Final Report

THE SOUTH DADE WATERSHED PROJECT

Center for Urban and Community Design, University of Miami, School of Architecture / South Florida Water Management District

SOUTH DADE WATERSHED PROJECT

A POINT IN TIME

Through our lack of vision, or merely through expediency, we have taken water -- one of the most beautiful and useful resources -- and drained it into a ditch. The time has come for us to put back into play this resource and realize that these ditches must be made into amenities and valued as a means to our future sustainability. The vision is that these canals should be part of a network of water that provides recharge to our regional water system, parks for our local communities, and increased flood protection for our neighborhoods.

Allan Milledge, former Chair South Florida Water Management District

This work must be pushed forward so that the quality of life that our great grandchildren will have will at least equal that of our great grandfathers'. This work will be expensive and like an oak tree, take time, but its value within the next few decades will far exceed its cost. A restored heritage and provisions for a sustainable future will set the long term course for South Dade.

Dennis Olle, Chair, Steering Committee South Dade Watershed Project

ACKNOWLEDGMENTS

As with any project of this scope, it is virtually impossible to credit all those who through their inspiration, forethought, and perspiration assisted in this project. It is, in fact, to all of those individuals who have ever thought about the responsibility we all share for the future that this project owes its timeliness.

Of those we must single out, we thank Allan Milledge for his insight and courage in parenting this project during his tenure as Chair of the South Florida Water Management District; Dennis Olle, Chair of the Steering Committee, for his energy and perspective on the long-term viability of all systems; Sam Poole, Executive Director of the South Florida Water Management District, for his understanding of the connection between land planning and water resource protection; Rick Alleman, Biscayne Bay SWIM Manager, South Florida Water Management District, for his understanding and knowledge of the Biscayne Bay watershed; the Community Advisors, Technical Advisors, and Steering Committee members who have served this project; and Howard Odum, for his searching and stimulating perspective on the systems approach to planning.

We would like to recognize co-researcher Mark T. Brown, for his invaluable assistance in defining the scope of this project. Also, Erick Valle and Chris Jackson for their fine contribution to this report, and Patricia Kahn, Bridgett Singleton, and Joel Hoffman for their helpful editorial comments.

We salute Marjorie Stoneman Douglas for her vision, insight, and perserverance on issues that affect us all.

This report is dedicated to the future towns, neighborhoods and children of South Dade. July 1995.

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PREFACE

Human sustainability is directly connected to the sustainability of nature.

Daniel Williams, **The New South Dade Planning Charrette**, 1992.

This report is a product of the South Dade Watershed Project, commisioned by the South Florida Water Management District in cooperation with the Center for Urban and Community Design to analyze the relationship between land and water in south Dade County.

The destruction wrought by Hurricane Andrew on August 24, 1992 has caused us to question many of our basic assumptions about the future. We have been forced by nature to take a hard look at ourselves and to make choices. In this process, we have gained a greater understanding of our connectedness -- our connectedness with each other, our connectedness with South Florida's environs, the connectedness of all things. Through this experience, we are beginning to realize our responsibility and power as individuals and as a community to create a unique vision for South Dade and to actively define our common future.

South Dade's watershed is increasingly recognized as one of the most critical watersheds in Florida. Located between Everglades National Park and Biscayne National Park, this area is expected to receive a very large percentage of the predicted 700,000 new residents that will come to Dade County by the year 2010. These new residents will consume an additional 125 million gallons of fresh water a day from an already stressed local aquifer; build over the last vestiges of our agricultural heritage; and generate a tremendous amount of stormwater runoff, threatening the already limited flood protection for existing residents and further diminshing the quality of water discharged to Biscayne National Park.

It is the challenge of anticipated water resource demands connected with future growth -- especially, the conflicting demands of too much and too little water -- that the South Dade Watershed Project is seeking to address. These efforts are vital to the long-term preservation and protection of our water resources. They are essential to restoring and protecting the qualitity of life and long-term economic viability of South Dade.

We must create a vision of our community's tommorrow.

We must take the incremental steps to preserve, protect, and define our future.

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ALTHOUGH WATER IS A RENEWABLE RESOURCE, IT IS ALSO A FINITE ONE. THE WATER CYCLE MAKES AVAILABLE ONLY SO MUCH EACH YEAR IN A GIVEN LOCATION. THAT MEANS SUPPLIES PER PERSON, A BROAD INDICATOR OF WATER SECURITY, DROP AS POPULATION GROWS. THUS PER CAPITA WATER SUPPLIES WORLDWIDE ARE A THIRD LOWER TODAY THAN IN 1970.

Sandra Postel, **Last Oasis**, Facing Water Scarcity, 1992.

INTRODUCTION

At significant milestones in time, we take a look at ourselves, our surroundings, and our relationship to one another; and if everything follows the way it has in the past, we rethink what we do, what we are, and why. It is this process that separates us from the birds and bees, the rocks, the geology, the air, the elements -- we learn!

As the Millenium approaches, there has never been a more desperate time to learn than now. As we look to the future of our children and grandchildren – those whose lives will be affected by the plans we make or don't make today -- we are reminded of an old "but true" tale: in the Orient a master of pottery made clay and buried it for his great-grandchildren. This simple act assured their future. Without this planning there would be no clay, no livelihood, no future generations. It is perhaps an oversimplification to say, but what isn't planned for the future, our children will not have.

Over the last hundred years there has been a notable lack of vision in planning for our country's future. As a people, we have changed from primarily a rural to an urban society. During this time we have created the worst urban sprawl since the beginning of settlements. The irony is that virtually no one wanted this sprawl, yet the roads we build today promise only to produce more of the same.

Perhaps in a world of unlimited land and unlimited resources we could sustain unlimited sprawl. However, South Florida is clearly limited by both the availability of land and the availability of water. This truth is realized today in times of drought and in times of flooding -- yet more and more people migrate to South Florida everyday.

What then are our plans for tomorrow? How will we resolve this conflict of land, water, and future growth?

THE FIRST LAW OF ECOLOGY IS THAT EVERYTHING IS CONNECTED TO EVERYTHING. BARRY COMMONER

WATER, NOT GROWTH MANAGEMENT CONTROLS, WILL BE THE ULTIMATE FACTOR IN DETERMINING HOW BIG FLORIDA CAN GROW, LT. GOV. BUDDY MACKAY SAID TUESDAY. HE NOTED A PLANNING REPORT SHOWED THAT FLORIDA'S POPULATION OF 13 MILLION RESIDENTS COULD EXPAND TO BETWEEN 40 MILLION AND 90 MILLION UNDER EXISTING GROWTH-MANAGEMENT REGULATIONS. "IT GIVES YOU AN IDEA THAT WHATEVER IT IS THAT'S GOING TO LIMIT GROWTH IN FLORIDA, IT'S NOT GOING TO BE GROWTH MANAGEMENT," MACKAY SAID.

Excerpt from **Water Limits May Halt Growth**, The Ledger, Lakeland, Florida,
September 26, 1994.

DEFINING THE PROBLEM

A mess is a series of problems that are intertwined, so that it is very difficult to sort them out one at a time. In problem solving -- dealing with messes -- the key to the whole thing is a technique known as "setting the problem." In other words, what is the base of the problem; what is the root of it? [If] you don't figure out how to set the problem before you start trying to solve it, in many instances, all you do is make the mess worse....I like to think of [this concept] in terms of an old time rod and reel, and a backlash. Anyone who used to fish in those days knows that when you get one of those you stopped, and started trying to figure out which string you pull. You didn't pull hard until you figured that out; and when you found it and pulled that one out, the whole backlash unraveled. Then you were straight. That's exactly what [we are] talking about with modern social problems; if you grab the wrong string and start pulling you will make the problem worse. In our effort to reconcile growth, economic development and the environment, we have got as complex a set of social problems as there is in the world today; and in that sense, ***Florida is a mess****. Our problem is not that nobody has any idea about how to deal with it; our problem is that everybody is pulling on the strings. Nobody has sat down and tried to figure out how to set the problem. As a result of that, while we are going along arguing about what to do, we're actually making the problem tighter and tighter.*

Excerpt from speech by Lieutenant Governor Buddy MacKay, giving the charge to the **Governor's Commission for a Sustainable South Florida**, West Palm Beach, April 27, 1994.

What is common to the greatest number gets the least amount of care.

Aristotle.

It has become apparent that the water we have been busily discarding over decades for flood protection, is the water we now desperately need to supply our growing population. We have also come to recognize that it is only by respecting the water needs of all users -- urban, agricultural, and natural -- that we can insure a future that is both desirable and sustainable.

Land use affects water supply as well as water quality. South Florida's water shortage problems are not so much an allocation problem as a problem of where to store the abundant wet season rainfall so that it can be used during the dry season. Land use decisions ultimately affect the amount of water that will be stored on the land and in surficial aquifers. As more and more land becomes developed, recognizing the influence of land use on water becomes more important.

South Florida Ecosystem Restoration: Scientific Information Needs, Science Subgroup, September 27, 1994, p. 12.

Water management and the construction of appurtenant works in the Everglades has gone through a dramatic evolution over the past 90 years. It began with the works of the Everglades Drainage District, which became the foundation for the federal flood control project that followed....The flood protection which the Central and Southern Florida Project secured helped spur phenomenal urban and agricultural growth....[As] the Central and Southern Flood Project was designed and constructed, appropriate consideration was not given to the concluding statement by Mason J. Young, Corps of Engineers Division Director, in House Document 643, which authorized the federal flood control project. He warned that if the region was to continue to prosper "the conservation of water resources is as important and urgent as the provision of additional drainage and the elimination of flood damage....Until the need for freshwater has been satisfied, only the irreducible minimum that cannot be conserved should be discharged to coastal waters."

Light and Dineen, **Everglades: The Ecosystem and It's Restoration**, Steven M. Davis and John C. Ogden, 1994, p. 81.

Today, we are left with a system of canals that is inadequate for flood control, functions contrary to water supply needs, and provides insufficient water quality protection. This is occurring at a time when there is increasing demand for flood protection, additional water supply, and enhanced water quality, due to continued growth within the region. In our haste to develop South Florida, we have failed to recognize the limits of our land and water resources; we have failed to respect the connectedness of all things.

Photo: SFWMD

In spite of more than two decades of growth management in the State of Florida, the health of the State's economy and environment continues to decline. This decline is the subject of intense scrutiny ranging from the Governor's Commission for a Sustainable South Florida to the many Army Corps of Engineers' restoration projects, which seek to mitigate the negative impact of landuse development. Although the causes of this decline are many and complex, clearly growth management has failed to successfully integrate land and water resource planning.

South Dade Watershed Workshop Report, Introduction, 1994.

The landscape is the way it is because of a breakdown in the relationship between people and the land. We do not understand how it works. And we're mismanaging a very valuable asset. Period. My primary interest is getting everybody to understand the larger picture and have a greater understanding of how natural systems work so that they'll make better decisions. When people are actually involved, they do see the larger picture. In fact, that is how they get to see the larger picture.

Quote from Leslie Sauer in **Orion: People and Nature**, Autumn 1994, p. 29, Coming Full Circle: The Restoration of the Urban Landscape, by Adelheid Fischer.

Separating entities from their surroundings is what allows us to perceive them in the first place. In order to discern any "thing," we must distinguish that which we attend from that which we ignore....[It is] the process through which we normally create order out of chaos....The way we cut up the world clearly affects the way we organize our everyday life....Things assume a distinctive identity only through being differentiated from other things, and their meaning is always a function of the particular mental compartment in which we place them. Examining how we draw lines will therefore reveal how we give meaning to our environment as well as to ourselves.

Excerpt from **The Fine Line: Making Distinctions in Everyday Life**, Eviatar Zerubavel, 1991.

THE FIRST MAN WHO, HAVING ENCLOSED A PIECE OF GROUND, BETHOUGHT HIMSELF OF SAYING "THIS IS MINE," AND FOUND PEOPLE SIMPLE ENOUGH TO BELIEVE HIM, WAS THE REAL FOUNDER OF CIVIL SOCIETY.

JEAN JACQUES ROUSSEAU

What we are seeking, is a commitment to connect land and water resource planning -- to connect the private use of land by individuals with the protection of community water resources.

Historically the zoning of land derived much of its legal directive from the public protection of ground water and the public right to sunlight and air movement. Over time, landuse regulations have come to focus almost exclusively on the "highest and best use" of land by individuals. Today, the environmental and social consequences of these regulations are increasingly being recognized in the growing effort to protect what has become known as the "common good."

Protecting the essential needs of society is logical, since the problems related to regional and community growth threaten both our individual and collective well-being.

One of New York City's most precious capital assets is the 2,000-square-mile watershed that stretches northwest of the city for 100 miles on both sides of the Hudson River. For 150 years, the watershed and its reservoir system have supplied New Yorkers with cheap, high-quality drinking water. But decades of careless development and shoddy regulation have put the watershed at risk. If the system is not cleaned up in three years, the Federal Government will require New Yorkers to pay as much as $8 billion to build a filtration plant and $300 million annually to operate ....The watershed serves one-half of the state's population -- 8 million in the city and 1 million in the watershed itself....Questions of fairness aside, what is at stake here is a larger issue of environmental stewardship. To give in to filtration is to concede that New Yorkers cannot strike a sensible compromise between man and nature.

The New York Times, editorial, 1994.

The lines of water supply and water budgets do not reflect the boundaries of users. That is, virtually all municipalities get their potable water supply from a watershed "outside" their urban development boundaries. New York City, as an example, has been purchasing land in the Catskills watershed for decades. However, in the face of continued urban growth around the Catskills, it has been determined that New York City must purchase additional land within the watershed to expand and protect its future water supply.

In South Florida we are fortunate that much of our watershed area, contributing to our water supply, is in public ownership. However, like New York City, the development of South Florida threatens the viability of our watershed. The solution to the problem, for New York City, and also the least expensive alternative, provided open space and community amenities within the Catskills watershed. We, too, must seek to preserve and protect our valuable resource in a similar manner to meet our future needs.

The role of government is to assume those functions that cannot or will not be undertaken by citizens or private institutions ....But forgotten is the true meaning and purpose of politics, to create and sustain the conditions for community life....In other words, politics is very much about food, water, life, and death, and thus intimately concerned with the environmental conditions that support the community....It is the role of government, then as a political act, to set standards within the community.

The Ecology of Commerce: A Declaration of Sustainability, Paul Hawken, 1993, p. 166.

We have a remarkable ability to define the world in terms of human needs and perceptions. Thus, although we draw the borders to demarcate countries, provinces, or counties, these lines exist only on maps that humans print. There are other boundaries of far greater significance that we have to learn to recognize....Natural barriers and perimeters of mountains and hills, rivers and shores, valleys and watersheds, regulate the makeup and distribution of all other organisms on the planet....We, in urban industrialized societies, have disconnected ourselves from these physical and biological constraints....Our human-created boundaries have become so real that we think that air, water, land, and different organisms can be administered within the limits of our designated jurisdictions. But nature conforms to other rules.

Excerpt from **Time to Change**, David Suzuki, 1994, pp. 34-35.

Photo: SFWMD

All land has a purpose and function over and above its real-estate value. That purpose and function needs to be understood, preserved, protected, and integrated into our planning and design efforts. This understanding will assist in preparing South Dade for a sustainable environmental and economic future.

South Dade Watershed Project Workshop Report, 1994.

A FRESH APPROACH TO WATER RESOURCE PROTECTION IS NEEDED. THE CURRENT APPROACH, LARGELY RELIANT ON GROWTH MANAGEMENT, HAS SIMPLY NOT WORKED. DIVIDING THE ROLE OF GOVERNMENT OVER SEVERAL AGENCIES, WITH VARYING LEVELS OF RESPONSIBILITIES, FORCES US TO RELY TOO HEAVILY ON REGULATION AND PENALTIES, AND NOT ENOUGH ON PROTECTING RESOURCES. WE NEED TO THINK ABOUT INCENTIVES TO ENCOURAGE PEOPLE TO “GET IT RIGHT”. WE NEED TO SEARCH FOR PERMANENT SOLUTIONS.

South Dade Watershed Project Workshop Report, Conclusions, 1994.

There is no endeavor more noble than the attempt to achieve a collective dream. When a city accepts as a mandate its quality of life; when it respects the people who live in it; when it respects the environment; and when it prepares for future generations, the people share the responsibility for that mandate. This shared cause is the only way to achieve that collective dream.

*Jaime Lerner, **Toward a Rechargeable City**, Whole Earth Review - Spring 1995.*

ALICE ASKED THE CHESHIRE CAT, "WOULD YOU PLEASE TELL ME WHICH WAY I OUGHT TO GO FROM HERE?" THE CAT RESPONDED, "THAT DEPENDS A GOOD DEAL ON WHERE YOU WANT TO GET TO."

LEWIS CARROLL

And so it is with us today. Where do we want to go? Toward this end, the South Dade Watershed Project takes the important step of beginning to define the proper connection and interaction of land and water. Driving this effort is the recognition of the need to:

- define problems in the larger "systems" context of ecosystems and watersheds;
- identify solutions that respect the connectedness of all things, and;
- secure universal "buy-in" to a comprehensive set of guiding principles that preserve and protect the state's natural resources, including water.

By acknowledging the water resource demands associated with different land uses and seeking to connect them beneficially to the regional water supply system, the **South Dade Watershed Project** seeks to provide long-term sustainable water resource protection.

WE HAVE TO MOVE FROM A LINEAR PATTERN TO A CIRCULAR ONE; TOWARD A RECHARGEABLE CITY. A CITY THAT WASTES THE MINIMUM AND SAVES THE MAXIMUM. WE CANNOT ASSUME OUR RESOURCES ARE INFINITE. I THINK, WE SHOULD HAVE AN ECO-CLOCK THAT SHOWS THE PROPORTION BETWEEN SAVING AND WASTING. IN EVERY CITY WE KNOW THE TIME, THE TEMPERATURE, BUT WE DON'T HAVE A MEASURE OF THE CITY'S COMMITMENT TO THE ENVIRONMENT.

THE CITY OF THE FUTURE - THE QUALITY CITY - WILL BE ABOUT THE RECONCILIATION OF PEOPLE WITH NATURE. IT WILL REPLENISH ITSELF, RESPECT ITS HISTORY, ITS HUMAN SCALE, ITS PART OF NATURE.

THE ONLY POWER CAPABLE OF QUICK ANSWERS IS LOCAL. THAT'S WHY THE NEXT CENTURY IS THE CENTURY OF THE CITIES.

Jaime Lerner, **Toward a Rechargeable City**, Whole Earth Review - Spring 1995.

NATURE CAN ONLY BE MASTERED BY OBEYING ITS LAWS.

Roger Bacon, thirteenth century.

NEW CONSTRUCT

In the past there was a false perception of unlimited natural resources. Their apparent abundance, combined with the seemingly limitless abilities of technology, was seen as sufficient to control the consequences of boundless growth. When an environmental problem arose, a technological solution was sought.

In recent years we have begun to recognize that there are limits to all resources and that technological solutions often cause problems greater than those they were intended to solve.

We have begun to experience the negative effects of our unbridled growth. These effects have been revealed in significant ways: inflation, higher taxes, energy and fuel shortages, and water scarcity. They have been revealed even more significantly in the breakdown of whole biological systems threatening the extinction of species and degradation of the very environment we came to live within. Examples include the dramatic decline in the number of wading birds and the threatened extinction of the Florida Panther in the Everglades; the algae blooms and the "Dead Zones" -- areas virtually devoid of life -- in Florida Bay; and the sick coral reefs of the Florida Keys. These are clear signs that human activities have begun to infringe on the processes of nature; the natural production, cycling, and recycling of materials and energy is being short circuited; more is being taken from the environment than is being returned; "natural capital" is declining.

Today, faced with limited resources, a dwindling tax base, and the increasing costs of government, we can ill afford to apply technology indiscriminately. Instead, we must discover how to do more with less and how to successfully design with nature – to ecologically design our human-made communities to take full advantage of the "free work" of natural systems.

To achieve an interactive network of humanity and nature – a landscape that has a "place" for both the needs of humans and the functions of nature – requires that planning and design re-orient themselves from providing "more" to a view that there are limits. It then becomes the responsibility of science, planning, and design to discover these limits and work within them. We must put form to a "common vision" and develop incremental strategies on how to get from "here" to "there."

What then are the critical elements in the South Florida landscape that must be taken into account to avoid calamity? What must be repaired and protected to prevent the continued decline in environmental quality and community quality of life? Once we have culled this information, we can begin to envision how we might incorporate development and environment into one system -- what must be undone, and what must be added. It is the mission of the New Construct to understand the science of the region, and to design within the limits imposed by both the natural environment and economics.

We find ourselves in the shoes of our forefathers: their job was to unravel the wilderness of nature; ours is to unfold the wilderness of civilization.

The essentials of the old exploration were actualities; the essentials of the new exploration are potentialities. The old exploration described that which is, while the new exploration projects that which can be. The first was based on descriptive science; the second is based on applied science.

We shall explore, first for the ends, and second for the means: we shall seek first our destination and then the way to get there.

Environment is the product of history.

Benton MacKaye, **The New Exploration**, 1928, 1962, 1990

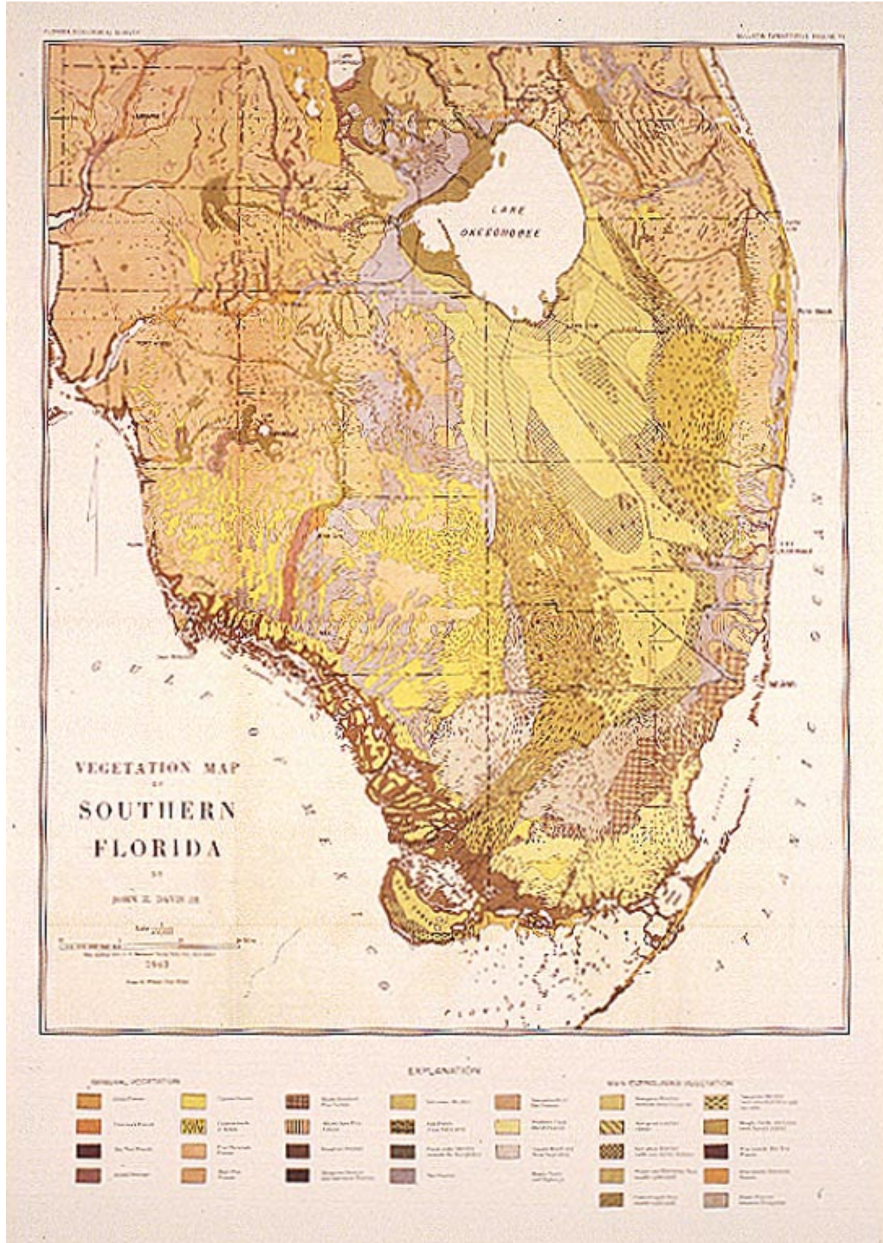
The Davis Map

The 1943 Davis Vegetation Map (p. 15) illustrates the driving forces behind the South Dade Watershed Project. It shows the South Florida system in its natural state, as it existed prior to development. Virtually everything we do is connected, controlled, or reacted to by this environment. This map's inherent value lies in understanding the thousands of years of "research" that brought us the hydrologic and vegetation system we have today.

Since the mid 1800's people have sought to tame this vast interconnected system, with varying degrees of success. However, the existing network of canals -- largely constructed after 1950 -- has allowed development to overtake much of the historic Everglades.

Today, the remnants of the Everglades comprise one of the most complex ecosystems in the world. It drives the life cycle for nature, and the water cycle for the people of South Florida. As water has defined the region, it has also defined the boundaries and the mission of the South Florida Water Management District.

Historically, rainfall from as far north as the Kissimmee chain of lakes traveled via the natural flood plain of the Kissimmee River to Lake Okeechobee – the second largest freshwater lake in the continental United States. Before the lake was diked to provide flood protection, water would overflow its southern boundary, flowing into the saw grass marshes and tree islands of the Everglades. Some water would filter into the region's vast underground storage reservoir, including the Biscayne Aquifer; some water would be carried east and west to the coastal estuaries of the Gulf of Mexico and the Atlantic Ocean; and in time large quantities of water would slowly travel via the "River of Grass" to the Ten Thousand Islands, Florida Bay, and Biscayne Bay. It is the disruption of this natural flow of water that has led to the decline of Lake Okeechobee, the Everglades and most recently Florida Bay. It is the disruption of this flow that has also seriously impacted the supply of water for all users – urban, agricultural, and natural.



The Davis Map showing the vegetation system prior to development

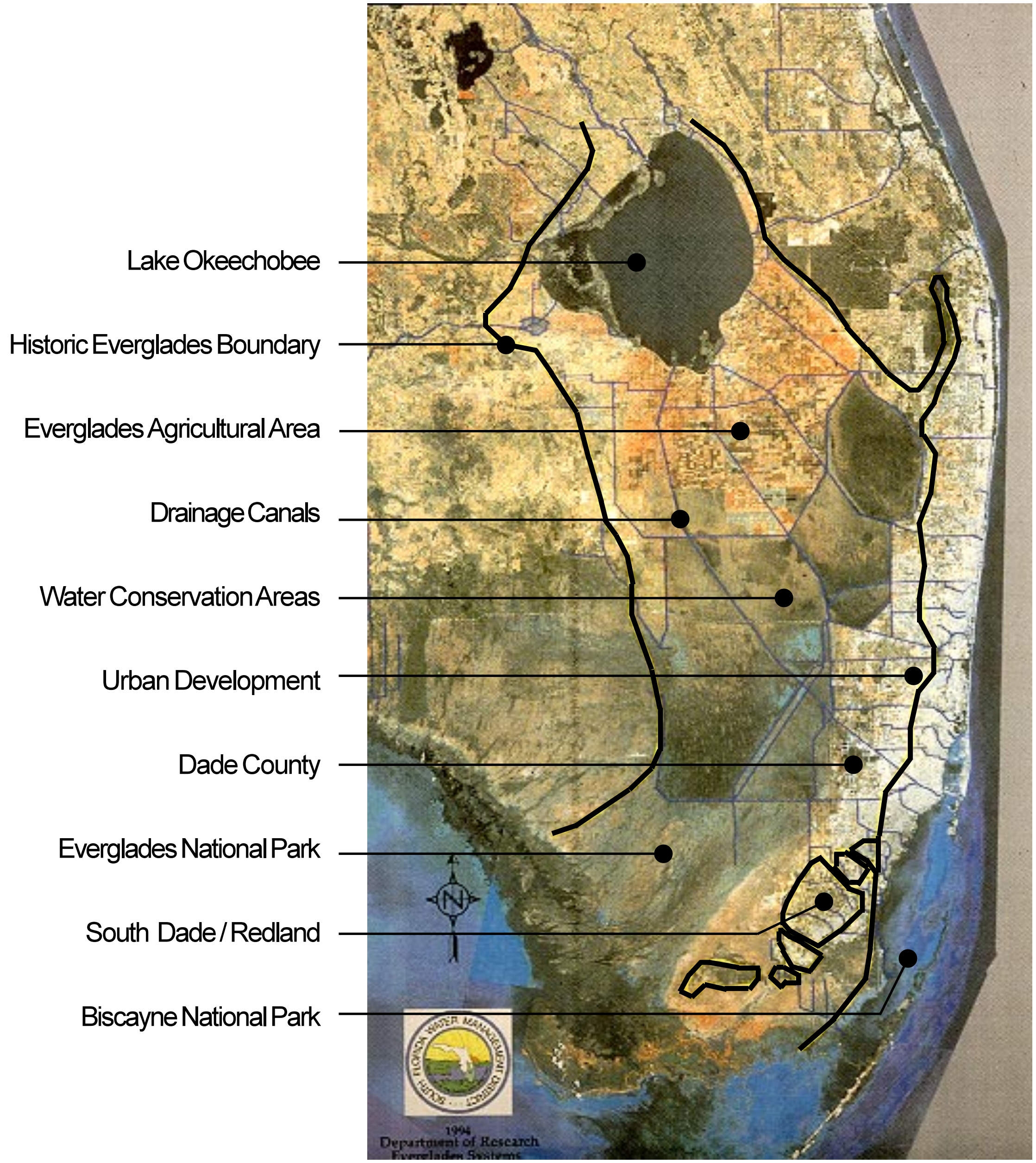
Everything is connected. No qualifications; no exceptions. All deeds have antecedents; all deeds have consequences. Every effect is also a cause, and every cause is also an effect. The actions that we take are like pebbles dropped in a pool: the ripples spread out and away, and no one can know what their effects will be on the far bank.

William Ashworth, **The Economy of Nature**, Boston, New York, 1995.

Satellite Image

A color enhanced satellite image shows the impact development in South Florida on the natural water system (p.17). Overlaid on the image is the generalized historic boundary of the Everglades and the 1500 mile network of canals, which have efficiently drained the area. From this image it can be seen that more than half of the historic Everglades has been lost to urban and agricultural development; and of the remaining 1.9 million acres, a large percentage has been adapted as water conservation areas for water storage and flood protection. The light (orange) area directly south of Lake Okeechobee is the Everglades Agricultural Area (EAA) encompassing approximately 700,000 acres. Agricultural pollution from this area has been a major issue in efforts to restore the Everglades. The lighter (white) areas along the eastern coast indicate the paving over of coastal forms by urban development. The increased stormwater runoff from this development has seriously impacted water quality for all users and resulted in the loss of local recharge of the aquifer -- the underground storage area for our drinking water supply. The draining of this area, though necessary to foster economic growth, will carry a huge cost.

From this image one can also see the unique "bookend" relationship of Everglades National Park and Biscayne National Park to Dade County. The economic benefits reaped from this relationship date to the early settlement of Miami. Unfortunately, we are only just beginning to recognize the true costs and responsibilities that are part of that permanent relationship.



Satellite image showing the impact of development on the natural system

"To grow" means to increase in size by the accretion or assimilation of material. "Growth" therefore means a quantitative increase in the scale of the physical dimensions of the economy. "To develop" means to expand or realize the potentials of; to bring gradually to a fuller, greater or better state. "Development" therefore means the qualitative improvement in the structure, design and composition of the physical stocks of wealth that results from greater knowledge, both of technique and of purpose. A growing economy is getting bigger; a developing economy is getting better. An economy can therefore develop without growing or grow without developing.

"Boundless Bull," Gannett Center Journal, summer 1990, pp. 116-117.

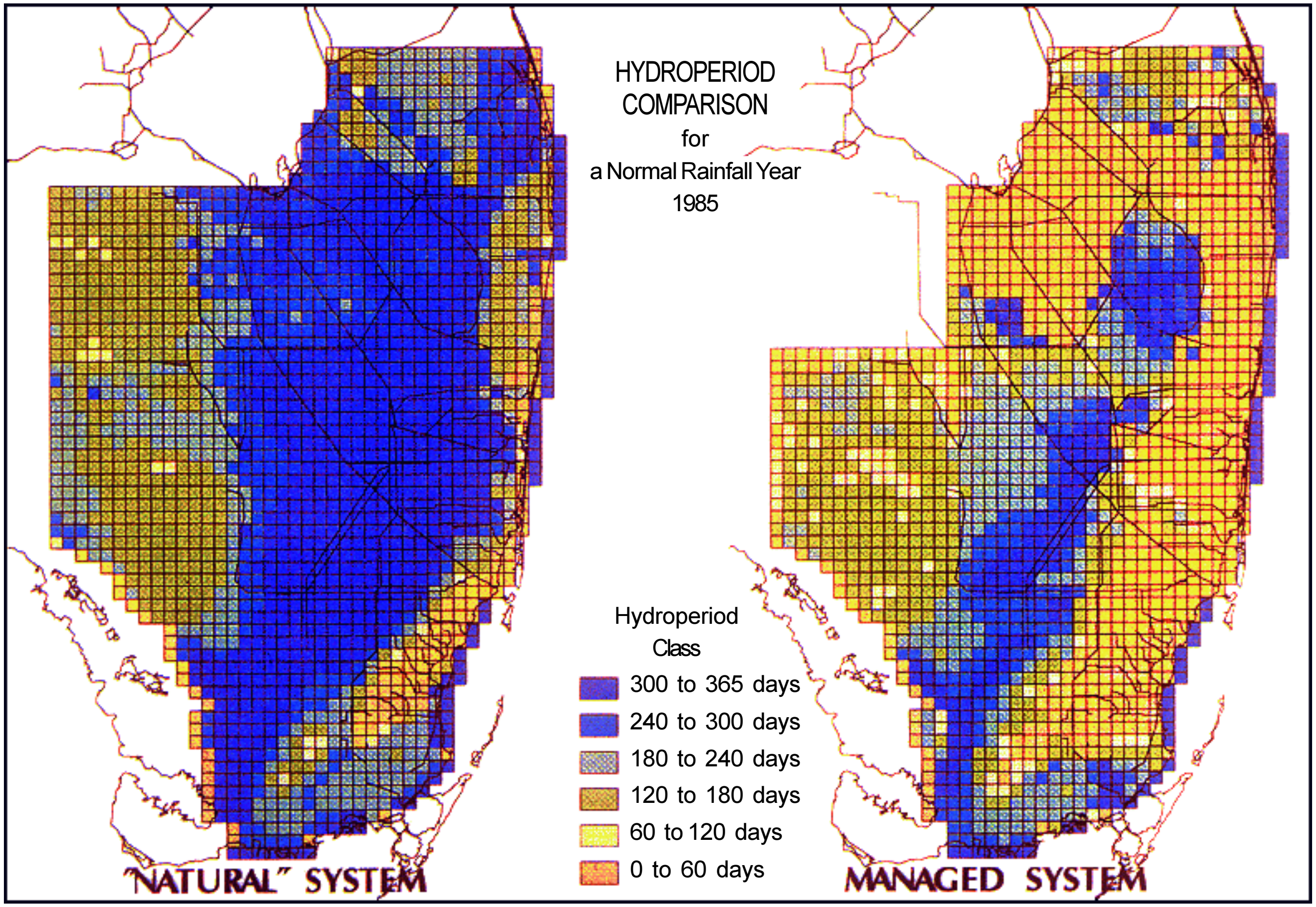
Hydroperiod Map

To illustrate graphically the changes that have occurred in the water regimen of South Florida, two images show the extreme change in hydroperiod, *i.e.*, the surface ponding of water measured in days, in the "natural" system (prior to canals) as compared with the "managed" system (after canals) that we have today (p.19). The darker (blue) zones depict areas that are predominantly flooded, while the lighter (orange) zones depict areas that have little if any flooding.

These images reflect the fact that a significant amount of fresh water has been drained from the Everglades system and discharged to the ocean to provide flood protection for humans. In so doing, this valuable water has been lost for use by humans and the Everglades alike. The further insult is that the untimely and voluminous discharge of this water resource to our coastal estuaries has severely impacted the health of our coastal estuaries. Supporting the base of the marine "food chain," the estuaries – defined by a subtle mix of salt and fresh water – are the nursery ground for most marine species, including shrimp, lobster, and fish of all types.

Over time, water projects have become increasingly complex, expensive to build, and more damaging to the environment.

Sandra Postel, **Last Oasis**, Facing Water Scarcity, 1992.

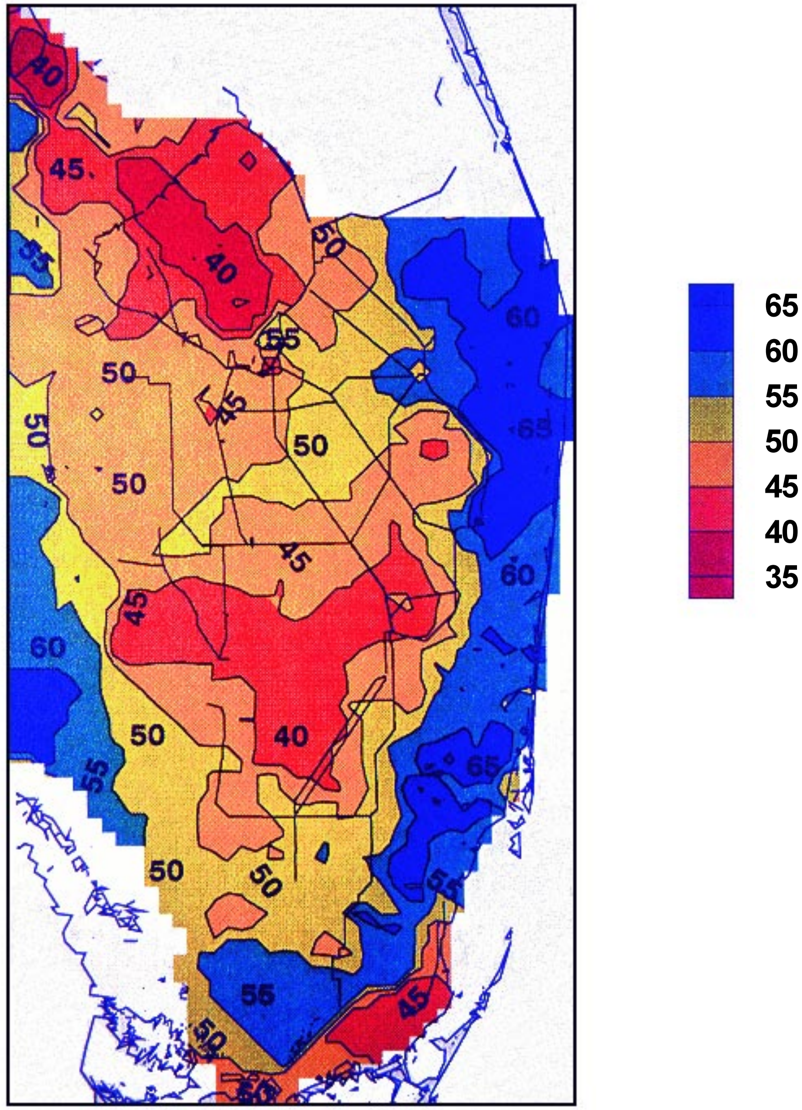


Natural and managed hydroperiod maps showing the changes that have occured in the water regimen of South Florida: SFWMD

Rainfall Map

A map derived from rainfall data over a 29-year period of record (1956-1985) illustrates the spatial distribution of average annual rainfall in South Florida (p. 23). The area of highest average rainfall (55"-65") corresponds to the area of intense development along the east coast; the area of the lowest average rainfall (35"-45") corresponds to the middle of the Everglades. This difference in rainfall pattern is significant in that as the coastal urban form is paved over with buildings and asphalt, less of the rainfall is able to permeate the ground and recharge the aquifer. Instead, the water is collected as highly degraded stormwater runoff and quickly diverted to flood control canals and ultimately the ocean. This loss in local resident recharge of the aquifer, *i.e.*, aquifer recharge at the rainfall location, represents a significant reduction in the total available water supply for all water users: urban, agricultural, and natural. The restoration of local aquifer recharge and water storage in the excessively drained areas of the urban form has been identified by the Army Corps of Engineers as the second largest potential source for storage within South Florida; second only to the maximum potential storage of water within Lake Okeechobee.

AVERAGE ANNUAL RAINFALL



Rainfall map showing spatial distribution of rainfall over a 29-year period: SFWMD

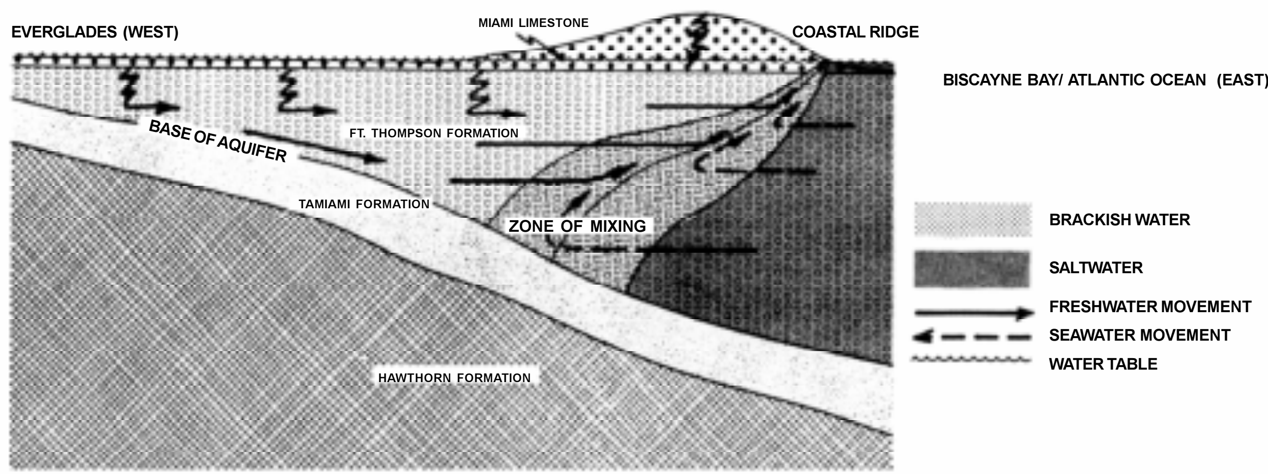
***A**lthough water is part of a global system, how it is used and managed locally and regionally is what really counts.*

Sandra Postel, **Last Oasis**, Facing Water Scarcity, 1992.

Aquifer Maps

Two maps detail the spatial location of the Biscayne Aquifer (pp. 24-25). This aquifer -- one of the most prolific in the world -- is the only storage of fresh water for public water supply and irrigation for Monroe, Dade, and Broward counties, and much of Palm Beach County. It is designated a "sole source aquifer" by the U.S. Environmental Protection Agency (EPA) under the provisions of the Safe Drinking Water Act – designating the highest protections afforded by federal law. As can be seen in the cross-sectional graphic below, the Biscayne Aquifer is located just under the land surface. Viewed as a wedge, the thickness of the aquifer varies from some 10 feet in the middle of the Everglades -- the most western part of Dade County – to as much as 200 feet along the coast and the shore of Biscayne Bay.

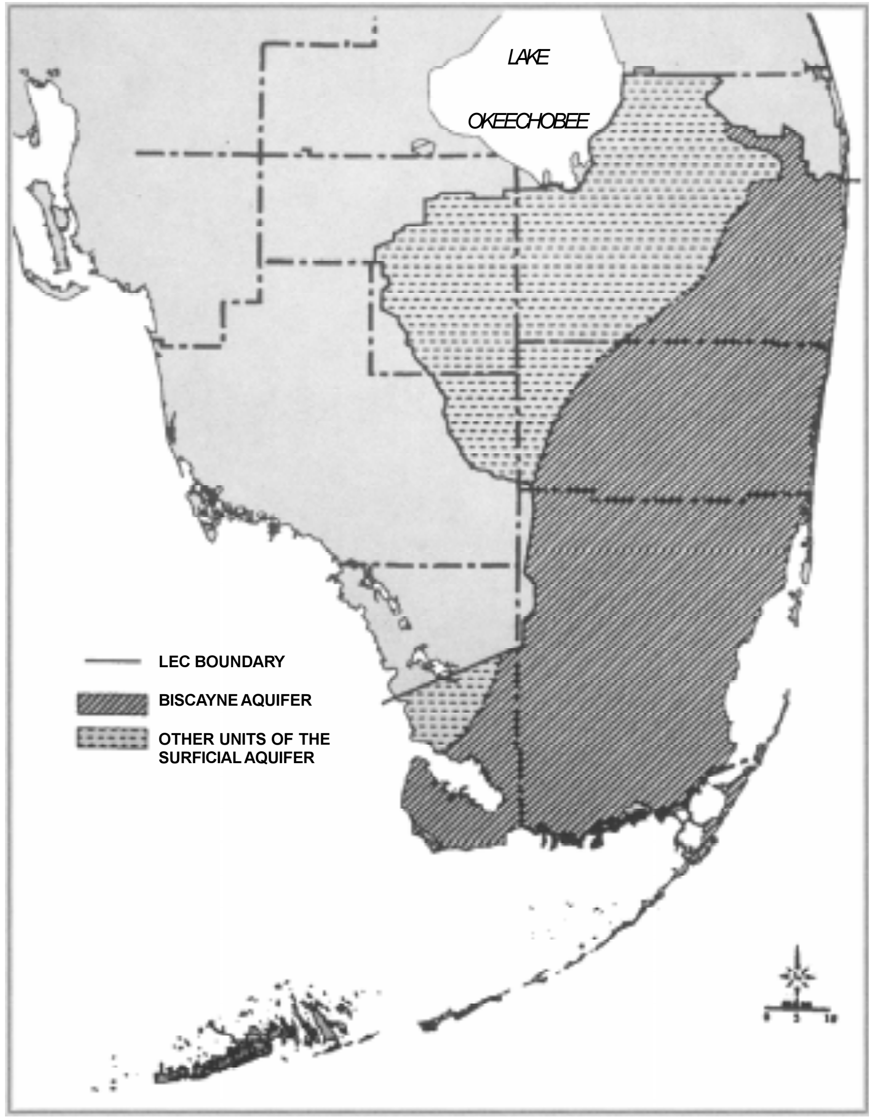
The arrows in the cross-sectional graphic illustrate the recharge of the aquifer from local resident rainfall and surface water from canals, lakes, rivers, and streams – including the "River of Grass." The arrows also show the movement of water, much like an underground river, through the aquifer. As can be seen, water collected by the aquifer out in the middle of the Everglades moves under the coastal ridge and our coastal communities and eventually flows to Biscayne Bay and the Atlantic Ocean. This underground movement of water is critical to holding back the movement -- in the opposite direction -- of saltwater from the Bay and Ocean to protect our public water supply well fields. It is this continuous flow that helps to maintain a steady supply of the water that is withdrawn daily for our urban and agricultural uses.



Cross Section of the Biscayne Aquifer: SFWMD

However, as our communities continue to grow – in population and area – and as we continue to indiscriminately pave over land surfaces, the recharge of the aquifer, locally, will be lost. The impact of this is that we will become ever more dependent for our water supply, on water that is captured and stored in the Everglades. It is this competition for Everglades water -- for flood protection and water supply – that threatens the health of the Everglades and Florida Bay today; it is the increasing competition for Everglades water that will eventually define the limits of the growth of all systems in South Florida. There is only so much and it is not being stored for future users.

A most important point emerges when the two aquifer maps are overlaid upon the preceding rainfall map: we are paving over the recharge area with the greatest amount of rainfall – the coastal urban area - and we are increasing our dependence on water that is recharged in the area of the least amount of rainfall – the Everglades. Figuratively, we are building on top of our own "water supply hose".



Map of the Biscayne Aquifer: SFWMD

***B**y re-establishing water storage within the land form we effectively create a new supply of water.*

South Dade Watershed Project, Workshop, July 1994.

Throughout history, the water cycle has served humans as a model of the natural world. Early civilizations saw in it a figure of the basic pattern of life, the cycle of birth, death, and return to the source of being. More recently, science has added to that ancient religious metaphor a new perception: the movement of water in an unending, undiminished loop can stand as a model for understanding the entire economy of nature.

