, marsh, littoral zone, etc.):
9. CONSTRUCTION METHODS (earth work):
10. DESIGN METHODS:
11. WHO DESIGNED MITIGATION?
12. MONITORING AND REPORTING:
    a) Baseline evaluation of wetlands to be impacted. Yes or no - date(s).

    b) Post-construction evaluations of mitigation and/or preserve areas.

    c) Was monitoring required by permit?

    d) Was monitoring, if undertaken, adequate to assess site characteristics, wetland structure and functions to evaluate project success?
13. DATE OF DEVELOPMENT CONSTRUCTION/COMPLETION:
14. DATE OF MITIGATION CONSTRUCTION/COMPLETION:
15. WHICH REGULATORY AGENCIES ARE INVOLVED?
16. SOIL CONDITIONS:
17. PRE OR POST DEVELOPMENT SOILS ANALYSIS:

18. PROBLEMS OBSERVED OR ANTICIPATED WITH SOILS:

19. DESCRIPTION OF VEGETATION:

20. PLANTING TECHNIQUE (planting, sprigging, mulch, overburden/natural colonization, seeding, etc.):

21. PROBLEMS OBSERVED OR ANTICIPATED (exotics, poor technique, wrong location/elevation, stress, etc.):

22. UPLAND ASSOCIATIONS
    a) Are upland associations part of the mitigation?

    b) Future of remaining upland habitat:

    c) What is their function?

23. ARE THERE ANY LONG TERM CONSIDERATIONS AND WHAT TYPE OF SYSTEM WILL EXIST IN THE NEXT 20 + YEARS?

24. HAVE MITIGATION PROJECT GOALS BEEN MET?

25. CAN THEY BE MET WITH CORRECTIVE ACTION?

26. IS THIS THE TYPE OF COMPENSATION DESIRABLE FROM AN ECOLOGICAL/ECONOMICAL LAND USE AND MANAGEMENT STANDPOINT?

27. WOULD SOME DEGREE OF OFFSITE REGIONAL RESOURCE COMPENSATION SERVE TO BETTER PROTECT THE RESOURCES AND OFFSET THE IMPACTS?

28. SUCCESS CRITERIA
    a) Are success criteria stated?

    b) Have they been met?

    c) Will they be met?

    d) Are the stated success criteria appropriate?

29. WHAT IS THE PROJECT STATUS (Re: Wetland creation, preservation, restoration, etc.)?

30. ARE PRESERVE AREAS PROTECTED/MANAGED?

31. IS EXOTIC REMOVAL REQUIRED BY PERMIT?

32. GENERAL DESCRIPTION OF PROJECT HYDROLOGY AND WATER SHED:

33. DESCRIPTION OF ACREAGE:

34. DESCRIPTION OF LAND USES (within/adjacent to project):

35. SOURCES OF WATER TO THE MITIGATION AND PRESERVE WETLANDS (ground, surface, stormwater, effluent, etc.):

36. TYPE OF DISCHARGE INTO THE WETLAND:

37. LOCATION OF WETLAND MITIGATION/PRESERVE AREA(S) IN THE LANDSCAPE. (adjacent to; lake, wetland preserve, upland preserve isolated in development).

38. SURFACE WATER LEVEL OBSERVATIONS:

39. SURFACE AND GROUNDWATER RELATIONSHIP:

40. ARE THERE ANY PROBLEMS OBSERVED OR ANTICIPATED REGARDING THE WATER LEVEL OR ELEVATION OF STRUCTURE?

41. WHO ESTABLISHED FINISHED DESIGN ELEVATIONS (SFWMD, consultant, other agency)?

42. WATER QUALITY CONDITIONS FROM KLECE SAMPLING?

43. ARE WATER QUALITY PROBLEMS ANTICIPATED IN 20 + YEARS?

44. BIOLOGICAL INTEGRITY/AQUATIC MACROINVERTEBRATE POPULATION:

45. TO WHAT DEGREE HAS THE WETLAND MITIGATION COMPENSATED FOR THE FUNCTIONAL VALUES PROVIDED BY THE WETLANDS IMPACTED?

| Functions | Good | Fair | Poor | None | Unknown | N/A |
|---|---|---|---|---|---|---|
| GW Recharge | | | | | | |
| GW Discharge | | | | | | |
| Flood Storage | | | | | | |
| Shoreline Anchoring | | | | | | |
| Sediment Trapping | | | | | | |
| Food Chain Support | | | | | | |
| Wildlife Habitat | | | | | | |
| Recreation Heritage & Education | | | | | | |
| Fishery Habitat | | | | | | |
| Water Quality | | | | | | |

46. WILDLIFE UTILIZATION OBSERVED/POTENTIAL:

# APPENDIX IV

## BIOLOGICAL INTEGRITY

Aquatic macroinvertebrates comprise a heterogeneous assemblage of animal groups that inhabit the sediment or live on or in other submersed substrates in the aquatic environment. They vary in size from forms that are small and difficult to see without magnification to individuals large enough to see without difficulty.