Donald Worster, **The Wealth of Nature**, Environmental History and The Ecological Imagination, 1993.

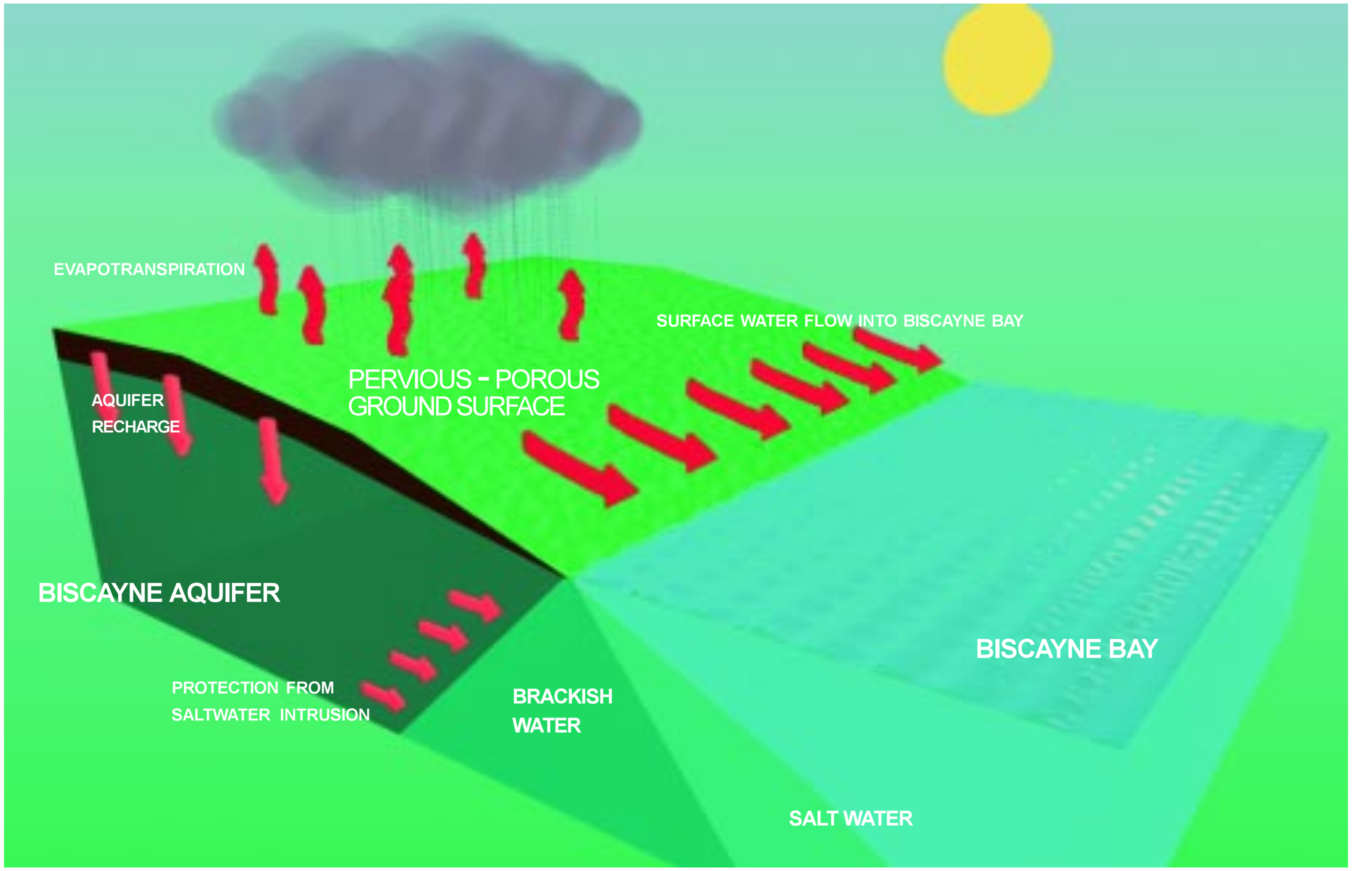


Diagram of the hydrologic cycle prior to development: UM, CUCD

The Natural System vs The Managed System

The hydrologic cycle is the natural cycling of water, where rainfall eventually recycles via evaporation and plant transpiration (evapotranspiration) to create more rainfall. Two conceptual graphics compare the "natural" system prior to development, and the "managed" system after development (pp 24-25). The principal changes to the land form in the managed system are the flood control/stormwater drainage canals, and the paving over of pervious (porous) undeveloped land surfaces with impervious (non-porous) developed surfaces (buildings, parking lots, roads). The combined impact of these two changes are: i) the overdraining of surface and ground water resources re-

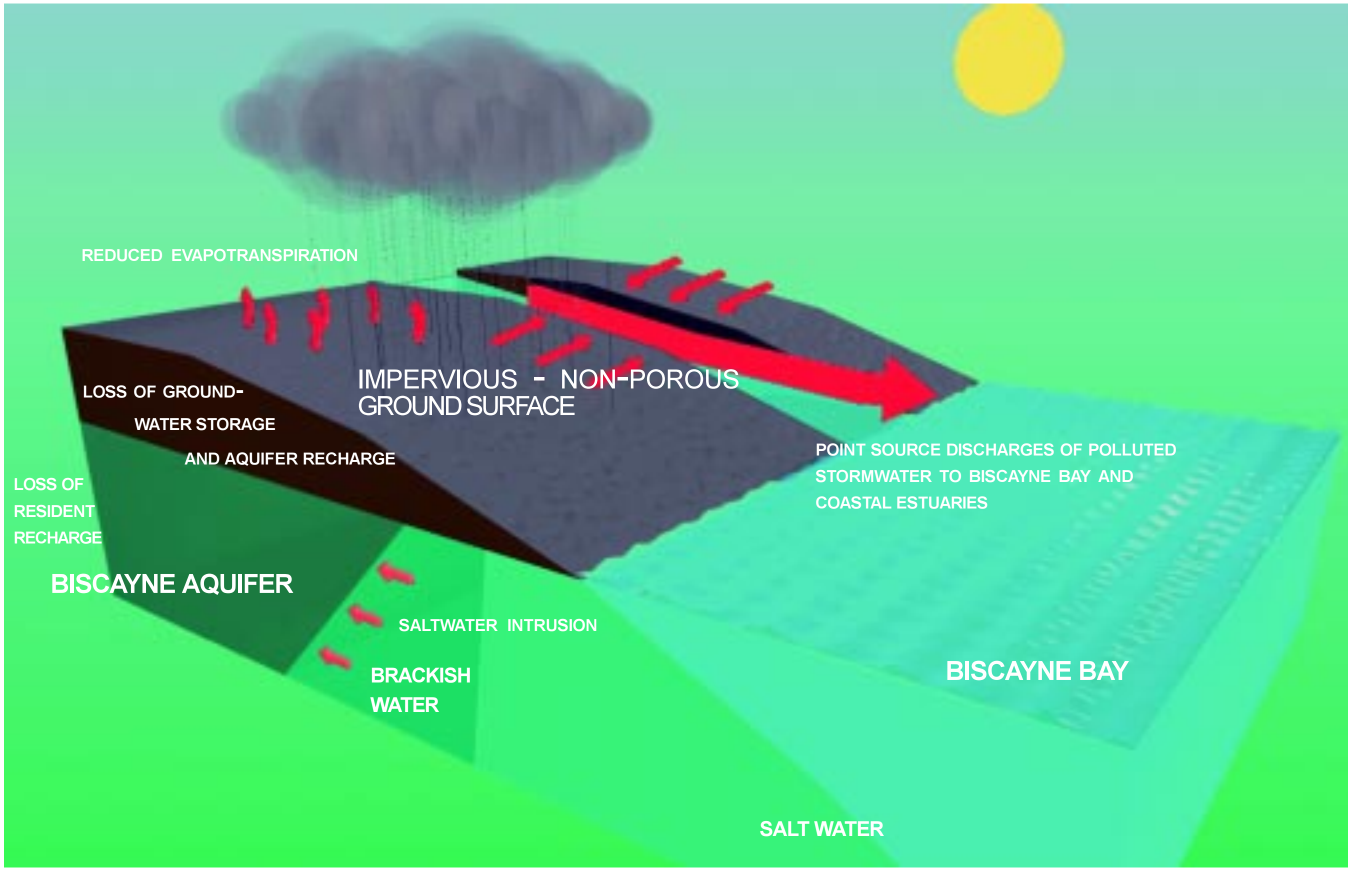


Diagram of the hydrologic cycle after development: UM, CUCD

Protecting water systems depends on regulating the use of those critical areas of land that help moderate water's cycling through the environment. Degradation of the watershed – the sloping land that collects, directs, and controls the flow of rainwater in a river basin – is a pervasive problem in rich and poor countries alike.

Sandra Postel, **Last Oasis**, Facing Water Scarcity, 1992.

sulting in the significant loss of freshwater supplies for all uses; ii) the loss of local aquifer recharge, *i.e.,* the resupply of water used by all users; iii) saltwater intrusion which threatens to pollute our public supply of water; iv) the transformation of clean rain water to highly polluted stormwater which in turn pollutes our aquifer, lakes, canals, and bays; v) large and untimely discharges of stormwater which threaten the health of our fragile coastal estuaries, and; vi) the reduction of local evapotranspiration, the effect of which is unknown. Each of these impacts - arising from the "use of land" - represents a negligent use of water that must be addressed in future planning.

Effects of Urbanization

Stormwater Quantity

As an area urbanizes, streets, sidewalks, parking lots and buildings cover the ground surface. In addition, the process removes natural vegetation and compacts the soil. The land's surface becomes impervious. Rainfall no longer soaks into the ground as readily as before. This causes an increase in runoff and accelerates the speed at which runoff flows (the peak discharge rate).

Historically, the primary concern about stormwater was to remove it from a developed area as quickly as possible after a storm for flood protection. This led to drainage systems that maximize local conveyance and flood protection, without considering other important factors such as off-site damage from accelerated flow, water pollution, or even the loss of a water resource. Other problems include increased channel erosion and flooding, deposition of sediment, flood plain and channel erosion with a resulting loss of property, wildlife habitat, natural vegetation, and total storage capabilities.

In an undeveloped area, a natural stream normally adjusts so that its cross section and slope are in approximate equilibrium. Increased volumes and peak discharge rates of stormwater produce drastic changes in the natural stream channel. Eroded banks and frequent flooding are not only unsightly but cause damage to adjacent property and homes. Structures are undermined, homes are damaged, recreational areas are threatened and aesthetic values are destroyed.

Accelerated channel erosion also creates downstream damages by the deposition of eroded sediment. Lakes and reservoirs fill, storm sewers and culverts become clogged causing flooding; and, areas adjacent to streams and lakes may become covered with mud and debris left after the flood.

Increased stream volumes and velocities, associated with the stormwater from urbanized areas, produce more frequent floods. Areas that previously flooded only once every five years may flood every year, or several times each year. Flood plain erosion and damage to structure and vegetation also increase.

Stormwater Quality

Land use directly affects water quality. In an undeveloped area, natural physical, chemical, and biological processes interact to recycle most of the materials found in stormwater. As human land use intensifies, these processes are disrupted and everyday activities add materials to the land surface. Leaves, litter, animal wastes, oil, greases, heavy metals, fertilizers, and pesticides *are washed off by rainfall and are carried by stormwater to our lakes, rivers and bays. These materials can create high pollutant loadings of:*

Sediment *which clogs waterways, smothers bottom living aquatic organisms and increases turbidity.*

Oxygen demanding substrates *which consume the oxygen in water, sometimes creating an oxygen deficit that leads to fish kills.*

Nutrients *(nitrogen, phosphorus) which cause unwanted and uncontrolled growth of algae and aquatic weeds like hydrilla or hyacinths.*

Heavy metals *(lead, cadmium, chromium, copper, zinc) which can disrupt the reproduction of fish and shellfish and accumulate in fish tissues.*

Petroleum hydrocarbons *(oils, greases) which are toxic to many aquatic organisms.*

Coliform bacteria and viruses *which contaminate lakes and shellfish waters and prevent swimming and harvesting.*

Excessive fresh water *which changes the salinity of estuaries, alters the types of organisms which live in estuaries, and disrupts this important nursery area.*

Stormwater is the major source of pollutants to Florida's lakes, estuaries and streams. Improved stormwater management will reduce pollution loads from new developments and from old stormwater systems that were built primarily for drainage.

Excerpt from ***Stormwater Management: A Guide for Floridians****, DEP.*

Average Rainfall Graph

A graph derived from data over a 74-year period of record from 1915 to 1989 shows the variability in average annual rainfall for all areas within the 16 county area of the South Florida Water Management District (p. 31). The line running horizontally across the graph represents the 52" average annual rainfall for the region; the vertical bars reflect the measured annual rainfall for each individual year. As can be seen from the graph there is tremendous variability in the measured rainfall from year to year, from a low of 35" in 1962 to over 70" in 1970. In fact, dry years have occurred as frequently as wet years, and there are relatively few years of so called "average" rainfall. This extreme variability, raises serious questions as to the set of conditions upon which a management program should be based: flooding, droughts or somewhere in between. Also, it is this variability that, from time to time, reveals the engineering "real world" design limitations of our managed canal system. Witness: Tropical Storm Dennis in 1981 and the 26" of rain that fell on Dade County in just 7 days; the drought of 1989-1991; and just last year, 1994, Tropical Storm Gordon and the more than 80" of rain that fell in some parts of South Florida.

This engineering frenzy has embodied the [false] hope that, by controlling an ever greater portion of nature's water cycle, humanity could be freed from the constraints posed by rainfall's unequal distribution in place and time.

Sandra Postel, **Last Oasis**, Facing Water Scarcity, 1992.

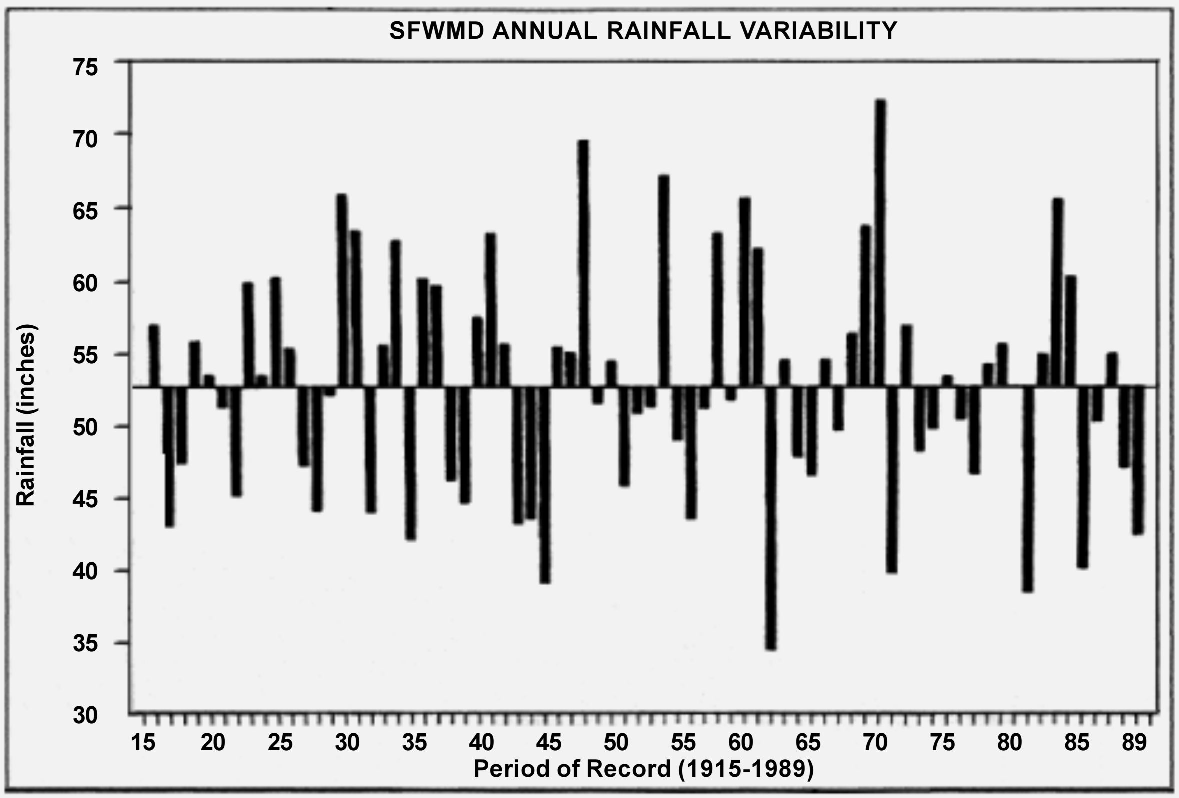


Figure I-6. Variation from Annual Average Rainfall within the South Florida Water Management District. (Source: SFWMD, 1991)

Graph comparing average rainfall to yearly totals

Seasonal Rainfall

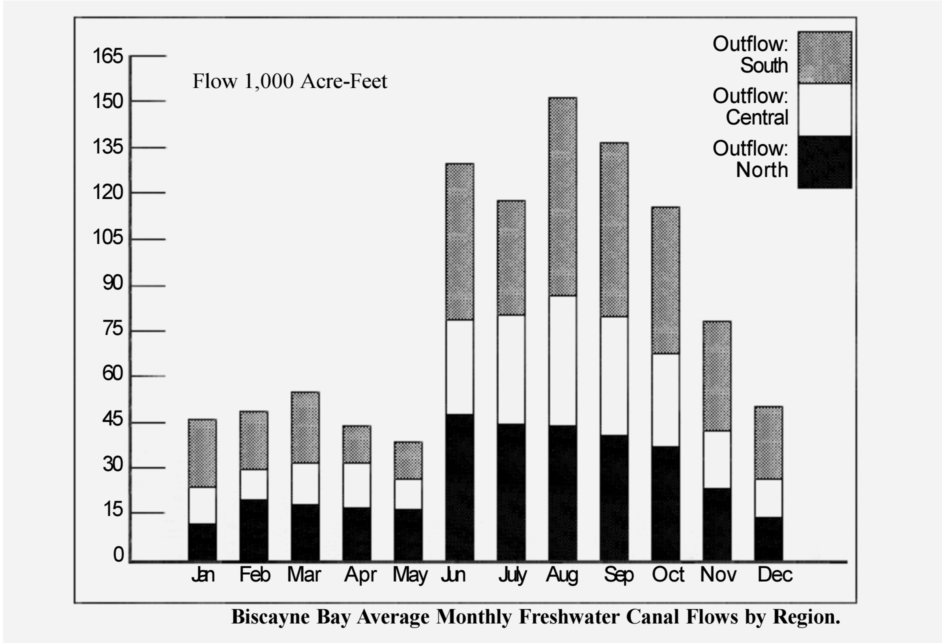
Two graphs speak to the seasonality of rainfall in South Florida: a wet season that runs typically from May through October, when we receive two-thirds of our rainfall, and a dry season that runs typically from November through April. These graphs also reveal the dilemma we face in satisfying our conflicting need for flood protection and water supply -- the need to get rid of too much water and the need to save water.

The top graph represents canal discharges into Biscayne Bay. Predictably the largest outflows occur during the rainy season. What is perhaps less obvious is the fact that the canals continuously discharge water year round. This occurs, in part, because water flows down hill, *i.e.*, the canals were designed with a slope to get rid of water. The other reason has to do with the water level in the canals, the soils, the hydrology and the continuous movement of water through the aquifer.

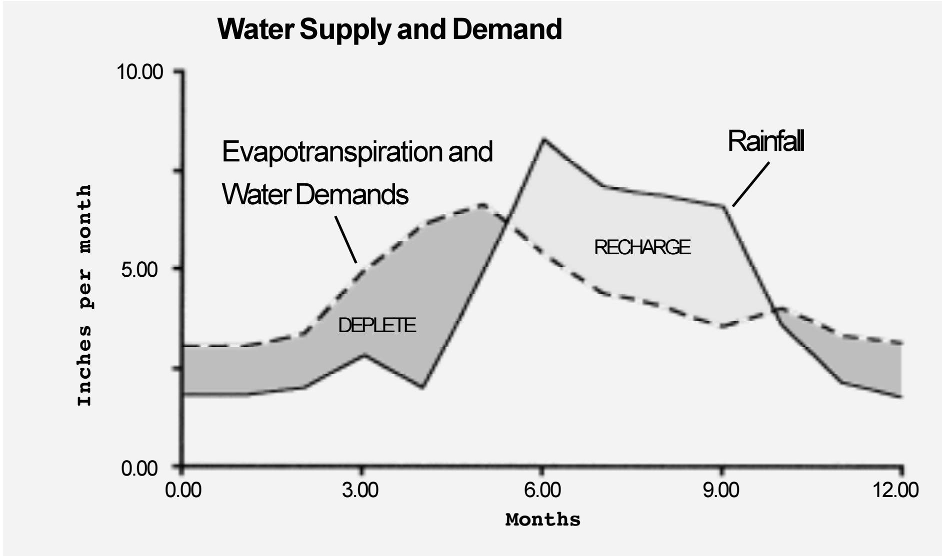
The bottom graph is a generalized plotting of supply and demand for water. It compares the annual supply of water coming from rainfall (the solid line) with the annual evapotranspiration and water supply demands (the dashed line). Not surprisingly, the shape of the rainfall curve mirrors the wet and dry seasons curve shown in the canal discharge graph just discussed. The demand curve, although similar in shape, is out of phase with the rainfall curve. What these two curves show is that the demand for water exceeds the supply of water during the dry winter months, and that the supply of water exceeds the demand for water during the wet summer months. In other words, we have a tendency to deplete our water supply during the winter, and to recharge our water supply during the summer.

Also, it is interesting to note that the amount of depletion is almost equal to the amount of recharge. Unfortunately, this fact does not hold true in the real world. The reason is that, as we have previously discussed, we have lost much of our ability to recharge the aquifer with local resident rain (remember, we're building on our "water supply hose"), and as we have just learned from the canal outflow graph, the excess water is readily discharged to the Bay.

The critical agenda is thus to increase our storage of water during the wet months and decrease our loss of water during the dry months. By reclaiming the storage of water under the coastal ridge we can buffer the effects of seasonal rainfall and the extremes of nature. In addition, we must recognize that the rainfall and storage within the region is that region's budget *i.e.,* supplies from outside the region are "borrowed" and cannot be counted on during times of drought.



Graph illustrating the flow of water through the canals: SFWMD



Conceptual graph comparing supply of rainfall to the demand for water: SFWMD

The flood control canals which have permitted the intense development of South Florida have effectively drained 30% of the region's water supply to the ocean.

Allan Milledge, SFWMD Governing Board, **South Dade Watershed Project Workshop**, July 1994.

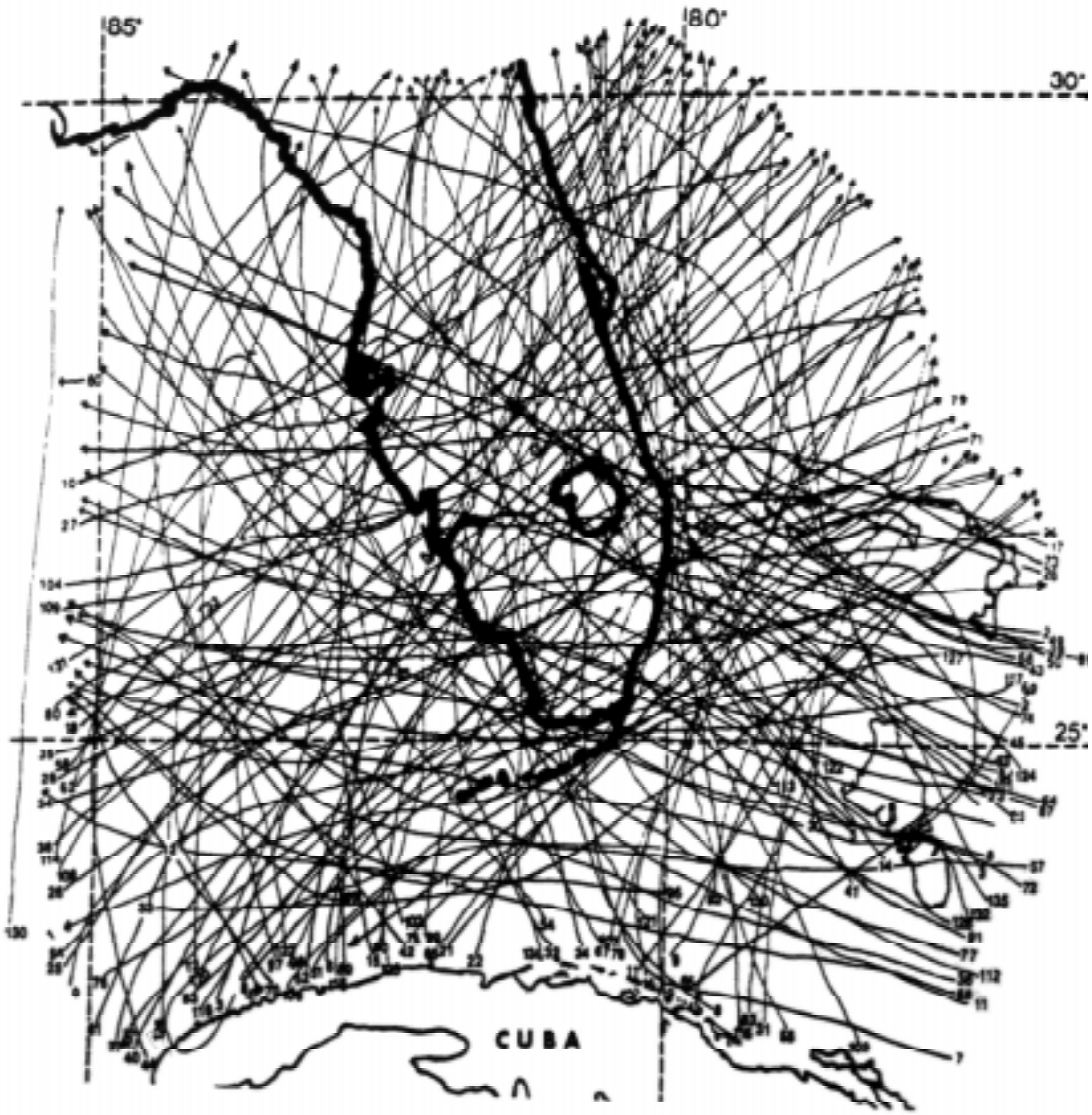
South Floridians learned a lot from Hurricane Andrew. One key lesson: The storm was a natural event, but it was a man made catastrophe. That is, most of the lives lost and much of the $25 billion or more in property damage – could have been prevented.

To Tame a Hurricane, Miami Herald, Editorial, March 23, 1995.

Photo: SFWMD

Hurricane Climax System

Much like in a natural system, an urban system is changed and rearranged by natural disasters. On August 24, 1992, such a rearrangement was made in South Dade by Hurricane Andrew. A similar rearrangement occurred in the floodplain of the Mississippi River as a result of intense rains and flooding in 1994. To avoid future loss of life and property, entire communities of people living along the Mississippi River have been permanently relocated out of the floodplain. In our rush to rebuild South Dade, however, we did not heed the threat of future disaster, and we have rebuilt many of our coastal floodplain communities. In making our plans for the future we must not repeat the mistakes of our past.



There have been 761 North Atlantic storms of at least tropical storm intensity in the 92 year period of record from 1886 through 1977. A large majority of these storms have impacted the climate of South Florida.

South Dade Watershed Project, Workshop, July 1994.

South Florida's Everglades and coastal areas, clearly already under stress, face an unusually difficult problem in the light of global climate change. Both are already vulnerable to sea level rise and intense tropical storms. Climate change could increase the current vulnerability to these events. Climate change may also result in a hotter and drier climate for South Florida. Whatever occurs, the future is likely to be increasingly stressful for South Florida. Cities are likely to continue to grow and will almost certainly be protected from sea level rise, but the expense of protecting them could be immense.

S. Light, L. Gunderson, and C. Holling, **The Everglades: Evolution of Management in a Turbulent Ecosystem**, unpublished manuscript, 1993.

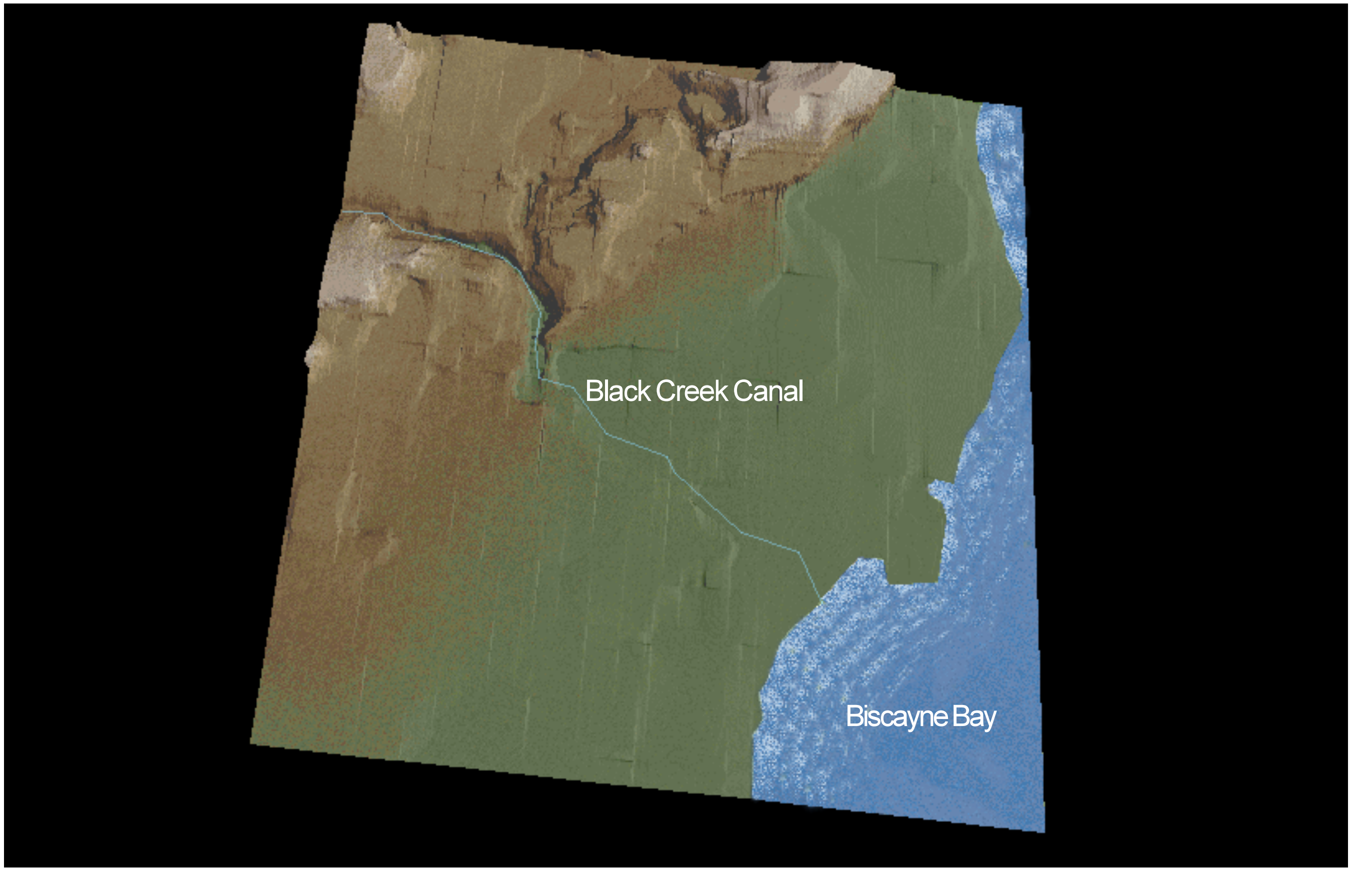


Figure: UM, CUCD

The Rising Sea Level

Two images represent what will happen to the coastal area in South Dade around Black Point if, as predicted, the sea level rises 72" within the next few hundred years (pp. 36,37). As the second graphic shows, if this prediction is realized, over two miles of the coastline will go under water (the dotted line indicates the current coastline) and the areas along the Old Cutler Slough -- today Old Cutler Road -- will be restored as coastal wetlands. This message is not intended to create panic. Our intent is to bring attention to the need to understand our human activities in the context of the larger environment, and to make plans that respect what we have "learned" about the region's naturally occurring systems.

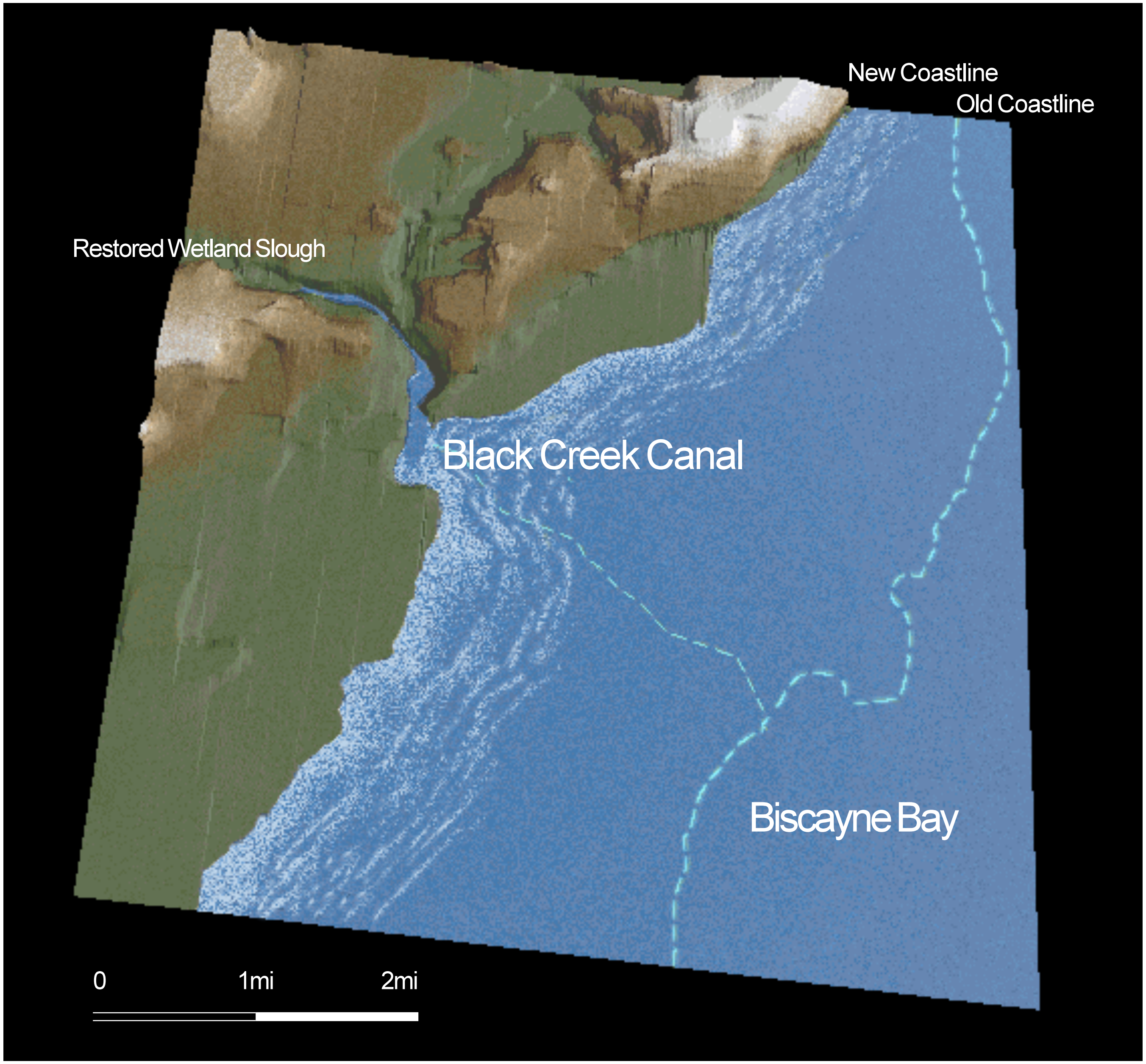


Figure: UM, CUCD

The destiny of humans cannot be separated from the destiny of earth.

Thomas Berry, as quoted in Philip Shabecoff, **A Fierce Green Fire**, The American Environmental Movement, 1993.

THERE IS A LIMIT TO THE NUMBER OF PEOPLE WHICH THE SOUTH FLORIDA BASIN CAN SUPPORT AND AT THE SAME TIME MAINTAIN A QUALITY ENVIRONMENT. THE STATE AND APPROPRIATE REGIONAL AGENCIES MUST DEVELOP A COMPREHENSIVE LAND AND WATER USE PLAN WITH ENFORCEMENT MACHINERY TO LIMIT POPULATION.

Governor's Conference, 1972.

One of the greatest challenges to planning for protection of the Biscayne Bay watershed is the regional population growth expected in the near future. It has been estimated that in the next 15 to 20 years, the population of South Dade may grow by 0.5 to 1.2 million people. The tendency will be for new development accompanying this influx of residents to sprawl towards the southern and western reaches of the county. This sprawling development will increase demands on freshwater supplies and create impervious surfaces contributing to stormwater runoff and sealing off valuable aquifer recharge areas. This growth will also create pressure to expand the Urban Development Boundary (UDB) beyond its present location. However, the area's ability to accommodate growth is limited by the natural environment. For instance, western and southern Dade County are prone to flooding, and the area's freshwater supplies are at risk of contamination. Furthermore, increased urban and agricultural development in the far western reaches of the county may negatively impact water deliveries to Taylor Slough and Florida Bay.

DeGrove, Regalado, **South Dade Watershed Project**, 1994.

With little or no [water] resources available from outside sources, the carrying capacity in South Dade is probably more on the order of 70,000 people. With moderate availability of outside [water] resources, the carrying capacity is probably on the order of 350,000 people. And under full development to intensities characteristic of Dade county, the population level would be over 1.7 million people. Which scenario is appropriate for South Dade, depends on global and national economies, and the degree to which the area is integrated into them.

Mark Brown and Sergio Lopez, **Carrying Capacity of South Dade County**, 1994.

Understanding the Limits

The various maps, graphs, models, drawings, and photos discussed so far have been presented to establish a better understanding of the science that drives our region: to understand the limits imposed by our natural environment.

These limits have been significantly redefined by the development of South Florida, in particular the re-engineering of hydrological systems and the overdraining of the Everglades and coastal land forms.

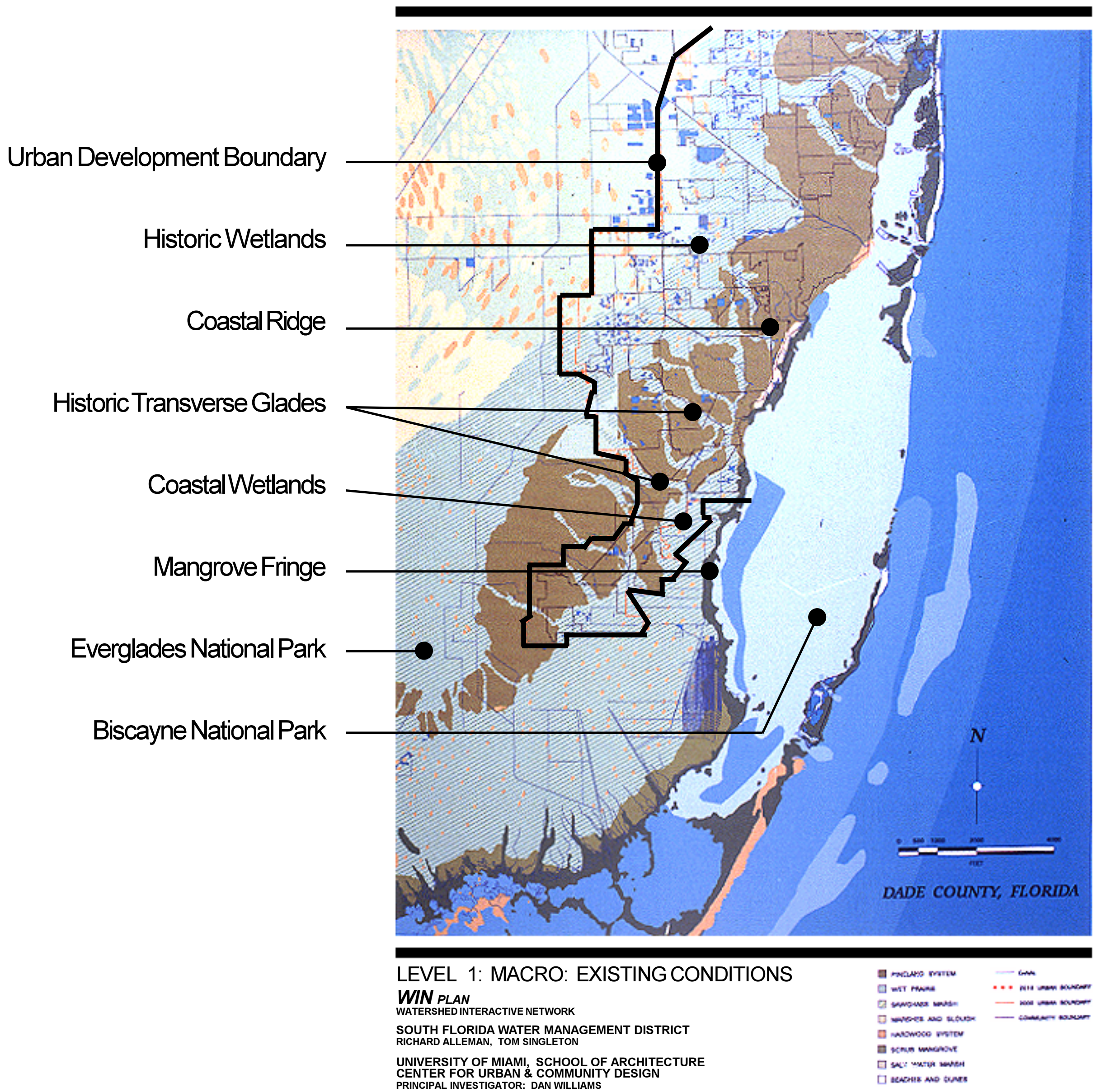
Regional Connections and Local Opportunities

This next section of the *New Construct* will apply the regional principles of land and water that we have discussed so far to the project study area of South Dade. To understand the forces that drive South Dade, we will start once again with the Davis Vegetation Map.

The map to the right shows the Dade county portion of the Davis Map. The broad dark (brown) area, running almost the full length of the county, is the pine upland that characterizes the coastal ridge of South Florida. This well-drained area was the only "high and dry" land in Dade County suitable for development at the turn of the century. It is along the coastal ridge that the early settlement of Miami began, where Flagler built his railroad, and where U.S. 1 is located today. The lighter (green and orange) areas depict various low-lying wetland vegetation systems that were once part of the historic Everglades system. These areas are poorly drained and, even today, periodically flooded. The thin dark (green) area running along the coastline, and encompassing the barrier islands, including Key Biscayne and Miami Beach, represent coastal mangrove communities that once dominated the Florida coastline.

You will note the lighter (green) areas transect the coastal ridge at various points in the county and especially South Dade. These wetland areas, known as "transverse glades," historically provided a hydrological connection between the Everglades and Biscayne Bay. Collecting rainwater from the coastal ridge, and from time to time, floodwaters from the Everglades, these areas contributed to the surface (overland) and sub-surface (aquifer) flows of freshwater necessary to sustain the coastal estuary of Biscayne Bay. Today, the transverse glades are transected by water management canals that were designed to provide flood protection for agriculture (*i.e.,* pervious/porous undeveloped land as opposed to impervious/nonporous developed land characteristic of urban development). Besides disrupting the historic flow of freshwater to Biscayne Bay and over-draining valuable groundwater resources stored in the Biscayne Aquifer, these canals provide limited flood protection for the existing residents of South Dade. They are not, however, designed to provide flood protection for the intensity of urban development that is likely to overtake South Dade in the next 15 years (Miami Herald quotation, p. 43).

Overlaid on the Davis Map is the Metro-Dade County 2010 Urban Development Boundary (UDB), which is shown as a solid black line. This line defines where urban development can and cannot occur. Since the UDB was first adopted by the County in 1975, population growth has continuously pushed the line further and further west to the Everglades and south into South Dade. This line will expand even further with predicted growth in Dade County. By overlaying the Davis Map and the UDB line you can see that almost two-thirds of the development in North Dade has occurred in historic Everglades; and in South Dade you can see where development is encouraged even today along the coastal wetlands of Biscayne Bay.



Existing conditions at a regional (macro) scale: UM, CUCD

Think we're overcrowded?

Just wait

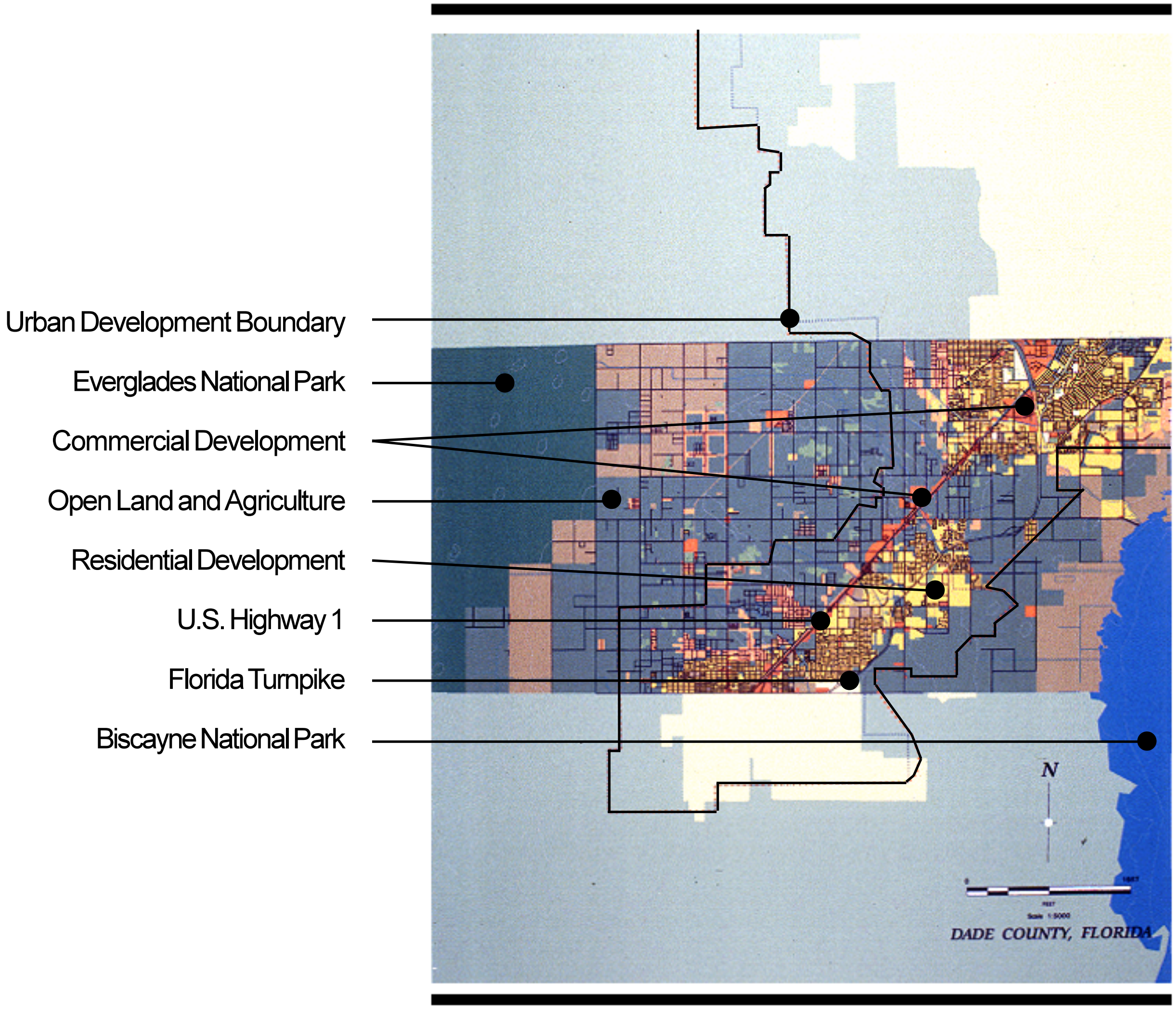
Dade Study predicts 35% growth by 2010...The projections forecast 700,000 more residents by the year 2010, an increase of 200,000 over previous calculations. It reflects the demographers new belief that the only constant in Dade's future will be change...Each of the 700,000 new residents is expected to use an average of 179 gallons per day, or together about 125 million gallons a day...Given the current restrictions on the Biscayne Aquifer, said Tony Clemente, director of the Miami-Dade Water and Sewer Department, "The cost of water is going to double in 2010."

The Miami Herald, March 23, 1995.

South Dade Watershed Project - Study Area

The map on the facing page illustrates the study area of the South Dade Watershed Project. Encompassing approximately 160 square miles, the northern and southern study boundaries correspond roughly with the path of Hurricane Andrew. The map details existing landuse, roads, and the 2010 Urban Development Boundary (UDB). The lighter areas located along U.S. 1 and proximal to the Florida Turnpike represent commercial (red) and residential (yellow) development. These two developed areas comprise approximately 20% of the study area. The balance of the study area consists of open land and agriculture (green). It is this undeveloped land – some of the last remaining vacant land in Dade county – that is expected to receive the largest percentage of the predicted 700,000 new residents who will move to Dade by the year 2010. As cited previously in the *Preface,* these new residents will consume an additional 125 million gallons of freshwater from an already stressed aquifer; build over much of the agricultural heritage of the Redland; require additional flood protection; and further impair the quality of water flowing to the Biscayne Aquifer and Biscayne National Park.

Without proper planning, the demands of future development on the land and water resources of South Dade could create the "Frog Ponds" and "Florida Bays" of tomorrow. Therefore, as we plan for the eventual buildout of South Dade, we must build solutions rather than problems. We must respect the connectedness of all things. We must look for a natural "fit" between all uses of land and water.



LEVEL 1: MACRO: STUDY AREA

WIN *PLAN*
WATERSHED INTERACTIVE NETWORK

SOUTH FLORIDA WATER MANAGEMENT DISTRICT
RICHARD ALLEMAN, TOM SINGLETON

UNIVERSITY OF MIAMI, SCHOOL OF ARCHITECTURE
CENTER FOR URBAN & COMMUNITY DESIGN
PRINCIPAL INVESTIGATOR: DAN WILLIAMS
RESEARCH TEAM: ERICK VALLE & DWIGHT DANIE

Study area: UM, CUCD

As Lewis Mumford once insisted, the new turn of events means that "all thinking worthy of the name must now be ecological, in the sense of appreciating and utilizing organic complexity, and in adapting every kind of change to the requirements not of man alone, or of any single generation, but of all his organic partners and every part of his habitat.

Donald Worster, **The Wealth of Nature**, Environmental History and The Ecological Imagination, 1993.

Falling freely from the sky, water has deluded us into believing it is abundant, inexhaustible, and immune to harm. The challenge now is to put as much human ingenuity into learning to live in balance with water as we have put into controlling and manipulating it.

Sandra Postel, **Last Oasis**, Facing Water Scarcity, 1992.

Photograph of the Everglades: SFWMD

Integrating Landuse and Water: Connecting Our Human Needs with the Workings of Nature

The inextricable connection of our human activities to the workings of Nature can be both positive and negative. As with most things, this difference depends a lot on our perspective.. Yet at the same time, the extreme complexity of a problem can virtually defy definition, let alone resolution.

Integrating the use of land with the management of water to produce benefits instead of damage is an example of such a problem. And yet this is the problem we face as we prepare to receive the ever-growing number of people who want to move to South Florida.

Photograph of urban development in South Florida: SFWMD

Why has so much of modern water management gone awry? And why is it that ever greater amounts of money and ever more sophisticated engineering have not solved [our] water problems? In part, we are trying to meet insatiable demands by continuously expanding a supply that has limits, both ecological and economic.

Sandra Postel, **Last Oasis**, Facing Water Scarcity, 1992.

How do we solve the conflicting problem of too much and too little water? How do we solve the most basic problem of preserving and protecting our sources and our supplies of water? These are but two of the many questions that must be answered to beneficially connect our human needs with the workings of Nature.

What, then, is the composite solution for successfully integrating the needs of the Everglades with the frequently divergent needs of our residents? Where do we begin? What will it look like? How do we get there? The answers to these questions will be addressed in the balance of this report.

The use of land in southern Florida began with both courage and ignorance – courage to inhabit a land that appeared to favor fish and wildlife, and ignorance that led to the destruction of parts of the richness of the region by indiscriminate clearing, draining, and filling.

Albert R. Veri, William W. Jenna, Jr., and Dorothy Eden Bergamaschi, University of Miami, **Environmental Quality by Design: South Florida**, 1975.

Wetland Functions

Two photographs capture the often overlooked magnificence and beauty of natural wetlands (pp. 20-21). We are just beginning to appreciate how valuable these environmental resources really are. Providing a natural system of flood control, water conservation/aquifer recharge, water purification, and climate moderation, wetlands play an important role in the natural cycling of water. They provide critical habitat for wildlife and, in the case of coastal estuaries, these systems support the base of the marine "food chain." Only today do we recognize the profound impact that the destruction of the vast wetland resource of South Florida has had on man and nature.

The restoration of historic wetland functions is recognized by the South Dade Watershed Project as a viable strategy for protecting our water resources from the negative impacts of urban development. Using the physical land form as a guide (vegetation, soils, and topography), this strategy seeks to reconnect existing hydrologic features in a way that mimics the natural system's ability to capture, cleanse and store stormwater runoff. By designing with nature instead of against nature, both our human needs and the natural resources that sustain us can be preserved.

Photo: "Over Florida"

Wetlands are a classic example of market failure; the wetland owner generally cannot capture the benefits of his resources for his own use or sale. The flood protection benefits of wetlands accrue to others downstream. Many of the fish and wildlife that breed in and inhabit the wetlands migrate, and are captured or enjoyed by others. The ground water recharge and sediment trapping benefits cannot be commercially exploited. For the owner of a wetland to benefit economically from his resource, he usually has to alter it, convert it, and develop it. This is the basis of the problem of the excessive development of wetland habitats.

Michelle Edwards Correia, FAU/FIU Joint Center for Environmental and Urban Problems, **The Role of Economics in the Valuation of Wetlands**, March 1995.

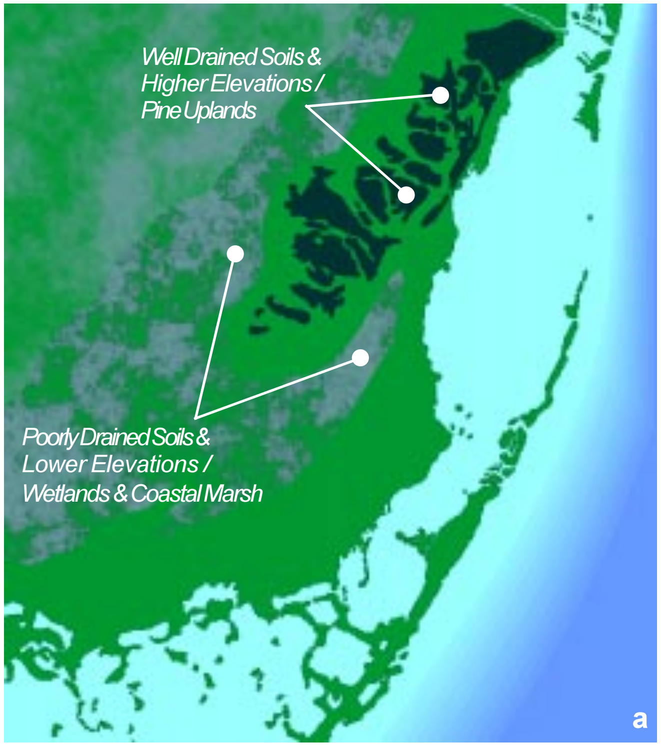
Photo: "Over Florida"

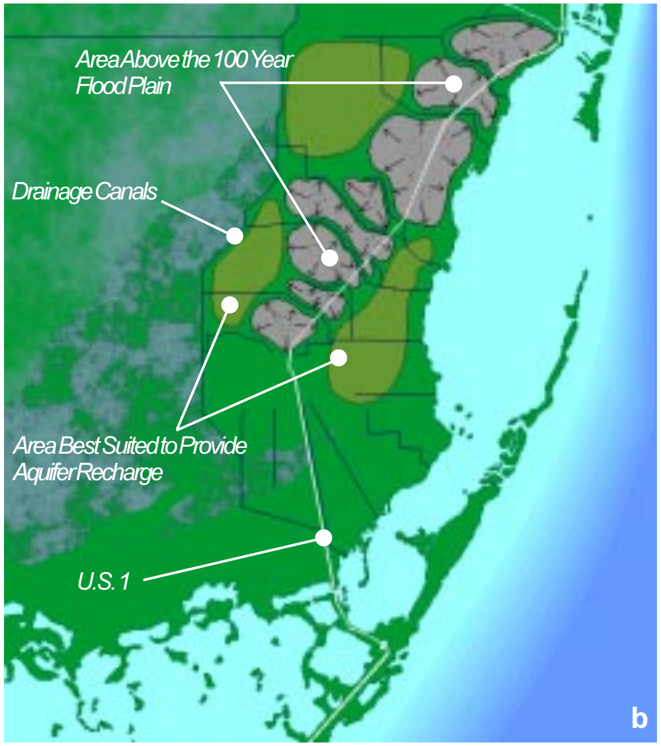
***A**s we learn more about the complexities of environmental systems and how environmental and economic systems are linked, it becomes increasingly difficult to define and assess environmental economic trade-offs. This lack of understanding has led to the undervaluing of natural resources. In turn this has led to heavy depletion of, and stress on, remaining wetland ecosystems.*

Michelle Edwards Correia, FAU/FIU Joint Center for Environmental and Urban Problems, **The Role of Economics in the Valuation of Wetlands**, March 1995.

In any endeavor, good design resides in two principles. First, it changes the least number of elements to achieve the greatest result. Second it removes stress from a system rather than adding it. Bad design is pinning our hopes for environmental and cultural survival on a change in human consciousness and behavior alone, because we therefore depend on the highest number of uncontrollable elements – people – to undergo a great change. Likewise, bad design is having to institute several hundred thousand rules and restrictions under the jurisdiction of the government and expecting business to know them all, much less obey them.

The Ecology of Commerce: A Declaration of Sustainability, Paul Hawken, 1993, p. 166.



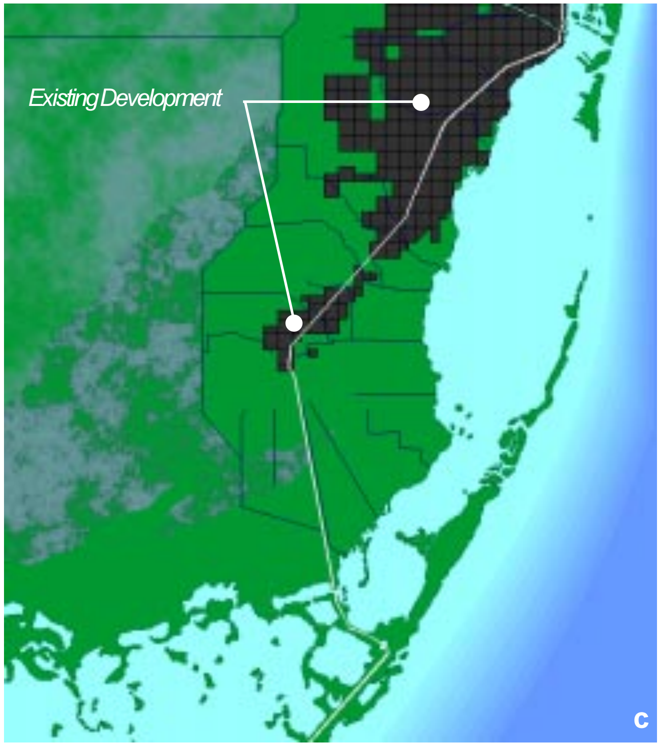


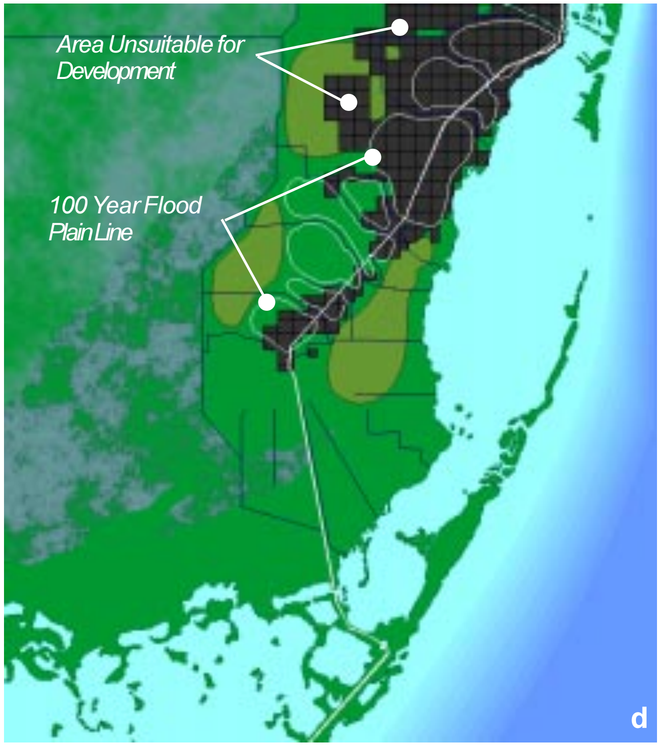
Figures: UM, CUCD

A Regional Sytems Approach to Sustainable Development

The following images explain a "regional systems" approach to establishing a proper fit between landuse and water. In the first image (**a**) we have consolidated the information from the Davis Map to differentiate well-drained and poorly drained soils . The dark (black) areas, representing the "higher" well-drained soils of the coastal ridge, are more suitable for development. The lighter (green) areas, representing the "lower" poorly drained soils of the Everglades, the transverse glades, and coastal marsh, are not suitable for development.

The next image (**b**) shows conceptually how the land and water interact naturally in South Dade. The lighter (grey) areas generally represent land areas located along the coastal ridge that are at topographic elevations above the 100-year flood plain. The small arrows show that stormwater flows off the coastal ridge from areas of higher land elevation to areas of lower land elevation. This water eventually flows to the drainage canals and ultimately Biscayne Bay. The light (green) areas, located on either side of the coastal ridge, are open pervious/porous land areas that provide critical water recharge to the Biscayne Aquifer.





Figures: UM, CUCD

These next two images show the existing pattern of development (**c**) and some of the conflicts that exist between the natural land form and our man-made environment. In both images, the existing development is shown as a dark (brown) grid; the drainage canals, cutting through the coastal ridge , are shown as black lines; and highway U.S. 1, running along the coastal ridge, is shown as a white line. The second image (**d**) overlays the 100 year flood plain on the existing development grid. As can be seen, much of the development in South Dade has occurred in areas that are less suitable for development These areas include historic Everglade wetlands, valuable coastal marshes, and critical recharge areas for public wellfields. Continued development within these areas will cause more local flooding, pave over critical aquifer recharge areas, and destroy valuable natural resources.

Given the limited land area that is suitable for development and the water resource limits of South Dade, how do we create a system that will insure the viability of the region in the face of predicted population growth?

Conservation, once viewed as just an emergency response to drought, has been transformed in recent years into a sophisticated package of measures that offers one of the most cost-effective and environmentally sound ways of balancing urban water budgets. Just as energy planners have discovered that it is often cheaper to save energy—for instance, by investing in home insulation and compact fluorescent lights–than to build more power plants, so water planners are realizing that an assortment of water efficiency measures can yield permanent water savings and thereby delay or avert the need for expensive new dams and reservoirs, groundwater wells, and treatment plants. Slowly the idea is spreading that managing demand rather than continuously striving to meet it is a surer path to water security–while saving money and protecting the environment at the same time.

Sandra Postel, **Last Oasis**, Facing Water Scarcity, 1992.

Water pure enough to drink serves many functions that do not require such high quality–including irrigating crops and lawns, manufacturing many kinds of industrial products, and flushing human waste into a sewer. By better matching supplies of varying quality to different uses, more value can be derived from each liter taken from a river, lake, or aquifer–and the economic and environmental costs of developing new freshwater sources can be lessened. The challenge, in a nutshell, is to take the "waste" out of wastewater.

Sandra Postel, **Last Oasis**, Facing Water Scarcity, 1992.

Using the physical features of South Dade as a guide – the soils, topography, vegetation and hydrology – and our knowledge of their interactive connections, we can re-create the historic hydrologic functions of the region. This approach, illustrated in the final image (**e**), is designed to use the workings of nature to efficiently collect, store, clean-up, and distribute water for all users – urban, agricultural, and natural.

This image shows the canals replaced by broad wetland systems similar to what had historically typified the transverse glades. These topographic low points are an integral part of the region's natural flood protection. The north-south canal, separating the developed part of Dade County from the Everglades, is expanded to provide valuable storage and cleansing of water. This will improve the quality of water while preserving a sustainable water supply for future users. The coastal canals become "spreader" canals to enhance the distribution, timing, quantity, and quality of that water which flows to Biscayne Bay while protecting the food chain of the eco-tourism based fishing industry.

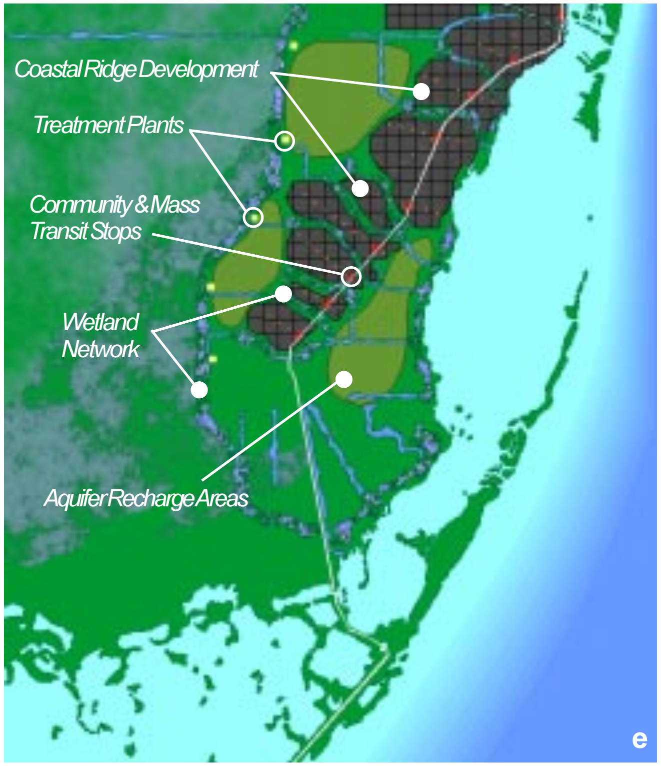


Figure: UM, CUCD

The light (yellow) points in west Dade represent sub-regional wastewater treatment plants that will provide for 100% re-use of the waste effluent. This requires enhanced water quality treatment, provided by technology supplemented with natural cleansing of the water in the newly created wetland areas. By ultimately recycling this water to the aquifer we can replenish much of the water that we use everyday without extensive use of pumping and other fuel driven systems.

In this plan, open pervious land uses that provide valuable recharge to the aquifer, are preserved. This will also provide for the preservation of the agriculture and quality of life that exists in the Redland today. To support this objective , development must be directed to the higher ground of the coastal ridge . Mass transit and community based transit centers, the lighter (red) dotted lines within the developed areas, must be established. These will encourage the development of tightly knit communities with strong regional connections, and reinforce the opportunity to provide for our future water needs.

Collectively, then, these graphics describe the Watershed Interactive Network, the "WIN" Vision, illustrated on the facing page.

Watershed Interactive Network

Everglades-Agricultural Zone: *water storage and aquifer recharge area. Sub-regional wastewater treatment plants with 100% reuse will recharge the aquifer at the "rate of use" creating a sustainable supply of water for Dade County.*

Coastal Ridge Development Zone and Transverse Glades: *urban development area. This zone receives the highest amount of rain in the region. The collection, storage, and cleansing of this water will significantly increase the total available supply of water.*

Biscayne Bay Coastal Zone: *coastal resource protection area. Provides natural buffer from hurricane storm-surge. Enhanced distribution, timing, quantity, and quality of freshwater flows through this zone will significantly improve the estuarine values of the Bay.*

Figure: UM, CUCD

Linear "hydric parks" combine the recreational and aesthetic benefits of "greenways" and "blueways" with the realization of water resource objectives. They create strong edges that define neighborhoods and communities.

The greatest potential for additional water storage lies within the coastal ridge. The development of neighborhood "hydric parks" increases local aquifer recharge, reduces local flooding, and enhances community identity.

Water storage areas located within communities recharge local wellfields.

Recreation of historic wetland sloughs for the collection, storage and biological clean-up of stormwater restores the regions image and identy.

It's simple! At least ten percent of the gross land area must function as wetlands – this will establish regional and local storages and recharge while providing for additional flood protection. The added fact, that these areas can serve as local and regional hydric parks while cleaning the water up makes it even more palatable to the tax payers.

South Dade Watershed Project, **Workshop**, July 1994.

Creating Water Storages in South Dade

In an effort to better understand the relationship of landuse and water, the University of Florida Center for Wetlands and Water Resources was asked to estimate the amount of stormwater pollution associated with the use of land in South Dade. To give greater meaning to the raw data generated in this effort, the Center was also asked to estimate the area of wetland that would be required to cleanse the polluted stormwater run-off so that it could be released to Biscayne Bay without causing negative impacts. The results of this study are summarized in the table on the facing page (p. 51).*

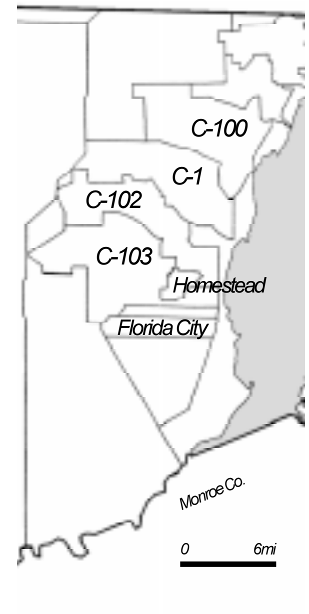
What the table shows us is that approximately 5% to11% of the total land area in the basins needs to be set aside for flood protection and water quality treatment. In some basins (C-1, C-102, C-103 and Florida City Canal) there is sufficient open land to meet this requirement, however, in other basins (C-100 and Homestead / Military Canal) there is insufficient land.

The implication of this information, is that guidelines must be developed to mitigate the impacts of existing and new development. In the case of existing development this may require guidelines for retro-fittting existing communities and the creation of large regional wetland treatment areas; and in the case of development, guidelines must be developed that require the development to be 100% responsible for the water resources associated with the site.

* The methodology and the final results of these efforts are detailed fully in the *Support Documents* attached to this report (see Wetland Stormwater Requirements p.129)

Drainage Basin	Total Land Area	Open Land	% of Total Land	Land Req. for Wetland Treatment	% of Total Land	% of Open Land
C-1 Black Creek	25,152	10,478	42%	2208	9%	21%
C-100	25,688	571	2%	2887	11%	506%
C-102	21,304	13,896	65%	978	5%	7%
C-103	31,502	16,910	54%	2124	7%	13%
Florida City	7,605	2,981	39%	462	6%	15%
Homestead / Military	2,157	101	4%	136	5%	134%
	113,768*	44,937*	39%	8796*	8%	20%

Table showing Drainage Basins of South Dade and Required Wetland Areas for Water Storage: UF, Center for Wetlands & Water Resources
*acres



Canal Basin Boundaries, Dade County: UF, Center for Wetlands & Water Resources

According to the Maryland Institute for Ecological Economics, even more jobs can be created by investing in "natural infrastructure", through the restoration of wetlands, streambeds, fisheries habitat, and other essential components of aquatic ecosystems. These economists predicted that investments in aquatic ecosystem restoration would produce an average of thirty jobs per million dollars spent, a job creation rate 37 percent higher than generated through public investment in roads, 24 percent higher than through water and sewer systems, and 28 percent higher than through major defense contracting. The National Academy of Sciences (NAS) proposes a long-range program to restore badly degraded aquatic resources. Investment in such a program could generate tremendous long-term ecological as well as economic benefits.

Robert W. Adler, Jessica C. Landman, Diane M. Cameron, **The Clean Water Act, 20 Years Later**, 1993.

Incident piled on incident no more makes life than brick piled on brick makes a house.

Edith Ronald Mirrieles (1878 - 1962), American educator and writer.

Photo: Dan Williams

Existing

The heritage of South Dade is captured within this scenic view of an agricultural landscape. This historic community is expected to receive a large percentage of the 700,000 new residents that are predicted to settle in Dade County by the year 2010 -- this is also the area that will supply Dade's future well fields. If protective steps are not taken, this landscape might not exist at all within 15 years.

The depicted flood control canal -- dug within the transverse glades -- is not designed to provide the flood protection needed to accommodate future development and a change of landuse from agriculture to urban. Building over of this area will constitute a loss of essential public water recharge.

Photo: Dan Williams

Trends are not visions.

Daniel Williams AIA, 1995.

Altered Urban

The above image shows a typical South Dade development -- built right up to the edge of the canal. By doing this we have lost the areas' natural ability to capture, store, and cleanse water; and we have built communities that are prone to flooding. Providing flood protection for these low areas has required the over draining of the coastal ridge -- resulting in the loss of critical ground water resources.

This canal edge condition presents an opportunity for an amenity rather than the ditch that exists today. The re-creation of the transverse glade would create identity and image for the community while increasing flood protection and neighborhood open spaces. This combined water storage area and open space not only defines better neighborhoods through quality edges but increases property values at the same time.

How can this work? All use and ownership of land changes over time. The following images show the gradual (50-100 years) reclaiming of the transverse glades as "hydric" parks.

Poison runoff impairs more waterbodies, surface and ground, urban and rural, than any other pollution source in the country. Poison runoff is the contaminated storm water and snowmelt that runs off of, or leaches through, land used and abused for human purposes without regard to ecological needs. Although poison runoff (nonpoint source water pollution) was widely acknowledged as a water quality problem even before 1972, in general we have failed to create and implement effective programs that protect and restore our nation's waters that are subject to this threat.

Robert W. Adler, Jessica C. Landman, Diane M. Cameron, **The Clean Water Act, 20 Years Later**, 1993.

Image: UM, CUCD

Computer Altered Image

In the image, above, we see the flood plain restored through the reclamation of senescent and storm-damaged structures. These areas were previously wetlands that functioned as storage and recharge for the region -- the soils are compatible with reclaiming that use. This first step reclaims the land area for lineal parks and recreation while slowly moving toward reclaimed wetlands that historically functioned as a regional water supply storage.

Image: UM, CUCD

Reclaimed Image

In this fully altered image, portions of the transverse glades have been reclaimed as regional water storage areas while providing increased flood protection for the neighborhoods. This exemplifies the concept of multi-agendas being solved simultaneously, *i.e.*, the need for additional water storage coupled with the requirement for water quality treatment. Also resolved are the urban requirements of stormwater collection, increased flood protection, and the pervasive need for additional open space.

Individual neighborhoods now have small "hydric parks" creating or reinforcing community ideals while complying with local flood and water storage needs.

Where excessive diversions have already caused ecological damage, as with central Asia's Aral Sea or Florida's Everglades, new laws and regulations will be needed to restore ecosystems to health. One such instrument is a legal principle called the "public trust doctrine," which asserts that governments hold certain rights in trust for the public and can take action to protect those rights from private interests. Widespread application of this doctrine could have sweeping effects, since even existing water rights could be revoked in order to prevent violation of the public trust.

Sandra Postel, **Last Oasis**, Facing Water Scarcity, 1992.

Moving toward more efficient, ecologically sound, sustainable patterns of water use requires major changes in the way water is valued, allocated, and managed.

Sandra Postel, **Last Oasis**, Facing Water Scarcity, 1992.

Guidelines for Regional Systems Planning:

- *treat South Dade as a whole, rather than a patchwork of small settlements;*
- *concentrate rebuilding efforts in infill areas, rather than expanding into undeveloped areas;*
- *question quick fixes that bring short term, local benefits, rather than long term, regional benefits;*
- *discontinue the spread of urban growth toward the west and east that is unsympathetic to the natural and agricultural systems;*
- *preserve the long-term natural resources of the region (i.e., Everglades National Park, Biscayne National Park, and Redland);*
- *protect the environment to insure the future of the national parks as well as the economic vitality of the area;*
- *protect water quality and quantity in order to sustain fresh water supplies for the natural system as well as for urban and agricultural land uses; and*
- *provide a "spine" of rapid transit to act as an anchor for future growth and "density centers"*

Daniel Williams, **The New South Dade Planning Charrette**, 1992.

Challenges and Opportunities

U.S. 1 Corridor in South Dade

The **South Dade Watershed Project** strives to provide for a sustainable water supply and natural resource protection. Critical to achieving this objective is the restoration of the hydrologic functions of the watershed. Such a plan must link transportation, land use, and natural resource protection in a strategy that directs new development and redevelopment into appropriate infill sites along the U.S. 1 corridor. This will reduce development pressures to expand the UDB further to the west, east, and south into sensitive agricultural and natural resource areas. The current location of the 2010 Urban Development Boundary should be re-assessed, and possible retraction of the boundary – especially along the Krome Avenue corridor -- should be considered

Krome Avenue: Emergency Evacuation Corridor

Metro-Dade County has determined that Krome Avenue provides the most direct route to persons in South Dade and the Florida Keys for emergency evacuation and for post-disaster recovery efforts. The county has proposed a comprehensive plan amendment that would allow widening Krome Avenue from South Dade to the Dade-Broward county line. Widening Krome Avenue would promote commercial development and urban sprawl along its length. To protect the water resources of the region, a plan must be created for the development of the Krome Avenue corridor that is consistent with water supply, flood protection, and Everglades restoration objectives. The lack of such controls would seriously undermine the efforts to redirect growth to infill areas within the U.S. 1 corridor.

Water Resource Overlay Zoning

Overlay zones apply a common set of standards to a designated area. These zones "overlay" existing zoning districts, and in doing so, apply additional development standards to those of the existing (underlying) district. These zones would be applied to the protection of wellfield areas, critical water recharge areas, and the network of canals. The Wellfield Protection Ordinance adopted by Dade County in 1981 is an example of the overlay zoning principle. These special protections must be established and adopted today, prior to the build-out of South Dade.

Homestead Airforce Base Redevelopment Area

The redevelopment of this area is critical to the economic future of South Dade As an existing Super Fund Site, this area provides to opportunity to serve as a highly visible example of development that is responsive to water and natural resource protection.

Principles for Sustainable Water Resource Planning

- *The total rainfall within the region is that region's water budget* -- supplies from outside the region are "borrowed or leased" and cannot be counted on during drought or after build out. The aquifer "storages" allow us to average the variations in rainfall and should not be used to calculate the allocation of water for public use.

- *Each landuse must spatially contribute its share to the region's water budget* – the loss of recharge that is associated with "typical" development must be restored and protected *i.e.*, the post development hydrologic condition must equal the pre development hydrologic condition.

- *Stormwater, greywater and wastewater must be recycled and recharged at a rate commensurate with use* – the storage and recharge of such must be achieved at the regional, community, and neighborhood scale.

- *The location of surface and groundwater storage areas for water resource sustainability must be integrated in urban and community design* – the development of "hydric parks" and the preservation of open space will create strong edges for communities and create a sense of "place."

THE WIN VISION

WATERSHED INTERACTIVE NETWORK

Sustainable development is about how we may use the natural resources of our environment, and pass them on to future generations. But the limiting factors nearly always reside not in the environment, but in human societies.

Martin Holdgate, **Partnerships in Practice**, Department of the Environment, UK.

We must foster intuition to anticipate changes before they occur; empathy to understand that which cannot be clearly expressed; wisdom to see the connection between apparently unrelated events; and creativity to discover new ways of defining problems, new rules that will make it possible to adapt to the unexpected.

Mihaly Csikszentmihalyi, **The Evolving Self**, A Psychology for the Third Millennium, 1994, p.42.

CONCLUDING COMMENTS

The shuttle image on the right can be viewed as a glass half full or a glass half empty. But science tells us that it is neither. **It is not working!** There is:

- a tremendous amount of water,
- but not enough water;
- a tremendous amount of land,
- but not enough land;
- too many people,
- yet, more people are coming;
- too much sprawl,
- but, more housing is needed.

These contradictions can be successfully addressed by understanding their connections -- land to water...land to people....people to water.

When we look at the places we love, ones we want to visit, we must recognize that the "postcard" qualities that make these communities desirable, are possible within our community.

Thus we must create a vision of our community's tomorrow and we must take the incremental steps to preserve, protect, and define our future.

Hurry up please, it's time. T. S. Eliot

Photo: NASA

"Big" solutions, which I would like to think of as those that show breadth of imagination, length of time horizon, and depth of commitment, are surely only attainable when many different kinds of people are involved. It is often the alliances between the most unlikely partners that are most effective. And it is difficult to think of any kind of development that is likely to be sustainable unless all the interests in a community -- poor as well as rich; young as well as old; women as well as men; labour as well as employers; industry as well as environmentalists – are brought together and contribute first to policy and then to implementation.

Martin Holdgate, **Partnerships in Practice**, Department of the Environment, UK.

THE SOUTH FLORIDA WATER MANAGEMENT DISTRICT IS CHARGED WITH MANAGING AND PROTECTING THE WATER RESOURCES FOR ONE OF THE FASTEST GROWING REGIONS IN THE NATION... AND IN ONE OF THE MOST ENVIRONMENTALLY SENSITIVE AREAS IN THE WORLD.

Sam Poole, South Florida Water Management District, **1994 Annual Report**, Director's Message.

LAND USE AND WATERSHED PLANNING ISSUES

Prepared for:

The South Dade Watershed Project

University of Miami
Center for Urban and Community Design

Prepared by:

FAU/FIU Joint Center for Environmental and Urban Problems

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and

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Research Associate

INTRODUCTION

Water is a vital element of Florida's natural and man-made environments. Freshwater underlies the state and periodically inundates much of its interior. Water is so fundamental to the state's character that its freshwater wetlands have been described as its "soul;" the Everglades, an expansive freshwater marsh that covers much of the state's interior, has been described as its "heart." The surface and underground freshwater reservoirs of the region are essential to the integrity of near shore ecosystems. These waters flow into coastal estuaries, mixing with the vast saltwater seas that surround the state's 1,200 miles of coastline. At the interface between salt and freshwater, sensitive and finely balanced estuaries provide nurseries for commercial fisheries and habitat for abundant marine life. As the foundation of Florida's natural environment and cornerstone of the state's recreation and tourism industries, water is essential to the state's sustained health and prosperity.

Appreciation of Florida's freshwater and marine resources has developed relatively recently. Historically, wetlands were considered not only worthless, but a threat to human survival. Estuaries were mosquito infested mangrove swamps and in dire need of "improvement." Marine environments were considered boundless resources created for man's exploitation.

The last one hundred years of Florida's history has been characterized by man's attempts to tame nature. It is a history marked by man's endeavors to adapt the natural landscape to human uses. As a result, Florida had become an impressive monument to human control over nature. More recently, our appreciation of natural resources has increased as our understanding of their values and functions has grown. Scientific research has identified numerous vital functions: food production, wildlife habitat, flood control, climate moderation, recreation and aesthetic experiences, nutrient removal, and aquifer recharge. This understanding has led to a new way of viewing and valuing nature. We have come to realize that to destroy nature is to destroy ourselves. We have come to realize that in order to ensure our long-term survival, we must preserve our natural resources by growing in harmony with nature.

With this realization, we have cast aside our pride in Florida's highly engineered environment. We are now seeking to mitigate the damage; to right the wrongs. Many areas of Florida will require extensive efforts to undo past modifications. Grand plans for restoring the Kissimmee River are already underway. Possible restoration of the Everglades through a "replumbing" of its drainage works is being studied. However, certain areas of the South Florida Ecosystem are still in grave need of attention. One of those areas is the South Dade watershed; the watershed that supplies the Biscayne Bay.

To be sure, Floridians have much to be proud of. For example, the state has the country's most ambitious environmentally sensitive lands acquisition program. Yet, even as we are acquiring land as quickly as possible, acres upon acres are still being lost each day to development. Even if we could buy land faster than bulldozers could destroy it, we do not have enough money to buy all that should be protected. Floridians must look to others answers - answers that utilize all potential tools ranging from regulation to acquisition. Time is running short. We must act quickly.

We are on the brink of experiencing a fundamental change in the way the state's natural resources are protected. Our goals must be redefined from ones that concentrate on preserving specific parcels to goals that support the health and integrity of entire ecosystems. Our management goals must be based on a regional scale, and must emphasize low-technology solutions that rely on natural processes. In order to do so, we must understand and mitigate man's impacts on those ecosystems. Thus, if we are to sustain both mankind and the natural environment of the South Florida Ecosystem we must adopt a new paradigm - *ecosystem management*. Ecosystem management recognizes that humans are "embedded" in nature, and that ultimately, human values shape our environmental policies and individual actions.

We have greatly modified the Biscayne Bay watershed. Therefore, planning for the bay's protection will require recognition of our enormous impacts, both past and present. As we face the prospect of increasing urbanization within the watershed, we must develop a plan that pro-actively addresses this issue. This chapter discusses the need to manage growth in the South Dade watershed and examines ways to utilize growth management and urban planning to achieve a sustainable South Florida Ecosystem. The chapter begins with an examination of Florida's natural resources and its history of land reclamation and development. The second section describes the evolution of Florida's growth management system. Section III discusses ecosystem management as the new paradigm in resource management. The fourth section presents models of ecosystem management from around the world. Section V examines, in light of ecosystem management, the strengths, weaknesses, and gaps in Florida's growth management system. Finally, the chapter concludes with a strategy for developing an ecosystem-based approach to planning and governance in the South Dade watershed.

REGIONAL AND HISTORICAL CONTEXT

Present day Florida is vastly different from that which existed when the first European settlement was established in 1565 at St. Augustine. The natural landscape of Florida changed little between the middle of the 16th century and 1855 when Florida became a state. By far, the most dramatic changes to Florida's natural environment have occurred relatively recently, within the last 100 years.

In order to understand the current state of Florida's natural environment and the changes needed to ensure its sustainability, it is useful to first examine the system as it functioned in its natural state. This examination is followed by a chronology of events leading to the devastation of South Florida's natural environment. Finally, the current state of Florida's environment is described and its contribution to setting the stage for adoption of a statewide system of growth management is noted.

Ecology of Southeastern Florida Prior to Drainage and Development

General Land Form

Florida is a gently sloping peninsular land form that projects southward from the North American continent into the subtropics. It is composed of sandy soils over a porous limestone platform (Floridan Plateau). Geologically, the peninsula is the youngest portion of the continent, as it was the last land area to emerge from the sea at the end of the most recent Ice Age. The state is surrounded on three sides by water - the Atlantic Ocean to the east, the Gulf of Mexico to the west and Florida Bay to the south - and no point within the state is further than 70 miles from the sea (Veri 1975).

The entire Floridian peninsula is flat; the highest elevation is no more than 200 feet above sea level. The state's highest elevations form a central spine through the Central Ridge and Lakes region. This spine of "highlands" generally runs through the middle of the state from the Tallahassee Hills to Lake Okeechobee. East of the highlands the Kissimmee River meanders from the Orlando area to Lake Okeechobee, a shallow natural freshwater reservoir that covers approximately 700 square miles of the state's interior. Just south of the lake, the Everglades, a wide, shallow depressional area 100 miles long and up to 40 miles wide gradually slopes south to Florida Bay. The Everglades is bounded on the east and west by higher lands - the Atlantic Coastal Ridge to the east and the Immokalee Ridge to the west (Myers 1990 and Tebeau 1980).

Aquifers

A complex system of aquifers flows through the Floridan Plateau, and is composed of three major elements: the Floridan, Intermediate, and Surficial aquifers. The Floridan Aquifer is an artesian aquifer that underlies much of the state. It is replenished primarily by rain that falls in Alabama, Georgia and northern Florida. In southeastern Florida, the Floridan aquifer is very deep (some 900 feet below sea level at Miami) and has a high mineral content. As a result, the Floridan is not used extensively for drinking water. The Intermediate Aquifer (also called the Hawthorn) has "only limited potential as an aquifer" (SFWMD 1992a:32). The Surficial Aquifer System underlies southeastern Florida. One component of the surficial aquifer is the Biscayne Aquifer, which extends from southern Palm Beach County through Dade County. The Biscayne Aquifer is considered one of the most productive aquifers in the world and supplies the majority of drinking water supply to southeastern Florida. In many places the water table (the upper surface of a surficial aquifer) of the Biscayne Aquifer is located within a few feet of the ground's surface, thus surface waters and groundwaters in most of southeastern Florida are closely linked. This proximity to the ground's surface also makes the Biscayne Aquifer extremely vulnerable to contamination (Veri 1975 and SFWMD 1993b).

Climate

Florida is the only portion of the North American continent that possesses a subtropical climate. Lying between 24° and 31°30' north latitude and between 79°48' and 87°38' west longitude, Florida is actually located mostly within the temperate zone. However, its climate, particularly in South Florida, is subtropical, with wet, humid summers and relatively dry and cool winters. This subtropical climate is greatly attributable to the moderating influences of the Gulf Stream (Fernald 1992).

The state's rainfall averages about 53 inches per year. However, the temporal distribution of this rainfall is seasonal, with 75 percent falling during the summer wet season (May through October). Prior to construction of extensive drainage works throughout much of southeastern Florida, flooding regularly occurred during the wet season. As heavy rains began to fall in late spring, the ground became saturated and the water table rose. Under those circumstances much of southeastern Florida was inundated (SFWMD 1992a).

The Kissimmee-Lake Okeechobee-Everglades Watershed

The interior of the southern half of the state is dominated by the Everglades, "a vast, shallow sawgrass marsh, dotted with tree islands and interspersed with wet prairies and aquatic sloughs" (SFWMD 1992a). The low, trough-shaped Everglades marshland is bordered on the east and west by higher lands - the Atlantic Coastal Ridge on the east and the Immokalee rise on the west. The pre-development Everglades was 40 miles wide and 100 miles long. The region originally included seven general vegetative communities: swamp forest, sawgrass plains, wet prairie/slough, tree island, sawgrass mosaic, sawgrass dominated mosaic, cypress strand, peripheral wet prairies, and the southern marl-forming marsh (SFWMD 1992a).

The historic Everglades watershed is referred to as the Kissimmee-Lake Okeechobee-Everglades (KLOE) watershed because it originates at the headwaters of the Kissimmee River and includes Lake Okeechobee and the Everglades. The Kissimmee River's headwaters are derived from a chain of lakes at the north end of the system. The Kissimmee River naturally drained into shallow Lake Okeechobee, which had no well-defined outlet. During the wet season, the lake regularly overflowed its banks and sent a sheet of freshwater south over the Everglades, west into the Caloosahatchee River and east into the Allapattah, Hungryland and Loxahatchee sloughs. Most of the surface water evaporated or seeped into the Biscayne Aquifer. However, some water drained off to the east through rivers such as St. Lucie, New, and Miami. Further south, the accumulated surface water found an outlet to the coastal estuaries through low marshy breeches in the Atlantic Coastal Ridge. These shallow freshwater marshes, or "transverse glades" constituted an important source of freshwater inflows to south Biscayne Bay. Furthermore, because the Biscayne Aquifer is so porous, groundwater seeped into Biscayne Bay as freshwater springs. In the southern reaches of the KLOE, surface water flow was concentrated into two major drainage systems, the Taylor and the Shark River sloughs. These sloughs provided freshwater to Florida Bay and the Ten Thousand Islands area (Myers 1990 and SFWMD 1993b).

The Everglades system is an interconnected "landscape-seascape" (Boesch 1993:ii). As described above, much of the freshwater that accumulated in the Everglades during each year's wet season eventually made its way to coastal waters. The receiving areas, where freshwater mixes with salt water, are estuaries. The quantity and timing of freshwater inflows determine the fundamental water chemistry of the estuary. This chemistry, in turn, is integral to determining other physical characteristics of the estuary.

Estuaries provide habitat for a variety of plant and animal organisms. These aquatic environments are also highly productive, serving as nursery grounds for many aquatic organisms including shellfish and finfish: "At least 65 percent of all marine organisms spend some portion of their life cycle in the brackish waters of estuaries and the fringing mangrove swamp" (Veri 1975:42). However, estuaries are particularly vulnerable to degradation because they are naturally sheltered harbors and, therefore, tend to be heavily used and polluted (DCA 1994).

The South Florida Ecosystem

Many efforts recently undertaken by federal, state and regional agencies to restore the Everglades include an area that extends beyond the traditional KLOE watershed. The emerging concept of ecosystem management has driven the delineation of a "greater" Everglades ecosystem - the South Florida Ecosystem. The South Florida Ecosystem encompasses an area of approximately 10,800 square miles comprising at least eleven major physiographic provinces, including the Kissimmee River Valley, Lake Okeechobee, the Immokalee Rise, the Big Cypress, the Everglades, Florida Bay, the Atlantic Coastal Ridge, Biscayne Bay, the Florida Keys, the Florida Reef Tract, and nearshore coastal waters, arranged along a topographic gradient of 1.75 inches per mile, with elevation ranging from about eighteen feet at Lake Okeechobee to below sea level at Florida Bay (Science Sub-Group 1994:vi).

Biscayne Bay

One of the most important estuaries in the South Florida Ecosystem is Biscayne Bay. The bay is approximately 40 miles long, and is located primarily between the mainland of Dade County and a band of islands that extends parallel to the coast to the Dry Tortugas. The basin of the bay is bordered on the west by the Atlantic Coastal Ridge and on the east by another limestone ridge which comprises Miami Beach, Virginia Key, Key Biscayne and Elliott Key (SFWMD 1994a).

The Atlantic Coastal Ridge forms a natural border of high land that runs between the bay and the Everglades. The ridge historically acted as a drainage barrier between the Everglades and the bay except at its lowest areas, where freshwater could flow to the bay. During the wet season, substantial volumes of freshwater flowed through low areas in Atlantic Coastal Ridge ("transverse glades" or freshwater marshes). Additionally, freshwater reached the bay via ground water seepage.

Historically, the average depth of the Biscayne Bay was three to nine feet. Its bottom was primarily composed of sand and mud and was dominated by seagrasses. The bay's shoreline was lined by mangroves which contributed substantially to the productive estuarine habitat of the bay (SFWMD 1994a).

Early development of Florida

Pre-drainage Settlement

The location of the first permanent European settlement in what is now the United States was established at St. Augustine in 1565. However, Florida remained relatively uninhabited well into the 19th century primarily due to its remote location and inhospitable environment. In 1821, when Florida became a territory, the region was still sparsely populated. The first territorial census, conducted in 1825, counted some 12,500 persons living north and west of St. Augustine and only 317 persons in South Florida. At that time, the principal settlements were at St. Augustine, Pensacola and Tallahassee. Though the primary value of the land appeared to be in its extensive forests (which promised to supply wood for building) and its rich organic soils and moderate climate (which promised to support a wide array of agricultural products), there was no early rush to settle Florida as there had been in so many other newly formed territories. Numerous barriers stalled an early rush of settlers. The swampy, humid land of southern Florida was difficult to travel and settle. Furthermore, the Army's engagement in the brutal Seminole Wars made the area particularly dangerous for settlers (Carter 1974, Fernald 1992, and Tebeau 1980).

When Florida became a state in 1845, it had only 55,000 residents, with 90 percent of the population living north of Gainesville. By that time, agriculture formed the basis of a young and growing economy. Crops such as cotton, tobacco, rice, and sugar cane were successfully grown and marketed. Livestock production included beef and hogs. However, agricultural production in much of the state, particularly in the south, was limited by wetlands. Draining these lands to make them more suitable for agriculture became a much sought after goal and would do much to shape Florida's future and reshape its natural environment (Carter 1974, Fernald 1992, Snyder 1993, and Tebeau 1980).

Settlement of much of Florida was restricted by a lack of adequate transportation. There was very little land-based transportation in Florida prior to 1850. Most transportation was conducted along rivers and streams. As the territory's population grew and people sought to settle the interior of the state, transportation into areas remote from navigable rivers and streams became a great concern.