The major taxonomic groups of freshwater macroinvertebrates include the insects, annelids, molluscs, flatworms, and crustaceans. These organisms are important members of food webs, and their well being is reflected in the well being of the higher forms such as fish and birds. Many freshwater macroinvertebrates are important for digesting organic material and recycling nutrients.

Benthic macroinvertebrates are frequently used as environmental indicators of biological integrity because they are found in most aquatic habitats. They are of a size that makes them easily collected. They can be used to describe the water quality conditions or health of the ecosystem components and to identify causes of impaired conditions.

A community of macroinvertebrates in an aquatic benthic ecosystem is very sensitive to stress: and, thus, its characteristics serve as a useful tool for detecting environmental perturbation resulting from introduced point and non-point sources of pollution. Because of the limited mobility of these benthic organisms and because many species have life cycles of a year or more, their characteristics are a function of conditions during the recent past, including reactions to infrequently discharged pollutants that would be difficult if not impossible to detect by periodic chemical sampling of the wetland.

Macroinvertebrates show responses to a wide array of potential pollutants (agricultural, domestic, industrial, etc.), including those with synergistic or antagonistic affects that adversely affect the physiological, biochemical, and reproductive functions of the species. The analysis of changes in the makeup of different aquatic communities is one way to detect water quality problems. Knowledge of changes in the community structure (abundance in composition) and in function of benthic macroinvertebrates helps to indicate water quality status and trends in the aquatic environment. For this reason the evaluation of the macroinvertebrate community within the restored, preserved, and created wetland systems is important.

The regular sampling of water quality and macroinvertebrates together can be used to document both the spacial and temporal changes in the biological integrity and quality of surface waters. Different types of environmental stress will often produce different macroinvertebrate communities.

Aquatic macroinvertebrates form the trophic link between wetland vegetation and higher level consumers like amphibians, fish, and waterfowl, and are therefore a critical component of proper ecosystem function (Toth 1990). The inclusion of macroinvertebrates as a criterion for evaluating the success of wetland restoration/creation is a requisite because it is a measure of the wetland's biological integrity (Erwin 1990) which is a fundamental building block of biological diversity.

Evaluation. At present there has been no indicator organism scheme developed for determining the health of Florida's lentic wetlands, as there has been for rivers and streams (Beck 1954, 1955). However, species richness is a useful parameter because it generally increases with improving water quality and increasing habitat heterogeneity/suitability. High diversity can be assumed to indicate successful utilization of the habitat by aquatic macroinvertebrates and therefore establishment of the habitat's biological integrity.

Methods. The qualitative method employed in this survey was a cost-effective, rapid bio-assessment protocol similar to those endorsed by the United States Environmental Protection Agency (Klemm, *et al.* 1990) and the Florida Department of Environmental Regulation (Ross 1990), and provided for a subjective judgement of the biological integrity of the wetland based on macroinvertebrate species richness and relative abundance.

Indicators of Environmental Changes. An assemblage of aquatic macroinvertebrates is very sensitive to stress, and thus its characteristics serve as a useful tool for detecting environmental perturbation resulting from introduced point and non-point sources of pollution (Klemm, *et al.* 1990). Because of the limited mobility of benthic organisms, and because many species have aquatic life cycles lasting several weeks to several months, their community structure is a function of the recent past, including reactions to infrequent pollutant discharge that may go undetected by periodic chemical sampling (Klemm, *et at.* 1990). Each species has a unique set of niche requirements; therefore, changes in environmental conditions will often result in measurable changes in the benthic community. These changes may be interpreted to determine both the degree of stress and the probable stress factors (Lenat, *et al.* 1980).

Pollutants would vary depending on project type. For example, herbicides, pesticides, and nutrients (from fertilizer applications) at agricultural projects; grease, oils, and heavy metals at commercial projects. Future biomonitoring of a selected subset of these created wetlands would be illustrative for determining whether water quality or habitat degradation has occurred because of these inputs, as well as for evaluating the long-term success of the various wetland creation strategies.