Improved travel by roads proved so difficult at first that much effort was directed at making existing watercourses more navigable. These efforts were hindered by a lack of funds and severe technical difficulties. Eventually, it became apparent that railroads offered the most promising solution to transportation problems. In 1836 a twenty-three mile line from Tallahassee to Saint Marks was completed. This relatively small project did little to alleviate dependence on transportation by water. Though many more projects were desired, initiation was difficult because the capital outlay required for start up was prohibitive (Tebeau 1980).

The Swamp and Overflowed Lands Act and the Internal Improvement Board

To promote economic development, land reclamation became the focus of state and federal government activities in Florida:

> The state's only ready resource was land, and land could be used to entice new settlers in the hopes of developing a viable economic base for the state. However, because much of the land in the nearly uninhabited and unknown interior of the peninsula was seasonally flooded, it was only natural that the drainage of these areas became a priority for the state (Snyder 1993:86).

In an effort to facilitate settlement, the federal government, under the Swamp and Overflowed Lands Act, declared two-thirds of the state swamp, overflowed and "unfit for civilization." Under this Act the federal government gave the state approximately 24 million acres (including 7,500 square miles of wetlands in the Everglades region). The Act specifically required that proceeds from the sale of these lands be used for reclamation. The next year the Internal Improvement Board was established to manage those lands. In 1854 the Board reported the need for a system of railroads to connect Jacksonville to Pensacola, Fernandina to Tampa and a Saint Johns-Indian River Canal. This report recommended that the state lands be used to assist private corporations to construct the needed works. The report also recommended that the Board be reorganized with the governor and other state officials as ex-officio members. In 1855 the General Assembly acted upon these recommendations and created the Internal Improvement Fund to be supervised by the governor and four other state officials - the comptroller, the treasurer, the secretary of agriculture and the registrar of lands - as trustees. Railroad and canal projects that met the approval of the trustees might receive state assistance. The approved companies would receive state assistance by being granted a 200-foot right-of-way through the state lands and alternate sections of land six miles deep on both sides of the railroad. These grants were very effective at promoting settlement and development (Tebeau 1980).

These overly generous land grants soon brought the Board to the brink of bankruptcy. "By the 1880s, 60 percent of the entire state was owned by five railroad companies, one drainage enterprise, and one man - Hamilton Disston who bought 4 million acres for 25 cents per acre" (Fernald 1992:5). Disston had agreed to "save" the Board from insolvency by buying those lands and contracting with the state to drain and reclaim land to the north and west of Lake Okeechobee. Disston's scheme envisaged the reclamation of some 9 million acres in the Kissimmee, Caloosahatchee, and Lake Okeechobee areas, principally by lowering the level of the lake and constructing channel improvements in the two rivers (DeGrove 1984).

Disston dredged the Caloosahatchee River all the way to Lake Okeechobee, making its upper reaches navigable. He also dredged the Kissimmee, deepening and straightening the river itself, and cutting canals to connect various lakes. Ultimately, only 80,000 acres were actually reclaimed by this project. Nonetheless, Disston's work made steamboat traffic possible on the Kissimmee to Lake Okeechobee and out to the Gulf of Mexico by way of the Caloosahatchee. Along with railroad construction, this opened the middle of the state to settlement and agricultural production (Tebeau 1980 and Blake 1980).

With the turn of the century, more people began to move into the central and southern portions of the state. On the east coast, a rail line was established to St. Augustine and then extended by Henry Flagler to Miami in 1896. In 1903 Flagler's line, the Florida East Coast (FEC) Railroad was extended to Homestead and, in 1912, to Key West. In central Florida and on the west coast, Henry B. Plante built a number of lines which were merged in 1902 into the Atlantic Coast Line. This created a continuous rail line from Richmond to Tampa (Tebeau 1980).

The Everglades Drainage District

Reclamation of land for agricultural and residential uses became an increasingly desired goal after the flood of 1903. In the governor's race of 1904 Napoleon Bonaparte Broward was elected on a platform that advocated full scale drainage of the Everglades to make it suitable for farming. Broward began his efforts by establishing public ownership of some 3 million acres of the Everglades. Broward then promoted drainage of Everglades by means of an extensive network of canals leading from Lake Okeechobee to the coast (DeGrove 1984).

Soon after his election, Broward created the Board of Drainage Commissioners which had the critical power to tax property owners. In 1907 he created the Everglades Drainage District (EDD). The EDD was some 60 miles wide and 150 miles long, consisted of approximately 4.3 million acres including all of the Everglades, adjoining prairie and adjacent timber lands. The taxing authority of the Board of Commissioners allowed a five cent per acre tax on drained land within the District. Work began immediately and by 1928 the basic system of canals was installed. The main works consisted of 440 miles of canals, including five major canals: the St. Lucie, the Hillsboro, the North New River, the Miami and the Caloosahatchee. The 24 mile St. Lucie was the main control canal for Lake Okeechobee, the Hillsboro (51 miles long), the North New River (58 miles long), and the Miami (85 miles long) ran from the south end of the lake to the Atlantic Ocean. Also, the West Palm Beach canal ran from the east side of the lake to the Atlantic Ocean. The Caloosahatchee Canal ran west to the Gulf of Mexico. The construction of these waterways resulted in the lowering of the level of Lake Okeechobee from 22 to 15 feet above mean sea level by 1927. Another result was the lowering of the water table in South Florida by five to six feet below the 1900 level (Carter 1974).

The Land Boom of the 1920s

Land reclamation was accompanied by a boom in land sales and settlement. The boom created a “national frenzy” and was fueled by promotions made by large land owners including the Bolles Company, the Everglades Land Company, the Everglades Plantation Company, and the Model Lands Company (Derr 1989:175). Settlers who wished to farm were enticed by promises of a “tropical paradise” possessing rich agricultural soils, providing four crops a year, and freedom from killing frosts and biting mosquitos. Many land sales made to families were of small (5-10 acre) farms. Other purchases were made sight unseen by speculators who expected to make a profit when the Everglades were drained. Though much of the land boom was caused by speculative land buying, enough new residents were enticed to the area to cause the population along the lower east coast to grow from 22,961 in 1900 to 228,454 in 1930. No where were land sales more frenzied than in Miami. (Light 1993).

In southeastern Florida, most development was originally confined to the Atlantic Coastal Ridge. This was the most favored area for development due to its higher elevation, less frequent flooding and fewer mosquitos. However, the soils of the ridge were composed primarily of sand and were less suitable for agriculture than the rich muck soils immediately to the west of the ridge. Ultimately, much low land was sold for agriculture primarily in a crescent along the southern rim of Lake Okeechobee and in Redland in southern Dade County (Carter 1974).

The land boom of the 1920s was also fueled by the growing use of automobiles. “If railroads opened the peninsula to development, automobiles transformed it, exposing more land to more people in the years following World War I than only the most fanciful promoters had considered possible” (Derr 1898:175).

Dredging and land reclamation continued until 1928 when the Florida land boom collapsed after the hurricanes of 1926 and 1928. These natural disasters demonstrated the need for better flood control, particularly around Lake

Okeechobee. The hurricane of 1928 had breached a weak eight-foot dike that held back the lake on its eastern and southern shores. As a result, 2,000 people were killed. In order to better control lake levels thereafter, the Hoover Dike was built. The dike ranged from 34 to 38 feet high and extended 140 miles around the southern rim of Lake Okeechobee (Myers 1991).

Pre-World War II Development of Southern Dade County

In many ways the settlement of Florida was shaped by Henry M. Flagler, who was responsible for extending the Florida East Coast Railroad from Daytona to Key West. Flagler is credited with building the cities of West Palm Beach, Palm Beach, Fort Lauderdale, Miami and the south Florida farming communities of Modello, Holland, Delray Beach, Deerfield Beach, Dania, Ojus, Perrine, Homestead, Kenansville, and Okeechobee (Derr 1989).

Flagler's influence on the development of Miami and South Dade was profound. The first wave of growth experienced by Miami followed the extension of the FEC railroad to the town in 1896. As a result, Miami grew from a village of several hundred people in 1895 to a town of 30,000 in 1910 and a city of 110,000 in 1920. Flagler extended the FEC to Homestead in 1903 and to Key West in 1912 (Carter 1974 and Fernald 1992).

In 1896 Flagler also established the Model Land Company to handle sales of land granted him by the Internal Improvement Board. Flagler attempted to develop a system that had each new town settled along his rail line producing cash crops which his trains could haul on their return trips to the north. Thus, Flagler's rail line hauled people and supplies south, and on return trips, brought agricultural products north. In order to make this system work, the Model Lands Company aggressively promoted agricultural development in the railroad towns of Modello, Perrine, Goulds, Princeton, Naranja, Modello, Homestead and Florida City. Eventually, Homestead was incorporated (1913) and became the commercial center of the Redland agricultural community (Derr 1989).

Dade County also experienced a wave of growth in the 1920s. Prior to this time most residential development was along the Atlantic Coastal Ridge. The ridge, approximately four miles wide, was bordered on the east by mangrove swamps and saw grass marshlands on the west. As drainage was provided, residential development began to spread west into areas that had been too wet to develop (Metro-Dade County 1993).

The predominant land use in southern Dade County was agriculture. Farms were located primarily in the Redland District which extended north of Homestead, south of Perrine and west from the FEC railroad to the Everglades. Redland gained considerable importance as the only location in the United States where exotic tropical fruits, vegetables and ornamental plants could be grown. Redland was also important as a producer of winter vegetables. Crops included avocados, papaya, lemons, limes, sapadillos, mangos, tomatoes and other row vegetables (Metro-Dade County 1993).

The tourist industry grew greatly in the 1920s and Miami became a prime destination. The city was valued by tourists for its warm winters and beautiful beaches. The Redland area was often visited by tourists who came to Miami. Day trips by automobile to the area's exotic fruit groves proved to be a popular excursion for sightseers. Tourism and agriculture was boosted further in 1927 when the CSX rail opened, running through the middle of the Redland (Metro-Dade County 1993).

The Central and Southern Florida Flood Control Project

The depression of the 1930s brought financial ruin to the EDD and an end to its major construction efforts. However, dry periods in 1930s and flooding in 1947 and 1948 eventually led to a renewed approach to water management in the Everglades. People were beginning to realize that a comprehensive water management plan was needed for the central and southern Florida regions. It was becoming apparent that the critical issue was not simply a matter of flood control but was also a matter of water supply, salt water intrusion, fish and wildlife protection and recreational uses. Restoring natural balance became an important goal. Efforts to drain the entire Everglades were abandoned. Instead, the Army Corp of Engineers (ACOE) recommended and Congress authorized the Central and Southern Florida Flood Control Project (C&SF) which would cover 15,000 square miles of southern Florida. Under this new plan the primary purposes of water management were: flood control; water supply (residential, industrial, and agricultural), prevention of overdrainage and salt water intrusion; preservation of fish and wildlife resources in the Everglades, water supply to Everglades national park; and recreation and navigation. Also under this plan the Everglades Agricultural Area (800,000 acres) was set aside on the south side of Lake Okeechobee, and 1.3 million acres of water conservation areas were also set aside (DeGrove 1984 and Science Sub-Group 1994).

The C&SF Project was designed by the ACOE. However, before construction could commence, a local sponsor was required. The Central and Southern Florida Flood Control District (which has since become the South Florida Water Management District) was created by the state legislature in 1949 to manage the works of the C&SF Project. The bulk of construction on the C&SF Project took place during the 1950s and 1960s. With an eventual cost of nearly $1 billion, the project features:

- channelization of the Kissimmee River into a 56-mile canal with control structures;
- a levee surrounding Lake Okeechobee with control structures, hurricane gates, and pumping stations;
- encirclement of the Everglades Agricultural Area by canals and levees, with seven pumping stations to provide forced drainage;
- an east coast protective levee (for urban flood control) extending from the eastern shore of Lake Okeechobee 130 miles southward to Homestead;
- local protective works along the developed lower east coast; and
- the water conservation areas west of the east coast levee with control structures to effect water transfer, including transfer to Everglades National Park (South Florida Ecosystem Restoration Working Group 1994:6).

The entire C&SF Project now includes 990 miles of levees; 978 miles of canals; 30 pumping stations; 212 flood control or water diversion structures; and secondary water management systems constructed by local interests (South Florida Ecosystem Restoration Working Group 1994).

Increased flood protection and drainage in South Dade was provided primarily through construction of the C&SF Project. Three major canals span the entire South Dade area: the

C-1 (Black Creek Canal), C-102 (Princeton Canal), and C-103 (Mowry Canal). Five other canals provide internal drainage within their respective basins: the C-100 (Cutler Drain), Military Canal (Homestead Air Force Base), North Canal, Florida City Canal, and the Model Land Canal. These canals were designed to provide flood protection by quickly moving large volumes of water away from urban and agricultural areas. Thus, construction and management of these canals decreased the incidence of flooding and allowed increased urban and agricultural uses in South Dade (SFWMD 1994b:TS-10).

The Post World War II Era

Beginning in the 1950s, Florida experienced a massive growth in population. Between 1950 and 1960 the population of Florida grew from approximately 2.7 million to 4.5 million. Many considered this growth desirable as it meant "dollars and profits, jobs and markets" (Myers 1991:vii). By the mid- 1960s, however, the damage to the natural environment caused by this growth was becoming apparent: "The extensive destruction of wetlands and beach and dune systems, the continued threat of salt water intrusion to the drinking water supplies (particularly in southeast Florida and in the Tampa Bay area), along with other negative impacts of unplanned growth, began to end Florida's love affair with growth by the mid-1960s" (DeGrove 1992:8).

South Florida clearly illustrated the "evils" of unplanned growth. Early development had tended to concentrate around major transportation routes, and though unplanned, was relatively compact and pedestrian oriented. In South Dade, development was concentrated along U.S. 1 and the FEC railroad. As late as the 1950s, urban areas tended to be well-defined and have hard edges. The heart of these areas was a highly concentrated central business district oriented to pedestrian travel. As travel by automobile became more commonplace, however, new development tended to sprawl across the landscape, into areas that were rather remote from major transportation corridors. New suburban residential development was accompanied by new suburban commercial and manufacturing development. The role of the downtown areas as employment bases began to decline and the urban pattern of South Dade was reshaped from a pattern of discrete communities connected by a major transportation route (i.e., U.S. 1 and the railroad), to one of sprawling, low density development.

Dade County experienced the greatest growth, and "the major growth that the area experienced in the period between 1950 and 1970 was basically a suburban phenomenon." Suburban Coral Gables' population grew by 215 percent, from 19,800 in 1950 to 42,500 in 1970. Hialeah grew from 19,700 in 1950 to 102,000 in 1970, a 500 percent increase. However, between 1950 and 1970, Miami grew from 250,000 to 335,000, or only 34 percent (Veri 1975:52).

Setting the Stage for Growth Management

> The use of land in southern Florida began with both courage and ignorance - courage to inhabit a land that appeared to favor fish and wildlife, and ignorance that led to the destruction of parts of the richness of the region by indiscriminate clearing, draining, and filling (Veri 1975:48).

According to Myers the "dewatering of south Florida was a giant, uncontrolled experiment" (1991:7). The consequences of this great experiment were both less than some people had hoped for and greater than others had feared. There is no doubt that early residents were disappointed that the complex and expensive system of canals and levees failed to drain the

Everglades. However, the level of Lake Okeechobee was lowered from 22 to 15 feet above sea level, drastically altering the historic pattern of sheetflow over the lake's banks and into the Everglades. During the dry season, water was diverted for agricultural and urban use. During wet years, excess water was dumped into the Everglades from the water catchment areas. As a result, the Everglades was subjected to greater extremes in drought and flood. The natural processes once experienced by the Everglades and the natural functions it once performed were disrupted.

These extremes led to a host of secondary problems. During dry seasons, muck soils oxidized and began to quickly subside. Worse yet, under extremely dry conditions, fires that were virtually impossible to extinguish, would burn the muck soils. Freshwater wells were taxed beyond their limits as the population grew. Increased withdrawals from the underground aquifer allowed salt water to intrude upon and contaminate the fresh water supplies of many coastal communities. Furthermore, as the water table was lowered and greater extremes in drought and flood were created by mismanagement of water resources, wildlife suffered badly. Huge losses of wildlife occurred as habitats were reduced to mere fractions of what they once were.

As Florida was experiencing huge losses of its natural resources, the environmental movement was gaining strength across the nation. The trend towards environmentalism in Florida was very strong. One of the problems that was most instrumental in galvanizing this movement was the issue of water supply. The droughts of 1960s and 1970s focused statewide attention on the competition for fresh water. Many residents could not understand how a region receiving some 60 inches of rainfall a year did not have enough water to meet the needs of humans, as well as those of the natural environment.

After the drought of 1961, minimum flows to Everglades National Park became a serious concern, however "the park received no significant amount of water from the [C&SF] project from 1962 until 1965" (Carter 1974:118). Biscayne Bay and Florida Bay were also threatened by lack of freshwater flows. With the drought of 1966, competition for water between Everglades national Park and farmers was also severe. The fear of future water shortages for both the Everglades and agricultural and urban users was growing. As a result, the benefits of future growth were questioned.

The drought of 1971 was one of the worst ever recorded in Florida. Fires burned over 400,000 acres of the Everglades. Thick smoke reached urban areas. Wells were contaminated by salt water. Many Floridians felt a crisis was at hand and that drastic measures were needed if South Florida was to survive the effects of rampant growth.

FLORIDA'S SYSTEM OF GROWTH MANAGEMENT

Florida's response to uncontrolled growth and widespread destruction of its natural resources was adoption of an innovative system of growth management. This system required each local government to adopt a comprehensive growth management plan which would be both internally consistent as well as compatible with those of neighboring governments.

1972 Legislation

A severe drought that began in 1970 and continued into 1971 prompted Governor Reuben Askew to convene the Governor's Conference on Water Management in South Florida in the drought's second year. This conference was a pivotal event in Florida's efforts to manage its natural resources and runaway growth. The Governor's Conference issued a short but hard-hitting report calling for a comprehensive approach in managing Florida's growth. The report emphasized the importance of wetland preservation in protecting the quality and quantity of the state's water supply. The report stated:

> There should be no further drainage of wetlands for any purpose. The need to preserve them stems from their value for recreation, water storage, aquatic productivity, nutrient removal, and aquifer recharge. A program should be initiated to reflood the marshes of the Kissimmee Valley. Agricultural lands and marshes not presently in production below Lake Okeechobee should also be reflooded. (Governor's Conference 1972:4)

The report also recommended that the population of South Florida be limited:

> There is a limit to the number of people which the South Florida basin can support and at the same time maintain a quality environment. The state and appropriate regional agencies must develop a comprehensive land and water use plan with enforcement machinery to limit population (Governor's Conference 1972:4-5).

Declaring that the state had a limited capacity for growth was a revolutionary change from Florida's traditional open-arms approach to growth. However, support for this new perspective was broad-based and very strong.

Following issuance of the conference Final Report, the Governor appointed a 15-member Task Force on Land Use. The Task Force was challenged to develop legislation that would implement the recommendations of the conference. The work of the Task Force led to the passage in 1972 of four interrelated land and water use and growth management bills.

The Environmental Land and Water Management Act (Chapter 380, F.S.) (Land Management Act) had the purpose of insuring a water management system that would reverse deterioration of water quality, provide optimum utilization of limited water resources, and facilitate orderly and well planned development. The Land Management Act focused on instances where land use decisions created impacts beyond the local level, i.e., having regional or statewide significance. The Act established a Development of Regional Impact (DRI) review process and an Area of Critical State Concern (ACSC) designation process (Blake 1980).

The State Comprehensive Planning Act's (Chapter 23, F.S.) primary goal was to provide direction and procedures relating to the "orderly social, economic, and physical growth of the state" (Blake 1980:228). The Governor was designated as the Chief Planning Officer for the state, and a Division of State Planning within the Department of Administration was created. The Division of State Planning, under the Governor's direction, was to prepare and submit to the legislature a State Comprehensive Plan.

The Land Conservation Act of 1972 (Chapter 259, F.S.) "set the stage for the development of the nation's most extensive public land acquisition program" (deHaven-Smith 1991:227). Implementation of the act allowed for issuance of $240 million in bonds to be used to acquire parks and environmentally sensitive lands.

Finally, the Water Resources Act (Chapter 373, F.S.) "was a progressive law that put Florida in the forefront nationally in managing its water resources" (deHaven-Smith 1991:227). Chapter 373 provides for: a State Water Use Plan; a Florida Water Plan; the creation of five water management districts, including the South Florida Water Management District; and the establishment of Basin Boards and Governing Boards for the water management districts. The water management districts, whose boundaries were drawn along watershed boundaries rather than political boundaries, were originally charged with flood control, water supply, and limited water quality responsibilities. Consumptive use permits assured that all users of water, including agriculture, would be subject to regulation. Surface water management permits allowed the districts to develop important policies relating to land use, including onsite retention of runoff. In the planning area, water management districts were charged with developing regional water use plans.

1975 Legislation

In 1975 the Local Government Comprehensive Planning Act (LGCPA) (Chapter 163, F.S.) was enacted, requiring every local government in Florida to adopt a comprehensive plan by 1979. These comprehensive plans were intended to facilitate orderly development. The LGCPA established minimum contents of local plans, required internal consistency between plan elements, mandated plans be economically feasible, and established ongoing procedures for planning, evaluation, and plan revision. Though originating from sound recommendations provided by the first ELMS Committee, this act lacked sufficient "teeth" to provide an effective framework for growing smart. Several loopholes and inadequacies eventually became apparent.

The law required each city and county in Florida to put a plan in place, but accomplishing this directive in the late 1970s was not as fruitful as anticipated. The state law requirements were oriented to process instead of substance and as a result the implementation requirements were weak. This process also undermined the state's credibility in mandating local planning when it failed to meet funding commitments to aid local governments' plan preparation. Furthermore, local plans were only subject to review and comment, not review and approval, at the regional and state levels. By the end of the decade it was clear that the Local Government Planning Act, even where plans and implementing regulations were in place, was not working effectively. Plans were changed willy-nilly virtually every time a city council or county commission met. Zoning continued, in effect, driving the plan rather than the plan framing zoning, subdivision regulations, and implementation mechanisms. The time was ripe for a thorough reappraisal of the system as Florida entered the 1980s. The reappraisal began in 1978 and continued until the adoption of sweeping new growth management legislation in 1984 and 1985 (DeGrove 1992:10).

1985 Legislation

Governor Bob Graham initiated new efforts to adopt effective comprehensive planning legislation in the early 1980s. He convened a second Environmental Land Management Study Committee (ELMS II) in 1982. Recommendations of this group, delivered in 1984, led to the adoption of the State and Regional Planning Act (SRPA) of 1984 (Chapter 186, F.S.) and the Omnibus Growth Management Act (GMA) of 1985. The SRPA required that the Governor's Office prepare a state plan and present it to the 1985 Legislature. The Comprehensive State Plan was adopted as Chapter 187, F.S., early in the 1985 session, requiring state agencies to prepare functional plans by July 1986. The SRPA also mandated that regional planning councils prepare comprehensive regional policy plans. In a move to correct the weak funding components of past legislation, funds ($500,000) were appropriated to support this initial planning effort, and an additional $2 million was provided in subsequent years.

The GMA contained important revisions to three key elements of the growth management system: (a) Chapter 163, Part II, F.S., establishing the Local Government Planning and Land Development Regulations Act; (b) substantial changes to Chapter 380, especially with regard to the DRI process; and (c) substantial strengthening of Florida's coastal legislation, Chapter 161, F.S.

The Chapter 163 amendment closed the missing link in the consistency requirement by mandating that all local governments prepare new or revised local comprehensive plans consistent with the State Plan, Regional Policy Plans (prepared at long last and adopted by rule before July 1, 1997), Chapter 163, and other applicable statutes and rules.

Required elements of plans

The State Department of Community Affairs (DCA) adopted Rule 9J-5, F.A.C., establishing the minimum criteria for comprehensive plans. Rule 9J-5 requires each plan to contain specific elements in general issue areas: Future Land Use; Traffic Circulation; General Sanitary Sewer, Solid Waste, Drainage, Potable Water, and Natural Groundwater Recharge; Conservation; Coastal Management; Recreation and Open Space; Housing; and Intergovernmental Coordination. The Rule was submitted to and accepted by the legislature in 1986.

Four of the required elements of comprehensive plans are intended to address natural resource conservation, including protection of wetlands systems, water quality and water supply. One of the primary purposes of the Future Land Use element is to coordinate land uses with environmental conditions such as soil types, topography, aquifer recharge areas, and floodplains. The Future Land Use element also requires consideration of available facilities such as drainage and potable water. The Conservation element has the purpose of promoting the conservation, use and protection of natural resources. The Conservation element requires local governments to adopt policies to protect and conserve the natural functions of existing marine habitat, fisheries, bays, floodplains, harbors, wetlands, estuarine marshes, beaches, and shores. The Coastal Management element addresses development impacts on coastal areas. The purpose of the element is to plan for such development, and where necessary, restrict development that would damage or destroy coastal resources. The Sanitary Sewer, Solid Waste, Drainage, Potable Water, and Natural Groundwater Aquifer Recharge element requires local governments to adopt policies and objectives intended to protect the function of natural drainage features. This element also addresses levels of service for sewer, stormwater management, and potable water. Existing facility deficiencies and future needs must be addressed in accordance with adopted LOS standards (May et.al. 1994).

Consistency

The 1985 growth management legislation (Chapter 163, Part II) incorporated a number of key policy elements, including requirements for consistency and concurrency. The policy framework of the law and the refining 1986 "glitch bill" required vertical integration of goals, policies, and implementation strategies, as well as horizontal compatibility within and among plans at the state, regional, and local levels. In order to ensure consistency, local government plans would be reviewed by DCA. Rule 9J-5 became DCA's chief yardstick for judging whether local plans were in compliance with state law, however, plans also were required to be consistent with the State Comprehensive Plan and Regional Policy Plans. In addition to vertical consistency, these local plans had to be compatible with plans of neighboring local governments (horizontal consistency) and internally consistent.

Concurrency

The requirement for concurrency is the "most powerful policy requirement of the 1985 legislation" (DeGrove 1992:16). Concurrency, as defined by Chapter 163, Part II and Rule 9J-5, requires local governments to refrain from issuing development orders unless the orders would not degrade mandated levels of service (LOS) for six kinds of public facilities. This requirement was developed in response to Florida's long-standing tradition of allowing development to outpace the provision of basic public facilities and infrastructure. Concurrency requires local governments to set levels of service standards for transportation, sewer, stormwater management, potable water, solid waste, and parks and recreation.

Compactness and Urban Sprawl

Though urban sprawl was a growing concern throughout the 1960s and 1970s, efforts to adequately address this issue in the 1985 legislation were limited. However, the State Plan did include the following language: "encourage the use of existing infrastructure," "promote infill and redevelopment," and "separate urban and rural uses." This language, along with language contained in Rule 9J-5 that authorized DCA to "discourage urban sprawl," was used by the department to develop an anti-urban sprawl policy. These policies required local governments to contain growth by either setting urban service boundaries for public facilities or by containing growth in otherwise designated urban areas. DCA supported the idea that compact development pattern promote efficient use of existing facilities and is important to natural resource protection.

DCA has developed a definition of urban sprawl:

> The term "Urban Sprawl," as it is applied by DCA in its review of local plans, is used to describe certain kinds of growth or development patterns. It refers to scattered, untimely, poorly planned urban development that occurs in urban fringe and rural areas and frequently invades lands important for environmental and natural resource protection. Urban sprawl typically manifests itself in one or more of the following patterns: (1) leap frog

> development; (2) ribbon or strip development; and (3) large expanses of low-density, single dimensional development" (DCA 1989).

It has been established that infill development leads to compact urban form. However, one problem arising from initial concurrency interpretations was its potential to conflict with compact urban development efforts including infill and redevelopment. Early interpretations of concurrency requirements had the effect of driving development to the urban fringe or rural areas where roadway capacity was available to satisfy the transportation concurrency requirement.

Land Development Regulations

Local land development regulations consistent with the adopted local plan and implementing the goals, objectives, and policies of the plan must be adopted within one year of the local government's comprehensive plan submission to DCA. A potential weakness is that these regulations are not reviewed by the DCA for consistency with the local plan unless DCA is requested to do so by an eligible party.

1993 Legislation - ELMS III

Governor Lawton Chiles created the third Environmental Land Management Study Committee (ELMS III) in late 1991. The 51 members of this committee were charged with reviewing the existing growth management system and making recommendations for its improvement. The Committee's final report made 174 recommendations, more than any other previous ELMS committee. These recommendations addressed eight general topics:

- the state role in planning and growth management;
- the regional role in planning and growth management;
- local comprehensive planning;
- evaluation and appraisal reports (EARs);
- concurrency and public facilities;
- programs that pre-date the 1985 Growth Management Act, including development of the DRI and ACSC programs;
- coastal zone management; and
- land acquisition and preservation (Community Planning Newsletter 1993).

In response to the ELMS III recommendations, the legislature passed the Planning and Growth Management Act of 1993 and the Florida Environmental Reorganization Act.

The Planning and Growth Management Act of 1993

Overall, the Planning and Growth Management Act of 1993 encourages greater coordination and vertical integration of policy, not only top to bottom, but also bottom to top. The Act re-enacted the Regional Planning Council Statute and significantly reduced the planning councils' role in the DRI process. To allow phase-out of the DRI process, the requirements for intergovernmental coordination were strengthened. The Act also refocused planning councils' attention on regional issues. New concurrency requirements for sanitary sewer, solid waste, drainage, potable water, parks and recreation, and transportation facilities were outlined. Finally, the Act contained substantial changes aimed at relaxing the transportation concurrency requirements in order to promote compact urban development patterns in downtowns, infill and redevelopment areas, and other designated urban areas inside urban service boundaries.

After much discussion of the need to update and focus the State Comprehensive Plan as the overarching policy framework for the entire growth management system, the 1993 Legislature settled on requiring the development of the growth management section of the State Comprehensive Plan. The section had been required by the original plan but had never been carried out. A State Plan Advisory Committee made recommendations with regard to the content and use of the growth management section of the State Plan, but the 1994 legislature postponed consideration of the proposed changes until 1995.

Transportation Concurrency Management Areas (TCMAs)

A new definition of transportation mobility is evolving in the 1990s - "the efficient movement of people, goods, and services from one location to another" - rather than the traditional definition of "efficient movement of the automobile from one location to another" (Taub 1993:2). This new perspective, coupled with the potential for inflexible concurrency requirements, has led to new transportation planning innovations.

One of these new innovations is the Transportation Concurrency Management Area (TCMA). This approach allows local governments flexibility in implementing their transportation concurrency requirements and establishing levels of service standards on certain urban highways. This new approach is achieved through a facility system perspective rather than the traditional piece-by-piece approach. The overriding intent of TCMAs is to encourage more innovative use of mass transit, promote alternatives to increased road-building, and discourage the one-car-one-rider phenomenon.

Florida's Rule 9J-5.0055 provides regulatory support for the TCMA approach:

> The purpose and intent of this section is to encourage planning for an appropriate mix and intensity of land uses within designated transportation concurrency management areas, and to target these areas to become primary centers for a mix of residential, retail, employment, recreation, cultural, educational, and institutional facilities. Successful use of the transportation concurrency management area approach will direct growth into development patterns that better support alternatives to single-occupant automobile transportation. It is recognized that achievement of development intensities and densities and mixed use patterns conducive to reducing dependence on single-occupant automobile travel may require a long-term strategy based on directing development into more intensive patterns coupled with an early and continued commitment to public transit and an accommodation and management of traffic congestion. Therefore, a long-term strategy may include use of level of service standards that are lower than recommended standards as long as it can be demonstrated that long-term land use patterns and development and mobility goals are integrated, internally consistent, and achievable.

Subparagraph (2) of the rule prescribes the parameters of what is termed "a transportation mobility element," the purpose of which is to:

> plan for a multi-modal, multi-option transportation system which places less emphasis on accommodating the single-occupancy vehicle and encourages the development of compact, pedestrian-oriented urban areas, promotes energy efficient development patterns, protects air quality, and provides more efficient mobility of residents and goods.

A critical component of the TCMA approach will be the required urban mobility plan, in lieu of local governments' transportation and mass transit elements (Taub 1993).

Evaluation and Appraisal Reporting Process

Section 163.3191, F.S., requires each local government to prepare a report that evaluates and appraises implementation of each local government's comprehensive plan. The Evaluation and Appraisal Report shall:

- present an assessment and evaluation of the success or failure of the comprehensive plan and its elements;
- describe obstacles or problems that contributed to underachievement;
- include new or modified GOPs needed to correct problems; and
- be submitted within six years of plan adoption.

The statute and 9J-5 constituted a "skeleton framework" for EAR content and process. ELMS III was given the task of "formulating specific recommendations regarding 'the content requirements for Evaluation and Appraisal Reports and recommended procedures for their review' by the Department of Community Affairs" (ELMS III 1992:51).

According to the ELMS III Committee, EARS should play an important role in community visioning:

> Evaluation and Appraisal Reports should be a means for identifying changed conditions, deficiencies in the existing local plan, and altered community expectations. It should be an opportunity for citizens to focus on community goals, rather than on the technical aspects of the planning program. In that respect, it should be an opportunity to articulate and incorporate a community vision into the planning process. Thus, local comprehensive plans should be evaluated in a broad context, with meaningful citizen participation (ELMS III 1992:51).

Florida Environmental Reorganization Act (FERA)

The Florida Environmental Reorganization Act (FERA) merged the Departments of Environmental Regulation and Natural Resource Protection into a single superagency, the Department of Environmental Protection (DEP). FERA consolidates laws governing wetland protection and permitting of wetland impacts into Chapter 373. This modification is intended to streamline the wetlands permitting process into a single "environmental resource permit" and allow transfer of permitting responsibility to the water management districts.

FERA also includes a mandate that DEP adopt an ecosystem approach to natural resource management. By making ecosystem management a mandate, Florida is - as it was when it adopted the Water Resources Act - at the forefront nationally in natural resource management.

A NEW PARADIGM

What is a Paradigm?

Public policy is influenced by the set of values and theories that are broadly held by the practitioners and researchers working in the relevant area of policy making. This underlying system of beliefs is often referred to as a "paradigm." That is, a paradigm is the "framework of understanding that is accepted by an entire professional community" (Cortner 1994:167). Paradigms are important because they affect how questions are framed, research is conducted, and actions are carried out. Paradigms are based upon a *consensus* of what constitutes accepted facts and theories. Thus, paradigms are strongly supported, usually "immune to criticism," and are not easily disproved or invalidated. However, on rare occasions, a paradigm may be discarded. When an existing paradigm is discarded and replaced with a new one, a paradigm "shift" is said to occur.

> A paradigm shift occurs with the accumulation of a significant body of knowledge or information that is contradictory to, or unexplained by, the accepted paradigm. In this case, a 'revolution' will occur within the discipline, new schools of thought will proliferate, and from them a new paradigm will emerge that accounts for deviations from the old paradigm (Cortner 1994:168).

A growing number of researchers and resource managers have begun to describe a fundamental paradigm shift in natural resource management.

The New Paradigm

Past attempts to properly manage the nation's natural resources have been woefully inadequate. Traditionally, natural resources located on public lands have been managed from a single user - single purpose perspective based on the legislatively determined mission of the federal, state, and local agencies involved. That is, public lands have been historically managed for purposes such as sustained yield, scenic resources, or protection of a particular animal species. This has led to a distinctively fragmented approach to natural resource management. These approaches are shaped by the individual missions of federal, state, and local agencies, and have led to the compartmentalization of duties and responsibilities as well as fierce "turf battles." Ultimately, this piecemeal approach has created a traditional paradigm of natural resource management defined by political rather than ecological boundaries, characterized by incremental decision-making, and has resulted in the loss of functioning ecosystems and a crisis in biodiversity (Dopplet 1993:59 and Grumbine 1992).

Historically, efforts to manage private lands have also been fragmented. Decisions regarding activities affecting natural resources are usually made on a case-by-case basis as requests for permits are made. Such an approach focuses on preserving fragments that have important attributes such as high biodiversity or significant populations of rare plant or animal species. Thus, on private lands preservation of functioning ecosystems has been rarely accomplished. Furthermore, this piecemeal approach fails to address the *cumulative* impacts of land development activities on natural resources. The fundamental failure of this approach to natural resource conservation is that it lacks the advance planning required to identify and protect significant natural resources. This flaw demonstrates that land managers cannot rely too heavily upon a regulatory approach. Rather, there is a need to adopt a flexible approach to resource management that utilizes a wide variety of tools.

The shortcomings of past methods of resource management have led to the recent development of a new paradigm: *ecosystem management*. Ecosystem management seeks to respond to more complex demands and pressures and relies on collaborative decision-making, cooperation, and interaction.

The Genesis of Ecosystem Management

Ecosystem management has recently received much attention and is the central theme of newly evolving resource management initiatives at both the federal and state levels. Ecosystem management "[r]egards natural phenomena such as watersheds, airsheds and wildlife habitats as the appropriate focus for management decisions," and strives to understand and manage according to structure, relationships and processes of ecosystems. However, there is still considerable debate regarding the meaning of ecosystem management, its principles and its methods of implementation (Keiter 1990:45).

The concept of managing natural resources based on natural phenomena rather than political boundaries was first advocated in the 1930s and 1940s by a few insightful ecologists. However, the concept remained rather obscure until 1970 when ecologist, Lynton Caldwell, wrote in an article titled, "The ecosystem as a criterion for public land policy," that "[a]n ecosystems approach to public land policy assumes a scope that embraces all land regardless of its ownership or custody under law" (Caldwell 1970:206). Since that time, the concept of ecosystem management has slowly gained support in the academic world, yet little understanding or support from resource managers. To this day, ecosystem management remains relatively untested: "That such an old idea remains relatively untried is a testament to the political difficulties of changing arbitrary existing management units, such as regions and municipalities, and the conceptual and practical difficulties of bridging traditional disciplinary and professional boundaries" (Slocombe 1993:612).

Clarification and definition of the concept of ecosystem management continues. Edward Grumbine, of the Sierra Institute, authored a recent literature review that presented a clear and current description of the evolving concept of ecosystem management. He has identified ten dominant themes:

1. **Hierarchical Context.** A focus on any one level of the biodiversity hierarchy (genus, species, populations, ecosystems, landscapes) is not sufficient....

2. **Ecological Boundaries.** Management requires working across administrative/political boundaries... and defining ecological boundaries at appropriate scales....

3. **Ecological Integrity.** Managing for ecological integrity is protecting total native diversity (species, populations, ecosystems) and the ecological patterns and processes that maintain that diversity. Most authors discuss this as conservation of viable populations of native species, maintaining natural disturbance regimes, reintroduction of native, extirpated species, representation of ecosystems across natural ranges of variation, etc.

4. **Data Collection.** Ecosystem management requires more re-

search and data collection (i.e., habitat inventory/classification, disturbance regime dynamics, baseline species and population assessment) as well as better management and use of existing data.

5. **Monitoring.** Managers must track the results of their actions so that success or failure may be evaluated quantitatively. Monitoring creates an ongoing feedback loop of useful information.

6. **Adaptive Management.** Adaptive management assumes that scientific knowledge is provisional and focuses on management as a learning process or continuous experiment where incorporating the results of previous action allows managers to remain flexible and adapt to uncertainty.

7. **Interagency Cooperation.** Using ecological boundaries requires cooperation between federal, state, and local management agencies as well as private parties. Managers must learn to work together and integrate conflicting legal mandates and management goals.

8. **Organizational Change.** Implementing ecosystem management requires changes in the structure of land management agencies and the way they cooperate. These may range from the simple (e.g., forming an interagency committee) to the complex (e.g., changing professional norms, altering power relationships).

9. **Humans Embedded in Nature.** People cannot be separated from nature. Humans are fundamental influences on ecological patterns and processes and are in turn affected by them.

10. **Values.** Regardless of the role of scientific knowledge, human values play a dominant role in ecosystem management goals.

These themes form the basis for Grumbine's definition of ecosystem management:

> *Ecosystem management integrates scientific knowledge of ecological relationships within a complex sociopolitical and values framework toward the general goal of protecting native ecosystem integrity over the long term.*

Clear goals are important to the process of ecosystem management. Grumbine found five goals that were consistently endorsed:

1. Maintain viable populations of all native species in situ.
2. Represent, within protected areas, all native ecosystems types across their natural range of variation.
3. Maintain evolutionary and ecological processes (i.e., disturbance regimes, hydrological processes, nutrient cycles, etc).
4. Manage over periods of time long enough to maintain the evolutionary potential of species and ecosystems.
5. Accommodate human use and occupancy within these constraints.

The concept of ecosystem management, as it has evolved, defines a quest for sustainability, and includes consideration of social issues such as economic development. Consideration of entire ecosystems allows planners to take into account the widest possible range of influences on the protected resource. This approach also allows planners to consider the future condition of the ecosystem and its sustainability. Furthermore, this new paradigm recognizes the significance of human impacts on biological systems and encourages managers to extend the scope of their work beyond political boundaries (such as national park borders) and into the adjacent built environment. Thus, ecosystem-based management of natural resources is defined on a regional scale, and includes people as an integral part of the biological system.

Integration of humans and social issues into the realm of natural resource management has made collaboration, public participation, and the development of a shared vision extremely important. Identification and inclusion of key stakeholders is critical to the success of a management strategy that strives to understand and influence human impacts on the environment. This represents a radically different and extremely difficult approach to resource management. If ecosystem management is to be successful, conservation biologists and resource managers must join forces with social scientists and begin to develop the skills required to accomplish effective community outreach.

Ecosystem Management at the Federal Level

Adoption of ecosystem management has begun at the federal level. Eighteen federal agencies including the Forest Service, National Park Service, and Fish and Wildlife Services have initiated programs that strive to incorporate the principles of ecosystem management into agency actions. In addition, an Interagency Ecosystem Management Coordination Group has been formed to foster communication and coordination among agency personnel. Each agency's approach to ecosystem management is, however, unique. The approaches are diverse in scale, focus, institutional relationships, and goals. Each is reflective of the agency's structure and culture. Nevertheless, two common themes are shared by all of the federal approaches: 1) improved coordination and communication based on forming new partnerships, information sharing, and establishment of agreements or definitions for key terms; and 2) improvement of natural resources, including protection of biodiversity (Morrissey 1994, U.S. Fish and Wildlife Service 1994, Kessler et. al. 1992, and Grumbine 1992).

The Evolution of Ecosystem Management in Florida

In Florida, the Department of Environmental Protection (DEP) has begun a process of defining and implementing an ecosystem-based approach to natural resource management. DEP is a newly formed "superagency," established by the merger of the Departments of Environmental Regulation and Natural Resources in 1993. The Florida Environmental Reorganization Act, which created DEP, required that the newly formed department develop and implement measures to "protect the functions of entire ecological systems through enhanced coordination of public land acquisition, regulatory, and planning programs."

DEP has adopted a "working" definition of ecosystem management:

> Ecosystem management is an integrated, flexible approach to management of Florida's biologi-

cal and physical environments - conducted through the use of tools such as planning, land acquisition, environmental education, regulation and pollution prevention -designed to maintain, protect, and improve the State's natural, managed, and human communities (DEP 1994b).

The department's program is based on three fundamental goals:

- better protection and management of Florida's ecosystems;
- agency structure and culture based on a systems approach to environmental protection and management; and
- an ethic within the citizenry of shared responsibility and participation in protection of the environment (DEP 1994b).

DEP recognizes that intergovernmental coordination is essential to accomplishing ecosystem management. The department also recognizes the need for a "new public ethic of shared responsibility" and that "government alone is not going to save the state; the public must pitch in" (McVety 1994). Thus, DEP's approach to ecosystem management relies heavily on collaboration, cooperation and public participation. DEP predicts that its approach to ecosystem management will result in "a new era of cooperative action between all levels of government and the public resulting in identification of shared goals and implementation of integrated planning and management across political boundaries. A true partnership between the citizens of the state and their government, in which all parties recognize a common responsibility for the environment and share a commitment to active involvement in its protection" (DEP 1994b).

Twelve committees comprised of governmental and non-governmental participants will share the work required to implement a statewide ecosystem approach to resource management. These committees are: Ecosystem Management Implementation Strategy, External Steering, Land Acquisition/ Greenways, Education, Incentive-Based Regulatory Alternatives, Pollution Prevention, Science and Technology, Public Land Management, Role of Private Landowners, Intergovernmental Coordination, Training, and Audit/Evaluation.

Currently, DEP is in the process of developing an Ecosystem Management Implementation Strategy (EMIS). The EMIS will serve as a guidance document that is closely tied to local government comprehensive plans, regional policy plans, water management district Water Plans, the Florida Water Plan, and other related plans. The process of developing the EMIS involves considerable public participation. Completion of the EMIS is set for March 1995. A period of public comment and revision, as needed, will follow.

The detail needed to guide ecosystem management activities will be provided by Area Implementation Strategies (AISs). AISs will be developed through a joint effort of DEP and the water management districts. Development of AISs will also involve local, state, and federal agencies, regional planning councils, environmental groups, the business community, and the public. According to DEP, AISs will stress shared public/private responsibility for environmental protection. Also, "as part of the AIS development process, each team, under the guidance of the water management districts, will determine the need and a schedule for establishing minimum flows and levels and protection areas for priority water bodies" (DEP 1994b:38).

Florida is moving quickly to embrace an ecosystem-based approach to natural resource management. The Ecosystem Management

Approach, as adopted by DEP, stresses management based on ecological boundaries that extend beyond political boundaries, intergovernmental coordination, and public participation. Florida's approach to ecosystem management is also mindful of the need to achieve sustainability by embracing human, social, economic, and political considerations. Rather than focusing solely on the management natural systems, the state is now taking a more holistic approach. This broad approach includes efforts that focus on managing human activities as a means of managing natural systems.

EXAMPLES OF WATERSHED AND ECOSYSTEM MANAGEMENT

Though the concept of ecosystem management has existed for over five decades, implementation of its principles is a relative new phenomenon. In spite of its relatively short history of implementation, there are a handful of existing examples of ecosystem management that may be examined for their strengths and weaknesses.

The Crown of the Continent and the Australian Alps

Several examples of watershed protection and ecosystem management are described by D. Scott Slocombe in his article, "Implementing Ecosystem Based Management" (1993). Among the case studies described by Slocombe are the Crown of the Continent (Waterton and Glacier National Park Biosphere Reserves) in Alberta and Montana, and the Australian Alps.

The Waterton and Glacier National Parks are adjoining biosphere reserves that encompass 1,839 square miles in southwestern Alberta and north-central Montana. Both parks are home to a diverse mix of vegetative communities, geological formations, and wildlife. Notably, the environmental importance of this biosphere has been recognized and protected by both the United States and Canada since the turn of the century.

The parks' overall health is threatened by a myriad of adverse human-produced impacts including tourism, mining (coal and gas), ranching, and forestry. In addition to developmental impacts, management difficulties are exacerbated because the protected area cannot be classified as a complete ecological unit. The Waterton and Glacier National Parks form an island surrounded by other protected areas that are either managed by independent agencies with conflicting agendas or by privately owned parcels. This scenario has resulted in management conflicts that created a strong need for collaboration.

To date, ecosystem management efforts in the Crown of the Continent have achieved a measure of success. The Crown of the Continent ecosystem has been roughly defined, and an interagency Crown of the Continent Board and Ecosystem Center proposed. The

Board's membership will include representatives of government and citizen groups. This effort exemplifies the current trend toward interagency cooperation and redefinition of the management unit in order to foster the creation of new institutional units that go beyond entrenched political boundaries.

The Australian Alps region offers a relatively successful example of coordinating governmental management over a large multi-jurisdictional area. This region covers approximately 9,660 square miles, including 5,910 square miles of contiguous national parks. The Alps geographic boundaries extend from the Brindabella Ranges of the Australian Capital Territory and New South Wales (NSW) through the Snowy Mountains of NSW, and into the mountains of northeast Victoria. The wide variety of terrains and weather systems in the Australian Alps create habitats for a rich mixture of plant life and animal species. The region is also home to many significant historical and archeological sites, contributing to its indisputable national and international historical and ecological significance. The Australian government manages this area as an entire ecosystem through a system of protected areas defined as a set of watersheds. Each national park is managed by the appropriate state or territorial government, with the federal government providing some oversight in critical areas of environmental concern, such as management of migratory species.

The present system of interagency management in the Australian Alps took nearly 50 years to evolve. First, park and management systems were stabilized, and a constituency supportive of an interagency network was built. These initial steps were followed by a period of conflict resolution, primarily related to grazing, hydroelectric, and skiing development. Subsequent stages included conceptualization of the interagency relationship, implementation, and professionalization. These stages spanned nearly two decades. Finally, community involvement and political pressures in the 1980s led to the end goal of integrating management activities. Implementation of this cooperative management is guided by the Alps Liaison Committee, a group of senior administrators from the governments involved. Fine tuning the management relationship of the various government agencies is necessarily an ongoing process.

Management of the Australian Alps region also demonstrates effective application of the principles of ecosystem management. Management of the Alps is based upon ecological boundaries - a system of protected areas defined as a set of watersheds which embrace the entire landscape. The place of humans in the landscape is also considered. Conflicts have been addressed and public participation has been encouraged. Finally, intergovernmental coordination has been fostered through the Alps Liaison Committee.

Management of the Chesapeake Bay Ecosystem

The following descriptions of the Chesapeake Bay and Great Lakes systems provide a more detailed analysis of two different approaches to ecosystem management. Both approaches center around water bodies and their watersheds.

The Chesapeake Bay is the largest estuary on the North American continent. The bay has a surface area of 2,200 square miles and average depth of only 21 feet. Fed by 150 tributary rivers and streams, the bay supports over 2,500 species of plants and animals as well as 13 million people. The entire watershed covers more than 64,000 square miles. The size of the Chesapeake's watershed renders it particularly vulnerable to damage. Numerous sources of degradation, many caused by land-based activities, are present within the watershed. For example, sprawling development has consumed thousands of acres of farm and forest lands, resulting in a general reduction of the bay's productivity (EPA 1991).

The Bay's health is a critical factor in maintaining the quality of life area residents expect. Further, this natural resource is an integral part in both the economy and recreation of the region. Thus, it is of great public and private concern that the Chesapeake Bay watershed has experienced serious ecological decline for decades. Recently, these problems have been addressed in a manner that demonstrates effective application of the principles of ecosystem management: integrating science into the governing and planning processes, widespread and coordinated monitoring and adaptive management, public participation, and interagency collaborative decision-making.

Early strategies aimed at dealing with the bay's problems were based on public education and participation. The Chesapeake Bay Foundation, a non-profit organization established in 1967, was created to help save the bay through public education and advocacy. This group now boasts 80,000 members, a staff of 120, hundreds of active volunteers, and offices in Maryland, Pennsylvania, and Virginia (Horton 1991).

The initial phase of growing public awareness was followed by a phase of intense data collection and analysis and interagency coordination. In 1977, Congress directed the U.S. Environmental Protection Agency (EPA) to investigate the causes of the bay's decline. Early intergovernmental coordination efforts included creation of the Chesapeake Bay Advisory Committee in 1978. In 1980 the Chesapeake Bay Commission, composed of ten state legislators from Maryland and Virginia, was created. The Commission was responsible for developing a cooperative agreement between the two states to clean up the bay (EPA 1991).

In 1983, the EPA's $27 million six-year study was completed and led to the signing of the first Chesapeake Bay Agreement. Under the 1983 Chesapeake Bay Agreement, the EPA, the Chesapeake Bay Commission, and the governments of Virginia, Maryland, Pennsylvania, and the District of Columbia agreed to develop and implement coordinated plans to improve and protect the bay's water quality and living resources. Tom Horton describes the meeting of the Agreement's signatories as "historic" because "for the first time, all these jurisdictions formally conceded that the bay was in decline and human activities were causing it. Jointly they committed themselves that day to halt and reverse the damage - a task they acknowledged would take years, even decades" (Horton 1991:xxii).

The Agreement established the Chesapeake Bay Program. Under the program, the Chesapeake Executive Council (comprised of the governors of Maryland, Pennsylvania, and Virginia, the mayor of the District of Columbia, the Chairman of the Chesapeake Bay Commission, and the administrator of the EPA) oversees implementation of basin-wide protection plans. A principals' staff committee of cabinet level officials provides support for this Executive Council. A 28-member Implementation Committee supervises day-to-day program direction through eight subcommittees. Furthermore, three separate committees provide advisory support to the Executive Council and continually reinforce the broad network of communication needed between government, science, and the public. These committees are: Citizens Advisory

Committee, Scientific and Technical Advisory Committee and the Local Government Advisory Committee. Another group of three committees address specific areas or needs: Federal Agencies Committee, Budget & Workplan Steering Committee, and the 1991 Nutrient Reevaluation Workgroup (EPA 1991).

The Agreement led to other attempts to revitalize the bay. Maryland adopted the Critical Area Protection Act of 1984 which called for protection of lands most intimately in contact with estuary: shorelines, marshlands, and submerged lands. It specifically targeted a "critical zone" in the first 1000 feet inland from the Bay's mean high water line, and required preparation of local critical area plans in accordance with criteria established in state legislation and regulations. Implementation of this act is overseen by the Chesapeake Bay Critical Area Commission (Chesapeake Bay Critical Area Commission 1993).

The Maryland Act had a limited effect on surrounding land uses; however, it did lead to improved agricultural management practices, upgrading of sewer treatment plants, increased compliance with industrial waste disposal standards, and increased control of non-point source pollution (Maryland Sea Grant Program 1991). In spite of the Act's considerable success, there is a growing concern that its progress will be erased if growth adds 2.6 million new residents by 2020, as projected (1991 Horton).

In 1987 a second Chesapeake Bay Agreement was signed. The 1987 Agreement expanded the scope of the previous agreement by outlining 29 commitments for action in six areas: living resources; water quality; population growth and development; public information, education and participation; public access; and governance. The Population Growth and Development Goal was to: "[p]lan for and manage the adverse environmental effects of human population growth and land development in the Chesapeake Bay watershed." In partial fulfillment of this goal a twelve-member Year 2020 Panel of experts was established to examine the consequences of population growth and development for the Chesapeake Bay watershed. The 2020 Panel was made up of representatives from Virginia, Maryland, Pennsylvania, the District of Columbia, the EPA, and the Chesapeake Bay Commission.

The panel's 1988 report: *Population Growth and Development in the Chesapeake Bay Watershed to the Year 2020*, concluded that "[w]ater quality is inextricably linked to population growth... [P]rocedures currently being used throughout the Bay region for managing and providing for growth and development are inadequate, and must be quickly changed if current trends are to be reversed.... Scattered unplanned development is wasteful and expensive, and generates greater net pollution than more rational patterns of development" (Year 2020 Panel 1988:1). The 2020 panel developed a series of six visions that would be implemented in part through the adoption of a Comprehensive Development and Infrastructure Plan by each local government involved in the Chesapeake Bay Agreement. The panel's vision of the region in 2020 included: development concentrated in suitable areas; protected sensitive areas; growth directed to existing population centers in rural areas and protected resource areas; stewardship of the Bay and the land as a universal ethic; conservation of resources, including a reduction in resource consumption, practiced throughout the region; and funding mechanisms in place to achieve all other visions (Year 2020 Panel 1988).

Each of the jurisdictions had different responses to the Panel 2020 report. Maryland, at the forefront of watershed protection, created the Governor's Commission on Growth in October 1989. Governor's Schaefer's charge was to "reconcile rapid economic growth and development with the conservation of Maryland's natural resources and the preservation of the state's unique way of life" (Governor's Commission on Growth in the Chesapeake 1991:8). This Commission presented a report that included five basic recommendations:

- Designate suitable areas for growth - Limiting new growth to already-developed areas or designated growth areas.
- Protect Sensitive Areas - focusing on Critical habitats for endangered species, stream buffers, 100-year floodplains, and steep slopes.
- Conserve Natural Resources through limited development.
- Make stewardship of the environment a universal ethic.
- Provide funds to achieve the recommendations.

The 2020 Panel also recommended enacting a law establishing a statewide land classification system. The proposed act, the Maryland Growth and Chesapeake Bay Protection Act of 1991, was intended to designate certain areas as suitable for growth, prohibit development in sensitive habitat areas, and limit growth in rural areas. The heart of the proposed legislation, establishment of the land use management classification system and the development of rules to guide county and municipality initiatives, would supersede any local land use categories presently in use. The Maryland Office of Planning would be required to review and approve all local land classification plans, greatly expanding Office of Planning authority. However, the act met with much disapproval from developers, property rights activists, and advocates of home rule. Ultimately, the legislation died in committee in 1991 (Haynes nd).

During the 1992 legislative session, a second attempt to adopt growth management succeeded. The Economic Growth, Resource Protection, and Planning Act of 1992 is weaker than the 1991 proposal, however, it incorporated into the statutes the recommendations of the Governor's Commission. The concept of stewardship of the Chesapeake as a universal ethic was included as a vision for guiding growth and development. With this adopted system, Maryland is ahead of the other watershed states, Virginia and Pennsylvania, as well as the District of Columbia in growth management planning. Thus, if the Chesapeake Bay is to be protected from future population growth and sprawling development, the challenge remains for these jurisdictions to adopt similar systems of growth management legislation (DeGrove 1992).

The efforts undertaken to protect and enhance the Chesapeake Bay provide good demonstrations of many of the principles of ecosystem management: a focus on ecological boundaries, support of public participation, consideration of the humans and their values, extensive data collection and monitoring, intergovernmental coordination, and organizational change. Yet, this approach has been focused primarily upon activities and sources of degradation that are adjacent to rivers, streams, creeks and other wetlands. The area's resource managers have come to realize that the advances gained by this approach will easily be lost to future population growth and development that is projected for the entire watershed. Efforts are now focused on adopting systems of growth management that control land use patterns within the entire watershed. These patterns of land use would direct development away from rural and sensitive areas and into less sensitive areas that already support significant development.

Management of the Great Lakes-St. Lawrence Basin Ecosystem

The basin of the St. Lawrence River and the Great Lakes is the largest linked fresh water sea in the world. Administration of this region includes two nations, eight states, two provinces, and many municipalities, counties, and townships. The enormous size of the Great Lakes basin contributes to the complexity of its governance and management frameworks. Located on the international border between Canada and the United States, the Great Lakes cover 94,281 square miles. The lake system's drainage basin covers 201,635 square miles and serves as the headwaters for the St. Lawrence River system. Moreover, the system contains eighteen percent of all the fresh water found on the Earth's surface. The size and magnitude of this system clearly indicates its global significance (Leith 1989 and Thomas 1988).

The Great Lakes-St. Lawrence system is located in the heart of an urban industrial area that supports a population of 38 million people.

> The United States portion of the basin produces one-sixth of the national income and accounts for over one-fifth of manufacturing employment and capital expenditure. In Canada the figures are more dramatic, for the basin produces nearly one-third of the national income and accounts for over one-half of the manufacturing employment and capital expenditure. Basin agriculture accounts for seven percent of all United States output and 25 percent of total Canadian output (Dworsky 1988:62).

As with the Chesapeake Bay, the quality of the Great Lakes system began to decline as man settled within its watershed. At first, water pollution, erosion and navigation problems were very localized. Today, the lakes system is experiencing problems on a regional scale, affecting all jurisdictions (Caldwell 1988).

Early awareness of the Great Lakes' decline and ensuing disputes over its use and protection led to adoption of the binational Boundary Waters Treaty of 1909. The treaty was used mainly to control navigation, water withdrawals, and water levels. It also contained a provision forbidding pollution of boundary waters. To oversee these activities, the International Joint Commission (IJC) was formed and was composed of three American and three Canadian members. The IJC is the most prominent binational organization shaping public policy in the Great Lakes basin. However, the IJC has a small budget and very limited authority. Its major responsibility lies in making recommendations to appropriate governments. Often, the IJC's recommendations have gone unheeded (Milbrath 1988 and Donahue 1988).

Since the mid-1970s there has been a call to manage the Great Lakes and St. Lawrence River on an ecosystem basis. However, efforts to implement such an approach have been only mildly successful. According to Lynton Caldwell, who has advocated a nationwide ecosystems approach since the late 1960s, "[t]here is much greater agreement that a basinwide ecosystem approach is needed [in the Great Lakes basin] than there is on how to achieve it" (Caldwell 1988:2).

Following a report completed by the IJC in 1970 on eutrophication of the lakes, the 1972 Great Lakes Water Quality Agreement (Agreement) was signed by the U.S. and Canada. Five years later, the Agreement was reviewed and revised after two somewhat negative reports were published. The IJC had requested that the Great Lakes Research Advisory Board provide advice on the possibility of adopting an ecosystem approach to management of the Great Lakes. The Advisory Board's report *The Ecosystem Approach* and another report, the final report of the Pollution from Land Use Activities Reference Group, provided recommendations for revising the 1972 Agreement. These two reports paved the way for adoption of an ecosystem approach subsequently incorporated into the 1978 Great Lakes Water Quality Agreement. The intent of the 1978 agreement clearly requires adoption of an ecosystem approach. The 1978 Agreement directs the two parties to the IJC to "restore and maintain the chemical, physical, and biological integrity of the waters of the Great Lakes Basin Ecosystem" (Donahue 1988, Thomas 1988, Caldwell 1988).

Another attempt at intergovernmental coordination and cooperation was made through the creation of the Great Lakes Basin Commission (GLBC). The GLBC, organized under the Water Resources Planning Act of 1965 "provided an important (but incomplete by itself) institution to forward the idea of Great Lakes Basin integrated ecosystem management" (Dworsky 1988:98). The commission, made up of representatives from the eight basin states and two provinces, promoted the concept of comprehensive, coordinated, and joint planning for the basin through the publication of its twenty-seven volume *Great Lakes Basin Framework Study*. Significantly, the study concluded, "[i]n sum, the critical deficiency in the Great Lakes Basin is that institutional arrangements for arriving at a political consensus do not exist" (Donahue 1988). The Commission's work ended with its sunset in 1981 (Dworsky 1988).

The Great Lakes Commission (GLC) was established through an eight-member interstate compact in 1955. The member states are Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania, and Wisconsin. The GLC was given direction by the U.S. Congress in 1968 to "promote the orderly, integrated, and comprehensive development, use, and conservation of the water resources of the Great Lakes Basin" (Article I, Great Lakes Basin Compact). The compact includes the following objectives:

- To plan for the welfare and development of the water resources of the Basin as a whole as well as for those portions of the Basin which may have problems of special concern.
- To make it possible for the states of the Basin and their people to derive the maximum benefit from utilization of public works....
- To advise in securing and maintaining a proper balance among industrial, commercial, agricultural, water supply, residential, recreational, and other legitimate uses of the water resources of the Basin.
- To establish and maintain an in-

> tergovernmental agency to the end that the purposes of this compact may be accomplished more effectively (GLC 1993:2).

The GLC is comprised of three to five representatives from each of its member states. Having no regulatory authority, the GLC's three principle functions are: information sharing among the Great Lakes States; coordination of state positions on issues of regional concern; and advocacy of those positions on which the states agree (GLC 1993).

In 1982 the Council of Great Lakes Governors was established. The council, composed of the governors of the six westernmost Great Lakes States, provides a "forum for identifying, discussing, researching, and formulating policy on various regional economic and environmental issues of common interest" (Donahue 1988).

Clearly, there are numerous organizations through which management of the Great Lakes is possible. However, a comparison of the membership, authority, functions, and geographic jurisdictions of four of the most prominent, the IJC, CLBC, GLC and Council of Governors, demonstrates that there are fundamental conflicts and inconsistencies between these organizations. Effective intergovernmental coordination has been stifled by these differences. In sum, a mechanism for accomplishing ecosystem wide coordination has not yet been developed.

In 1985 an attempt was made by the Council of Great Lakes Governors to address the issues of navigation, recreation, hydroelectric power, and water allocation in a coordinated and cooperative manner through the adoption of the Great Lakes Charter. Under the charter, the Great Lakes States and the Provinces of Ontario and Quebec agreed to the following principles:

- The planning and management of the water resources of the Great Lakes Basin should recognize and be founded upon the integrity of the natural resources and ecosystem of the Great Lakes Basin. The water resources of the Basin transcend political boundaries within the Basin, and should be recognized and treated as a single hydrologic system. In managing Great Lakes Basin waters, the natural resources and ecosystem of the Basin should be considered as a unified whole.

- The signatory States and Provinces agree that new or increased diversions and consumptive uses of Great Lakes Basin water resources are of serious concern. ...[t]he States and Provinces agree to seek (where necessary) and to implement legislation establishing programs to manage and regulate the diversion and consumptive use of Basin water resources.

- It is the intent of the signatory States and Provinces that no Great Lake State or Province will approve or permit any major new or increased diversion or consumptive use of the water resources of the Great Lakes Basin without notifying and consulting with and seeking the consent and concurrence of all affected Great Lakes States and Provinces.

- The Governors and Premiers of the Great Lakes States and Provinces commit to pursue the development and maintenance of a common base of data and information regarding the use and management of Basin water resources, to the establishment of systematic arrangements for the exchange of water data and information, to the creation of a Water Resources Management Committee, to the development of a Great Lakes Water Resources Management Program, and to the additional and concerted and coordinated research efforts to provide improved information for future water planning and management decisions (Great Lakes Charter 1985).

The agreements made under the 1985 Charter may enhance attempts to manage the Great Lakes on an ecosystem wide basis. It is still too early to tell. However, the barriers erected by the political boundaries and mandates may prove to be too great to bridge. Many of those involved in Great Lakes management have recently called for abandoning the concept of legislatively solving problems of intergovernmental cooperation and coordination. The new paradigm is "a *commitment* to the cooperative management of a shared resource... a commitment that must be fostered within each individual involved." That is, "fostering an ecosystem consciousness in the region is perhaps more important than investigating an institutional design for the same purpose" (Donahue 1988:135).

In response to this newly advocated approach, the Great Lakes Commission drafted a binational charter that promotes an "ecosystem consciousness." The *Ecosystem Charter for the Great Lakes-St. Lawrence Basin* describes the problem faced by the Great Lakes region in the following manner:

> Many of our laws, programs, policies and institutions support the concept of an ecosystem approach, yet application of the concept is difficult due to their often narrow, single media or issue specific mandates. The problem is the absence of a single, clearly articulated statement - or charter - that explicitly defines goals for an ecosystem approach to management and ties a common thread through these many activities and mandates (GLC 1994).

The *Ecosystem Charter* advocates an ecosystem approach to management and "summarizes in a concise and convenient form, commonly held principles drawn from existing laws, treaties, agreements and policies." The Charter includes a vision statement and a series of actions that all members of the community can endorse or undertake. The Charter is meant to be signed by any public or private entities that wish to do so. The document does not legally bind those who sign it to any action. Rather, it is a "good faith" agreement that promotes an ecosystem approach to management in the Great Lakes-St. Lawrence Basin (GLC 1994).

Though the concept of ecosystem management has been advocated in the Great Lakes region since the late 1970s, its future is uncertain. Past attempts to adopt an ecosystem-based approach to management have failed miserably. The fundamental weakness of natural resource management in the Great Lakes Basin has been the stakeholders' inability to adopt an overarching institutional framework for implementation. The experience of the Great Lakes demonstrates the formidable barriers erected by political boundaries. A binational governmental framework for carrying out an ecosystem-based approach to watershed management has been impossible to forge. In an effort to circumvent this barrier, efforts are now being focused on the public. The Great Lakes Commission is, through an *Ecosystem Charter for the Great Lakes-St. Lawrence*, fostering a public commitment to management of a shared and highly valued resource. Today, the fate of Great Lakes rest squarely on the shoulders of the watershed's residents.

FLORIDA'S GROWTH MANAGEMENT AND PROTECTION OF NATURAL RESOURCES: STRENGTHS, WEAKNESSES, AND GAPS

Florida's Growth Management system strives to provide effective protection for all of the state's natural resources. However, its ability to protect entire ecosystems is extremely limited. In theory, the system's regional approaches to growth management, through designation of Areas of Critical State Concern (ACSC) and through special review of Developments of Regional Impact (DRI), could be effective means of implementing ecosystem-based approaches to natural resource protection. In practice though, these approaches have been less than effective in providing protection to whole systems. On the local level, where individual development approvals are sought, Florida's growth management laws allow a piecemeal approach based on municipal and county boundaries, and fail to take into account the cumulative effects of individual development approvals on ecosystems.

Nevertheless, the original intent of the framers of Florida's growth management legislation was to provide the state's natural resources with strong legal protection. Coincident with the growing strength of the environmental movement nationwide in the 1960s, Florida began its efforts to strengthen its environmental protection laws. The first laws to attempt a comprehensive approach to managing growth and protection of natural systems were the products of the Governor's Conference on Water Management in South Florida, as noted above.

An Aggressive Beginning: The Governor's Conference on Water Management

The Governor's Conference policy statement featured a number of powerful recommendations that, had they been fully implemented in the 1970s, would have moved the state far along the road toward a mandatory comprehensive planning and land development regulation approach for coping with massive population increases. Joined with this approach were strong recommendations regarding the protection of wetlands, and the development of land and water management plans that were regional in scope, and that had the "teeth" to assure their implementation. The ELMS I recommendations for mandatory local planning were aimed at ending the "planning in isolation" syndrome afflicting individual cities and counties. Local plans were to be internally consistent, and compatible with neighboring local governments. What follows, drawing from the overview of Florida's growth management system that frames this analysis, is an examination of the strengths, weaknesses, and gaps that became all too clear by the end of the first decade of implementing the legislation passed in the early 1970s.

A Regional Approach to Resource Protection: ACSC and DRI

The 1972 and 1975 set of laws broke sharply with Florida's past by giving state and regional agencies limited but significant oversight over certain actions of local government. The requirement that particular local government actions having a "greater-than-local" impact be subject to regional and statewide review (and possible rejection) was a giant step in the direction of comprehensive state and regional planning as well as implementation of goals that could be based on an ecosystem/comprehensive land and water management approach.

One of the mandates of the 1972 legislation was that the Governor, as Chief State Planning Officer, and the newly established Division of State Planning, prepare a comprehensive state plan that would set the goals and policies framework for the implementation of the other statutes passed in 1972, especially the Environmental Land and Water Management Act (Chapter 380, F.S.) and the Water Resources Act (Chapter 373). The failure to develop such a plan in a timely manner and to have it acted on by the legislature, substantially weakened the effectiveness of the Land and Water Management Act, and to some extent the Water Resources Act.

Areas of Critical State Concern. An assessment of the Land Management Act, through its two key components, Areas of Critical State Concern and Developments of Regional Impact, reveals both the strengths and weaknesses of Chapter 380. The ACSC provision clearly had the potential to apply a comprehensive planning/ecosystem based approach to reconciling the negative impacts of growth with the protection of natural systems. The first three designated ACSCs were large enough to allow an ecosystem approach, and the power of the state to oversee the management of growth so as to protect and restore natural systems were sufficient to the accomplish the task. The first ACSC, the Big Cypress (1973), contained some 800,000 acres; the second, the Green Swamp (1974), about 400,000 acres, and the third, the Florida Keys, contained all of the chain of islands making up the Keys, some 60,000 acres.

The Principles for Guiding Development that were mandated to be incorporated into local plans *and* implementing land development regulations contained much of the needed goals, policies, and implementing framework for a managed growth/ecosystem approach. Subsequent Resource Planning and Management Committees (RPMCs), established in 1979 amendments to Chapter 380, contained a defined geographic area and mandated goals and implementing actions that were also comprehensive and contained all or substantial parts of ecosystems. When tough-minded assessments of the implementation of these promising designations began in the early 1980s, a sad and sorry tale of underfunding, and an unwillingness by the state to use its authority to assure full implementation of Principles for Guiding Development was painfully evident. Efforts to correct these deficiencies have not been fully successful. Furthermore, a meaningful State Comprehensive Plan was not in place to guide the selection of critical areas. The ACSC section of Chapter 380 did focus attention in a comprehensive way on flood plains, river valleys, and coastal ecosystems. Although some positive achievements can be documented, on balance, a very important ecosystem management tool has not been fully utilized. (For a detailed account of efforts to use the critical area approach, the emerging weaknesses and efforts to correct them, see DeGrove, J. 1984. *Land, Growth and Politics*, Chapter Four, pp. 130-151 and Degrove, J. 1988. Critical Area Programs in Florida: Creative Balancing of Growth and Environment. *Journal of Urban and Contemporary Law* 34:51-97).

Developments of Regional Impact. The second provision of the Land Management Act, Developments of Regional Impact, required local governments to look beyond their own borders to regional or even statewide impacts of development that had "an impact on the citizens of more than one county." The famous (or infamous) DRI process had very positive impacts on the character and quality of individual developments, including the protection of wetlands or other natural systems. The concept of assessing *regional* impacts of development by a *regional* agency to assure that local governments mitigated negative impacts (along with the ability of the State Planning Agency or the relevant regional planning council to appeal a local government action to the State Administration Commission) had the potential to move the state towards regional management *not* constrained by the political boundaries of local governments.

For all its positive impacts on particular developments, the DRI system has severe limitations in bringing a broad, comprehensive planning/ecosystem approach to development. It was never envisioned that more than approximately 10 percent of all development in the state would come under the DRI process. However, the triggering thresholds for magnitude, character, and location were sufficiently high that in many areas the amount of development coming under DRI review was significantly lower than 10 percent. On the positive side, many counties adopted "little DRI" processes that extended the domain of the DRI approach (such as Dade County). On the negative side, the DRI process was not able to pick up the cumulative impacts of development under DRI thresholds. This undermined severely the whole concept, especially in the absence of local plans and strong development regulations.

In identifying weaknesses in the "greater-than-local" concept that underlies the Land and Water Management Act, none is so substantial as the failure to bring *land* and *water* management elements into harmony with each other through some kind of integrative effort. When the DRI process was first implemented in 1973, the state Senator who guided the Land and Water Management Act through the legislature and the chairman of the Task Force on Land Use, both urged that in at least one region of the state, the DRI process be administered by a water management district with input from the relevant regional planning councils. The clear purpose of this recommendation was to bring about an integration of land and water management practices; an absolute prerequisite to a successful ecosystem approach to protecting natural systems. The failure of the state to carry out that recommendation began a long line of failed efforts to bring land and water management together in a full and integrated fashion. Numerous task forces, committees, and commissions have addressed the issue; several have recommended some partial or complete merger of water management districts with regional planning councils, others have been content with recommending greater coordination between the two key regional agencies in land and water management, and we are now awaiting the recommendations of the latest effort, the Governor's Land Use and Water Planning Task Force. Successful reconciliation of development and resource protection goals through a sustainable development/ecosystem approach cannot be achieved until this problem is solved.

Linking Water and Land Use Planning

The companion problem (and until the 1993 legislative session equally resistant to solution), the efficient joining of water quality and water quantity will be addressed below. The landmark set of laws in 1972 included one which, given its potential for integrating water quantity and quality as well as land and water resource issues, may have been the most important statute of the 1972 set of four laws. The Water Resources Act, in both its preamble language and in other language in the law, is broad enough to allow water management district governing boards to direct staff to consider water quality *and* land use implications of its directly mandated tasks. For the three districts in the most populous areas (South Florida Water Management District, Southwest Florida Water Management District, and St. John's River Water Management District) and the Suwanee River Water Management District, in a sparsely populated area, these mandated tasks included the granting of surface water management permits in connection with all development not specifically exempted. Here the link between land and water management is clear, but the water management districts have not been eager to expand their involvement in land use. Furthermore, the links between the water use plans of the water management districts and the comprehensive plans and land development regulations of local governments, have not been consistently achieved. Repeated calls for consistency, or at least compatibility, between local plans and regulations and water management district plans and regulations have either fallen on deaf ears, or have been achieved sporadically in one water management district or another.

A variety of factors, too numerous to detail here, have caused the failure to address this issue. Both water management district governing boards and staff have been typically reluctant to enter the "land use" thicket in any direct way. This has been so despite recognition that neither level of government can manage growth and protect natural systems unless both the water management districts and local government plans are compatible. Local governments have been just as reluctant to have water management districts tell them "what they can and cannot do." Again a number of task forces have looked at this issue, strong recommendations have been made, but none have been implemented. The Land Use and Water Planning Task Force will presumably speak to this issue, hopefully in a clear and strong fashion. In the meantime, it is an unfinished agenda item, and full and effective protection of ecosystems is unlikely until it is addressed by statute and rule.

Integrating Water Quality and Water Quantity Planning

Finally, the problem of integrated water quality and water quantity planning and decision-making stubbornly resisted solution until the passage of the Florida Environmental Reorganization Act of 1993. First, it is important to recall that Chapter 373, F.S., allowed (some would say encouraged) the delegation of water quality permitting matters to water management districts that have the capacity to carry out such permitting. Such a step would have brought water quality and quantity permitting into one integrated decision-making process - a result almost all objective observers have long held as critical to a comprehensive system of protecting natural systems. Resistance came from many quarters, not the least of which was the Department of Environmental Regulation (DER) and water management district governing boards and staffs. DER tended to jealously guard its "right" to issue thousands of environmental permits under Chapter 403, F.S., and related statutes, although they had little or no ability to address environmental regulation from an ecosystem approach. Permits were largely unique actions that did not take into account the cumulative impacts of those projects permitted before or those that would be permitted after. Issuing the permit within the statutory timeframe was the driving force in the system. Furthermore, relationships with water management districts were often strained, most environmental groups opposed any delegation to the districts, and the districts themselves were reluctant to seek the delegation. Water management district resistance often came from staff even when the boards were ready to accept the added responsibility. In spite of all these negative forces some delegation in dredge and infill permits and other areas was achieved, especially to the SFWMD. The Governor's Environmental Efficiency Study Committee, reporting in 1987, strongly recommended consolidating virtually all environmental permitting in water management districts. While the legislature failed to take such broad action, it did spur some additional delegation of environmental permitting to the districts.

The road block to comprehensive, ecosystem-wide protection, restoration and maintenance of natural systems posed by fragmented water quality and water quantity planning and decision-making has been removed. The Florida Environmental Reorganization Act of 1993 merged DNR and DER and mandated the delegation of virtually all wetland permitting to the water management districts where a single environmental resource permit will be issued. If this action results in increased protection of the state's wetlands and leads to an ecosystem approach by the districts, the meaningful marriage of land and water planning, management, and regulation is just over the horizon. If so, Florida's ability to creatively and responsibly reconcile a healthy economy and equally healthy environment may be achievable at last. The work of the Governor's Commission on a Sustainable South Florida as well as the federal and SFWMD efforts to take an ecosystem approach to saving the Everglades Ecosystem appear to be moving in the right direction. The SFWMD's cutting edge South Dade Watershed Project is an important sub-regional effort that will, if implemented successfully, have important lessons for the overall effort to ensure a sustainable South Florida Ecosystem in all its dimensions - economic, social, and environmental.

THE SOUTH DADE WATERSHED

PROJECT

The South Florida Ecosystem

At the beginning of the 20th century, draining and reclaiming land in the historic South Florida Ecosystem were much sought after goals. In contrast, the close of this century is marked by equally elaborate efforts to *reverse* those early, misguided endeavors:

> The state and the federal governments now find themselves in the position of having to repurchase or provide regulatory protection to large tracts of land included in the original land grant to preserve and restore critical hydrological and biological functions of the same Everglades considered 150 years ago to be 'utterly worthless to the United States for any purpose whatever.' Other lands are being identified by state, county, and local governments for repurchase or zoning protection to ensure a clean and sufficient supply of water for a growing population and economy. Significant contributions to these purposes are also being made voluntarily by some private landowners and non-governmental organizations. The result is a mosaic of land uses, protection activities, and strategies across the South Florida Ecosystem (South Florida Ecosystem Working Group 1994:102).

The need to *coordinate* this mosaic of land uses, protection activities, and strategies into a *comprehensive* watershed plan that protects the South Florida Ecosystem and ensures its sustainability, has been recognized by numerous agencies and organizations. These include the South Florida Ecosystem Restoration Task Force, the South Florida Ecosystem Restoration Working Group, the Army Corps of Engineers (ACOE), the South Florida Water Management District (SFWMD), the Governor's Commission for a Sustainable South Florida, the National Audubon Society, and the Everglades Coalition.

A plan for the region that is based on the principles of ecosystem management is essential to the long term sustainability of southern Florida. The region must be managed as a collection of the interrelated watersheds that comprise the South Florida Ecosystem. Multiple efforts to devise management strategies and techniques are currently underway. The major efforts include the C-111 General Reevaluation Report (ACOE), the Experimental Program of Modified Water Deliveries to Everglades National Park (ACOE), the C&SF Reconnaissance (ACOE), the South Florida Ecosystem Restoration effort (Federal Task Force), the East Coast Buffer - Flow Way Concept (SFWMD and National Audubon), and the Man and the Biosphere Everglades Project (United States National Committee for the Man and the Biosphere Program).

A Focus on Biscayne Bay - The South Dade Watershed Project

One watershed that has received only limited attention is that of the Biscayne Bay. The problems of Biscayne Bay can be divided into three broad categories: water and sedimentation degradation; loss and alteration of habitats; and alteration of hydrology. Degradation of water and sediment quality can be attributed to leaking sewage systems, untreated urban stormwater runoff, leachate from local landfills, and pollution caused by the marine and agricultural industries. Loss and alteration of habitats have been caused by coastal development. Direct impacts have also been caused by filling of wetlands and other physical alterations. Indirect impacts have been caused by degradation of water and sediment quality resulting from activities carried out on surrounding urban lands (SFWMD 1994a).

Current freshwater flow patterns to the bay have changed drastically from predevelopment patterns. Before canals were dredged, surface water flowed to the bay via the Miami River and a few natural flow ways running through the transverse glades. Channelization of low points in the Atlantic Coastal Ridge has now directed and concentrated runoff. Runoff is no longer spread across the bay's broad coastal shore. Freshwater flows to the bay have also been altered by water management practices that deliver more sudden releases than occurred under natural conditions. Some groundwater inflow still occurs, but appears to be greatly reduced from historic levels (SFWMD 1994a).

Pollution has affected plant and animal life. It has limited the geographic distribution of some species and has affected the composition of particular plant communities. Pollution has also caused deformities in plant and animal organisms. In one study, seven percent of the finfish sampled from the northern and southern portions of the bay exhibited physical deformities; nineteen percent of blue crabs from the northern end of the bay were deformed; and oyster tissues sampled from several locations throughout the bay contained significant levels of metals and organic compounds (SFWMD 1994a).

Hurricane Andrew's Effects on Biscayne Bay

Though Biscayne Bay has been experiencing a gradual decline for many decades, the need for a plan to provide for its protection and enhancement was demonstrated by Hurricane Andrew. Hurricanes are a central feature of subtropical Caribbean ecosystems and probably essential to the natural evolutionary processes of those ecosystems. Yet, no significant hurricane had passed over South Dade in the 33 years preceding Andrew. Within the span of those three decades, however, man had dramatically altered the South Dade Ecosystem. Concern had begun to grow that, should a strong hurricane pass over the South Dade region, the ability of the altered environment to withstand the effects of such a storm had been significantly impaired. These fears were borne out as Hurricane Andrew passed directly over South Dade and demonstrated how fragile South Dade's degraded environment had become (Pimm, et. al. 1994).

Hurricane Andrew caused considerable damage to the upland and wetland areas of South Dade. Trees in the Rock Pinelands were either leveled by the hurricane-force winds, or suffered stress or eventual death as a result of salt water contamination, insect and exotic plant infestation, or disease. A large expanse of mangrove wetlands in Biscayne National Park was destroyed. Some bottom areas in the park were scoured. Though the storm did not produce large amounts of rain, the bay received large doses of stormwater runoff. The bay's estuarine waters also received pollutants from sewage, oil and fuel spills, and solid waste. One month after the storm event, a heavy plume of fuel discharging into the bay from the collapsed boat dry-storage building at the Black Point Marina was still evident. Furthermore, three months after the storm, the bay was still receiving higher than normal levels of nutrient loadings (SFWMD 1994a and Tilmant et. al. 1994).

Hurricane Andrew also caused extensive damage to the residential, commercial, and agricultural development within its path. Communities such as Kendall, Cutler Ridge, Homestead, and Florida City sustained extensive damage. The hurricane destroyed or damaged 109,000 homes causing some 100,000 people to move from South Dade, with 7,000 households permanently relocating out of the area (Miami Herald 24 August 1994).

Within three months of the storm many communities were ready to begin preparing long-term redevelopment plans to improve their communities. A number of planning and design charrettes were conducted to translate ideas and preferences into visions of how communities in South Dade could look and function in the future. Many of the plans placed considerable importance on aesthetics and preservation of natural resources. One such charrette, the New South Dade Planning Charrette, considered the entire South Dade region.

The South Dade Watershed Project

In the aftermath of Hurricane Andrew, satisfying the immediate needs of the storm's victims was the first order of business. However, a handful of people looked beyond the short term impacts of the disaster and recognized that the hurricane provided an opportunity to reshape the long-term (50 to 100 years) future of South Dade and the quality of life of its residents. As a result, the New South Dade Planning Charrette was held in Miami to chart the course for the long-term sustainable growth, health, and economic vitality of South Dade. Guidelines for developing the future plan included:

- treat South Dade as a whole, rather than a patchwork of small settlements;
- concentrate rebuilding efforts in infill areas, rather than expanding into undeveloped areas;
- question quick fixes that bring short term, local benefits, rather than long term, regional benefits;
- discontinue the spread of urban growth toward the west and east that is unsympathetic to the natural and agricultural systems;
- preserve the long-term natural resources of the region (i.e., Everglades National Park, Biscayne National Park, and Redland);
- protect the environment to insure the future of the national parks as well as the economic vitality of the area;
- protect water quality and quantity in order to sustain fresh water supplies for the natural system as well as for urban and agricultural land uses; and
- provide a "spine" of rapid transit to act as an anchor for future growth and "density centers" (Williams 1993).

These guidelines, as well as the objectives developed by the charrette's Natural Patterns and Urban and Agricultural Land Use Regional Studies, embody the fundamental elements of what was to become the South Dade Watershed Project. The Natural Patterns and Agricultural Land Use Regional Studies objectives included:

- reclaim wetlands;
- reforest;

- create a regional greenway network;
- reconnect the Everglades to Biscayne Bay, Card Sound, and Barnes Sound;
- create clear boundaries between urban, agricultural, and natural lands; and
- reduce the urban boundary and rebuild compact, mixed use, pedestrian friendly communities (Bueno 1993 and Guyton 1993).

The South Dade Watershed Project is derived from the need to protect Biscayne Bay from water quality and quantity problems caused by past alterations and current land uses. The project focuses on modifying the works of the C&SF "to address the impacts to Biscayne Bay of altered timing, distribution, and volumes of fresh water flow, as well as non-point source pollution from agricultural and urban stormwater runoff." Since some 80% of the South Dade watershed is undeveloped, considerable opportunity exists to accommodate the needed modifications. The modified canal system is envisioned as providing greenways, water quality treatment areas, recreational opportunities, as well as habitat and corridors for wildlife. These reconfigured and restored canals, as they cross U.S. 1, would also create a natural vista between neighboring communities, counteracting the tendency towards continuous development along the length of U.S. 1 (University of Miami nd).

Beyond reconfiguring the canals, if enhancement of Biscayne Bay is to be truly effective, non-point source pollution arising from land-based activities that are remote from these canals (and located within the watershed) must be addressed, as must water supply and aquifer recharge. There are many ongoing programs that provide opportunities for developing a comprehensive watershed plan for protection and restoration of Biscayne Bay. These opportunities must be integrated into the overall plan for the watershed. In developing the plan, the key to success will require a linkage between growth management strategies and plans for restoring and managing entire ecosystems.

The South Dade Watershed Plan: Opportunities and Resources

There are many past and ongoing plans, programs, and research that could provide significant resources and opportunities for protecting Biscayne Bay. As the South Dade Watershed Plan is developed, the following efforts should be considered.

Surface Water Improvement and Management (SWIM) Planning

An important vehicle for watershed planning is the SWIM Act, which was passed by the Florida Legislature in 1987. The Act initially identified Lake Okeechobee, Biscayne Bay, the Indian River Lagoon, Tampa Bay, Lake Apopka, and the Lower St. Johns River as needing special efforts to protect and restore their water quality. Within the first year of adoption, other priority water bodies of regional and state significance were identified. The Act requires that the water management districts prepare watershed-based plans addressing major sources of water pollution and causes of water quality degradation such as stormwater runoff, point source pollution, land use patterns, and agricultural activities. A SWIM trust fund was also established to finance planning and implementation efforts. SWIM plans are important planning and management tools - management goals and objectives are enumerated, other entities having regulatory or management responsibilities over the water bodies are identified, and coordination with other plans to help meet water quality improvement goals is considered (SFWMD 1994a).

The first Biscayne Bay SWIM Plan was adopted in 1988 and modified in 1989. Through the SWIM program, the SFWMD has conducted more than 50 projects (many in cooperation with Metro-Dade County) and expended $12.7 million to address bay-related issues. These projects include research, monitoring, restoration, and education. The Biscayne Bay SWIM plan was updated in 1994. The updated plan reviews progress on the recommendations of the 1988 plan, and recommends revised goals, objectives, and strategies for the next three year period. Because the SWIM Plan provides important guidance for planning, scientific inquiry, and monitoring, it should figure prominently in the development of a South Dade Watershed Plan.

Lower East Coast Regional Water Supply Plan (LECRWSP)

The SFWMD is developing a LECRWSP, which has the overall objective of identifying water management strategies to ensure the future water supply demands of all water users within the planning area are met. The plan will address issues and concerns related to water supply demands of urban and agricultural users and water needs of the environment, including the role of the regional water storage and delivery system. The final plan will include guidance for local government programs such as comprehensive and utility planning processes and land use decisions. The SFWMD will also develop three more detailed water supply plans. The areas included in these subregional plans are Palm Beach County, Broward County, and Dade County-Florida Keys. The analysis and recommendations provided by the LECRWSP should also be considered during development of the South Dade Watershed Plan (SFWMD 1993a).

Stormwater Master Planning

In the near future, Metro-Dade County will begin to prepare a Stormwater Master Plan based upon individual drainage basins located within the county. The purpose of the plan will be to describe the existing stormwater systems of the county, identify the main water quantity and water quality issues, and prioritize and develop projects needed to reduce existing impacts to water quality and quantity. Preparation and implementation of the plans is to be financed, in part, by funds collected through a newly created stormwater utility. The SFWMD will collaborate with Metro-Dade County on the preparation of the plan, and will contribute to implementation of the plan. The Stormwater Master Planning process should provide a valuable opportunity to plan for protection of the South Dade watershed (SFWMD 1993b).

Other Biscayne Bay Watershed Protection Plans, Programs, and Research

Other plans, programs, and research relating to the Biscayne Bay watershed include:

- Metro-Dade County Comprehensive Development Master Plan (CDMP);
- Biscayne National Park General Management Plan;
- Stormwater Retention Basin at the South Dade Landfill;
- Biscayne Bay Restoration and Enhancement Program;

- Biscayne Bay Routine Surface Water Quality Monitoring Program;
- Southwest Biscayne Bay Advance Identification (ADID) Project;
- Stormwater Monitoring Program;
- Biscayne Bay Aquatic Preserve Plan;
- Biscayne Bay Management Plan;
- Miami River Master Plan; and
- Miami River Water Quality Plan.

Everglades Restoration - Regional Plans, Programs, and Research

A number of regional plans programs, and research may also impact the South Dade watershed. These include:

- C&SF Reconnaissance (will consider South Dade Watershed Project's concept of modifying canal banks in its alternatives study);
- C-111 General Re-evaluation Report;
- Experimental Program of Modified Water Deliveries to Everglades National Park;
- Experimental Water Deliveries to Everglades National Park;
- East Coast Buffer Strip Flow Way; and
- Freshwater Lake Belt Plan.

Acquisition Programs

Florida has the most ambitious land acquisition program in the nation. The program is made up of state, regional, and local components. The statewide programs include the Conservation and Recreational Lands (CARL) Program and Preservation-2000 (P-2000). The Conservation and Recreational Lands (CARL) program is the state's major acquisition program. The program has approximately $45 million available each year for acquisition of environmentally sensitive lands. Under CARL, high priority is given to lands containing naturally occurring and relatively unaltered flora and fauna, habitat critical to endangered or threatened plant or animal species, or significant geological features. P-2000 is a ten-year, $3 billion land acquisition program, the funds of which are distributed between various land acquisition programs in the following percentages: CARL, 50%; Save our Rivers (SOR), 30%; Communities Trust, 10%; State Park in-holdings, 2.9%; forest lands for recreation, 2.9%; Game and Fresh Water Fish Commission Wildlife Management Area Lands, 2.9%; and Rails to Trails, 1.3% (Gluckman 1991).

SOR is a regional program, and is administered by each of the five water management districts. Each water management district has developed its own acquisition program based on a model provided by the state. The lands purchased under the SOR program are those "necessary for water management, water supply, and the conservation and protection of water resources." However, SOR funds may not be used to acquire rights-of-way for canals and pipelines (Gluckman 1991).

Metro-Dade County has a local land acquisition program, the Environmentally Endangered Lands Acquisition Program (EELAP), financed by a special 2-year property tax that produced $90 million for the purpose of purchasing and managing environmentally sensitive lands. Under the EELAP program, Metro-Dade has been working to acquire both uplands and wetlands throughout Dade County. The relationship (i.e., location, size, and interconnectedness) of potential acquisition sites to other previously acquired environmentally sensitive lands and park sites is a major consideration in the selection process. Additional sources of funding are also considered. Many candidates on the EELAP "Priority List A" are candidates for additional funding through state acquisition programs, such as the SOR and CARL programs.

Greenways

There are two active greenway initiatives in Dade County. The first, "Greenways for Dade," has the objective of providing greenways throughout Metro-Dade County. Under this program, the Land Trust of Dade County, the Trust for Public Land, and the Metro-Dade County Parks and Recreation Department have joined together to develop a series of linear corridors and greenways linking agricultural communities, parks, natural areas, and public places. Another greenway initiative focuses on South Dade and envisions a greenway network as an important feature of the "New" South Dade. Through this effort, the Redland Conservancy is promoting a greenway/bikeway/trail network throughout the region. One of the Conservancy's primary objectives is to establish a 150-mile network of trails including wildlife corridors; pedestrian, equestrian and bicycle paths; and non-vehicular links between South Dade communities and parks.

Redland Preservation and Tourism Plan

Redland was hit extremely hard by Hurricane Andrew; its exotic fruit groves and historic structures sustained heavy damage. Many feared that this rural agricultural community would be unable to recover from the storm. A number of concerned individuals joined with Metro-Dade County and the University of Miami to develop a strategy for rebuilding and preserving Redland. The *Redland Preservation and Tourism Plan* calls for maintenance of the rural and agricultural character of Redland, and may complement the South Dade Watershed Plan which seeks to preserve open space where development may lead to degradation of water quality and water supplies.

The Florida Department of Environmental Protection's (DEP) Ecosystem Management Initiative

Ecosystem Management has become a statewide initiative, and the plan for the South Dade Watershed should attempt to involve DEP and its commitment to this new approach. DEP is currently developing an Ecosystem Management Implementation Strategy (EMIS). The EMIS will serve as a guidance document that is closely tied to local government comprehensive plans, regional policy plans, water management district Water Plans, the State Water Plan, and other related plans. Once the EMIS is completed (March 1995), DEP will develop Area Implementation Strategies (AISs). The AISs will be developed in coordination with local governments, water management districts, state and federal agencies, regional planning councils, environmental groups, the business community, and the public. One way to facilitate development of an ecosystem-based plan to watershed management in South Dade may be through development of an AIS (DEP 1994a).

Infill Development Along the U.S. 1 Corridor

Shortly after Hurricane Andrew hit, a number of planning charrettes were conducted. The first was the New South Dade Planning Charrette, which considered the entire South Dade region. Following was a series of charrettes that focused on individual communities including the City of Homestead, Florida City, West Perrine, and South Miami Heights. The resulting plans embodied the visions and preferences of many area residents, however, they lacked a unifying strategy for coordination and implementation.

In response to the need for integration and implementation of these plans, the FAU/FIU Joint Center for Environmental and Urban Problems established the South Dade Planning and Design Work Group (Work Group). The Work Group provided a forum for the architectural and urban planning community, public officials, special interests, and other stakeholders to collaborate and develop a vision of a new urban form for South Dade.

In cooperation with the Work Group, the Joint Center integrated the redevelopment plans of individual communities with regional planning efforts (i.e., natural resource protection, mass transit, economic development, agricultural land preservation) into a Comprehensive Development Strategy for the U.S. 1 Corridor. This strategy focuses infill and transit-oriented development within the U.S. 1 corridor where basic infrastructure and services exist. This strategy also directs development away from sensitive and rural lands and into the U.S. 1 corridor, establishing a more efficient and sustainable urban form.

The Comprehensive Development Strategy for the U.S. 1 Corridor embodies many of the guidelines and objectives adopted by the South Dade Watershed Project: treating South Dade on a regional basis; promoting compact, transit-oriented, and pedestrian-friendly, infill development within the U.S. 1 corridor; creating clear boundaries between urban, agricultural, and natural land uses; and protecting agricultural lands, aquifer recharge areas, and other natural resources. Thus, the South Dade Watershed Protection Plan should be linked with this plan for development within the U.S. 1 corridor.