Two hundred seventy-five aquatic macroinvertebrate taxa were collected in this wetland evaluation survey. Table 18 contains a list of these species and indicates the number of samples in which they occurred. Representatives of all major orders of lentic aquatic insects were collected, as well as planarians, nemerteans, annelids, crustaceans, hydracari, and molluscs. The most diverse insect orders were Diptera (true flies, 90 taxa), Coleopera (beetles, 58 taxa), Hemiptera (true bugs, 30 taxa), and Odonata (dragonflies and damselflies, 28 taxa). The dipteran family Chironomidae (true midges) contained the greatest number of species (61). Two non-insect groups were also relatively diverse, naidid worms (18 species) and snails (16 species).

TABLE 18. A TAXONOMIC LISTING OF AQUATIC MACROINVERTEBRATES COLLECTED FROM PRESERVED, CREATED AND ENHANCED WETLANDS ASSOCIATED WITH PROJECTS PERMITTED BY THE SOUTH FLORIDA WATER MANAGEMENT DISTRICT. ALSO SHOWN IS THE NUMBER OF QUALITATIVE SAMPLES IN WHICH THE SPECIES OCCURRED.

| | P | C | E |
|---|---|---|---|
| **PLATYHELMINTHES** | | | |
| **TURBELLARIA** | | | |
| **TRICLADIDA** | | | |
| **PLANARIIDAE** | | | |
| *Dugesia tigrina* | 2 | 9 | - |
| **NEMERTEA** | | | |
| **HOPLONEMERTEA** | | | |
| **TETRASTEMMATIDAE** | | | |
| *Prostoma graecense* | - | 1 | - |
| **ANNELIDA** | | | |
| **HIRUDINEA** | | | |
| **ERPOBDELLIDAE** | | | |
| *Mooreobdella tetragon* | - | 3 | - |
| **GLOSSIPHONIIDAE** | | | |
| *Helobdella triserialis* | 1 | 1 | - |
| **OLIGOCHAETA** | | | |
| **AEOLOSOMATIDAE** | | | |
| *Aeolosoma travancorense* | 1 | - | - |
| *Aeolosoma* sp. | 1 | 1 | - |
| **LUMBRICULIDAE** | | | |
| * Unidentified | - | 2 | - |
| **NAIDIDAE** | | | |
| *Allonais inaequalis* | - | 1 | - |
| *Allonais pectinata* | 1 | 2 | - |
| *Bratislavia unidentata* | 3 | 2 | - |
| *Dero digitata* | 3 | 5 | 1 |
| *Dero furcata* | 1 | 1 | - |
| * *Dero multibranchiata* | - | 5 | - |
| *Dero nivea* | 3 | 10 | 1 |
| *Dero obtusa* | 1 | - | - |
| *Dero pectinata* | 4 | 5 | 1 |
| *Dero trifida* | 2 | 5 | - |

| | P | C | E |
|---|---|---|---|
| **NAIDIDAE (Cont.)** | | | |
| * *Dero vaga* | 7 | 3 | - |
| *Haemonais waldvogeli* | 1 | 1 | - |
| *Nais elinguis* | - | 1 | - |
| *Pristina aequiseta* | 2 | 8 | - |
| *Pristina leidyi* | 2 | 11 | 1 |
| *Pristinella longisoma* | 1 | 1 | - |
| *Pristinella osborni* | - | 1 | - |
| * *Slavina appendiculata* | - | 3 | - |
| **TUBIFICIDAE** | | | |
| *Limnodrilus hoffmeisteri* | 2 | 1 | - |
| **ARTHROPODA** | | | |
| **CRUSTACEA** | | | |
| **ANOSTRACA** | | | |
| * Unidentified | - | - | 1 |
| **CONCHOSTRACA** | | | |
| **LIMNADIIDAE** | | | |
| *Eulimnadia* sp. | - | 1 | - |
| **AMPHIPODA** | | | |
| **TALITRIDAE** | | | |
| * *Hyalella azteca* | 8 | 20 | - |
| **DECAPODA** | | | |
| **CAMBARIDAE** | | | |
| *Procambarus alleni* | - | 1 | - |
| *Procambarus fallax* | - | 1 | - |
| [a] * *Procambarus* sp. | 5 | 7 | - |
| **PALAEMONIDAE** | | | |
| * *Palaemonetes paludosus* | 9 | 12 | 1 |
| **ARACHNOIDEA** | | | |
| **HYDRACARINA** | | | |
| **ARRENURIDAE** | | | |
| *Arrenurus* sp. (♀) | 3 | 9 | - |
| **EREMAEIDAE** | | | |
| *Heterozetes* sp. | - | 1 | - |
| **EYLAIDAE** | | | |
| *Eylais* sp. | - | 1 | - |
| **HYDRACHNIDAE** | | | |
| *Hydrachna* sp. | - | 2 | - |
| **HYDRODROMIDAE** | | | |
| *Hydrodroma* sp. | - | 2 | - |

| | | P | C | E |
|---|---|---|---|---|
| **HYDRACARINA (Cont.)** | | | | |
| **HYDRYPHANTIDAE** | | | | |
| *Hydryphantes* sp. | | 1 | - | - |
| **LIMNESIIDAE** | | | | |
| *Limnesia* sp. | | - | 3 | - |
| **INSECTA** | | | | |
| **EPHEMEROPTERA** | | | | |
| **BAETIDAE** | | | | |
| * *Callibaetis floridanus* | 12 | 19 | 2 | |
| * *Callibaetis pretiosus* | | 4 | 8 | - |
| **CAENIDAE** | | | | |
| * *Caenis diminuta* | | 5 | 31 | 2 |
| **ODONATA** | | | | |
| **ANISOPTERA** | | | | |
| **AESHNIDAE** | | | | |
| * *Anax junius* | | 5 | 5 | - |
| *Coryphaeschna ingens* | | 2 | 7 | - |
| *Nasiaeschna pentacantha* | | 2 | - | - |
| **LIBELLULIDAE** | | | | |
| *Brachymesia gravida* | | - | 2 | - |
| * *Celithemis* sp. | - | 4 | - | |
| *Crocothemis servilia* | | - | 5 | - |
| * *Erythemis simplicicollis* | | 4 | 24 | 1 |
| *Erythemis vesiculosa* | | - | 2 | - |
| *Erythrodiplax connata minuscula* | | 1 | 3 | - |
| *Erythrodiplax umbrata* | | 1 | - | - |
| *Libellula* sp. | | 1 | 2 | - |
| *Miathyria marcella* | | - | 1 | - |
| *Orthemis ferruginea* | | - | 2 | - |
| * *Pachydiplax longipennis* | | 7 | 14 | - |
| *Pantala flavescens* | | - | 2 | - |
| * *Pantala hymenea* | | - | 1 | - |
| *Perithemis tenera* | | - | 4 | - |
| * *Tramea carolina* | | 3 | 11 | - |
| **MACROMIIDAE** | | | | |
| *Macromia* sp. | | - | 1 | - |
| **ZYGOPTERA** | | | | |
| **COENAGRIONIDAE** | | | | |
| *Argia fumipennis* | | - | 1 | - |
| *Argia sedula* | | - | 1 | - |
| *Enallagma pollutum* | | - | 8 | - |
| * *Enallagma signatum* | | 1 | 2 | - |

| | P | C | E |
|---|---|---|---|
| **COENAGRIONIDAE (Cont.)** | | | |
| * *Ischnura hastatum* | 10 | 15 | - |
| *Ischnura posita* | 2 | 4 | - |
| * *Ischnura ramburi* | 4 | 28 | 2 |
| * *Nehalennia* sp. | 2 | 5 | - |
| **LESTIDAE** | | | |
| *Lestes* sp. | 1 | 1 | - |
| **HEMIPTERA** | | | |
| **BELOSTOMATIDAE** | | | |
| *Abedus/Belostoma* sp. | 10 | 7 | - |
| *Abedus immaculatus* | 2 | 1 | - |
| *Belostoma lutarium* | - | 6 | - |
| *Belostoma testaceum* | 1 | - | - |
| *Lethocerus uhleri* | 4 | 1 | - |
| **CORIXIDAE** | | | |
| *Ramphocorixa* sp. | - | 1 | - |
| *Sigara bradleyi* | - | 1 | - |
| *Trichocorixa louisianae* | - | 1 | - |
| *Trichocorixa minima* | 3 | 3 | 1 |
| *Trichocorixa sexcincta* | - | 1 | - |
| **GERRIDAE** | | | |
| *Limnoporus canaliculatus* | 2 | - | - |
| * *Neogerris hesione* | 4 | 17 | - |
| *Rheumatobates rileyi* | 1 | - | - |
| **HEBRIDAE** | | | |
| * *Hebrus consolidus* | 2 | 1 | - |
| * *Merragata brunnea* | 2 | 11 | - |
| * *Merragata hebriodes* | - | 1 | - |
| **HYDROMETRIDAE** | | | |
| *Hydrometra australis* | 9 | 17 | 1 |
| *Hydrometra barei* | 3 | 4 | - |
| **MESOVELIIDAE** | | | |
| *Mesovelia amoena* | 2 | 3 | - |
| * *Mesovelia mulsanti* | 10 | 18 | 1 |
| **NAUCORIDAE** | | | |
| * *Pelocoris femoratus femoratus* | 7 | 16 | 1 |
| **NEPIDAE** | | | |
| * *Ranatra drakei* | - | 1 | - |
| *Ranatra nigra* | 2 | 3 | - |
| **NOTONECTIDAE** | | | |
| * *Buenoa confusa* | 5 | 2 | - |
| * *Buenoa scimitra* | 1 | 2 | - |
| *Notonecta indica* | 3 | 4 | 1 |