Growth Management - Evaluation and Appraisal Report (EAR) Process

Under Florida's system of growth management, Metro-Dade County and the South Florida Water Management District have failed in many ways to protect South Dade's natural resources. Metro-Dade has, like many other counties within the state, adopted a piecemeal approach to development that fails to consider the cumulative impacts of development approvals falling under the DRI threshold. Furthermore, the SFWMD has been somewhat reluctant to become involved in issues of land use, even when freshwater supplies have been threatened by increased development.

The state's growth management legislation, due to its emphasis on political boundaries, is inherently weak in its ability to promote ecosystem-based protection of natural resources. Under the current system, each local government must adopt its own comprehensive plan *for the area under its jurisdiction*. Elements that relate to natural resources such as the Conservation and Coastal Management elements, as well as the Aquifer Recharge and Drainage sub-elements, address conditions and issues occurring within the boundaries of each local government. Natural resources, of course, do not conform to political boundaries and many extend through multiple jurisdictions. Though intergovernmental coordination and consistency are called for under the Growth Management Act, little has been mandated.

Florida's system of growth management is not necessarily an ineffective tool for managing land use and protecting natural resources. Rather, the critical issue is the manner in which growth management is used by local governments to promote watershed protection planning. Local governments should look to the EAR process as a means of adopting policies that take a regional approach to natural resource protection.

Metro-Dade County is required to adopt its EAR by November 1995. The purpose of the EAR is to evaluate the effectiveness of local government comprehensive plans. The EAR process also provides an opportunity to amend comprehensive plans in ways that will increase their effectiveness. Furthermore, the Department of Community Affairs is encouraging local governments to use the EAR process to develop community visions. Therefore, public participation will be an important component of the EAR process. The EAR process should be recognized as a primary method of incorporating a South Dade Watershed Plan into Metro-Dade County's Comprehensive Development Master Plan, and it should be utilized for that purpose to the maximum extent possible.

The South Dade Watershed Plan: Challenges

Many challenges to developing a South Dade Watershed Plan exist. These include: population growth; existing boundaries, zoning, and land uses; the existing governance structure; public opposition; and funding. Consideration of these challenges and solutions for overcoming them are critical to the planning process.

Population Growth

One of the greatest challenges to planning for protection of the Biscayne Bay watershed is the regional population growth expected in the near future. It has been estimated that in the next 15 to 20 years, the population of South Dade may grow by 0.5 to 1.2 million people. The tendency will be for new development accompanying this influx of residents to sprawl towards the southern and western reaches of the county. This sprawling development will increase demands on freshwater supplies and create impervious surfaces contributing to stormwater runoff and sealing off valuable aquifer recharge areas. This growth will also create pressure to expand the Urban Development Boundary (UDB) beyond its present location. However, the area's ability to accommodate growth is limited by the natural environment. For instance, western and southern Dade County are prone to flooding, and the area's freshwater supplies are at risk of contamination. Furthermore, increased urban and agricultural development in the far western reaches of the county may negatively impact water deliveries to Taylor Slough and Florida Bay (Singleton 1994).

Existing Boundaries, Zoning, and Land Uses

The South Florida Ecosystem is split by a wedge of urban development that separates Everglades National Park from Biscayne National Park. This wedge has severed almost all connections, except hydrological ones maintained through ground and surface waters. This wedge of urban development exposes the parks to deterioration caused by activities occurring outside the parks' formal boundaries. Yet, park superintendents have no authority to influence activities outside park boundaries. This situation demonstrates the difficulty of managing ecosystems when jurisdictions are based on political boundaries rather than on ecological ones. The importance of adopting a "transboundary" approach to ecosystem management is evident.

Since the South Dade Watershed Plan relies on modifications of existing canals to enhance their water treatment and aesthetic values, existing zoning designations and land uses may pose significant barriers to implementation of the plan. Current zoning designations and land uses along these canals include residential, commercial, and agriculture. In order to implement a plan that requires land for mitigation, stormwater treatment, and other open areas, conflicts with existing zoning must be reconciled, and acquisition of privately-held land may be required.

Existing Institutional and Governance Structures

Political boundaries imposed upon the South Florida Ecosystem give no one entity complete responsibility for it or total authority over the entire system. This is also true for Biscayne Bay and its watershed. The number of public agencies having some degree of jurisdiction within the watershed is quite large. The federal agencies exercising regulatory and management functions in the bay are: the U.S. Army Corps of Engineers, the U.S. Coast Guard, the U.S. Environmental Protection Agency, the National Oceanic and Atmospheric Administration, the U.S. Fish and Wildlife Service, the U.S. Geological Survey, the National Park Service, the National Biological Survey, and the Soil and Water Conservation Service. State agencies include the Department of Environmental Protection, the Game and Fresh Water Fish Commission, the Department of Community Affairs, Department of Health and Rehabilitative Services, the Department of Transportation, Florida Inland Navigation District, the Marine Fisheries Commission, and the Department of Agriculture and Consumer Services. At the regional level, the SFWMD and the South Florida Regional Planning Council have jurisdiction. At the local level, Metro-Dade County, Florida City, and Homestead have jurisdiction over land use decisions. Clearly, there is a need for continuous communication and coordination of permitting, land use plans, funding, and management strategies among this array of agencies to assure a comprehensive effort that avoids duplication; maintains funding sources and linkages; resolves conflicting agency positions; and, above all, protects the natural systems (SFWMD 1994a:II-1).

One of the most difficult challenges to intergovernmental coordination relates to the role of the SFWMD in planning for comprehensive growth management and watershed protection. In an analysis of Chapter 163, F.S., district staff concluded that the agency's role in comprehensive planning is essentially non-existent:

> [The statutes] confer authority and responsibility to water management districts only for providing a limited amount of water resource information to local governments and for commenting and cooperating in the comprehensive planning process.... There are few requirements that local governments actually use any information that is provided by the districts, no guidelines or standards for evaluating whether plans are actually based on the information, and no procedures or penalties for ensuring that it is.
>
> Consequently, water management districts' expertise and responsibilities as a regional management agency are essentially omitted from the local government comprehensive planning process. It is possible for a local government to develop plans and land development regulations that are based on inadequate water resource data, and are inconsistent with the districts' planning and regulatory programs. It is essential for the districts to be included in the local government comprehensive planning process because water resources are greater-than-local in nature, and a greater-than-local perspective is necessary to manage them properly (Nall nd.).

If effective watershed and water supply planning is to be accomplished, the role of the water management districts should be clarified and strengthened.

Another critical issue is the provision of adequate freshwater supplies to meet the needs of natural systems as well as the needs of agricultural and urban interests. At the heart of the issue is the freshwater demands of new development. In order to effectively address this issue, a strong link between land use and water supply planning is needed. In the past, this link has been difficult to establish. The SFWMD has been reluctant to involve itself in local government land use issues, and local governments have been reluctant (or unable) to consider the impacts of new development on water supplies. This reluctance is demonstrated by local government and the SFWMD's approaches to developing water supply plans. In planning for the lower east coast region, a Lower East Coast Regional Water Supply Plan Advisory Committee was established to aid in development of plan objectives reflective of local issues and concerns. The Advisory Committee identified six objectives, including one that calls for "improve[d] local and regional resource management through the integration of water supply and land use planning." On the other hand, the Advisory Committee also adopted an objective that supports strong local control over land use: "Respect local control over land use planning and local water supply options, consistent with regional water supply, flood control, and environmental protection objectives" (SFWMD 1993a:I-8). Hinging land use and water supply planning on "consistency" has proved to be a weak approach. Options for strengthening land use and water supply planning must be developed. The Land Use and Water Planning Task Force is currently considering this issue and may make recommendations to help resolve this dilemma.

Public Opposition

In the area considered by the South Dade Watershed Plan, there are numerous stakeholders including developers, politicians, bureaucrats, farmers, urban residents, environmentalists, and other special interest groups. These stakeholders will necessarily have conflicting goals and expectations. There will be those who wish to focus restoration efforts on other watersheds, including the Everglades and Florida Bay. There will be those who wish to promote growth and economic development regardless of its impact on natural systems. There will be urban residents who will oppose higher density development along the U.S. 1 corridor. There will also be suburban residents who will be threatened by any unique land use proposals including wetland reclamation and greenways. Finally, though many residents may wish to support the South Dade Watershed Plan due to its numerous potential benefits, they may doubt government's ability to effectively carry out such a plan no matter how desirable the goals of the proposed program. If the South Dade Watershed Plan is to be truly effective, considerable community outreach and education must be undertaken.

Funding

Funding for South Florida Ecosystem restoration and South Dade Watershed Planning may come from a variety of sources. These sources of funding are determined by the individual projects proposed and the mission or mandate of the funding agency. Clearly, funding for projects focused on ecosystem restoration is fragmented and lacks the coordination required to effectively implement an ecosystem-based approach to management. The solution to this challenge is to increase communication and coordination among resource managers and researchers, rather than among funding agencies. It is the responsibility of managers and researchers to coordinate their work and collaborate when identifying funding sources. This approach would have multiple benefits: coordination of research and management, reduction of project duplication, and efficiency in funding.

The South Dade Watershed Plan: Potential Components of an Implementation Strategy

Above all, the South Dade Watershed Plan must be based on an ecosystem approach to management. The plan must consider not only the bay's relationship to the entire South Florida Ecosystem but must also consider the bay as an ecosystem itself, which is impacted by activities occurring beyond the boundaries that delineate it as a national park. An ecosystem approach should: adopt a multilevel approach; be based on ecological rather than political boundaries; manage for ecological integrity; utilize continuous research and data collection as well as monitoring; employ adaptive management techniques; promote interagency cooperation; support organizational change; recognize that humans are embedded in nature; and recognize that human values play a dominant role in ecosystem management goals.

When developing and implementing a watershed protection plan, the following steps should be taken:

1) Assess watershed conditions/ identify natural resource needs and flood protection limitations;

2) Identify areas that need particular attention;

3) Set plan goals and objectives/ refine with public input;

4) Develop a plan/identify alternative solutions;

5) Refine plan/identify alternatives based on public input;

6) Implement solutions through integration, coordination, and partnerships; and

7) Monitor and report/use adaptive management.

Before a plan can be developed, the natural resource needs of Biscayne Bay must be determined. This analysis must take a multi-level approach, considering biodiversity, rare and threatened species, and water quality (e.g., pollutant load reduction goals) and water quantity. The analysis must also consider the needs of Everglades National Park and the impacts of modified water flows to the bay on the Everglades. Finally, the analysis must consider the needs of the built environment and the people who live and work there. Minimum flood protection needs will be a critical issue and must be balanced against the needs of the natural environment. In determining resource needs and the needs of the bay, consideration should be given to the objectives and strategies identified under the SWIM Plan's water quality, water quantity, and environmental protection goals.

Identification of plan goals and objectives should consider the work of existing Task Forces, committees, and other relevant entities. For example, the Interagency Working Group of the South Florida Ecosystem Restoration Task Force has recommended the following broad objectives that can be applied to the South Dade Watershed Project:

Fresh Water

- Manage the hydrological conditions in the remaining undeveloped and potentially restorable lands in a way that maximizes natural processes characteristic of the historic South Florida Ecosystem....
- Develop and manage the total hydrologic system to maximize ecosystem restoration while providing appropriate consideration to meet the needs of urban, agricultural, and man-made components.

Development

- Ensure that any development plans or permits for development are fully coordinated among affected governmental agencies and are compatible with restoration of the South Florida Ecosystem.
- Ensure that existing development having an adverse impact reduces or eliminates degradation and that new development does not contribute to degradation.
- Develop and use a system-wide integrated mitigation plan, coordinating all levels of government, which contributes to overall restoration.
- Ensure that regardless of any future development there is a sufficient land, water, and resource base to conduct the required natural resource restoration efforts (1994:11-12).

Public input will be critical to the process of developing plan goals and objectives. It will also be critical to subsequent steps that identify and plan alternatives.

Elements

Once watershed conditions, natural resource needs and flood protection limitations, and goals and objectives have been determined, the primary elements of the South Dade Watershed Plan may be developed. Suggested elements include: an Urban Corridor District (UCD) for U.S. 1; Canal Protection and Enhancement Overlay Zones; a Krome Avenue Access Plan; and a Modified Urban Development Boundary. These four elements are described below:

Element 1: An Urban Corridor District (UCD) for U.S. 1 in South Dade

The South Dade Watershed Project strives to protect and enhance the waters of Biscayne Bay. A key criterion for attaining this goal is to restore, to the greatest degree possible, the hydrological functions of the bay's watershed. To do so, the issue of future population growth must be adequately addressed. As the population of South Dade increases, future development of open areas within the watershed is certain unless a pro-active plan is adopted that directs new development away from open land and sensitive areas. Such a plan should link transportation, land use, and natural resource protection in a strategy that directs new development and redevelopment into appropriate infill sites along the U.S. 1 corridor. This will reduce development pressures on the urban "fringe" where agricultural and sensitive lands are located.

The UCD should identify suitable areas for compact infill development at densities higher than is currently allowed. Within the corridor, locations for major activity centers (and the transit lines and stops that will service them) should also be identified. Areas in need of redevelopment and economic enhancement may be identified. Because transportation concurrency could become a constraint if higher density development is permitted along the corridor, suitable Transportation Concurrency Management Areas should also be identified. Permitting higher density development in the UCD would enable the county to allow transfers of development rights (TDRs) from sensitive areas.

Element 2: Canal Protection and Enhancement Overlay Zones

Overlay zones apply a common set of standards to a designated area. These zones "overlay" existing zoning districts, and in doing so, apply additional development standards to those of the existing (underlying) district. Canal overlays could be adopted for South Dade's major canals including the Mowry, Black Creek, and Princeton canals. The overlay zones would identify a corridor in which special measures must be taken to protect canal water quality and recharge areas. The Canal Protection and Enhancement Overlay Zone could also be used to designate areas where the following planning tools would be allowed: TDRs, mitigation banking, easements, cluster development, tax incentives for land donations, and other forms of land preservation.

Element 3: Krome Avenue Access Control Plan

Metro-Dade County has determined that Krome Avenue provides the most direct route to persons in South Dade and the Florida Keys for emergency evacuation and for post-disaster recovery efforts. The county has proposed a comprehensive plan amendment that would allow widening Krome Avenue from South Dade to the Dade-Broward county line. There is considerable concern that widening Krome Avenue would promote commercial development and urban sprawl along its length. To address this concern, the county has proposed that a limited access plan for Krome Avenue be developed. Should the county proceed with the widening, a limited access plan is essential. The lack of such controls would seriously undermine other plans that strive to redirect growth to infill areas within the U.S. 1 UCD (Singleton 1994).

Element 4: Modified Urban Development Boundary (UDB)

With elements one, two, and three of the South Dade Watershed Plan in place, new development will be directed into the UCD and away from sensitive areas surrounding the UDB. As a result, the current location of the 2010 UDB should be reassessed, and possible retraction, especially along the Krome Avenue corridor, should be considered. The South Dade Watershed Plan should include an analysis of the UDB based on projected population growth and available densities within the newly established UCD. The location of the UDB should be modified to make it a more effective tool for discouraging "leap frog development" within the watershed.

Tools

A variety of tools are available for implementing the South Dade Watershed Plan. These tools range from those that are regulatory in nature to those that are voluntary and based on incentives and rewards. Though there are significant benefits to regulatory approaches, approaches that are incentive-based may be more likely to win community acceptance and long-term support. A few of the many regulatory and non-regulatory tools available to planners and resource managers are listed below:

Tool 1: Special Zoning/Permitted Use Restrictions

A regulatory approach to implementation of the South Dade Watershed Plan might include adoption of special zoning districts within the UCD and the Canal Protection and Enhancement Overlay Zones. These zoning designations could be performance-based, i.e., based upon the permissible impacts of a proposed use rather than on specifically permitted uses. Development proposals that would exceed acceptable standards for the zone would not be permitted. The South Dade Watershed Plan might adopt zoning districts that establish special standards for stormwater runoff, sewage treatment, erosion control, impermeable surfaces, wastewater reuse, chemical and pesticide use, vegetative buffers, and natural area preservation.

Tool 2: Transfer of Development Rights (TDRs)

A Transfer of Development Rights program allows the development rights of one parcel to be transferred to another parcel. Development rights may be sent from parcels that are located within a specially designated "sending area." Development rights may be received by any parcel located within a specially designated "receiving area." Public agencies may establish a development rights bank or private individuals may buy and sell the rights on the open market.

There are two areas of the country where TDRs have been used very successfully: Maryland and New Jersey. In Maryland, TDRs have been used to preserve farmland and farming. This technique has helped reduce farmland conversions and, when integrated with agricultural best management practices, have reduced adverse impacts (such as sedimentation) to Chesapeake Bay. In New Jersey, a Pinelands Development Credit program has been designed to encourage a shift of development away from forested and agricultural regions of the Pinelands to towns, villages, and growth areas (Urban Land Institute 1994).

TDRs are often used to compensate property owners whose land is the subject of zoning changes restricting development. This may be the case where the Canal Protection and Enhancement Overlay Zones are applied. TDRs would allow the development rights of a parcel of land within the canal overlay zone to be transferred, or “sent,” to a “receiving” parcel where higher density is permitted, that is, in the UCD.

Tool 3: Cluster Development

Cluster zoning allows higher densities (clusters) on one portion of a site in return for preservation of more open space on the site. Under cluster zoning, a property owner may develop at the approved density, however, negative environmental impacts can be reduced by clustering development away from sensitive areas such as wetlands, lakes, canals, and other natural areas. It is important to note that cluster zoning does not allow increased overall density, rather, it allows higher density on less sensitive areas of a site while maintaining the approved overall site density. Cluster zoning could be used in the South Dade Watershed to protect important natural areas including wetlands, aquifer recharge areas, and water storage areas.

Tool 4: Tax Incentives in Return for Land Donation

Incentive programs encourage natural resource protection by offering landowners a financial incentive such as a lower tax rate on property preserved as open area. The strength of this type of preservation tool is that it encourages *voluntary* protection of sensitive lands by making preservation less costly or even more profitable than conversion. The South Dade Watershed project’s canal overlay zones could designate those areas were incentives such as lower tax rates would be available for property owners who agree to donate their lands for the purposes of preservation or mitigation.

Tool 5: Mitigation Banking

An important component of the South Dade Watershed Plan will include re-creation and enhancement of wetlands, and establishment of littoral zones along reconfigured canal banks. Mitigation banking may provide an effective means of accomplishing these goals because it involves restoring or creating wetlands in one area to compensate for wetland losses at other sites. Traditionally, mitigation for wetland impacts has involved onsite creation of new wetlands or enhancement of existing wetlands. However, this approach has led to small, isolated wetlands that have limited values and functions. Mitigation banks, on the other hand, are located on large parcels of land that can provide significant water treatment and recharge benefits, as well as wildlife habitat. Mitigation banks can be owned and operated by public agencies, such as water management districts, or by private companies. In Broward County the first commercial wetlands mitigation bank has been recently permitted by the SFWMD. The South Dade Watershed Plan could identify areas suitable for mitigation banking. The SFWMD could operate the bank, or a private company could purchase the designated land and operate the bank.

Tool 6: Conservation Easements

Conservation and agricultural easements may be useful tools for preserving open land and minimizing degradation of natural resources in the South Dade watershed. Florida law allows a landowner to voluntarily set permanent limitations on the use of his land in order to protect the land's natural qualities. The right to limited use, or conservation easement, may be granted to a governmental agency or other nonprofit organization. Easements are attractive to property owners because they allow the owner to protect his land while still retaining ownership. Furthermore, though a conservation easement may cause the market value of the land to decrease, this loss may be compensated by a decrease in tax liability. A specific type of conservation easement involves the purchase of an agricultural conservation easement. This type of easement compensates landowners for agreeing to perpetually limit the use of their land to agricultural purposes (Hutchinson 1991).

Tools 7 and 8: Negotiated Free Market Acquisition and Land Swapping

Free market acquisition of land by public agencies and nonprofit organizations may be used to protect open areas within the South Dade watershed. The state, county, and SFWMD each have acquisition programs that allow such purchases. However, these funds are limited, and many funds are already earmarked for existing land acquisition projects. Other acquisition mechanisms such as land swapping should be considered. In the case of South Dade, where a UCD and canal overlay zones are established, land swapping may provide a viable means of promoting infill development as well as preservation of open space.

Processes

The general seven-step process of plan development and implementation is outlined above. Additional processes that are embedded within this overarching framework are examined below:

Process 1: A Multi-agency Approach - Collaborative Decision-making

Since the South Dade Watershed Plan must address land use and water issues that cut across political boundaries, extensive multi-agency coordination and cooperation will be required. If the plan is to be meaningfully supported and implemented, decision-making must necessarily be collaborative. Inter- as well as intra-agency cooperation will be required. Furthermore, some degree of change within each of the participating organizations may be required. This cooperative multi-agency approach may help to clarify and strengthen linkages between land and water use planning.

The team brought together to create the South Dade Watershed Plan must represent the area's diverse array of stakeholders: Everglades National Park, Biscayne Bay National Park, Metro-Dade County, SFWMD, DEP, ACOE, the Florida Department of Transportation (FDOT), and affected municipalities.

One possible method of formalizing the multi-agency approach is to utilize a Memorandum of Agreement to create a South Dade Watershed Planning and Management Committee responsible for creating a plan and strategy for implementation. The Committee could be chaired by three individuals representing Metro-Dade County, the SFWMD, and Biscayne National Park. Other members might include the ACOE, DEP, Everglades National Park, Florida City, Homestead, FDOT, community leaders, and special interest groups.

Process 2: Public Education and Participation

Public support will be critical to advancing the goal of developing a coordinated, well-supported, and balanced restoration effort. In order to have strong support for the project, the public must be given the opportunity to participate in the planning and implementation processes. The public must not be left with the impression that they are being told what they can and cannot do with their land or in their communities. Rather, the public must be given real opportunities to participate in the decision-making process through which the future urban form of South Dade is determined. Emphasis should be placed on providing opportunities for participation from the beginning of the plan preparation process. This will assure the public that they are helping to select the criteria and objectives of the plan, not solely the means of implementing someone else's vision and values. Furthermore, public input must be seriously considered and incorporated into the planning process as often as possible. Preparation of the South Dade Watershed Plan should include: (a) frequent and open meetings with the public; (b) real opportunities for the public to be involved in decision-making; and (c) feedback to the public regarding the effect of their input on the planning process.

A citizen education program will be critical to effective public participation. Before the planning process begins and throughout development of the plan, public educational opportunities should be provided. The efforts should be coordinated with those identified in the Biscayne Bay SWIM Plan, which has identified public awareness and education as a high priority (SFWMD 1994a). Accordingly, the SWIM Plan includes the following goal and implementing strategies:

> Develop an understanding of human demands and impacts on Biscayne Bay and the concomitant impacts of a healthy bay on local economies.
>
> Strategies:
>
> - Develop a series of symposia around a wide variety of bay issues involving academic and business communities.
> - Organize a facilitated informational town meeting on current bay issues for the county's yearly Baynanza Festival.
> - Continue support of "water issues" schools for elected officials to highlight bay issues.
> - Enlist public support and active participation for Biscayne Bay restoration and protection programs.
> - Organize annual bay clean ups or field trips on the bay.
> - Train members if the community at large so that a speakers bureau can be developed.
> - Develop and implement programs and material for primary and secondary schools (SFWMD 1994a:VI-9).

In addition to its efforts to provide opportunities for public input to the planning process, the South Dade Watershed Project should consider the above strategies as opportunities for increasing public awareness and support for its goals.

Process 3: Adoption of a Biscayne Bay Ecosystem Charter

A significant barrier to greater public support of ecosystem restoration is the lack of understanding regarding its definition and purpose. As is the case in the Great Lakes Region, a single, clearly articulated statement that explicitly defines goals for ecosystem management (in the Biscayne Bay watershed) is lacking. Following the example set by the Great Lakes Commission, a common vision and sense of stewardship may be promoted through adoption of an ecosystem charter. An Ecosystem Charter for the Biscayne Bay Watershed could provide a unifying conceptual framework for the many policies, programs, agreements, and institutional mandates that affect the region. The charter could simply and explicitly list goals, objectives, principles, and action items, providing a shared vision of the watershed and a plan for achieving the vision.

Process 4: Comprehensive Plan and Land Development Regulation Amendments

As described in previous sections, the Metro-Dade County CDMP and land development regulations should be amended to include all components of the South Dade Watershed Plan. A significant opportunity to begin this process is presented by the upcoming EAR process. Metro-Dade County will begin its EAR process by the end of 1994, with the intent of adopting an EAR by November 1995.

Process 5: Adaptive Management

Ultimately, the South Dade Watershed Plan is an experiment in ecosystem management. The plan is an experiment simply because uncertainty abounds. Though the plan will be based upon the best scientific information available, the manner in which the plan will function cannot be known at the outset. Thus, flexible, adaptive policies that can be modified as the plan is implemented will be critical to the success of the South Dade Watershed Plan.

Regarding an ecosystem restoration plan as a series of experiments is called "adaptive management." Adaptive management is radically different from traditional management strategies:

> With traditional management, action is based on existing knowledge and established modes of operation. The course is altered if it appears unproductive, but information is not sought aggressively or strategically, and, when it is gathered, it is drawn from a relatively narrow range of conditions. In contrast, adaptive management implies an active search for key hypotheses and a commitment to test them (Volkman 1993:1255).

The concept of adaptive management should be embraced by the designers of the South Dade Watershed Plan. This will require that management strategies be based on hypotheses and carried out in a manner that provides feedback from which learning may occur. Management strategies designed to give resource managers a greater understanding of nature and its processes have greater value than those that do not. Through the adoption of an ecosystem/adaptive management approach to protecting Biscayne Bay, the South Dade Watershed Project may provide invaluable information that other resource managers might utilize in their quests to save more of Florida's natural resources.

REFERENCES

Blake, Nelson M. 1980 *Land into Water - Water into Land: A History of Water Management in Florida*. Tallahassee: University Presses of Florida

Born, Stephen M. 1993. Towards Integrated Environmental Management: A reconnaissance of State Statutes. Natural Resources Law Center, University of Colorado, School of Law.

Boesch, Donald F. 1993. *Deterioration of the Florida Bay Ecosystem: An Evaluation of the Scientific Evidence* Washington, D.C.: National Fish and Wildlife Foundation.

Bueno, Juan A. and Joseph D Ford. 1993. Natural Patterns Study. The New South Dade Planning Charrette: From Adversity to Opportunity. University of Miami.

Caldwell, Lynton K. 1970. The Ecosystem as a Criterion for Public Land Policy. *Natural Resources Journal* 10(2): 203-221.

Caldwell, Lynton K. (ed) 1988. *Perspectives on Ecosystem Management for the Great Lakes*. Albany: State University of New York Press.

Carter, Luther J. 1974. *The Florida Experience: Land and water policy in a growth state*. Baltimore: John Hopkins University Press.

Cortner, Hanna J. and Margaret A. Moote. 1994. Trends and Issues in Land and Water Resources Management: Setting the Agenda for Change. *Environmental Management* 18 (2): 167-173.

Chesapeake Bay Critical Area Commission. 1993. *Critically Speaking* 1 (4).

DeGrove, John M. 1984. *Land, Growth and Politics*. Washington, D.C.: American Planning Association.

DeGrove John M. 1992. *Planning and Growth Management in the States*. Cambridge: Lincoln Institute of Land Policy.

Derr, Mark, 1989. Some Kind of Paradise: *A Chronicle of Man and the Land in Florida*. New York: William Morrow and Company.

Donahue, Michael J. 1988. Institutional Arrangements for Great Lakes Management. Pages 115-139 in Lynton K. Caldwell (ed), *Perspectives on Ecosystem Management for the Great Lakes*. Albany; State University of New York Press.

Dopplet, Bob, M. Scurlock C. Frissell and J. Karr. 1993. *Entering the Watershed: A New Approach to Save America's River Ecosystems*. Washington, D.C.: Island Press.

Dworsky, Leonard B. 1988. The Great Lakes: 1955-1985. Pages 59-113 in Lynton K. Caldwell (ed). *Perspectives on Ecosystem Management for the Great Lakes*. Albany: State University of New York Press.

Environmental Land Management Study Committee III (ELMS III) 1992 Final Report: *Building Better Communities*.

Environmental Protection Agency. 1991. *The Chesapeake Bay.. A Progress Report, 1990-1991*. Annapolis: The Chesapeake Bay Program Office, U.S. EPA Region III.

Fernald, Edward A. 1992. *Atlas of Florida*. Gainesville: University Press of Florida.

Florida Department of Community Affairs. 1994 *Coastal Currents*: Tallahassee.

Florida Department of Community Affairs. 1989. Discouraging Urban Sprawl in Local Comprehensive Plans. *Technical Memo* 4(4).

Florida Department of Environmental Protection. 1994a. *Toward Ecosystem Management in Florida*. Tallahassee.

Florida Department of Environmental Protection. 1994b. *Beginning Ecosystem Management*. Tallahassee.

Gluckman, David. 1991. *Florida Land Acquisition Handbook*. Tallahassee: The Trust for Public Land.

Governor's Commission on Growth in the Chesapeake Bay Region. January, 1991. *Protecting the Future: A Vision for Maryland*. Baltimore: Maryland Office of Planning.

Great Lakes Commission. 1994. *Ecosystem Charter for the Great Lakes - St. Lawrence Basin*.

Grumbine, R. Edward. 1994. What is Ecosystem Management? *Conservation Biology* 8 (1): 27-38.

Guyton, Elizabeth. 1993. Urban and Agricultural Land Use Study. The New South Dade Planning Charrette: From Adversity to Opportunity. University of Miami.

Haynes, Don and Larry Thomas. No date. Growth Limitations and Popular Support: The Case of Maryland. Baltimore: Schaefer Center for Public Policy.

Horton, Tom and William M. Eichbaum. 1991. *Turning the Tide: Saving the Chesapeake Bay*. Washington, D.C.: Island Press.

Hutchinson, Robert (ed) 1991. *Land Preservation for Floridians.* Gainesville: Florida Land Trust Association.

Keiter, Robert B. 1990. NEPA and the Emerging Concept of Ecosystem Management on the Public Lands. *Land and Water Law Review* 25 (1): 43-59.

Kessler, Winifred B., Hal Salwasser, Charles Cartwright, Jr. and James A. Caplan. 1992. New Perspectives for Sustainable Natural Resources Management. *Ecological Applications*, 2 (3): 221-225.

Leith, Donna M. 1989. *Towards and Ecosystem Charter for the Great Lakes - St. Lawrence* Ottawa: Rawson Academy of Aquatic Science.

Light, Stephen S. and J. Walter Dineen. 1994 Water Control in the Everglades: A Historical Perspective. Pages 85-116 *in* S.M. Davis and J.C. Ogden (eds) *Everglades: The System and its Restoration*. Delray Beach: St Lucie Press.

Lincoln Institute of Land Policy. 1994 *Managing Growth on Cape Cod: The Use of Transferable Development Rights in Local Comprehensive Plans*.

Lodge Thomas E. 1994. *The Everglades Handbook*. Delray Beach: St. Lucie Press

May, James W. and Patricia Metzger, et. al. 1994. *Local Planning for Coastal Nonpoint Source Pollution, Volume 2*. Tallahassee: homer Hoyt Center for Land Economics and Real Estate.

Metro-Dade County. 1993. *Redland: A Preservation and Tourism Plan*. Miami: Office of Community Development.

McVety, Pamela. 10 September 1994. Address to participants, Governor's Conference on Ecosystem Management. Orlando.

McIvor, Carolyn C., Janet A. Ley and Robin D. Bjork. 1994. Changes in freshwater inflow from the Everglades to Florida Bay including effects on biota and biotic processes: a review. Pages 117-146 *in* S.M. Davis and JC. Ogden (eds)., *Everglades; The System and its Restoration* Delray Beach: St. Lucie Press.

Miami Herald. 1994. Andrew: Recovery by the Numbers. 24 August 1994: 18A

Milbrath, Lester W. 1988. A Governance Structure Designed to Learn Would Better Protect the Great Lakes Ecosystem. Pages 141-167 *in* Lynton K. Caldwell (ed), *Perspectives on Ecosystem Management for the Great Lakes*. Albany: State University of New York Press.

Morrissey, Wayne A., Jeffrey A. Zinn, and Lynne Corn. 1994. *Ecosystem Management: Federal Agency Activities*. Washington, D.C.: Congressional Research Service.

Myers, Ronald L. and John J. Ewel (eds) *Ecosystems of Florida*. Orlando: University of Central Florida Press.

Nall, Sarah. nd. " Comments on the Relationship of Chapter 163 Part 11, Florida Statutes, the Water Management Districts , and Special Districts." West Palm Beach: South Florida Water Management District.

Parks, Arva Moore. 1991. *Miami: The Magic City*. Miami: Centennial Press.

Pimm, Stuart L. Gary E. Davis, Lloyd Loope, Charles T. Roman, Thomas J. Smith III, and James T. Tilmant. 1994 Hurricane Andrew, *Bioscience* 44(4): 224-229.

Science Sub-Group. 1994. *South Florida ecosystem restoration: scientific information needs*. Draft, September 27, 1994. Management and Coordination Working Group, Interagency Task Force on the South Florida Ecosystem.

Singleton, Thomas. 2 August 1994. Personal communication.

Slocombe, D. Scott. 1993. Implementing Ecosystem-based Management: Development of theory, practice, and research for planning and managing a region. *BioScience* 43(9): 612-622.

South Florida Ecosystem Restoration Working Group. 1994. *Draft 1994 Report Interagency Working Group Ecosystem Restoration and Maintenance*. (August 19, 1994).

South Florida Water Management District. March 1992a. *Surface Water Improvement Plan for the Everglades, Planning Document*. West Palm Beach.

South Florida Water Management District. March 1992b. *Surface Water Improvement Plan for the Everglades, Supporting Information Document*. West Palm Beach.

South Florida Water Management District. March 1993a. *Working Document in Support of Lower East Coast Regional Water Supply Plan*. West Palm Beach.

South Florida Water Management District. August 1993b. *District Water Management Plan*.

South Florida Water Management District. 8 June 1994a. *An Update of the Surface Water Improvement and Management Plan for Biscayne Bay. Planning Document*. West Palm Beach.

South Florida Water Management District. 8 June 1994b. *An Update of the Surface Water Improvement Management Plan for Biscayne Bay. Technical Supporting Document and Appendices*. West Palm Beach.

Snyder, G.H. and J.M. Davidson. 1994. Everglades Agriculture: Past, Present, and Future in S.M. Davis and J.C. Ogden (eds)., *Everglades: The System and its Restoration*. Delray Beach: St. Lucie Press.

Taub. Ted. 1993. Dealing with Transportation Moratoria and Transportation Management Plans ALI-ABA Summer Course.

Tebeau, Charlton W. 1980. *A History of Florida*. Coral Gables: University of Miami Press.

Thomas, R.L. J.R. Vallentyne, K. Oglive, and J.D. Kingham. 1988. The Ecosystem Approach: A Strategy for the Management of Renewable Resources in the Great Lakes Basin. Pages 31-57 in Lynton K. Caldwell (ed)., *Perspectives on Ecosystem Management for the Great Lakes*. Albany: State University of New York Press.

Tilmant, James T., Richard W. Curry, Ronald Jones, Alina Szmant, Joseph C. Zieman, Mark Flora, Michael B. Robblee, Deweitt Smith, R.W. Snow and Harold Wanless. 1994. Hurricane Andrew's Effects on Marine Resources. *Bioscience* 44(4): 230-237.

U.S. Fish and Wildlife Service. March 1994. *An Ecosystem Approach to Fish and Wildlife Conservation. An Approach to More Effectively Conserve the Nation's Biodiversity*.

University of Miami School of Architecture. 1994. *South Dade Watershed Project Workshop Report*. Miami: Center for Urban and Community Design.

Veri, Albert R. William W. Jenna, Jr. and Dorothy Eden Bergamaschi. 1975. *Environmental Quality by Design: South Florida*. Miami: University of Miami.

Volkman, John M. and Willis E. McConnaha. 1993. Through a Glass, Darkly: Columbia River Salmon, the Endangered Species Act, and Adaptive Management. Journal of Environmental Law 23: 1249-1272.

Williams, Daniel. 1993. Regional Studies- Introduction. The New South Dade Planning Charrette: From Adversity to Opportunity. University of Miami.

World Wildlife Fund. 1992. *Statewide Wetlands Strategies: A Guide to Protecting and Managing the Resource*. Washington, D.C.: Island Press.

Year 2020 Panel. 1988. *Population Growth and Development in the Chesapeake Bay Watershed to the Year 2020*. The Report of the Year 2020 Panel to the Chesapeake Executive Council.

DATA INVENTORY AND COMPILATION, EVALUATION OF WETLAND STORMWATER REQUIREMENTS, AND PARTIAL RANKING OF DRAINAGE BASINS

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INTRODUCTION

Background

The Biscayne Bay SWIM Plan recommends that wetland habitats be restored as a means of mitigating the negative effects of canal point discharges of freshwater to the Bay. As a result, the National Park Service and the South Florida Water Management District have initiated a demonstration project to redistribute freshwater flow from the canal system entering Biscayne National Park as sheet flow through mangrove wetlands. However, further improvement of water quality and timing of discharges may be desirable and can be achieved if areas of wetland storage for surface waters can be constructed inland from the coastal mangroves.

This project seeks to investigate the potential of reclaiming, reconstructing, or constructing new inland freshwater wetlands as part of a stormwater storage and water quality enhancement system that will lower peak discharges and enhance water quality. The project, organized into two phases, will evaluate storage requirements, develop a physical plan of the spatial organization of landuses and wetland storage areas (evaluating and ranking the most desirable locations), select 2 or more sites for demonstration projects, design and implement demonstration projects, and finally provide a comprehensive master plan for implementing a new south Dade hydrologic system as a diverse network of wetlands and human dominated landuses.

Project Objectives

A main overall objective of the South Dade Watershed Project was to provide a comprehensive understanding of the relationship between landuse in South Dade County and regional water management objectives. To accomplish that objective we have compiled data on:

- •Present landuse (from SFWMD Information Resources Division),
- •Future landuse (from SFWMD Information Resources Division, 2000-2010 Comprehensive Dade Master Plan)
- •Impervious surface by landuse type
- •Stormwater runoff by landuse type
- •Pollutant loading by landuse type
- •Water quality from the Biscayne Bay Water Quality Monitoring Program
- •Average monthly discharge from Biscayne Bay SWIM Plan
- •Wetland uptake rates for various stormwater constituents

A specific objective of Phase 1 was to evaluate wetland requirements for South Dade drainage basins using the major pollutants in runoff. The methodology employed involves three different techniques for estimating pollutant loadings. To accomplish this objective: (1) spatial data bases of existing and future landuse for the region were constructed, (2) the literature was reviewed and data compiled on runoff coefficients, pollutant loadings, and impervious surface by landuse type, and (3) wetland uptake rates were summarized from the literature and regression equations based on inputs and hydraulic loading rates were developed.

Plan of Study

As part of the South Dade Watershed Project, this Phase 1 report inventories and summarizes available data, summarizes the methodology used to evaluate the wetland treatment area requirements by basin, and provides a partial ranking of basins for detailed evaluation in Phase 2 of the project that will lead to a wetland watershed management plan. The study focused on a regional study area that includes mainland south Dade county from Tamiami Trail on the north to the Dade County line on the west (see Figure 1, p. 171).

MATERIALS AND METHODS

The methodology for evaluating wetland treatment area requirements and ranking of drainage basins was organized into 5 steps. Data

were complied from the literature and discussions with Dade County Department of Environmental Resources Management (DERM). ARC/Info landuse coverages were clipped to the regional boundaries and to drainage basin boundaries. Three methods for calculating pollutant loadings for each basin were developed from the literature: (1)Landuse based event mean concentrations (2) 5-year storm regression equations, and (3) average pollutant concentrations in canals. Wetland treatment area requirements were generated based on wetland uptake rates for major pollutants from the literature. And finally, a partial ranking of basins for further detailed study in Phase 2 of the project was conducted based on trends and practicality .

Detailed methods are given for each step in the evaluation as follows:

Summary Of Existing Data

Landuse/Land Cover

Table 1 summarizes landuse/land cover data for the South Dade Region. Both present (1988) and future (2000-2010) landuse data were provided by SFWMD Information Resources Division. Landuse coverages were clipped to conform to the study area and to each of the drainage basins. Evaluation of present and future pollutant loadings were based, in part, on pollutant generation by landuse type.

Rainfall - Runoff Relationships

Given in Table 2 are data on runoff as a percent of rainfall that have been taken from the literature and DERM/SFWMD. Table 3 summarizes the average and median values for each of 15 landuse types. Conservation, and preservation, landuse types have been assigned 5% runoff based on the assumption that they were similar to open land. Wetlands have been assigned a runoff value of 0% based on the assumption they were similar to open water.

Impervious Surface

Table 4 summarizes data for impervious surface by landuse type. These data are used in calculations of runoff quality for the 5 year storm event pollutant loading. Data from Brown (1980) were measured areas of impervious surface on aerial photographs of urban areas in Gainesville, Ft. Myers, and Tampa, Florida.

Event Mean Concentrations

The EMC values for twelve constituents of stormwater from agriculture, forest, urban, institutional, highway, wetlands, residential, industrial, utility, commercial, and open lands have been obtained from DERM and the literature as shown in Table 5. Values from various sources are listed for each landuse type and the average, median, maximum, minimum and the number of reported values are given. In calculations of annual loading, we have used the mean values.

Data for pollutant loading of metals is relatively scarce, but the data that does exist can vary as much as one order of magnitude. While we have developed the database to include metals, we have not found much in the literature concerning uptake of metals in wetland stormwater systems. Therefore, evaluation of treatment capacities for a wetland system relies more on the nutrients, BOD, and TSS and less on metals.

Canal Water Quality and Quantity

Metro-Dade Department of Environmental Resources Management (DERM) has provided water quality data for the canals and the bay. As part of the Biscayne Bay Water Quality Monitoring Program DERM samples over 20 water quality parameters in upstream, mid canal, outfall and mid-Bay stations. Some of the monitoring dates back to 1979 while many of the parameters and stations were initiated more recently. Mean concentrations at canal outfalls were used as one of three methods to evaluate wetland requirements for stormwater treatment. Mean concentrations for constituents are given in Table 6.

Water Quantity

Water quantity data were taken from the 1994 Draft -- Biscayne Bay SWIM Plan. The Draft Plan contains average monthly discharge flows for each of the following canals: Snake Creek, Biscayne Canal, Little River, Miami Canal, Tamiami Canal, Comfort Canal, Snapper Creek, Cutler Drain, Black Creek, Princeton Canal, Mowry Canal and Aerojet Canal. The period of record for this data is 1980-1989. Table 7 shows the median, maximum and minimum yearly flows for the twelve canals.

Wetland Uptake and Storage

Knight, et. al. (1993) provide a thorough summary of the current knowledge on wetland wastewater treatment efficiencies. Their database includes 83 wetland sites from all over North America with periods of record from 0.1 to 15 years, sizes ranging from 0.023 to 498 ha and flows between 1.0 and 34,254 m3/d. Pollutant constituents included are BOD-5, TSS, TN and TP. These data are summarized in Table 8. Unfortunately, Knight, et. al. do not report treatment efficiencies for other constituents that are of concern such as lead, zinc, copper, cadmium and COD.

Water storage capacities for various wetland systems are summarized in Table 9. High water levels are used to determine sustained hydraulic loadings, while maximum water levels are used as pulsed event loadings (no longer than 72 hours).

Evaluation of Storm Water Quality

Three different methods were used to evaluate stormwater pollutant loadings. In the first, Event Mean Concentrations (EMC's) were used with average annual rainfall to generate annual pollutant loadings. In the second, mean concentrations of pollutants in canal discharges were combined with average annual discharges to generate average annual pollutant loadings. And in the third, regression equations that relate EMC to a 5-year, 24 hour storm event were used to generate 5 year event pollutant loadings. The equations and discussion for each method are provided below.

Event Mean Concentration Method

The first method used for estimating stormwater pollutant loads was the event mean concentration or unit load method (U.S. EPA, 1993). The pollutant loadings for individual basins are calculated using Equation 1:

$$TL_j = {}_{i=1\ to\ n}\ 10 * A_i * RO_i * EMC_{ij}\ ;\ {}_{j=1\ to\ m} \qquad (1)$$

Where:

- i = Landuse Type i, e.g., Residential, Commercial, etc.
- j = Pollutant j, e.g., BOD, TSS, TN, etc.
- n = Number of Landuses within the Basin

m = Number of Pollutants to Estimate

A_i = Total Basin Area in Landuse i (hectares)

RO_i = Annual Runoff from Landuse i (m/y)

EMC_{ij} = Event Mean Concentration for Pollutant j from Landuse i (mg/l)

TL_j = Total Loading of Pollutant j from a Basin (kg/y)

The runoff volume is calculated using Equation 2:

$$\mathbf{TRO = {}_{i=1\ to\ n}\ A_i * RO_i} \qquad (2)$$

Where:

TRO = Total Runoff for the Basin (ha-m/y)

Equations (1) and (2) are used to estimate the pollutant loadings and runoff volumes for the existing and future landuse. Values for area (A_i) were taken from the landuse maps provided by the District. Values for annual runoff (RO_i) were obtained using Equation 3:

$$\mathbf{RO_i = 132\ cm/y * C_i} \qquad (3)$$

Where:

C_i = Fraction of Rainfall that becomes Runoff from Landuse i

132 cm/y = Average Annual Rainfall for South Dade County (DERM, 1994)

In Equations (1) and (3), C_i and EMC_{ij} are values taken from the literature and are presented in Tables 4 and 6. It is evident that, based on the difference between maximum and minimum values for C_i and EMC_{ij} there is variability within the data sets. For example, the maximum and minimum C_i's for residential landuse differ by 61% and the maximum EMC_{ij} for total suspended solids (TSS) from residential areas is thirty (30) times as large as the minimum. In order to evaluate the effect of this variability on the loading rates, we performed a sensitivity analysis by using both average and maximum C_i and EMC_{ij} values in Equations (1) and (3). For both the existing and future landuse scenarios we estimated a mean and maximum annual pollutant loading. The mean annual loading is based on mean runoff (RO_i) and mean EMC_{ij} value. The maximum pollutant loading was calculated using the maximum runoff (RO_i) and maximum EMC_{ij} value.

Canal Water Quality/Quantity Method

A second method for estimating the annual pollutant loadings from a basin used the mean monthly concentration in the canals and the mean monthly discharge from the canals. These were taken to be representative of the quality and quantity of water that a wetland system constructed in downstream locations would need to treat and store. Metro-Dade DERM has provided water quality data for the canals and the bay. Unfortunately, these data do not contain all of the parameters of concern. DERM no longer includes Total Suspended Solids, Total Nitrogen or Biological Oxygen Demand making the value of existing data questionable because they instead, sample for Nephelometric Turbidity, NOx-N and NH3-N, and Dissolved Oxygen. Average canal discharge is taken from the Biscayne Bay SWIM Plan — Draft 1994. For those parameters included in DERM's sampling program, the annual pollutant loading per basin were calculated using Equation 4:

$$\mathbf{TL_j = 0.001 * {}_{i=1to12}\ CC_{ij} * D_i ;\ {}_{j=1\ to\ m}} \qquad (4)$$

Where:

TL_j = Total Annual Loading of Pollutant j (kg)

CC_{ij} = Canal Concentration for month i and Pollutant j (mg/l)

D_i = Average Canal Discharge for the Period of Record for month i (m3)

m = Number of Pollutants

Without more complete data the analysis of wetland treatment area using canal water quality relied on Total Phosphorus and Total Nitrogen (based on NOx-N and NH3-N). Since experience has shown that in most instances the controlling constituent is phosphorus, we felt that the limitations imposed by the data did not preclude using this method for sizing wetland treatment systems.

Five(5)-year 24-hour Design Storm Method

The first two methods cannot predict runoff volume and pollutant loadings from a single large storm event. To evaluate the impact of single storm events on treatment requirements, the wetland treatment area was calculated based on a 5-yr 24-hr storm event. The design storm amounts to 19 cm (7.5in) of rainfall.

In essence, regression models with drainage basin characteristics as the parameters were used to determine the pollutant loading for a 5 year, 24 hour storm event. The resulting pollutant load was then used to size a wetland treatment area assuming a 72 hour residence time.