| | P | C | E |
|---|---|---|---|
| **HEMIPTERA (Cont.)** | | | |
| **PLEIDAE** | | | |
| *Paraplea* sp. | 3 | 1 | 1 |
| **VELIIDAE** | | | |
| *Microvelia albonotata* | - | 1 | - |
| * *Microvelia hinei* | 6 | 14 | 1 |
| *Microvelia pulchella* | - | 2 | - |
| *Paravelia brachialis* | - | 5 | - |
| **NEUROPTERA** | | | |
| **SISYRIDAE** | | | |
| *Sisyra apicalis* | 1 | - | - |
| **LEPIDOPTERA** | | | |
| **PYRALIDAE** | | | |
| *Parapoynx* sp. | 1 | 1 | - |
| *Samea multiplicalis* | - | 1 | - |
| * *Synclita obliteralis* | - | 2 | - |
| **TRICHOPTERA** | | | |
| **HYDROPTILIDAE** | | | |
| *Orthotrichia* sp. | - | 1 | - |
| *Oxyethira* sp. | - | 1 | - |
| **LEPTOCERIDAE** | | | |
| *Nectopsyche exquisita* | - | 1 | - |
| *Oecetis* sp. VII - Cantrell | 1 | 1 | - |
| *Oecetis* sp. VIII - Rutter | - | 1 | - |
| **POLYCENTROPODIDAE** | | | |
| *Cernotina* sp. | - | 1 | - |
| **COLEOPTERA** | | | |
| **CURCULIONIDAE** | | | |
| *Brachybamus electus* | - | 1 | - |
| *Lissorhoptrus lacustris* | 5 | 3 | - |
| *Lissorhoptrus simplex* | - | 2 | - |
| *Listronotus cryptops* | 1 | - | - |
| *Onychylis nigrirostris* | 1 | 1 | - |
| **DRYOPIDAE** | | | |
| * *Pelonomus obscurus gracilipes* | 3 | 2 | 1 |
| **DYTISCIDAE** | | | |
| *Anodocheilus exiguus* | - | 2 | - |
| *Celina angustata* | - | 7 | - |
| *Copelatus caelatipennis princeps* | 6 | 3 | - |
| *Copelatus chevrolati chevrolati* | 1 | - | - |
| *Cybister fimbriolatus crotchi* | 1 | 3 | - |
| * *Hydrovatus pustulatus compressus* | 2 | 8 | - |

| | P | C | E |
|---|---|---|---|
| **DYTISCIDAE (Cont.)** | | | |
| *Laccophilus gentilis* | 2 | 1 | - |
| *Laccophilus proximus* | 4 | 2 | - |
| *Liodessus flavicollis* | - | 1 | - |
| *Pachydrus princeps* | 2 | - | - |
| *Thermonectus basillaris* | 2 | 2 | - |
| **GYRINIDAE** | | | |
| *Dineutus carolinus* | 3 | - | - |
| *Gyrinus elevatus* | 1 | - | - |
| **HALIPLIDAE** | | | |
| *Haliplus confluentus* | 3 | - | - |
| *Haliplus mutchleri* | - | 3 | - |
| *Haliplus punctatus* | - | 1 | - |
| *Haliplus* sp. I - Rutter | - | 1 | - |
| *Peltodytes lengi* | - | 5 | - |
| *Peltodytes sexmaculatus* | - | 1 | - |
| **HYDRAENIDAE** | | | |
| *Hydraena marginicollis* | 1 | - | - |
| **HYDROPHILIDAE** | | | |
| *Berosus aculeatus* | - | 1 | - |
| * *Berosus exiguus* | 2 | 1 | - |
| * *Berosus infuscatus* | 3 | 4 | - |
| *Derallus altus* | 5 | 1 | 1 |
| *Enochrus blatchleyi* | 2 | 3 | - |
| *Enochrus ochraceus* | 3 | 6 | - |
| *Enochrus pygmaeus nebulosus* | - | 4 | - |
| *Enochrus sublongus* | 1 | - | - |
| *Enochrus* sp. I - Rutter | - | - | 1 |
| *Helobata striata* | - | 1 | - |
| *Hydrobiomorpha casta* | 1 | 1 | - |
| *Hydrochus foveatus* | - | 1 | - |
| *Hydrochus inaequalis* | 1 | - | - |
| *Hydrochus simplex* | 2 | 2 | 1 |
| *Hydrochus subcupreus* | - | 2 | - |
| *Paracymus degener* | 1 | - | - |
| *Paracumus nanus* | 2 | 3 | 1 |
| *Paracymus reductus* | 1 | - | - |
| *Paracymus subcupreus* | - | 1 | - |
| *Phaenonotum exstriatum* | - | 1 | - |
| *Tropisternus collaris striolatus* | 1 | 1 | - |
| * *Tropisternus lateralis nimbatus* | 4 | 9 | 2 |
| * *Tropisternus natator* | 3 | 2 | - |

| | P | C | E |
|---|---|---|---|
| **COLEOPTERA (Cont.)** | | | |
| **NOTERIDAE** | | | |
| * *Hydrocanthus oblongus* | 17 | 23 | 1 |
| * *Hydrocanthus regius* | 2 | 2 | - |
| *Mesonoterus addendus* | - | 1 | - |
| *Suphis inflatus* | 4 | 4 | - |
| * *Suphisellus gibbulus* | 9 | 20 | - |
| * *Suphisellus insularis* | 2 | 1 | - |
| *Suphisellus puncticollis* | 4 | 2 | - |
| **SCIRTIDAE** | | | |
| *Prionocyphon* sp. | 1 | - | - |
| *Scirtes* sp. | 3 | 2 | 1 |
| **DIPTERA** | | | |
| **CERATOPOGONIDAE** | | | |
| *Alluaudomyia* sp. | 1 | 3 | - |
| Ceratopogoninae Type I - Rutter | 2 | 4 | - |
| Ceratopogoninae Type IV - Rutter | - | 1 | - |
| Ceratopogoninae Type IX - Rutter | - | 1 | - |
| * Ceratopogoninae Type XI - Rutter | 5 | 21 | 1 |
| Ceratopogoninae Type XV - Rutter | - | 1 | - |
| *Dasyhelea* sp. II - Rutter | 1 | 3 | - |
| * *Dasyhelea* sp. IV - Rutter | - | 3 | - |
| *Dasyhelea* sp. V - Rutter | - | 1 | - |
| *Dasyhelea* sp. VI - Rutter | - | 2 | - |
| Forcipomyiinae Type II - Rutter | 1 | - | - |
| Forcipomyiinae Type V - Rutter | 1 | - | - |
| Forcipomyiinae Type VI - Rutter | - | 1 | - |
| **CHAOBORIDAE** | | | |
| *Chaoborus albatus* | 1 | 2 | 1 |
| *Chaoborus punctipennis* | - | 1 | - |
| **CHIRONOMIDAE** | | | |
| **CHIRONOMINAE** | | | |
| * *Apedilum elachistus* | 1 | 7 | - |
| * *Chironomus decorus* grp. | 9 | 11 | - |
| *Chironomus stigmaterus* | 1 | 1 | - |
| *Cladopelma* sp. I - Rutter | 1 | 2 | - |
| * *Cladopelma* sp. II - Rutter | - | 3 | - |
| *Cladopelma* sp. III - Rutter | - | 1 | - |
| * *Cladotanytarsus mancus* grp. | - | 1 | - |
| *Cryptochironomus fulvus* | - | 1 | - |
| *Dicrotendipes modestus* | - | 1 | - |
| *Dicrotendipes neomodestus* | - | 1 | - |