Regression models published by Driver and Troutman (1989) were used to estimate the pollutant loading and runoff volume from a 5-yr storm. The general form for these models is shown in Equation 5:

$$\mathbf{TL = B0 * X_1^{B1} * X_2^{B2} * .... * X_n^{Bn} * BCF} \quad (5)$$

Where:

- TL = Total Loading
- B0 = Regression Constant
- X_i = Basin Characteristics, e.g., Drainage Area, Total Storm Rainfall
- B_i = Regression Coefficients
- n = Number of Basin Characteristics in Equation BCF = Bias Correction Factor

Basin characteristics used in these equations vary, depending, upon the constituent being modelled. Below is a list of basin characteristics that appear in the models:

Drainage Area (DA)
Impervious Area as a percent of DA
Industrial Landuse as a percent of DA
Residential Landuse as a percent of DA
Non-Urban Landuse as a percent of DA
Total Storm Rainfall
Mean Annual Rainfall
Mean Annual Nitrogen in Rainfall
Mean January Temperature

Regression equations were generated for Total Phosphorus and Total Nitrogen and loadings were limited to these two constituents. The TSS loading generated using this method was excluded from calculations for wetland sizing due to a lack of confidence in the applicability of the regression model (R2 = .56, standard error of estimate = 265%) and to previous experience with wetland treatment systems which suggests that most often TP was the controlling constituent.

Evaluation of Wetland Uptake Rates

The wetland uptake rates are taken almost exclusively from the database assembled by Knight, et. al. (1993). Serious consideration was given to development of regression equations that related uptake to inflow concentration and hydraulic loading rate, however after much effort, the equations could not be fine tuned enough to prove useful. Instead, we have used best estimates of wetland performance based on literature and personal experience. Uptake rates used in the evaluations for TSS, BOD, TP, and TN were 20.0, 8.0, 0.2, and 2.0 kg/ha-d, respectively.

To estimate the area of wetland needed for treatment of a constituent, target outflow concentrations (receiving water body criteria) were assumed for Biscayne Bay as follows:

BOD — 5 mg/l
TSS — 18 mg/l
TN — 0.1 mg/l
TP — 0.007 mg/l

The nutrient (TN and TP) and suspended solids target levels are taken from the Biscayne Bay SWIM Plan — Draft 1994 and are based on background concentration levels for that part of Biscayne Bay that is within the study boundary. Since BOD is not reported in the SWIM Plan, its target level is based on typical outflow limits used for wastewater wetland treatment systems as given by G. R. Best (pers. comm.).

The following method was used to estimate the required wetland treatment area. The target outflow concentrations were used in combination with the runoff volumes for each drainage basin to calculate the allowed outflow pollutant mass using Equation 6.

$$O_{ij} = 0.001 * TC_i * RO_j ; \qquad (6)$$

Where,

O_{ij} = Mass Output for Pollutant i and Basin j (kg/d)
TC_i = Target Concentration for Pollutant i (mg/l)
RO_j = Runoff Volume for Basin j (m3/d)

The mass to be removed is then simply the input minus the output, using Equation 7.

$$R_{ij} = I_{ij} - O_{ij} ; \qquad (7)$$

Where,

R_{ij} = Mass Removed for Pollutant i and Basin j (kg/d)
I_{ij} = Mass Input for Pollutant i and Basin j (kg/d)
O_{ij} = Mass Output for Pollutant i and Basin j (kg/d)

For the EMC and Canal Quality method the required wetland treatment area is calculated by dividing the mass to be removed by the uptake rate using Equation 8. The 5yr - 24hr storm method takes into account a 72 hr residence time, so the uptake rates are increased by threefold.

$$WTA_{ij} = R_{ij} / U_i ; \qquad (8)$$

Where,

WTA_{ij} = Required Wetland Treatment Area for Pollutant i and Basin j (ha)
U_i = Uptake Rate for Pollutant i (kg/ha-d)

The required wetland area was also estimated based on storage capacity and runoff volume generated by the 5yr - 24hr storm. Water storage capacities for various wetland systems are summarized in Table 9. For the purposes of this analysis, we assumed the wetland treatment system had characteristics similar to a wet prairie and thus will have an average storage capacity of 0.5 m and a maximum capacity of 1.5 m for pulsed event loadings (no longer than 72 hours). Using 0.5 m as the long term storage capacity of the wetland treatment system and a residence time of 3 days, the loading rate and thus wetland treatment area was calculated as follows:

$$WTA_j = RO_j/V\,; \qquad (9)$$

Where,

WTA_j = Wetland Treatment Area for Basin j (ha)

RO_j = 5yr Storm Event Runoff Volume (ha-m/d)

V = 0.5 m/3 = 0.17

RESULTS

Basin Characteristics

Landuse and Impervious Surface

Tables 10 and 11 give total area, area of impervious surface, percent impervious surface and percent of total land area in commercial, industrial, residential, and non-urban uses for each of the drainage basins in the study area. Data are given for both the existing (Table 10) and future (Table 11) landuse scenarios. For the present landuse impervious surface area ranged from 59% (C-6 basin) down to less than 1% (East Collier basin). Those basins with highest percent impervious surface were relatively small portions of larger basins that were included in the study area by virtue of the study area boundary. Discounting these smaller basins, the more urbanized basins averaged between 25% and 35% impervious surface. Several of the basins (C-102, C-111, DA-2, DA-4, Florida City, and North Canal) had impervious surface area below 10 percent.

The future landuse scenario has percent impervious surface ranging from 72% to less than 1%. As can be expected, since the urbanized portions of the south Dade area were greatly expanded on the future landuse map, all basins had increases in percent impervious surface. The largest increases where experienced in the smaller basins, some increasing by over 100 percent. Urbanized basins increased from 40 to 60 percent. While the less urbanized basins had increases of between 50 and 150%. When expressed in terms of percent of the area, the less urbanized basins still had percent impervious surface areas less than 16 percent.

Storm Water Pollutant Loadings

Event Mean Concentration

The pollutant loadings generated by the EMC method for existing and future landuse scenarios were estimated using the mean EMC. Tables 12 and 13 give estimated loadings by basin for BOD, COD, TSS, TDS, TN, TKN, TP, DP, Cd, Cu, Zn, Pb and runoff volume. Total basin area is given in column 2, runoff volumes in hectare-meters/year are given in column 3, and the various pollutant loading in kg/year are given in columns 4 through 11.

Canal Quality/Quantity Method

The mean daily loading of TP, TN (as NOx-N and NH3-N) and discharge volume in canals are given in Table 14 as estimated using the canal quality/quantity method. No estimates based on the canal method were done for the future landuse condition.

In general, many of the loadings in Table 14 are at least an order of magnitude less than results obtained from the EMC method and two orders of magnitude less than the results from the 5yr storm event method. This reflects, in part, canal uptake of constituents and in part, the fact that loading rates and runoff coefficients for the event mean concentration and 5 year storm event methodologies were designed to be provide maximum loadings. Canal water quality may also not reflect loading from basin landuse because of dilution.

5yr - 24hr Storm Event Method

Mean daily loading resulting from the 5yr - 24hr Storm Event Method are given in Tables 15 and 16 for the existing and future landuses, respectively. The constituents included in this method are TN, TP and runoff volume. TSS was not calculated using this method because of a lack of confidence in the regression equation.

Generally, these 24hr loadings are an order of magnitude greater than the mean daily loading generated with the EMC method.

Wetland Treatment and Storage Requirements

The sizing of the wetland treatment system was based on assimilation of projected loadings of TSS, TN, TP, and BOD (if known) and storage capacity of the estimated runoff volume. Wetland treatment area was based on relatively liberal estimates of constituent loading and calculated assuming relatively conservative estimates of wetland uptake rates. Thus areas given should be considered relatively liberal estimates.

Event Mean Concentration

For the EMC method Tables 17 and 18 show the mean daily loading of TSS, TN, TP, BOD and runoff volume and the required wetland area for these constituents under existing and future landuse conditions, respectively. Treatment areas are given in hectares and as percent of the basin. The largest treatment areas are required for TSS loadings, ranging from a low of less than 1% of the basin area to as large as 11% of the basin area. Total Phosphorus removal required the next largest wetland treatment areas, requiring about 1 to 3% of total basin area.

Canal Quality/Quantity Method

Given in Table 19 are the wetland treatment area requirements that result from the use of canal water quality and quantity data for average loading rates. In all cases, the hydraulic loading controls wetland treatment area requirements because of the relatively low concentrations of constituents in canal water.

5yr - 24hr Storm Event Method

Wetland treatment are requirements resulting from the loadings calculated using the 5yr-24 hour storm event method are given in Tables 20 and 21. TP was generally the constituent which required the largest wetland treatment areas. Size of treatment areas ranged from about 3% to about 18% of the total basin area.

Land Required vs. Land Available for Wetland Treatment System

Treatment wetland area requirements and potential land availability, as a first step in selecting a drainage basin for more detailed study in Phase 2, are given in Table 22. Total area of wetland, agricultural and rangeland in each basin are given in columns 2 through 4 and totaled in column 5. It was felt that these landuse types are more easily converted to wetland treatment areas since their conversion is less likely to require extensive purchases of developed lands and structure. Basins with relatively low requirements and relatively large amounts of available lands are more desirable.

Columns 6 through 11 give the controlling treatment area requirements for the EMC and 5yr - 24 hour storm event loading methods, for both the existing and future landuse scenarios.

As is evident from the table, some drainage basins simply do not have the land necessary for a Wetland Treatment System (at least within our South Dade Regional boundary), while other drainage basins have adequate area.

Basin Ranking

Ranking of basins rests on qualitative judgments of practicality (is there sufficient land?) and trends (current trends, based on changes between the existing and future landuse scenarios, suggest that hydrologic and water quality problems are likely to get worse). Highest ranking basins will be more carefully evaluated and master drainage plans developed in Phase 2 of the project. Our ranking has identified the following basins:

Basin	Practicality	Trends
C-1	14%	49%
C-1	7%	0%
C-103	10%	23%
C-111	4%	5%
DA-4	5%	19%
Fl City	9%	80%
Model Land	4%	0%
North Canal	9%	28%

Combining ranking criteria, we believe the following basins represent opportunities for further, more detailed study in Phase 2: C-1, C-103, Florida City, and North Canal.

Cost Analysis Of BMP+s And Stormwater Treatment Technologies

Cost comparisons of stormwater wetland systems and stormwater best management practices (BMP+s) are given in Table 23. The comparison is based on total costs per kg of total phosphorus (TP) removed from the runoff. Total costs are the annual operating and maintenance cost (O&M) plus the construction costs amortized over 30 years. Eight different treatment systems were evaluated as listed in column one of Table 23. Costing data for all treatment technologies with the exception of wetland systems were taken from Metro-Dade DERM's Stormwater Master Plan (CH2M Hill, 1994). The costing data for wetland systems were taken from Ramakrishna (1994). The table includes the quantity of the costing unit required (column 2), the total phosphorus removed (kg/yr), total construction costs, amortized construction costs ($/yr), operation and maintenance costs ($/yr), and annual costs per kg of TP removed ($/kg/yr).

Assumptions

The cost estimates are based on a 100 acre drainage area that receives 52 in/yr of rain. This representative drainage area has a landuse mix of 5% transportation, 15% institutional, 20% commercial, and 60% residential. It has a runoff coefficient of 50% (26 in/yr) and a TP loading of 192 lbs/yr (87 kg/yr). The results of the cost comparisons should not be sensitive to these assumptions since they are applied to each of the treatment technologies in the same manner.

However, some assumptions made that are applied to only one or two technologies may affect comparisons between practices. The most important of these assumptions was the rate of infiltration of drainage wells and auger holes. Although PBS&J, Inc. (1992) reported an average infiltration rate of 2000 gpm for south Dade, this value may be only appropriate for the size of well that they cite (15" diameter, 70' deep). We put this rate on a surface area basis by dividing the infiltration rate (2000 gpm) by the sq. ft. of drainage well surface area (275 sq. ft.) to obtain a unit infiltration rate of 7.28 gpm/sq. ft. of surface area. We applied this to a drainage well that had 3.4 times as much surface area (942 sq. ft., 100' deep by 3' diameter). The relationship between infiltration rate and drainage area may be somewhat less than linear, but without better data, we have assumed a linear relationship. A second assumption of concern is related to the stormwater capture fraction for infiltration devices (SCFi). We have assumed that it is equal to 48% for infiltration devices without storage facilities and 90 % for infiltration and storage basins in combination. This may underestimate the costs as well as the TP removal rate for drainage wells, French drains and auger holes.

Evaluation

The two principal components used in evaluating stormwater treatment technologies were the percent of total phosphorus removed and the total costs per kg of TP removed. The wetland system had the lowest costs/kg TP removed ($29.00/kg) and the second highest TP removal efficiency (90%). The grassed swale technology had the highest removal efficiency (99%), but its cost/kg of TP removed ($239.80/kg TP) was 8.3 times that of the wetland system. The next least expensive technology was the 30" diameter drainage well. Its cost per kg TP removed was $76.81 (2.6 times higher than wetlands) and its removal efficiency is only 29%.

A criterion not directly addressed in this comparison but which is important, relates to the treatment technology's effect on the next larger system, i.e., the ecological-economic system of south Dade. Infiltration-only technologies (e.g., drainage wells, auger holes, and French drains) make negligible use of the phosphorus in the runoff, relying on absorptive capacity of soils and geology for removal. The practice of disposing of stormwater into deeper groundwater storages may be a questionable one. While there may be some absorption of phosphorus within limestone underlying most of the area, other pollutants may not be absorbed, only -disposed+ of below ground. We have always believed that surface and ground waters should not be mixed. Unless there is sufficient filtration and biological action to naturally clean waters that may infiltrate. Dirty waters are best kept on the surface separated from clean ground water.

A wetland stormwater system, on the other hand, uses the phosphorus and other nutrients, for plant growth which will eventually lead to a biologically diverse and productive ecosystem, capable of self maintenance, and long term filtration and biological action for the removal of stormwater pollutants.

DISCUSSION

Comparison of Methods

Comparison of the three methods for calculating constituent loads reveals that the 5-yr 24-hr Storm Event Method produces the highest daily loading and runoff volume; the event mean concentration method gives a medium values, and the canal water quantity/quality method produces lowest constituent and hydraulic loading. Thus the sizing of wetland stormwater systems is sensitive to placement within a given drainage basin. In upper basin areas, where the wetland will be subjected to pulses from storm events, area of stormwater wetlands will be larger for the same level of treatment and controlled by the loadings generated by 5yr - 24 hour method . In lower areas (i.e. toward the coast) wetlands will have the benefit of canal treatment and their size will be correspondingly smaller. Size of wetland treatment areas in lower basin areas will be determined by hydraulic loading, while in upper basin areas size will be determined more by pollutant loading.

The wetland treatment area requirements should be considered as maximum sizes. There are several factors that could greatly reduce the area of treatment needed. When using the 5yr-24 hour method, no allowance was made for further treatment in down steam canal segments, but output water quality was assumed to have to meet receiving water body quality criteria. Combinations of treatment systems were not considered; that is, small wetland stormwater basins for on-site treatment prior to canal discharge were not taken into account. The effect of travel time and possible uptake in canals and swales was not considered in either the event mean concentration nor 5yr - 24 hour storm event methods.

In all, this exercise in sizing wetland treatment area requirements should be understood with these limitations in mind. The exercise was aimed at developing two parameters for judging feasibility. The first, given the worst case, is there sufficient area for wetland treatment? And the second, are the trends such that some basins would benefit more from constructing wetlands than others? In both cases it appears that the answer is yes. It appears that in several basins in the south Dade region, there is sufficient land area that might be used for wetland treatment areas and several basins show trends of increasing water quality problems in the future.

BIBLIOGRAPHY

Best, G.R., 1994. Director, Center for Wetlands and Water Resources, University of Florida, Gainesville.

Bliven, L.F., F.J. Humenik, F.A. Koehler and M.R. Overcash, 1980. Dynamics of Rural Nonpoint Source Water Quality in a Southeastern Watershed. *Transactions of the American Society of Agricultural Engineers*, 23(6):1450-1456.

Brabets, T. P., 1983. Quantity and Quality of Urban Runoff from the Chester Creek Basin, Anchorage, Alaska. *U.S. Geological Survey Water-Resources Investigations Report* 86-4312. 58p.

Brown, M.T., 1980. *Energy Basis for Heirarchies in Urban and Regional Systems*. Ph.D. dissertation. Department of Environmental Engineering Sciences, University of Florida,Gainesville. 360 pp.

Brown, M.T. and E.M. Starnes with C. Diamond, B. Dunn, P. McKay, M. Noonan, S. Schreiber, J. Sendzimir, S. Thompson, and B. Tighe, 1983. A Wetlands Study of Seminole County Identification, Evaluation, and Preparation of Development Standards and Guidlines. *Center for Wetlands Technical Report* 41, University of Florida.

CH2M Hill, 1994. *Metropolitan Dade County DERM Stormwater Master Plan*, Phase I C-9 East Basin Study Work Autorization No. 2 Stormwater Control Technologies Performance and Cost.

Correll, D. L.,, J.W. Pierce and M.A. Faust., 197?. *A Quantitative Study of the Nutrient, Sediment, and Coliform Bacterial Constituents of Water Runoff from the Rhode River Watershed*.

Dornbush, J. N., J. R. Andersen, and L. L. Harms, 1974. *Quantification of Pollutants in Agricultural Runoff*. EPA-660/2-74-005. U.S. Environmental Protection Agency Office of Research and Development.

Driver, N.E. and B.M. Troutman, 1989. Regression Models for Estimating Urban Storm-Runoff Quality and Quantity in the United States. *Journal of Hydrology* 109(1989):221-236.

Guay, J.R. and P.E. Smith, 1988. Simulation of Quantity and Quality of Storm Runoff for Urban

Catchments in Fresno, California. *U.S. Geological Survey Water-Resources Investigations Report* 88-4125. 76p.

Haith, D.A. and J.V. Doughtery, 1976. Nonpoint Source Pollution from Agricultural Runoff. *Journal of the Environmental Engineering Division, American Society of Civil Engineers*, 102(EE5):1055-1069.

Kappel, W. M., R.M. Yager and P.J. Zarriello, 1986. Quantity and Quality of Urban Storm Runoff in the Irondequoit Creek Basin Near Rochester, New York (Part 2). *U.S. Geological Survey Water-Resources Investigations Report* 85-4113. 93p.

Knight, R.L., R.W. Ruble, R.H. Kadlec and S. Reed, 1993. Wetlands Wastewater Treatment: Performance Database. In: G.A. Moshiri, (ed) *Constructed Wetlands for Water Quality Improvement*, pp. 35-58.

Mattraw, H.C. and R. A. Miller, 1981. Stormwater Quality Processes for Three Land-use Areas in Broward Co., FL. *U.S. Geological Survey Water-Resources Investigations* 81-23. 56p.

Metro-Dade Department of Environmental Resources Management (DERM), Dorian K. Valdes, Section Chief Stormwater Monitoring and Evaluation Section.

Metro-Dade Department of Environmental Resources Management (DERM) Stormwater Monitoring and Evaluation Section. National Pollutant Discharge Elimination System Stormwater Permit Application, 1993.

Metro-Dade Department of Environmental Resources Management (DERM). Biscayne Bay Surface Water Quality Monitoring Program, 1994.

Miller, R. A., 1978. *The Hydraulically effective impervious area of an urban basin, Broward Co., Florida.* In: International Symposium on Urban Stormwater Management, Lexington, University of Kentucky.

Polls, I. and R. Lanyon, 1980. Pollutant Concentrations from Homogenous Landuses. *Journal of the Environmental Engineering Division, American Society of Civil Engineers*, 106(EE1):69-80.

Post, Buckley, Schuh & Jernigan, Inc., 1992. *Wastewater Reuse Feasibility Study*, Vol. 1. For Miami-Dade Water and Sewer Authority Dept. Miami, Fl.

Pyrch, E. A. and R. N. Brenner, 1983. Effects of Landuse on Discharge and Water Quality in Newaukum Creek Basin, King County, Washington. *Municipality of Metropolitan Seattle and U. S. Geological Survey*.

Ramakrishna, H., 1994. *Emergy and Economic Analysis of Two Constructed Wetlands in Florida for Wastewater Treatment*. M.E. Thesis, University of Florida, Gainesville. 61 pp.

Schueler, T., 1987. Metropolitan Washington Council of Governments. *Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMP's*. Prepared for Washington Metropolitan Water Resources Planning Board. Washington, D.C.

South Florida Water Management District, Information Resources Division, 1994a. West Palm Beach, FL.

South Florida Water Management District, Lower East Coast Planning Division, 1994b. Draft — *An Update of the Surface Water Improvement and Management Plan for Biscayne Bay*, Technical Supporting Document and Appendices. West Palm Beach, FL.

Stockdale, E.C., 1991. *Freshwater Wetlands, Urban Stormwater, and Nonpoint Pollution Control: A Literature Review and Annotated Bibliography* (Revised). Resource Planning Section, King County Dept. of Parks, Seattle, WA. 275 p.

Waller, Bradley G., H. Klein and L. J. Lefkoff, 1984. *Attenuation of Stormwater Contaminants from Highway Runoff within Unsaturated Limestone*, Dade County, Florida.

U.S. EPA, 1993. U.S. Environmental Protection Agency. *Handbook Urban Runoff Pollution Prevention and Control Planning*. EPA/625/R-93/004. U.S. Office of Research Development, Center for Environmental Research Information.

Table 1 Existing (1988) and Future (2000-2010) Land Use for Regional Study Area

Land Use	Land Use Code	Existing (1988) ha	Future (2000-2010) ha
Agriculture	A	34,937	33,092
Barren Land	B	383	
Forested Upland	F	11,789	
Water	H	152,004	871
Not Identified	NOID	156	3,407
Rangeland	R	2,002	
Commercial	UC	2,131	4,044
Industrial	UI	1,183	2,042
Urban Open	UO	5,835	16,665
Residential	UR	32,900	42,300
Institutional	US	2,118	2,864
Transportation	UT	2,873	1,203
Wetland	W	98,888	
Conservation	NAC		82,916
Preservation	NAP		157,734

SFWMD Information Resources Division

Multiply hectares by 2.47 to obtain acres

Table 2 Literature Review of Rainfall - Runoff Relationships

Land Use	Data Source	LU Code	Fraction of Rainfall
Agriculture	c	A	0.70
Commercial	b	UC	0.50
Commercial	a	UCHM	0.57
Commercial	a	UC	0.72
Commercial	a	UCCE	0.75
Commercial	a	UCPL	0.76
Commercial	a	UCSC	0.80
Commercial	d	UC	0.98
Commercial	e	UCSC	1.11
Industrial	a	UILT	0.71
Industrial	a	UIJK	0.71
Institutional	a	USGF	0.51
Institutional	a	USMD	0.55
Institutional	a	USRL	0.60
Residential	d	UR	0.10
Residential	e	URMF	0.43
Residential	e	URMF	0.48
Residential	a	URMF	0.65
Residential	a	URMH	0.71
Residential	b	URSF	0.26
Residential	b	URSF	0.29
Residential	c	URSH	0.20
Residential	c	URSM	0.18
Residential	e	URSM	0.27
Residential	a	URSM	0.66
Transportation	d	UTHW	0.19
Transportation	a	UTEP	0.23
Urban	c	U	0.70
Urban Open	a	UOUN	0.50
Urban Open	a	UOGC	0.60

a — DERM/SFWMD
b — Anchorage, Alaska; Brabets, 1987.
c — Near Rochester, NY. Kappel, et. al., 1986.
d — Broward Co., Mattraw and Miller, 1981.
e — Fresno, CA, Guay and Smith, 1988.

Table 3 Summary of Runoff Coefficients Gathered from DERM/SFWMD and Literature Review

Land Use	LU Code	Fraction of Rainfall				
		Average	Median	Maximum	Minimum	
Agriculture	A	0.60	0.60	0.70	0.60	
Barren Land	B	0.60	0.60	0.60	0.50	Assumed Similar to Urban Open
Forested Uplands	F	0.60	0.60	0.60	0.50	Assumed Similar to Urban Open
Open Water	H	0.00	0.00	0.00	0.00	
Conservation	NAC	0.60	0.60	0.60	0.50	
Preservation	NAP	0.60	0.60	0.60	0.50	
Unidentified	NOID	0.47	0.50	1.00	0.50	Aggregated for all Land Uses
Rangeland	R	0.60	0.60	0.70	0.60	Assumed Similar to Agriculture
Commercial	UC	0.77	0.76	1.11	0.50	
Industrial	UI	0.71	0.71	0.71	0.71	
Urban Open	UO	0.60	0.60	0.60	0.50	
Residential	UR	0.39	0.29	0.71	0.10	
Institutional	US	0.55	0.55	0.60	0.51	
Transportation	UT	0.21	0.21	0.23	0.19	
Wetland	W	0.00	0.00	0.00	0.00	

Table 4 Percent Imperviousness for Various Land Use Types

Land Use	Data Source	LU Code	Percent Imperviousness
Agriculture	c	A	3.70
Commercial	a	UC	74.70
	a	UC	77.80
	a	UC	83.20
	b	UC	98.04
Highway	b	UT	36.19
Institutional	a	US	51.50
Residential	a	URSL	12.40
	a	URSM	18.70
	a	URSH	29.60
	a	URMF	48.15
	a	URMH	34.65
	b	UR	43.87
	c	URSM	15.00
	c	URSH	17.00

a — M. T. Brown, 1980.
b — Miller, 1978.
c — Near Rochester, NY. Kappel, et. al., 1986.

Table 5 Literature Review of Event Mean Concentration Values by Land Use Classification

Land Use	Note	Land Use Code	EMC Values in mg/l BOD-5	COD	TSS	TDS	TN	TKN	TP	DP	Cd	Cu	Pb	Zn
Agriculture	g	A	3.8		55		2.32		0.32	0.27				
Agriculture — lower limit#	n	AC					3.42		1.09					
Agriculture — upper limit#	n	AC					7.56		2.44					
Agriculture	p	AP		49	38		2.10	1.70	0.49					
Agriculture	p	AC		22	40		1.10	0.80	0.35					
Agriculture	p	AC		148	1021		4.10	2.60	1.05					
Agriculture	m	A	13.0	122	762			2.90	0.27					
Agriculture	L	A		7	120			1.02	0.12		0.8100		0.6700	0.3943
Agriculture	i	A	9.4		158		3.30		0.67	0.37		0.1400		0.2400
Agriculture	a	AC					0.46		0.90					
Agriculture	a	AP					0.38		0.14					
Average			8.7	70	313		2.75	1.80	0.64	0.32	0.8100	0.1400	0.6700	0.2091
Median			9.4	49	120		2.32	1.70	0.35	0.32	0.8100	0.1400	0.6700	0.2091
Maximum			13.0	148	1021		7.56	2.90	2.44	0.37	0.8100	0.1400	0.6700	0.3943
Minimum			3.8	7	38		0.38	0.80	0.90	0.27	0.8100	0.1400	0.6700	0.2400
Number			3	5	7		9	5	11	2	1	1	1	2
Forest	a	F					0.50		0.30					
Forest	o	F		42				1.32	0.14					
Forest	m	F	2.0		34			0.50	0.40					
Forest	i	F	1.3		132		0.99		0.10	0.70				0.1000
Average			1.7	42	83		0.52	0.91	0.80	0.70				0.1000
Median			1.7	42	83		0.52	0.91	0.70	0.70				0.1000
Maximum			2.0	42	132		0.99	1.32	0.14	0.70				0.1000
Minimum			1.3	42	34		0.50	0.50	0.30	0.70				0.1000
Number			2	1	2		2	2	4	1				1
Open Water	g	H	0.0	0	0	0	0.00	0.00	0.00	0.00	0.0000	0.0000	0.0000	0.0000
Urban	b	U	8.0	71				1.50	0.29					
Urban	l	U		8	54			0.84	0.10		0.5500		0.6900	0.3601
Urban	l	U		60	154			1.48	0.20		0.1260		0.5160	0.6137
Urban	j	U				55	1.62		0.22	0.30		0.3000	0.7600	0.1710
Urban	h	U	14.8	85	119	118	1.43	0.86	0.29	0.14	0.7000	0.3360	0.4200	0.1128
Urban	i	U	2.7		61		1.36		0.24	0.90				0.1600
Average			8.5	56	97	87	1.47	1.17	0.22	0.90	0.6300	0.3180	0.4410	0.2547

Table 5 (cont.)

Land Use	Note	Land Use Code	EMC Values in mg/l											
			BOD-5	COD	TSS	TDS	TN	TKN	TP	DP	Cd	Cu	Pb	Zn
Median			8.0	66	90	87	1.43	1.17	0.23	0.90	0.5500	0.3180	0.4680	0.1710
Maximum			14.8	85	154	118	1.62	1.50	0.29	0.14	0.1260	0.3360	0.7600	0.6137
Minimum			2.7	8	54	55	1.36	0.84	0.10	0.30	0.7000	0.3000	0.6900	0.1600
Number			3	4	4	2	3	4	6	3	3	2	4	5
Commercial	d	UC	14.0	84	169		2.30	1.50	0.29	0.15		0.5000	0.2030	0.4180
Commercial	e	UC	7.9	67	94	150	1.82	1.75	0.21		0.8200	0.2310	0.5580	0.3510
Commercial	m	UC	22.0	168	386			2.00	0.24					
Commercial	j	UC				104	2.18		0.39	0.11	0.7000	0.7200	0.4600	0.3580
Commercial	k	UCSC	5.4	71	45		1.10		0.10		0.9000	0.1500	0.3870	0.1280
Commercial	g	UC	9.5	54	77	180	1.61	1.45	0.24	0.18	0.8000	0.2300	0.2730	0.1590
Cultural/Entertainment	g	UCCE	9.5	54	77	180	1.61	1.45	0.24	0.18	0.8000	0.2300	0.2730	0.1390
Hotel/Motel	g	UCHM	9.5	54	77	180	1.61	1.45	0.24	0.18	0.8000	0.2300	0.2730	0.1390
Hospitals	g	UCMD	9.5	54	77	180	1.61	1.45	0.24	0.18	0.8000	0.2300	0.2730	0.1390
Parking Lots	g	UCPL	6.7	61	103	103	1.39	1.03	0.31	0.19	0.8200	0.3200	0.2180	0.1380
Retail Commercial	g	UCSC	9.5	54	77	180	1.61	1.45	0.24	0.18	0.8000	0.2300	0.2730	0.1390
Mixed Commercial	g	UCSS	9.5	54	77	180	1.61	1.45	0.24	0.18	0.8000	0.2300	0.2730	0.1390
Average			10.3	70	114	160	1.68	1.50	0.25	0.17	0.7200	0.4890	0.3149	0.2043
Median			9.5	54	77	180	1.61	1.45	0.24	0.18	0.8000	0.2300	0.2730	0.1390
Maximum			22.0	168	386	180	2.30	2.00	0.39	0.19	0.8200	0.2310	0.5580	0.4180
Minimum			5.4	54	45	103	1.10	1.03	0.10	0.11	0.9000	0.1500	0.2030	0.1280
Number			11	11	11	9	11	10	12	9	10	11	11	11
Industrial	d	UI	9.7	62	108		2.54	1.62	0.42	0.15		0.3200	0.1160	1.0630
Industrial	e	UI	17.5	187	518	173			1.71			0.3100	0.3970	0.8800
Industrial	g	UI	9.1		74		1.42		0.21					
Light Industrial	m	UILT	14.0	78	302		1.40	0.19						
Junk Yards/Equip. Storage	g	UIJK	9.1	78	74	173	1.42	1.12	0.21	0.18	0.8000	0.3100	0.3970	0.8800
Light Industrial	g	UILT	9.1	78	74	173	1.42	1.12	0.21	0.18	0.8000	0.3100	0.3970	0.8800
Average			11.4	97	191	173	1.70	1.32	0.49	0.17	0.8000	0.3130	0.3268	0.9258
Median			9.4	78	91	173	1.42	1.26	0.21	0.18	0.8000	0.3100	0.3970	0.8800
Maximum			17.5	187	518	173	2.54	1.62	1.71	0.18	0.8000	0.3200	0.3970	1.0630
Minimum			9.1	62	74	173	1.42	1.12	0.19	0.15	0.8000	0.3100	0.1160	0.8800
Number			6	5	6	3	4	4	6	3	2	4	4	4
Open Space	g	UO	1.5		32		1.25		0.11	0.00				

Table 5 (cont.)

Land Use	Note	Land Use Code	EMC Values in mg/l											
			BOD-5	COD	TSS	TDS	TN	TKN	TP	DP	Cd	Cu	Pb	Zn
Golf Courses	g	UOGC	1.5	12	32	100	1.25	0.99	0.11	0.00	0.2000	0.9000	0.4500	0.3200
Vacant Land	g	UOUN	1.5	12	32	100	1.25	0.99	0.11	0.00	0.2000	0.9000	0.4500	0.3200
Average			1.5	12	32	100	1.25	0.99	0.11	0.00	0.2000	0.9000	0.4500	0.3200
Median			1.5	12	32	100	1.25	0.99	0.11	0.00	0.2000	0.9000	0.4500	0.3200
Maximum			1.5	12	32	100	1.25	0.99	0.11	0.00	0.2000	0.9000	0.4500	0.3200
Minimum			1.5	12	32	100	1.25	0.99	0.11	0.00	0.2000	0.9000	0.4500	0.3200
Number			3	2	3	2	3	2	3	3	2	2	2	2
Residential	a	UR					1.10		0.58					
Residential	d	UR	13.0	102	228		1.80	0.48	0.62	0.21		0.5600	0.2930	0.2540
Residential	k	URSM	7.9	41	26		2.04		0.31			0.8000	0.1670	0.8600
Residential	l	URSM		21	86			1.74	0.25				0.6530	0.9592
Residential	l	URSH		99	290			3.69	0.63		0.4500		0.2381	0.5619
Residential	e	UR	10.6	66	47	105	2.53	1.67	0.53		0.3500	0.1600	0.1040	0.5800
Residential	m	URS	17.0	104	513			1.70	0.14					
Residential	m	URM	16.0	117	797			2.10	0.23					
Residential	j	URSL				158	3.48		1.10	0.17		0.4400	0.1730	0.1720
Residential	j	URSH	59	2.39	0.22	0.14	0.1400	0.1090	0.1900					
Residential	g	UR	10.1	59	45	105	1.55	1.24	0.40	0.18	0.4000	0.1800	0.9000	0.6200
Multi-Family Resid	g	URMF	10.1	59	45	105	1.55	1.24	0.40	0.18	0.4000	0.1800	0.9000	0.6200
Mobile Homes	g	URMH	10.1	59	45	105	1.55	1.24	0.40	0.18	0.4000	0.1800	0.9000	0.6200
Single-Family Resid	g	URSM	10.1	59	45	105	1.55	1.24	0.40	0.18	0.4000	0.1800	0.9000	0.6200
Average			11.7	71	197	106	1.95	1.63	0.44	0.18	0.4000	0.2330	0.1372	0.2299
Median			10.1	59	47	105	1.68	1.46	0.40	0.18	0.4000	0.1800	0.1040	0.8600
Maximum			17.0	117	797	158	3.48	3.69	1.10	0.21	0.4500	0.5600	0.2930	0.9592
Minimum			7.9	21	26	59	1.10	0.48	0.14	0.14	0.3500	0.8000	0.6530	0.5800
Number			9	11	11	7	10	10	14	7	6	9	11	11
Government	g	USGF	9.5	54	77	180	1.61	1.45	0.24	0.18	0.8000	0.2300	0.2730	0.1390
Religious Facilities	g	USRL	9.5	54	77	180	1.61	1.45	0.24	0.18	0.8000	0.2300	0.2730	0.1390
Average			9.5	54	77	180	1.61	1.45	0.24	0.18	0.8000	0.2300	0.2730	0.1390
Median			9.5	54	77	180	1.61	1.45	0.24	0.18	0.8000	0.2300	0.2730	0.1390
Maximum			9.5	54	77	180	1.61	1.45	0.24	0.18	0.8000	0.2300	0.2730	0.1390
Minimum			9.5	54	77	180	1.61	1.45	0.24	0.18	0.8000	0.2300	0.2730	0.1390
Number			2	2	2	2	2	2	2	2	2	2	2	2

Table 5 (cont.)

Land Use	Note	Land Use Code	EMC Values in mg/l											
		Code	BOD-5	COD	TSS	TDS	TN	TKN	TP	DP	Cd	Cu	Pb	Zn
Utilities	g	UTEP	9.1	78	74	173	1.42	1.12	0.21	0.18	0.8000	0.3100	0.3970	0.8800
Highway	c	UTHW					2.63		0.67		0.1700		0.1714	0.1264
Highway	m	UTHW	14.0	128	266			1.20	0.70					
Highway	k	UTHW	9.0	55	15		0.96		0.80		0.7000	0.6500	0.2820	0.9000
Highway	d	UTHW		103	143			1.79				0.5200	0.5250	0.3680
Highway	e	UTHW	6.7	112	39	103	2.00		0.28		0.7300	0.3600	0.3990	0.1890
Highway	g	UTHW	6.7	61	39	103	1.39	1.03	0.31	0.19	0.8200	0.3160	0.2180	0.1380
Average			9	89	96	126	1.68	1.29	0.27	0.18	0.5200	0.3140	0.3321	0.2986
Median			9.0	91	56	103	1.42	1.16	0.25	0.18	0.7300	0.3160	0.3395	0.1635
Maximum			14.0	128	266	173	2.63	1.79	0.67	0.19	0.8200	0.5200	0.5250	0.8800
Minimum			6.7	55	15	103	0.96	1.03	0.70	0.18	0.7000	0.6500	0.1714	0.9000
Number			5	6	6	3	5	4	6	2	5	5	6	6
Wet Areas	a	W					-15.00		-0.42					
Wetland	g	W	4.6		10		1.60		0.19	0.13			0.2500	0.6000
Average			5		10		-7		-0	0			0.2500	0.6000
Median			4.6		10.2		-6.7		-0.1	0.1			0.2500	0.6000
Maximum			4.6		10.2		1.6		0.2	0.1			0.2500	0.6000
Minimum			4.6		10.2		-15.0		-0.4	0.1			0.2500	0.6000
Number			1		1		2		2	1			1	1

Notes to Table 5

— data reported as a range
a — Chesapeake Bay, Correll, et.al., 197?.
b — Nationwide Urban Runoff Program, EPA, 1983. Summarized in Stockdale, 1991.
c — Dade County, Waller, et. al., 1984.
d — Nationwide Urban Runoff Program data obtained from Dorian K. Valdes, Metro-Dade DERM Stormwater Monitoring and Evaluation Section
e — State of Florida data obtained from Dorian K. Valdes, Metro-Dade DERM Stormwater Monitoring and Evaluation Section
f — Intentionally Skipped.
g — South/Central Florida data obtained from Dorian K. Valdes, Metro-Dade DERM Stormwater Monitoring and Evaluation Section
h — Dade County excluding City of Miami, Metro-Dade DERM Stormwater Monitoring and Evaluation Section, 1993.
i — King County, Wash. Pyrch and Brenner, 1983.
j — Anchorage, Alaska. Brabets, 1987.
k — Broward Co., FL. Mattraw and Miller, 1987.
l — Near Rochester, NY. Kappel, et. al., 1986.
m — Northeastern Illinois, Polls and Lanyon, 1980.
n — Southern New York, Haith and Dougherty, 1976.
o — Va. - N.C. border. Bliven, et. al., 1980.
p — South Dakota. Dornbush, et. al., 1974.

Table 6 Average Annual Flow to Biscayne Bay (1,000,000's m^3)

Canal	Canal #	Median	Max	Min
Snake Creek	C-9	247	361	122
Biscayne Canal	C-8	59	111	26
Little River	C-7	93	139	59
Miami Canal	C-6	86	305	20
Tamiami Canal *	C-4	101	162	47
Comfort Canal *	C-5	5	6	4
Snapper Creek	C-2	68	174	19
Cutler Drain *	C-100	11	74	2
Black Creek	C-1	139	282	28
Princeton Canal *	C-102	80	185	38
Mowry Canal	C-103	179	250	57
Aerojet Canal *	C-111	35	142	0
Total		1121	1849	405

* — Missing at least two years of data
Period of Record = 1980-1989
Source: 1994 Draft — Biscayne Bay SWIM Plan

Table 7 Canal Quality — Mean Annual Concentrations at Outfalls

Basin/Canal	Canal #	Station I.D.	TP mg/l	TN mg/l
Area B		TM02	0.220	0.412
Black Creek	C-1	BL01	0.140	0.420
Cutler Drain	C-100	CD02	0.120	0.116
Princeton Canal	C-102	PR01	0.190	1.420
Mowry Canal	C-103	MW01	0.700	0.454
Aerojet Canal	C-111	AR01	0.120	0.150
Snapper Creek	C-2	SP01	0.130	0.131
Miami Canal	C-6	MR01	0.140	0.155
Coral Gables	C-3	CG01	0.130	0.141
Homestead		MI01	0.140	0.614
Florida City		N/A	N/A	N/A
Model Land		N/A	N/A	N/A
North Canal		N/A	N/A	N/A
East Collier		N/A	N/A	N/A
Tamiami East		N/A	N/A	N/A

N/A — Data Not Available

Table 8 Wetland Uptake Rates for BOD, TN, TP, TSS

BOD				TN				TP				TSS			
Area	HLR	Input	Uptake	Area	HLR	Input	Uptake	Area	HLR	Input	Uptake	Area	HLR	Input	Uptake
ha	cm/d	kg/ha-d		ha	cm/d	kg/ha-d		ha	cm/d	kg/ha-d		ha	cm/d	kg/ha-d	
46.5	0.192	0.460	-0.480	100.0	0.337	0.112	0.109	35.2	3.422	0.479	-0.130	100.0	1.404	0.700	-0.800
498.0	0.542	0.163	0.270	100.0	0.200	0.600	0.200	100.0	0.200	0.100	0.000	2.5	0.956	0.966	-0.402
100.0	1.404	0.211	0.340	63.7	0.618	0.890	0.879	204.0	0.460	0.200	0.100	6.3	2.724	1.662	-0.136
6.1	0.200	0.380	0.360	68.9	0.106	0.197	0.173	22.0	0.210	0.500	0.300	498.0	0.542	0.217	0.270
36.5	0.510	0.230	0.770	1.1	0.357	0.343	0.306	88.7	0.384	0.190	0.170	6.1	0.200	0.380	0.330
22.0	0.210	0.900	0.780	0.2	0.222	0.167	0.121	0.3	0.500	0.520	0.180	68.9	0.106	0.159	0.118
68.9	0.106	0.143	0.126	88.7	0.384	0.131	0.660	486.0	0.705	0.370	0.300	21.0	0.649	0.389	0.292
486.0	0.705	0.338	0.190	486.0	0.705	0.281	0.215	68.9	0.106	0.450	0.430	110.0	0.123	0.442	0.417
0.1	0.195	30.871	0.195	46.5	0.192	0.147	0.750	0.1	1.889	0.196	0.530	486.0	0.705	0.740	0.515
110.0	0.123	0.344	0.221	498.0	0.542	0.490	0.391	18.0	0.318	0.650	0.590	0.3	0.500	1.140	0.710
20.0	1.254	0.790	0.414	21.0	0.649	1.298	1.194	21.0	0.649	0.402	0.650	20.0	1.254	1.342	0.966
6.3	2.724	1.389	0.545	0.2	0.553	0.417	0.290	46.5	0.192	0.800	0.680	0.1	1.308	2.982	1.778
0.3	0.500	0.980	0.580	0.2	1.370	1.033	0.737	0.1	1.308	0.136	0.710	2.2	1.558	3.022	2.087
21.0	0.649	0.753	0.584	100.0	1.404	0.816	0.475	1.5	2.493	1.132	0.800	32.0	1.679	4.650	2.166
63.7	0.618	0.939	0.871	20.0	1.254	1.404	0.962	0.2	6.667	0.220	0.930	35.2	3.422	3.045	2.224
2.5	0.956	1.444	0.966	5.9	4.128	4.033	3.550	0.9	0.817	0.278	0.106	2.9	1.669	3.238	2.320
0.8	0.513	1.901	1.153	8.9	2.192	1.953	1.409	6.0	0.442	0.127	0.108	7.0	1.246	3.737	2.491
35.2	3.422	1.813	1.163	32.0	1.679	2.753	2.132	20.0	1.254	0.534	0.114	0.1	1.889	4.307	2.607
0.9	14.034	7.157	1.263	35.2	3.422	2.926	2.286	156.0	1.045	0.343	0.133	0.4	1.051	9.262	3.312
7.0	1.246	2.703	1.457	0.8	0.513	1.763	0.661	1.5	2.493	1.132	0.140	5.9	4.128	4.499	3.509
0.1	1.889	3.702	1.568	0.2	2.935	14.969	13.002	63.7	0.618	0.185	0.172	47.0	0.213	3.830	3.706
0.1	1.308	2.563	1.569	0.4	12.052	41.218	21.694	100.0	1.404	0.425	0.187	0.1	4.900	17.738	4.018
32.0	1.679	2.736	1.645	0.1	16.923	32.662	12.354	47.0	0.213	0.234	0.229	63.7	0.618	6.611	6.117
5.9	4.128	2.394	1.734	0.1	17.308	33.404	11.077	1.1	0.357	0.304	0.286	0.9	0.817	6.783	6.538
156.0	1.045	2.916	2.247	0.1	19.538	37.709	13.482	498.0	0.542	0.512	0.292	6.0	1.047	8.237	7.149
8.9	2.192	4.735	2.433	14.0	N/A	7.573	3.112	0.1	1.308	0.416	0.335	0.4	12.052	11.570	7.713
47.0	0.213	2.511	2.453	8.9	2.192	1.124	0.344	1.8	5.034	9.766	7.753				
6.0	1.047	3.130	2.564	1.5	1.270	0.766	0.365	2.1	5.590	10.844	8.273				
0.1	0.173	27.346	3.115	0.1	1.809	0.575	0.396	0.2	3.800	12.882	8.284				
0.1	16.923	26.738	3.215	5.9	4.128	0.743	0.417	8.9	2.192	14.445	9.075				
1.5	2.493	6.383	3.341	32.0	1.679	0.687	0.442	1.5	2.493	14.312	10.447				

Table 8 (cont)

	BOD				TN				TP				TSS			
	Area	HLR	Input	Uptake	Area	HLR	Input	Uptake	Area	HLR	Input	Uptake	Area	HLR	Input	Uptake
	ha	cm/d	kg/ha-d		ha	cm/d	kg/ha-d		ha	cm/d	kg/ha-d		ha	cm/d	kg/ha-d	
	0.9	0.817	4.576	3.841	0.1	4.900	0.823	0.446	1.5	1.270	11.674	10.632				
	1.5	2.493	6.383	3.989	N/A	N/A	1.057	0.560	156.0	1.045	15.991	10.692				
	0.2	2.935	4.491	4.197	6.3	2.724	1.991	0.820	1.5	2.493	14.312	11.669				
	0.4	12.052	16.029	5.182	0.1	17.308	15.421	1.298	0.4	2.103	17.073	12.237				
	0.1	1.308	7.375	6.120	0.1	19.538	17.409	1.465	0.1	1.308	14.515	13.469				
	1.5	1.270	8.562	7.368	0.2	2.935	1.761	1.673	0.4	4.179	30.719	14.168				
	0.1	1.809	10.200	7.560	0.4	12.052	7.243	2.049	0.1	1.809	20.074	17.977				
	0.1	4.900	10.143	7.889	0.1	16.923	15.078	5.094	0.2	2.935	18.696	18.109				
	N/A	N/A	27.202	10.900	0.4	4.462	44.526	29.446								
	0.4	1.051	15.244	12.699	0.9	14.034	35.786	29.471								
	0.2	3.800	20.064	13.338	0.4	4.205	41.294	32.800								
	0.4	0.210	27.333	21.698	0.2	6.667	56.933	34.333								
	2.1	0.124	35.051	22.000	0.1	19.538	107.071	38.882								
	0.4	0.420	54.333	33.519	0.1	17.308	94.846	42.750								
	0.4	0.420	59.292	46.467	2.1	12.429	65.875	44.745								
	0.4	0.450	67.369	47.382	0.1	16.923	92.738	49.585								
	0.2	0.156	115.000	65.313	0.20	36.087	115.478	90.217								
	0.20	0.361	137.130	83.000												
Average	37.5	2.001	15.577	8.944	65.1	3.575	7.257	3.490	53.8	3.070	1.847	0.460	35.5	4.468	20.011	12.593
Maximum	498.0	16.923	137.130	83.000	498.0	19.538	41.218	21.694	498.0	19.538	17.409	5.094	498.0	36.087	115.478	90.217
Minimum	0.20	0.200	0.380	-0.480	0.1	0.200	0.600	0.200	0.1	0.200	0.100	-0.130	0.20	0.200	0.380	-0.800
Median	1.5	1.001	3.702	2.247	17.0	0.705	1.166	0.808	6.2	1.289	0.416	0.140	1.6	1.849	9.514	6.843
Std. Dev.	101.2	3.465	28.055	17.402	130.6	5.939	13.056	5.723	114.6	4.953	4.304	0.903	101.6	6.686	29.223	17.585
Count	48	48	49	49	26	25	26	26	38	38	39	39	48	48	48	48

Summarized from Knight, et. al., 1993.