| | P | C | E |
|---|---|---|---|
| **CHIRONOMINAE (Cont.)** | | | |
| *Dicrotendipes tritomus* | - | 6 | - |
| *Glyptotendipes lobiferus* | 1 | - | - |
| *Glyptotendipes meridionalis* | - | 3 | - |
| * *Goeldichironomus carus* | 1 | 2 | - |
| * *Goeldichironomus holoprasinus* | 11 | 14 | 2 |
| * *Goeldichironomus natans* | 6 | 5 | - |
| * *Kiefferulus dux* | 4 | 2 | - |
| * *Microtendipes* sp. IV - Rutter | 2 | 1 | - |
| *Nilothauma bicornis* | - | 1 | - |
| *Nimbocera pinderi* | - | 4 | - |
| * *Parachironomus directus* | - | 3 | - |
| *Parachironomus hirtalatus* | - | 3 | - |
| *Parachironomus schneideri* | 1 | - | - |
| * *Parachironomus* sp. II - Rutter | 1 | 6 | - |
| *Paratanytarsus* sp. | - | 1 | - |
| *Polypedilum halterale* | 1 | 5 | - |
| *Polypedilum illinoense* | - | 4 | - |
| * *Polypedilum laetum* | - | 1 | - |
| * *Polypedilum scalaenum* | - | 3 | - |
| * *Polypedilum trigonus* | 4 | 8 | 1 |
| * *Polypedilum* sp. II - Rutter | 3 | - | - |
| *Pseudochironomus fulviventris* | - | 1 | - |
| Tanytarsini Type I - Cantrell | - | 2 | - |
| *Tanytarsus glabrescens* grp. | - | 2 | - |
| *Tanytarsus* sp. I - Cantrell | - | 1 | - |
| *Tanytarsus* sp. III - Cantrell | - | 1 | 1 |
| * *Tanytarsus* sp. IV - Rutter | 1 | 3 | - |
| *Tanytarsus* sp. IX - Rutter | - | 2 | - |
| *Tanytarsus* sp. XIII - Rutter | 1 | 1 | - |
| * *Tanytarsus* sp. XIX - Rutter | - | 5 | - |
| *Tribelos fuscicorne* | - | 1 | - |
| **ORTHOCLADIINAE** | | | |
| *Corynoneura* sp. IV - Cantrell | - | 1 | - |
| *Corynoneura* sp. V - Rutter | 1 | - | - |
| *Parakiefferiella* sp. | - | 4 | - |
| **TANYPODINAE** | | | |
| *Ablabesmyia hauberi* | - | 1 | - |
| *Ablabesmyia mallochi* | - | 1 | - |
| * *Ablabesmyia parajanta* | 1 | 4 | - |
| *Ablabesmyia peleensis* | - | 5 | - |
| *Ablabesmyia* sp. I - Rutter | - | 2 | - |

| | P | C | E |
|---|---|---|---|
| **TANYPODINAE (Cont.)** | | | |
| *Clinotanypus* sp. | 1 | 2 | - |
| *Fittkauimyia* sp. | 1 | 1 | - |
| *Guttipelopia guttipennis* | - | 1 | - |
| *Labrundinia neopilosella* | - | 1 | - |
| *Labrundinia virescens* | - | 3 | - |
| *Labrundinia* sp. 4-Roback | - | 1 | - |
| * *Larsia decolorata* | - | 23 | 2 |
| *Monopelopia boliekae* | 1 | 1 | - |
| *Paramerina* sp. | 1 | 1 | - |
| *Tanypus carinatus* | 1 | 4 | - |
| *Tanypus neopunctipennis* | - | 1 | - |
| **CULICIDAE** | | | |
| *Anopheles crucians* | 1 | 5 | - |
| *Anopheles quadrimaculatus* | 3 | 2 | - |
| *Culex erraticus* | 4 | 2 | - |
| *Culex pilosus* | - | 1 | 1 |
| * *Mansonia titillans* | 1 | 2 | - |
| *Psorophora columbiae* | - | 1 | - |
| *Uranotaenia lowii* | 1 | - | - |
| *Uranotaenia sapphirina* | - | 2 | - |
| **SCIOMYZIDAE** | | | |
| Unidentified | 1 | 1 | - |
| **STRATIOMYIDAE** | | | |
| *Myxosargus* sp. | 1 | - | - |
| *Odontomyia/Hedriodiscus* sp. | 2 | 4 | 1 |
| **TABANIDAE** | | | |
| *Tabanus* sp. | 2 | 3 | - |
| **TIPULIDAE** | | | |
| *Helius* sp. | 1 | - | - |
| *Limonia* sp. I - Rutter | - | 3 | - |
| **MOLLUSCA** | | | |
| **GASTROPODA** | | | |
| **ANCYLIDAE** | | | |
| * *Ferrissia hendersoni* | - | 1 | - |
| * *Hebetancylus excentricus* | 4 | 6 | - |
| *Laevapex fuscus* | 2 | 1 | - |
| **HYDROBIIDAE** | | | |
| * *Pyrogophorus platyrachis* | - | 4 | - |
| **LYMNAEIDAE** | | | |
| *Fossaria cubensis* | 2 | - | - |
| *Pseudosuccinea columella* | - | 3 | - |

| | P | C | E |
|---|---|---|---|
| **GASTROPODA (Cont.)** | | | |
| **PHYSIDAE** | | | |
| * *Physella* sp. | 11 | 34 | 2 |
| **PILIDAE** | | | |
| *Pomacea paludosa* | - | 2 | - |
| **PLANORBIDAE** | | | |
| * *Biomphalaria havanensis* | 2 | 1 | - |
| * *Gyraulus parvus* | 1 | 10 | - |
| * *Micromenetus dilatatus avus* | 3 | 1 | 1 |
| *Micromenetus floridensis* | - | 1 | - |
| * *Planorbella duryi* | 2 | 8 | - |
| *Planorbella scalaris* | 1 | 5 | - |
| *Planorbella trivolvis intertexta* | 2 | 4 | - |
| **THIARIDAE** | | | |
| *Melanoides tuberculata* | - | 2 | - |
| **PELECYPODA** | | | |
| **SPHAERIIDAE** | | | |
| *Musculium securis* | - | 2 | - |
| * *Pisidium* sp. | - | 1 | - |
| Total Taxa | 154 | 243 | 38 |
| (Total samples collected) | (23) | (51) | (3) |

Grand taxa total = 275

* Relatively abundant in at least one qualitative sample

[a] Either *Procambarus alleni* or *P. fallax*

Some species occurred in a relatively high percentage of the total number of qualitative samples collected, indicating that they are commonly found inhabitants of the emergent vegetation zones of wetlands. These species were:

*Physella* sp., snail (found in 61% of the samples)
*Hydrocanthus oblongus*, burrowing water beetle (53%)
*Caenis diminuta*, mayfly (49%)
*Ischnura ramburi*, Rambur's forktail damselfly (44%)
*Callibaetis floridanus*, mayfly (43%)
*Erythemis simplicicollis*, eastern pondhawk dragonfly (38%)
*Mesovelia mulsanti*, water treader bug (38%)
*Suphisellus gibbulus*, burrowing water beetle (38%)
*Hyalella azteca*, amphipod (36%)
Ceratopogoninae Type XI, biting midgefly (35%)
*Goeldichironomus holoprasinus*, true midgefly (35%)
*Hydrometra australis*, water measurer bug (35%)
*Ischnura hastatum*, citrine forktail damselfly (32%)
*Larsia decolorata*, true midgefly (32%)
*Pelocoris femoratus femoratus*, creeping water bug (31%)
*Palaemonetes paludosus*, prawn (28%)
*Microvelia hinei*, broad-shouldered water strider bug (27%)
*Neogerris hesione*, water strider bug (27%)
*Pachydiplax longipennis*, blue dasher dragonfly (27%)
*Chironomus decorus*, true midgefly (26%)

Not only were these macroinvertebrates frequently encountered, they (except for *Hydrometra australis*) were also present in high numbers in at least one (often more) of the samples.

A breakdown by major taxonomic group of the organisms collected from the four project types is given in Table 14. For created wetlands, an average of 20.4, 21.8, 16.7, and 18.0 species was collected per sample from agricultural, commercial, public, and residential projects, respectively. These average values are reasonably similar; the public project mean was relatively low, but was based on only three samples. In general, Chironomidae, Hemiptera, Odonata, and Coleoptera were the most diverse groups among all project types.

The majority (61%) of preserved wetland samples were collected from agricultural projects. An average number of 20.7 species per sample was recorded, and Coleoptera, Hemiptera, and Chironomidae were the most species rich groups. Few preserved wetlands were associated with the commercial, public and residential projects included in this study, and only 2, 4, and 3 samples, respectively, were collected. Even fewer restored wetlands were sampled due to site conditions (low water level or no water present). Only three samples were taken altogether. The range of values recorded for these samples fell well within the range of values recorded from the created and preserved wetlands.

Macroinvertebrates had colonized all the created wetlands included in this survey. On the average, 19.3 (range 4-37) species were collected in a qualitative sample. In those instances where richness was unusually low (eight species or less), it was attributable to an early stage of colonization due either to recent project completion (sparse emergent vegetation) or recent re-wetting of an established macrophyte community. Species richness was enhanced in the immediate vicinity of an outfall because of the creation of a flowing water habitat. In general, more species were collected from terraced (as opposed to narrow, sloped) littoral zones.