Table 9 Pertinent Parameters for Estimating Water Storage Capacities of Wetlands

	Hydric Hammock	Mixed Hardwood Swamp	Cypress Dome	Bayhead	Wet Prairie	Shallow Marsh	Deep Marsh
E-T (mm/day)	4.8	5.8	3.8	3.0	5.4	5.6	5.6
Hydroperiod (days)	100-150	200-250	250-300	200-250	150-200	365	365
High Water (m)	0.1	0.6	0.5	0.3	0.5	0.7	1.0
Low Water (m)	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Max. Level (m)	0.3	1.5	1.5	1.0	1.5	2.0	2.0

Source: Brown, et.al., 1983.

Table 10 Basin Characteristics for Existing Land Use — Total Imperviousness, Percent Commercial, Industrial Residential and Non-Urban

Basin	Total Area (ha)	Impervious Area (ha)	Impervious Area (%)	Commercial %	Industrial %	Residential %	Non-Urban %
AREA B	16,894	2,134	12.63%	1.21%	1.04%	33.56%	64.17%
Black Creek (C-1)	10,183	1,494	14.67%	2.08%	2.66%	29.19%	66.05%
Cutler Drain (C-100)	10,400	2,136	20.54%	3.51%	1.45%	65.61%	29.42%
Princeton Canal (C-102)	8,625	658	7.62%	0.64%	1.00%	18.94%	79.39%
Mowry Canal (C-103)	12,754	1,346	10.55%	1.88%	1.58%	27.07%	69.45%
Aerojet Canal (C-111)	38,648	698	1.80%	0.00%	0.05%	2.69%	97.24%
Snapper Creek (C-2)	4,465	1,041	23.31%	4.90%	0.96%	73.64%	20.48%
Miami Canal (C-6)	58	34	58.92%	54.48%	0.00%	7.71%	37.79%
Coral Gables (C-3)	4,937	1,302	26.36%	7.52%	3.27%	74.63%	14.56%
DA-1	2,463	738	29.97%	9.37%	0.47%	79.40%	10.75%
DA-2	708	50	7.12%	0.62%	0.00%	38.73%	60.63%
DA-3	1,040	106	10.17%	0.14%	0.00%	27.82%	72.03%
DA-4	10,340	168	1.62%	0.00%	0.16%	1.64%	98.18%
EAST COLLIER	1,758	0	0.01%	0.00%	0.00%	0.13%	99.86%
FLORIDA CITY	3,079	107	3.48%	0.16%	0.00%	0.22%	99.60%
HOMESTEAD	1,019	335	32.88%	0.05%	0.45%	24.63%	74.86%
INTRACOASTAL	19	9	50.07%	57.07%	0.00%	0.07%	42.85%
MODEL LAND	7,290	81	1.11%	0.14%	0.00%	0.00%	100.00%
NORTH CANAL	1,343	56	4.15%	0.00%	0.00%	2.50%	97.49%
TAMIAMI EAST	1,112	367	33.00%	15.05%	2.41%	67.70%	14.82%

Multiply hectares by 2.47 to obtain acres

Table 11 Basin Characteristics for Future Land Use — Total Imperviousness, Percent Commercial, Industrial Residential and Non-Urban

Basin	Total Area (ha)	Impervious Area (ha)	Impervious Area (%)	Commercial (%)	Industrial (%)	Residential (%)	Non-Urban (%)
AREA B	16,894	3,332	19.72%	3.08%	1.18%	48.05%	47.67%
Black Creek (C-1)	10,183	2,477	24.32%	4.22%	4.77%	53.20%	37.79%
Cutler Drain (C-100)	10,400	2,856	27.46%	5.39%	5.27%	80.22%	9.10%
Princeton Canal (C-102)	8,625	692	8.02%	0.75%	0.98%	17.76%	80.49%
Mowry Canal (C-103)	12,754	2,212	17.34%	5.94%	2.40%	33.33%	58.30%
Aerojet Canal (C-111)	38,648	960	2.48%	0.16%	0.05%	3.52%	96.25%
Snapper Creek (C-2)	4,465	1,277	28.59%	7.48%	1.49%	80.65%	10.36%
Miami Canal (C-6)	58	41	71.85%	74.31%	1.26%	0.00%	24.41%
Coral Gables (C-3)	4,937	1,620	32.81%	10.93%	3.06%	73.79%	12.20%
DA-1	2,463	1,009	40.95%	14.31%	0.31%	73.93%	11.43%
DA-2	708	112	15.80%	0.00%	0.00%	56.80%	43.19%
DA-3	1,040	167	16.10%	0.12%	0.00%	42.29%	57.57%
DA-4	10,340	415	4.01%	0.19%	0.00%	10.52%	89.28%
EAST COLLIER	1,758	0	0.00%	0.00%	0.00%	0.00%	100.00%
FLORIDA CITY	3,079	318	10.34%	1.38%	0.88%	35.83%	61.89%
HOMESTEAD	1,019	465	45.56%	0.05%	2.50%	6.47%	90.96%
INTRACOASTAL	19	12	63.36%	63.90%	0.00%	0.00%	36.09%
MODEL LAND	7,290	108	1.48%	0.00%	0.00%	0.00%	99.99%
NORTH CANAL	1,343	142	10.56%	0.00%	7.87%	23.54%	68.58%
TAMIAMI EAST	1,111	529	47.57%	25.78%	0.63%	66.77%	6.80%

Multiply hectares by 2.47 to obtain acres

Table 12 Existing Land Use — Estimated Mean Annual Pollutant Load Based on EMC Method

Basin	Area (ha)	Runoff (ha-m)/y	Annual Pollutant Loading (kg/y)							
			BOD-5	COD	TSS	TN	TKN	TP	DP	Zn
AREA B	16,894	4,086	441,066	2,840,998	7,559,871	78,916	64,682	17,160	7,427	9,954
Black Creek (C-1)	10,183	2,888	302,142	2,023,369	5,237,164	55,306	44,991	11,926	5,448	7,776
Cutler Drain (C-100)	10,400	4,490	496,068	3,172,854	7,971,631	84,172	70,659	18,173	7,785	10,885
Princeton Canal (C-102)	8,625	1,544	156,793	1,093,292	3,356,325	32,175	24,924	7,264	3,255	3,859
Mowry Canal (C-103)	12,754	3,004	314,486	2,124,355	6,012,697	59,803	47,850	13,256	5,902	7,709
Aerojet Canal (C-111)	38,648	1,570	133,771	982,617	3,330,222	32,441	24,536	7,048	3,278	2,997
Snapper Creek (C-2)	4,465	2,128	238,140	1,503,134	3,787,466	40,100	33,775	8,618	3,725	4,989
Miami Canal (C-6)	58	39	3,938	27,982	45,160	653	571	101	66	83
Coral Gables (C-3)	4,937	2,593	290,295	1,846,994	4,554,757	48,497	40,876	10,418	4,523	6,736
DA-1	2,463	1,302	146,566	918,193	2,296,245	24,534	20,769	5,189	2,283	2,953
DA-2	708	162	16,667	103,389	284,803	3,005	2,509	646	252	329
DA-3	1,040	233	22,708	144,770	358,317	4,120	3,495	831	370	439
DA-4	10,340	313	23,885	187,003	512,600	5,546	4,410	1,121	517	635
EAST COLLIER	1,758	1	141	866	2,390	24	20	5	2	3
FLORIDA CITY	3,079	221	8,924	108,847	300,995	2,556	2,588	495	293	157
HOMESTEAD	1,019	384	38,622	292,256	494,301	6,787	5,533	1,256	698	958
INTRACOASTAL	19	11	1,135	7,856	12,664	188	167	28	19	23
MODEL LAND	7,290	159	5,578	70,969	151,814	1,427	1,701	232	162	75
NORTH CANAL	1,343	122	7,524	70,758	239,357	2,075	1,708	452	231	159
TAMIAMI EAST	1,112	609	67,317	434,281	1,020,376	11,238	9,540	2,311	1,056	1,508

Multiply hectares by 2.47 to obtain acres

Table 13 Future Land Use — Estimated Mean Annual Pollutant Load Based on EMC Method

Basin	Area (ha)	Runoff (ha - m)/y	Annual Pollutant Loading (kg/y) BOD-5	COD	TSS	TN	TKN	TP	DP	Zn
AREA B	16,894	5,649	608,243	3,900,848	10,284,783	107,968	89,042	23,268	9,891	13,498
Black Creek (C-1)	10,183	4,382	483,350	3,132,254	7,843,702	82,977	68,768	18,085	7,953	12,578
Cutler Drain (C-100)	10,400	5,579	633,708	4,089,158	10,206,144	105,278	88,042	23,368	9,801	16,148
Princeton Canal (C-102)	8,625	1,488	152,147	1,038,829	3,338,415	32,179	24,438	7,256	3,223	3,734
Mowry Canal (C-103)	12,754	3,878	418,508	2,785,538	7,439,502	76,545	61,842	16,552	7,463	10,451
Aerojet Canal (C-111)	38,648	3,910	197,252	1,423,137	4,492,878	65,031	49,670	10,634	3,902	4,428
Snapper Creek (C-2)	4,465	2,384	268,746	1,684,157	4,230,995	44,933	37,960	9,620	4,185	5,682
Miami Canal (C-6)	58	51	4,798	33,636	54,428	829	730	122	79	103
Coral Gables (C-3)	4,937	2,736	304,550	1,943,217	4,691,968	50,839	43,012	10,708	4,763	6,949
DA-1	2,463	1,445	156,021	982,888	2,345,720	26,517	22,579	5,335	2,452	3,091
DA-2	708	247	24,632	152,028	417,839	4,540	3,775	957	368	486
DA-3	1,040	375	35,775	217,136	531,556	6,601	5,583	1,280	566	663
DA-4	10,340	1,441	89,565	574,430	1,526,515	22,845	18,635	3,761	1,323	1,760
EAST COLLIER	1,758	139	2,089	16,709	43,862	1,741	1,379	153	6	45
FLORIDA CITY	3,079	776	77,625	494,672	1,349,138	14,472	11,884	3,067	1,231	1,727
HOMESTEAD	1,019	678	65,535	382,947	602,701	11,113	9,878	1,777	1,224	1,164
INTRACOASTAL	19	15	1,283	8,848	14,728	239	210	33	21	26
MODEL LAND	7,290	592	11,362	84,169	201,646	7,520	6,008	693	79	223
NORTH CANAL	1,343	337	34,466	244,055	639,302	6,379	5,033	1,491	586	1,382
TAMIAMI EAST	1,111	703	76,958	496,633	1,111,441	12,815	10,995	2,494	1,220	1,568

Multiply hectares by 2.47 to obtain acres

Table 14 Canal Quality/Quantity Data — Mean Daily Loading

Basin/Canal	Station I.D.	Mean Daily Loading TP kg/d	TN kg/d	Volume m3/d
Area B	TM02	6.01	114.22	277,452
Black Creek (C-1)	BL01	5.29	160.59	382,342
Cutler Drain (C-100)	CD02	0.37	3.53	30,452
Princeton Canal (C-102)	PR01	4.16	312.36	219,932
Mowry Canal (C-103)	MW01	3.29	222.85	490,616
Aerojet Canal (C-111)	AR01	1.12	14.19	94,740
Snapper Creek (C-2)	SP01	2.36	24.29	186,096
Miami Canal (C-6)	MR01	3.38	36.79	236,849
Coral Gables (C-3)	CG01	N/A	N/A	N/A
Homestead	MI01	N/A	N/A	N/A
Florida City	N/A	N/A	N/A	N/A
Model Land	N/A	N/A	N/A	N/A
North Canal	N/A	N/A	N/A	N/A
East Collier	N/A	N/A	N/A	N/A
Tamiami East	N/A	N/A	N/A	N/A

N/A — Data Not Available

Table 15 Existing Land Use — 5 yr 24 hr Storm Load per Basin

Basin	Basin Area (ha)	24hr Loading TN kg/d	TP kg/d	Volume m3/d
AREA B	16,894	432	475	2,053,289
Black Creek (C-1)	10,183	370	323	1,483,774
Cutler Drain (C-100)	10,400	454	434	1,867,688
Princeton Canal (C-102)	8,625	237	232	867,458
Mowry Canal (C-103)	12,754	342	380	1,457,504
Aerojet Canal (C-111)	38,648	243	612	1,412,975
Snapper Creek (C-2)	4,465	327	238	1,007,298
Miami Canal (C-6)	58	72	7	50,604
Coral Gables (C-3)	4,937	369	293	1,184,634
DA-1	2,463	286	177	724,481
DA-2	708	70	31	105,733
DA-3	1,040	102	38	179,640
DA-4	10,340	125	194	454,572
EAST COLLIER	1,758	30	40	55,790
FLORIDA CITY	3,079	98	66	239,121
HOMESTEAD	1,019	199	36	371,356
INTRACOASTAL	19	38	2	17,832
MODEL LAND	7,290	93	133	294,451
NORTH CANAL	1,343	72	35	132,359
TAMIAMI EAST	1,112	208	92	399,774

Multiply hectares by 2.47 to obtain acres

Table 16 Future Land Use — 5 yr 24 hr Storm Load per Basin

Basin	Basin Area (ha)	24hr Loading TN kg/d	TP kg/d	Volume m3/d
AREA B	16,894	558	578	2,717,221
Black Creek (C-1)	10,183	496	413	2,045,447
Cutler Drain (C-100)	10,400	538	559	2,250,597
Princeton Canal (C-102)	8,625	244	233	894,207
Mowry Canal (C-103)	12,754	453	471	1,985,202
Aerojet Canal (C-111)	38,648	278	644	1,632,647
Snapper Creek (C-2)	4,465	369	284	1,149,056
Miami Canal (C-6)	58	81	6	57,671
Coral Gables (C-3)	4,937	420	319	1,364,825
DA-1	2,463	345	187	887,604
DA-2	708	109	31	171,951
DA-3	1,040	132	41	238,915
DA-4	10,340	186	237	701,214
EAST COLLIER	1,758	30	39	55,171
FLORIDA CITY	3,079	172	115	444,918
HOMESTEAD	1,019	242	31	459,372
INTRACOASTAL	19	44	2	20,815
MODEL LAND	7,290	102	130	328,235
NORTH CANAL	1,343	118	46	227,106
TAMIAMI EAST	1,112	258	113	507,455

Multiply hectares by 2.47 to obtain acres

Table 17 Existing Land Use — Mean Daily Pollutant Load per Basin and Required Wetland Treatment Area

Basin	Basin Area (ha)	BOD-5 kg/d	TSS kg/d	TN kg/d	TP kg/d	VOL m3/d	TSS Area (ha)	TSS % BasinArea	TN (ha)	TN % BasinArea	TP (ha)	TP % BasinArea	BOD (ha)	BOD % BasinArea	Volume (ha)	Volume % Basin
AREA B	16,894	1,208	20,712	216.21	47.01	111,941	935	6%	103	1%	231	1%	81	0%	67	0%
Black Creek (C-1)	10,183	828	14,348	151.52	32.67	79,112	646	6%	72	1%	161	2%	54	1%	47	0%
Cutler Drain (C-100)	10,400	1,359	21,840	230.61	49.79	123,019	981	9%	109	1%	245	2%	93	1%	74	1%
Princeton Canal (C-102)	8,625	430	9,195	88.15	19.90	42,305	422	5%	42	0%	98	1%	27	0%	25	0%
Mowry Canal (C-103)	12,754	862	16,473	163.84	36.32	82,311	750	6%	78	1%	179	1%	56	0%	49	0%
Aerojet Canal (C-111)	38,648	366	9,124	88.88	19.31	43,018	417	1%	42	0%	95	0%	19	0%	26	0%
Snapper Creek (C-2)	4,465	652	10,377	109.86	23.61	58,304	466	10%	52	1%	116	3%	45	1%	35	1%
Miami Canal (C-6)	58	11	124	1.79	0.28	1,055	5	9%	1	1%	1	2%	1	1%	1	1%
Coral Gables (C-3)	4,937	795	12,479	132.87	28.54	71,037	560	11%	63	1%	140	3%	55	1%	43	1%
DA-1	2,463	402	6,291	67.22	14.22	35,673	282	11%	32	1%	70	3%	28	1%	21	1%
DA-2	708	46	780	8.23	1.77	4,446	35	5%	4	1%	9	1%	3	0%	3	0%
DA-3	1,040	62	982	11.29	2.28	6,381	43	4%	5	1%	11	1%	4	0%	4	0%
DA-4	10,340	65	1,404	15.19	3.07	8,580	62	1%	7	0%	15	0%	3	0%	5	0%
EAST COLLIER	1,758	0	7	0.60	0.10	33	0	0%	0	0%	0	0%	0	0%	0	0%
FLORIDA CITY	3,079	24	825	7.00	1.36	6,065	36	1%	3	0%	7	0%	-1	-0%	4	0%
HOMESTEAD	1,019	106	1,354	18.60	3.44	10,531	58	6%	9	1%	17	2%	7	1%	6	1%
INTRACOASTAL	19	3	35	0.51	0.80	308	1	8%	0	1%	0	2%	0	1%	0	1%
MODEL LAND	7,290	15	416	3.91	0.63	4,355	17	0%	2	0%	3	0%	-1	-0%	3	0%
NORTH CANAL	1,343	21	656	5.68	1.24	3,348	30	2%	3	0%	6	0%	0	0%	2	0%
TAMIAMI EAST	1,112	184	2,796	30.79	6.33	16,691	125	11%	15	1%	31	3%	13	1%	10	1%

Multiply hectares by 2.47 to obtain acres

Table 18 Future Land Use — Mean Daily Pollutant Load per Basin and Required Wetland Treatment Area

Basin	Basin Area (ha)	Mean Daily Loading BOD-5 kg/d	TSS kg/d	TN kg/d	TP kg/d	VOL m3/d	Treatment Area TSS Area (ha)	TSS % BasinArea	TN (ha)	TN % BasinArea	TP (ha)	TP % BasinArea	BOD (ha)	BOD % BasinArea	Volume (ha)	Volume % Basin
AREA B	16,894	28,177	296	64	1,666	154,771	1270	8%	140	0.8%	313	1.8%	112	0.6%	93	0.5%
Black Creek (C-1)	10,183	21,490	227	50	1,324	120,066	966	9%	108	1.0%	244	2.3%	90	0.8%	72	0.7%
Cutler Drain (C-100)	10,400	27,962	288	64	1,736	152,849	1261	12%	137	1.3%	315	3.0%	121	1.1%	92	0.8%
Princeton Canal (C-102)	8,625	9,146	88	20	417	40,779	421	5%	42	0.4%	98	1.1%	27	0.3%	24	0.2%
Mowry Canal (C-103)	12,754	20,382	210	45	1,147	106,241	923	7%	100	0.7%	223	1.7%	77	0.6%	64	0.4%
Aerojet Canal (C-111)	38,648	12,309	178	29	540	107,112	519	1%	84	0.2%	142	0.3%	1	0.0%	64	0.1%
Snapper Creek (C-2)	4,465	11,592	123	26	736	65,320	521	12%	58	1.3%	129	2.9%	51	1.1%	39	0.8%
Miami Canal (C-6)	58	149	2	0	13	1,385	6	11%	1	1.8%	2	2.8%	1	1.3%	1	1.4%
Coral Gables (C-3)	4,937	12,855	139	29	834	74,963	575	12%	66	1.3%	144	2.9%	57	1.1%	45	0.9%
DA-1	2,463	6,427	73	15	427	39,587	286	12%	34	1.3%	72	2.9%	29	1.1%	24	0.9%
DA-2	708	1,145	12	3	67	6,777	51	7%	6	0.8%	13	1.8%	4	0.5%	4	0.5%
DA-3	1,040	1,456	18	4	98	10,282	64	6%	9	0.8%	17	1.6%	6	0.5%	6	0.5%
DA-4	10,340	4,182	63	10	245	39,482	174	2%	29	0.2%	50	0.4%	6	0.1%	24	0.2%
EAST COLLIER	1,758	120	5	0	6	3,815	3	0%	2	0.1%	2	0.1%	-2	0.0%	2	0.1%
FLORIDA CITY	3,079	3,696	40	8	213	21,247	166	5%	19	0.6%	41	1.3%	13	0.4%	13	0.4%
HOMESTEAD	1,019	1,651	30	5	180	18,570	66	6%	14	1.4%	24	2.3%	11	1.0%	11	1.0%
INTRACOASTAL	19	40	1	0	4	411	2	9%	0	1.6%	0	2.3%	0	0.9%	0	1.3%
MODEL LAND	7,290	552	21	2	31	16,228	13	0%	9	0.1%	9	0.1%	-6	0.0%	10	0.1%
NORTH CANAL	1,343	1,752	17	4	94	9,238	79	6%	8	0.6%	20	1.4%	6	0.4%	6	0.4%
TAMIAMI EAST	1,112	3,045	35	7	211	19,272	135	12%	17	1.4%	33	3.0%	14	1.2%	12	1.0%

Multiply hectares by 2.47 to obtain acres

Table 19 Wetland Treatment System based on Canal Quality/Quantity Data

	Treatment Area		
Basin/Canal	TP Area (ha)	TN Area (ha)	Volume Area (ha)
Area B	20	43	166
Black Creek (C-1)	13	61	229
Cutler Drain (C-100)	1	0	18
Princeton Canal (C-102)	13	145	132
Mowry Canal (C-103)	0	87	294
Aerojet Canal (C-111)	2	2	57
Snapper Creek (C-2)	5	3	112
Miami Canal (C-6)	9	7	142
Coral Gables (C-3)	N/A	N/A	N/A
Homestead	N/A	N/A	N/A
Florida City	N/A	N/A	N/A
Model Land	N/A	N/A	N/A
North Canal	N/A	N/A	N/A
East Collier	N/A	N/A	N/A
Tamiami East	N/A	N/A	N/A

N/A — Data Not Available

Multiply hectares by 2.47 to obtain acres

Table 20 Wetland Treatment System based on Existing Land Use and 5 yr 24 hr Storm

Basin	Basin Area (ha)	Treatment Area TN Area (ha)	TN % Basin	TP Area (ha)	TP % Basin	Volume Area (ha)	Volume % Basin
AREA B	16,894	38	0.2%	767	4.5%	137	0.8%
Black Creek (C-1)	10,183	37	0.3%	522	5.1%	99	0.9%
Cutler Drain (C-100)	10,400	45	0.4%	702	6.7%	125	1.1%
Princeton Canal (C-102)	8,625	25	0.2%	377	4.3%	58	0.6%
Mowry Canal (C-103)	12,754	33	0.2%	617	4.8%	97	0.7%
Aerojet Canal (C-111)	38,648	17	0.0%	1004	2.5%	94	0.2%
Snapper Creek (C-2)	4,465	38	0.8%	386	8.6%	67	1.5%
Miami Canal (C-6)	58	11	19.4%	11	18.4%	3	5.8%
Coral Gables (C-3)	4,937	42	0.8%	474	9.5%	79	1.5%
DA-1	2,463	36	1.4%	286	11.6%	48	1.9%
DA-2	708	10	1.3%	51	7.1%	7	0.9%
DA-3	1,040	14	1.3%	61	5.9%	12	1.1%
DA-4	10,340	13	0.1%	317	3.0%	30	0.2%
EAST COLLIER	1,758	4	0.2%	65	3.7%	4	0.2%
FLORIDA CITY	3,079	12	0.3%	107	3.4%	16	0.5%
HOMESTEAD	1,019	27	2.6%	56	5.5%	25	2.4%
INTRACOASTAL	19	6	32.8%	3	17.3%	1	6.4%
MODEL LAND	7,290	11	0.1%	219	3.0%	20	0.2%
NORTH CANAL	1,343	10	0.7%	58	4.2%	9	0.6%
TAMIAMI EAST	1,112	28	2.5%	149	13.4%	27	2.3%

Multiply hectares by 2.47 to obtain acres

Table 21 Wetland Treatment System based on Future Land Use and 5 yr 24 hr Storm

Basin	Basin Area (ha)	TN Area (ha)	TN % Basin	TP Area (ha)	TP % Basin	Volume Area (ha)	Volume % Basin
AREA B	16,894	48	0%	932	5.5%	181	1.0%
Black Creek (C-1)	10,183	49	0%	665	6.5%	136	1.3%
Cutler Drain (C-100)	10,400	52	1%	905	8.7%	150	1.4%
Princeton Canal (C-102)	8,625	26	0%	378	4.3%	60	0.6%
Mowry Canal (C-103)	12,754	42	0%	762	5.9%	132	1.0%
Aerojet Canal (C-111)	38,648	19	0%	1055	2.7%	109	0.2%
Snapper Creek (C-2)	4,465	42	1%	459	10.2%	77	1.7%
Miami Canal (C-6)	58	13	22%	9	16.4%	4	6.6%
Coral Gables (C-3)	4,937	47	1%	516	10.4%	91	1.8%
DA-1	2,463	43	2%	302	12.2%	59	2.4%
DA-2	708	15	2%	50	7.0%	11	1.6%
DA-3	1,040	18	2%	66	6.3%	16	1.5%
DA-4	10,340	19	0%	386	3.7%	47	0.4%
EAST COLLIER	1,758	4	0%	64	3.6%	4	0.2%
FLORIDA CITY	3,079	21	1%	187	6.0%	30	0.9%
HOMESTEAD	1,019	33	3%	46	4.5%	31	3.0%
INTRACOASTAL	19	7	38%	3	17.8%	1	7.4%
MODEL LAND	7,290	12	0%	213	2.9%	22	0.3%
NORTH CANAL	1,343	16	1%	74	5.4%	15	1.1%
TAMIAMI EAST	1,111	35	3%	182	16.3%	34	3.0%

Multiply hectares by 2.47 to obtain acres

Table 22 Land Available and Required for Wetland Reclamation Using Loadings from Various Methods as Determining Factor

	Available Land				Land Required for Wetland Treatment System						
	Agriculture	Wetland	Rangeland	Total	Exist EMC TSS	Future EMC TSS	Exist 5yr TP	Future 5yr TP	Exist 5yr Volume	Future 5yr Volume	Canal Volume
Basin	(ha)	(ha)	(ha)	(ha)	(ha)	(ha)	(ha)	(ha)	(ha)	(ha)	(ha)
AREA B	3,769	327	637	4,734	935	1,270	767	932	137	181	166
Black Creek (C-1)	4,167	11	64	4,242	646	966	522	665	99	136	229
Cutler Drain (C-100)	208	20	2	231	981	1,261	702	905	125	150	18
Princeton Canal (C-102)	5,467	110	49	5,626	422	421	377	378	58	60	132
Mowry Canal (C-103)	6,726	91	29	6,846	750	923	617	762	97	132	294
Aerojet Canal (C-111)	7,890	19,284	514	27,688	417	519	1,004	1,055	94	109	57
Snapper Creek (C-2)	39	0	0	39	466	521	386	459	67	77	112
Miami Canal (C-6)	0	0	0	0	5	6	11	9	3	4	142
Coral Gables (C-3)	0	16	0	16	560	575	474	516	79	91	N/A
DA-1	0	1	0	1	282	286	286	302	48	59	N/A
DA-2	0	38	0	38	35	51	51	50	7	11	N/A
DA-3	45	80	0	125	43	64	61	66	12	16	N/A
DA-4	853	5,415	536	6,804	62	174	317	386	30	47	N/A
EAST COLLIER	0	0	0	0	0	3	64	64	4	4	N/A
FLORIDA CITY	623	517	68	1,207	36	166	107	187	16	30	N/A
HOMESTEAD	41	0	0	41	58	66	56	46	25	31	N/A
INTRACOASTAL	0	0	0	0	1	2	3	3	1	1	N/A
MODEL LAND	136	5,598	90	5,825	17	13	219	213	20	22	N/A
NORTH CANAL	641	1	0	642	30	79	58	74	9	15	N/A
TAMIAMI EAST	0	0	0	0	125	135	149	182	27	34	N/A
Total	30,607	31,509	1,989	64,105	5,873	7,499	6,231	7,254	957	1,210	

Multiply hectares by 2.47 to obtain acres

Table 23 Monetary Cost Comparison of Stormwater Treatment Technologies

Treatment System	Costing Unit	Unit	TP Removed kg/yr *	Construction Costs Total $	Construction Costs $/yr (30yr life)	O&M Costs $/yr	Annual Costs $/kg TP removed
Wetland System	2.9	ac	79.0	$48,024	$1,601	$690	$29.00
Drainage Wells							
30" Dia., 100' Deep	1	Wells	25.1	$30,031	$1,001	$927	$76.81
36" Dia., 100' Deep	1	Wells	25.1	$36,897	$1,230	$927	$85.93
18" Dia., 100' Deep	2	Wells	25.1	$46,000	$1,533	$1,854	$134.95
Wet Ponds	344,124	cu. ft.	45.9	$85,956	$2,865	$3,438	$137.31
Street Sweeping	33.1	curb mi/y	5.3	N/A	N/A	$1,033	$194.60
Grassed Swales	123,600	sq.ft.	86.4	$65,372	$2,179	$18,540	$239.80
Auger Holes							
18" Dia. & 15' Deep	8	Holes	29.3	$20,000	$667	$7,696	$285.42
French Drains							
Dia. = 15"	28,046	lin. ft.	62.7	$1,119,877	$37,329	$68,432	$1,686.05
Dia, = 30"	7,010	lin. ft.	62.7	$416,604	$13,887	$17,104	$494.06
Dia. = 60"	1,753	lin. ft.	62.7	$172,548	$5,752	$4,277	$159.88
Slab Covered Trenches							
Width = 3'	7,647	lin. ft.	55.0	$160,969	$5,366	$18,659	$436.81
2'	11,470	lin. ft.	55.0	$191,549	$6,385	$27,987	$624.94

Assumptions

Drainage Area = 100 ac

Landuse Mix is: 5% Transportation, 15% Institutional, 20% Commercial and 60% Residential

Total Phosphorus loading is 192 lb/yr (87 kg/yr)

Total Annual Rainfall is 52 in/yr

Total Annual Runoff is 26 in/yr or 260 ac-ft/y (50% of Rainfall based on Assumed Landuse Mix)

Total Fraction of Stormwater Runoff Captured and/or Infiltrated by Infiltration/Storage System is 90%.

Fraction of Stormwater Runoff Captured and Infiltrated by Infiltration Systems alone is 48%.

Street Sweeping Interval = 30 days using Mechanical Sweeper

* TP removed = PAF x PCF x EFF(TP) x Loading of TP (except for Street Sweeping, Wet Ponds, Wetlands).

Notes to Table 23

Definitions:
PAF is Pollutant Availability Factor, ratio of area tributary to infiltration device to total area of subbasin (CH2M Hill, 1994)
PCF is Pollutant Capture Fraction. Amount of pollutant that enters treatment device (CH2M Hill, 1994)
EFF(TP) is pollutant removal efficiency for total phosphorus (CH2M Hill, 1994)
SCF is Stormwater Capture Fraction. Fraction of stormwater entering treatment device (CH2M Hill, 1994)

Street Sweeping
Efficiency of Mechanical Sweeper = 20%
Sweep Interval = 30 days
Load Reduction = 6.1% (CH2M Hill, 1994)
Curb Mileage “Density” based on 5634 ac Sample from South Dade ARC/INFO coverages.

Wetland Treatment System
TP uptake rate = 22.2 lbs/ac/yr (55 kg/ha/yr)

Drainage Wells
Annual Infiltration Required = 2.8314e8 cu. ft./yr
Infiltration rate = 2000 gallons per minute (gpm) for 15" dia., 70' deep well. (PBS&J, Inc., 1992)
Annual Infiltration Available = 5.17e5 cu. ft./yr x Surface Area of Drainage Well
# Wells Needed = Ann. Infiltration Required divided by Ann. Infiltration Available per Well
PAF = 1
PCF = .48
EFF(TP) = .60

Wet Ponds
SCF = .90
Annual Storage Volume / Annual Runoff Volume (Vs/Vr)= 0.0304 (CH2M Hill, 1994)
Annual Storage Volume (Vs) = 7.9 ac-ft
Average Depth Assumed = 3 ft.
Surface Area of Wet Pond = Storage Volume / Avg. Depth = 2.63 ac
TP removal rate = 59% of TSS removal
Ratio of Area of Wet Pond to Drainage Area (Awp/Ada) = 0.0263
TSS removal = 0.891 (based on Vs/Vr and Awp/Ada) (CH2M Hill, 1994)

Grassed Swales
Vs = 7.9 ac-ft/y
Average Depth = 3 ft.
Surface Area = Vs / average depth = 2.6 ac-ft
Swale Width = 15 ft
Must take into account trapezoidal cross-section of swale,
therefore, actual surface area is larger
Surface Area of Bottom = 22,600 sq ft
Surface Area of Side = 101,000 sq ft
Actual Surface Area = SA of Bottom and Sides
PAF = 1
PCF = .90
EFF(TP) = .80 (CH2M Hill, 1994)

Auger Holes
Same Method as applied to Drainage Wells to calculate # Holes needed
PAF = 1
PCF = 0.48
EFF(TP) = 0.70

French Drains
Vs = 7.9 ac-ft = 344,124 cu. ft.
Linear Feet Needed = Vs / Storage Volume per ft of French Drain
For 15" dia. drain: 344,124 cu ft / 12.27 cu ft per lin. ft = 28,040 lin ft
PAF = 1
PCF = 0.90
EFF(TP) = 0.80

Slab Covered Trenches
Depth = 15 ft
Width = 2 or 3 ft
Linear Feet Needed = Vs / Cross-sectional Area of Trench = 344,124 cu ft / (width x 15 ft depth)
PAF = 1
PCF = 0.90
EFF(TP) = 0.70

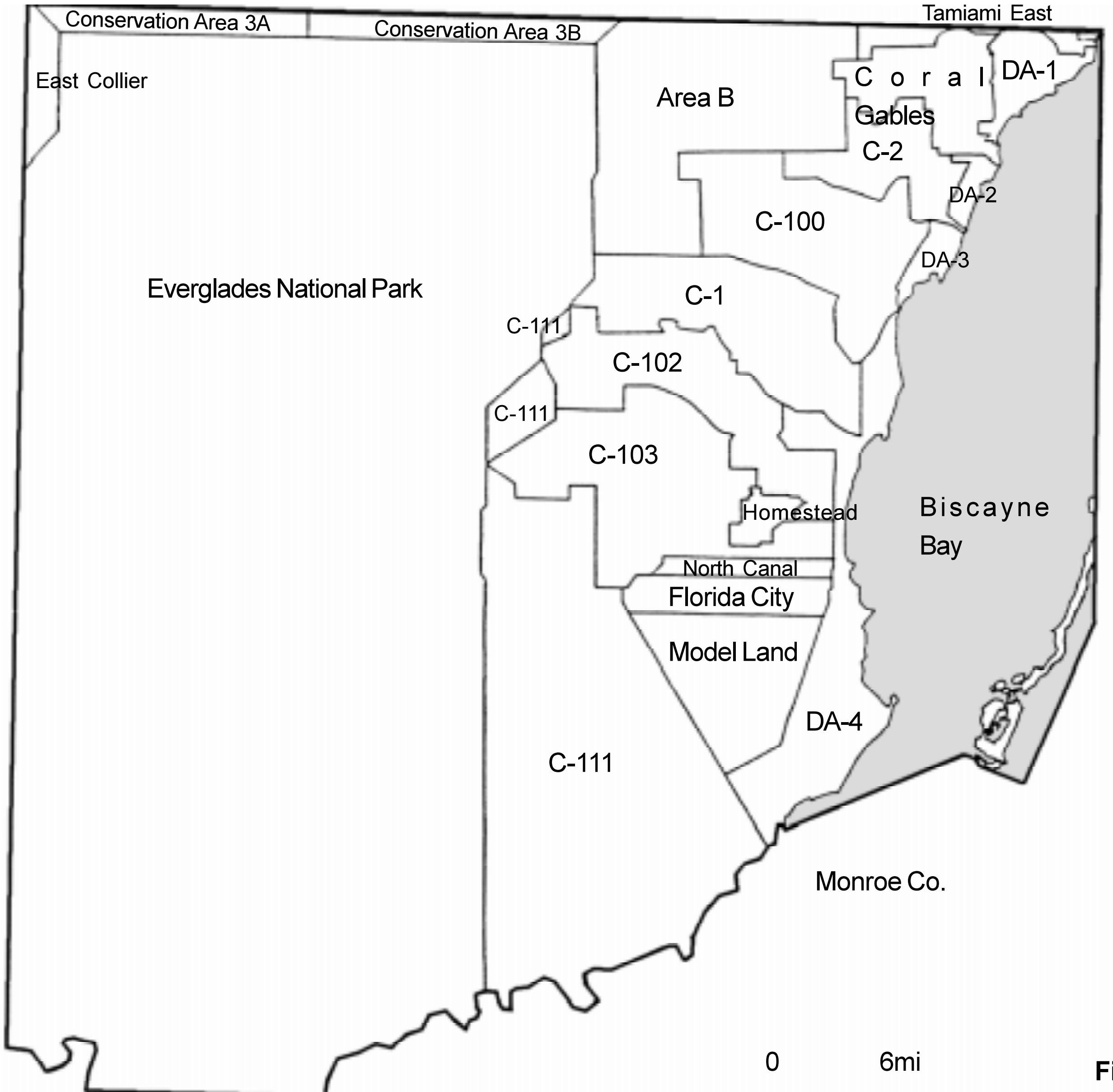

Figure 1. South Dade Regional Study Area with Canal Basin Boundaries

THE ROLE OF ECONOMICS IN THE VALUATION OF WETLANDS

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Historically, wetlands were plentiful throughout much of the United States. According to a recent report by the U.S. Department of Interior, only 104 million acres (47 percent) of the original 221 million acres of wetlands remain in the contiguous 48 states. Of these remaining wetlands, few remain in pristine condition.

The following report is a review of the use of economic analysis in the valuation of wetlands. This review reflects the multiplicity of ways and means for assessing environmental values. Such multiplicity represents the diversity of benefits provided by the many environmental functions, therefore the method to measure the socioeconomic value of one function may not be appropriate to measure the value of another function.

From the perspective of land economics there is no basic difference between the development of wetlands and the development of any other type of land. Land is devoted to a particular use when that particular use is the most beneficial to the owner of that land. An owner will select the alternative that yields the highest return. The only difference between wetlands and other types of land is that wetlands would typically have higher development costs associated with drainage. Theoretically, these higher development costs would keep wetlands from being developed until after less costly lands have been developed.

Early conversions of wetlands were due primarily to the abundance of these areas and a lack of understanding of the important environmental services and amenities they provide. Public policy decisions such as the Swamp

Lands Acts in 1849 and 1850 and federally funded drainage programs made development of these areas economically competitive with lands that had lower development costs.

As we learn more about the complexities of environmental systems and how environmental and economic systems are linked, it becomes increasingly difficult to define and assess environmental-economic trade-offs. This lack of understanding has led to the undervaluing of natural resources. In turn this has led to heavy depletion of, and stress on, remaining wetland ecosystems.

INTRODUCTION

Significant public policy concerns have surfaced recently in regard to wetland loss. Advances in our understanding of wetland habitat, their function in nature and in relation to human welfare have resulted in an increased focus on their importance to society.

Ordinarily, the economic measure of real value of anything is expressed by a trade-off. How much of some good is a person willing to give up to acquire one more unit of something else? This is known as the marginal rate of substitution. The basic concept is no different for the services of natural resources. The differences arise in measuring these values. For the case of commodities available on markets, the assumed behavior underlying people's choices allows us to conclude that relative prices, under ideal conditions, reveal thee incremental values. When the commodities are available largely outside markets, it becomes more difficult to infer what trade-offs people would be willing to make to acquire the resource's services. Because of externalities and the common property and public characteristics of at least some of these services, market forces cannot be relied on to guide them to their most highly values uses, nor to reveal prices that reflect their true social values. It is the failure of the market system to allocate and price resource and environmental services correctly that creates the need for economic measures of values to guide policy making. For this reason it is difficult to determine the economic value of wetlands, and so there is no price signal indicating that the value of wetlands increases along with their scarcity and that they merit conservation. Wetlands are a classic example of market failure; the wetland owner generally cannot capture the benefits of his resources for his own use or sale. The flood protection benefits of wetlands accrue to others downstream. Many of the fish and wildlife that breed in and inhabit the wetlands migrate, and are captured or enjoyed by others. The ground water recharge and sediment trapping benefits cannot be commercially exploited. For the owner of a wetland to benefit economically from his resource, he usually has to alter it, convert it, and develop it. This is the basis of the problem of the excessive development of wetland habitats[1]

PROBLEMS ASSOCIATED WITH THE VALUATION OF WETLANDS

In order for an economic valuation of wetlands to accurately reflect their true costs and benefits, the analysis must be comprehensive in scope, variables and consideration of techniques. Past analysis has often ignored important techniques and failed to monetize all benefits exhibited by wetlands. These failures have led to an underestimation of the value of wetlands and encouraged their destruction. Recent improvements in techniques and methodologies have improved upon the deficiencies of past attempts. Modern techniques now exist that are excellent tools for monetizing non market benefits of wetlands. Although there are till inherent difficulties in this type of analysis, they do not preclude it from being an important tool in evaluating development decisions. The difficulties involved in carrying out wetland valuation can be described in three categories: economic theory; scientific knowledge; and political/institutional problems.

Economic Theory

Standard economic techniques are lacking in their ability to adequately reflect the true environmental and socioeconomic value of natural resources and ecosystems. This is because standard techniques are typically not well-suited for valuing public goods. Economic techniques must be altered, often making them complicated and data intensive. Moreover, although much has been done in recent years to improve the scope and accuracy of wetland valuation techniques, little has been accomplished in regard to techniques for incorporating these valuation methods into the decision-making processes.

The ideal economic model for wetland valuation should combine economic techniques with comprehensive scientific data on the biological and physical relationships, linking wetland characteristics with the benefits they give to society.

Scientific Knowledge

The valuation of welfare to humans in regard to wetland development involves detailed scientific analysis and information to comprehensively identify and quantify the changes in benefits and costs due to development. A major shortfall in this analysis is that, to this day, environmental systems remain so complicated and composed of so many variables, as to be a significant challenge to comprehensive scientific analysis. The interactions of the wetland environmental system, which produces benefits to humans, are still not completely understood by man, and thus can only be modeled with some amount of error. Scientific methods for determining how development might affect the nature and supply of wetland benefits and for quantifying wetland functions are greatly lacking, even for those functions which we have the greatest understanding.[2] Even through complicated scientific analysis, it is difficult to quantify the benefits and costs that wetlands exhibit This quantification is essential and must be done accurately in order to use the data in economic analysis. The level of scientific knowledge and expertise we do have can support this analysis and aid in the decision making process. These imperfections should not preclude attempts at analysis which can still support policy.

Political/Institutional Problems

The decision making process which utilizes non-market valuation techniques should be flexible to meet the needs of particular situations, as well as specific enough to apply the appropriate techniques. However, the political and institutional framework of decision-making holds other priorities which often preclude the goal of economically sound results. Historically, public policy has allowed monetized benefit-cost criteria to be used in agency project decision making. Political decisions tend to value market goods and services over nonmarket environmental goods and services. This tendency has been institutionalized through standardized government guidelines for benefit-cost analysis. This process has led to the undervaluing of nonmarket goods and services of the environment in the decision making process.

ECONOMIC METHODOLOGIES FOR THE VALUATION OF WETLANDS

Despite the economic, scientific, and political barriers to wetlands valuation, tremendous strides have been made in recent years utilizing various techniques for wetland's valuation. Critical to the sustainability of wetland resources are the use of acceptable methods for assessment of wetland functions and values. Such an evaluation should include an ecological assessment and socioeconomic valuation of environmental functions. There are a number of different techniques used for wetland valuation. The type of methodology to use depends on the context of the situation and what is being valued. For example, a wetland valuation may be performed in a real estate transaction between private parties. In this situation a valuation would be performed in order to determine the property value of the wetland in conjunction with any attached property. Other valuation methods measure the value of the wetland in terms of the environmental goods and services. The purpose of the analysis determines the type of valuation methodology to use. However, variations of the came methodology may be used in different situations.

The following methodologies are organized according to the context of the valuation. The first section examines valuation methods used to measure the physical goods produced by wetlands. The second section presents methodologies used to measure wetland services. The third section examines valuation methods for measuring the aesthetic and recreational opportunities that wetlands supply. The fourth section contains methods that are used to determine the real estate value of wetlands. The final section discusses other concepts and methods that are related to the valuation of wetlands, such as the option, intrinsic value, and wetlands mitigation banking.

Physical Goods

This section describes methodologies that are used to measure the physical goods produced in wetlands. The value of these goods determines the value of the wetlands, thus "the value of the wetland is calculated by the dollar value of its yield."[3] Physical goods include those goods produced and gathered in wetlands, and any intermediate goods that may be input into a final good or service collected or consumed outside of the wetland. There are three different models in the section: Net Factor Income Method, Present Value Generated Per Acre Model, and the Residual Rent Model.

Net Factor Income (NFI) Method [4]

This method determines the income appropriate to natural resources for their part in the production of commercial goods and activities. The economic profits of a commercial activity are estimated, subtracting all costs of production such as labor, capital, and management. This profit estimation is equivalent to the value of the natural resources used in the commercial production process. One form of the NFI valuation method is the bioeconomic model. This model has been used to estimate the value of wetlands in the production of commercial goods such as blue crabs on the Florida Gulf Coast. The NFI method can also be used to measure wetland services such as water supply and tertiary waste treatment.

Present Value Generated Per Acre Model [5]

This model was created in 1974 by J.G. Gosselink, E.P. Odum, and R.M. Pope. The model uses a “life-support” valuation to estimate the value of unaltered wetlands. The economic value of the products of wetlands, such as the profits generated from the sales of furs, is calculated and then divided by the number of wetland acres. This produces the annual flow per year, which gives the economic value of wetland acre per year.

Residual Rent Model [6]

This model is based on the Present Value Generated Per Acre Model but with alterations suggested by Tihansky and Meade (1976) to account for the overestimates made by Gosselink, Odum, and Pope. In the case of fisheries, the share of the landed revenues accruing to capital and labor would be deducted from the total landed value to estimate the net worth of the actual fishery resources. This net worth, according to Tihansky and Meade, may depend upon the carrying capacity of existing wetlands.

Marginal Productivity Model [7]

Wetlands are often only one input in the overall production process of many outputs. The Marginal Productivity Model can be used to determine how incremental changes in a wetland will affect certain outputs, such as the number of fish caught. A linear function is used to calculate the marginal productivity of one acre of wetland services in relation to the number of fish caught. An increase (or decrease) in wetland acreage will increase (or decrease) the fish catch by a proportional amount. The amount that consumers are willing to pay for this additional amount of fish is then calculated to produce the marginal value to society of the additional wetland acreage.

Wetland Services

This section describes the methodologies that are used to measure the services that wetlands provide. The following examples represent both monetary approaches to wetland’s valuation and scientific approaches to function valuation. It should be understood that there is some overlap in the uses of these methodologies, and in some circumstances they can also be applied to the valuation of goods.

Energy Analysis (EA) Biological Productivity Method

This method was developed by H.T. Odum in 1977, and is based on the energy content of the natural environment. The EA approach rests on the assumption that the amount of energy required to produce a good is reflected in the good’s value. Net energy flow is used to estimate the work performed by the wetland in reproducing a good. A formula is used to value the calculated energy yield from an acre of wetland. This is done by dividing the gross national product (GNP) by the kilocalories consumed in the U.S. The formula[8] is written as follows:

$$\$/acre/year = kcal/acre/yr\left(\frac{\text{Gross National Product}}{\text{National Energy Consumption}}\right)$$

There are many criticism of this model, namely that it is not a true model of economic perspectives. According to Scodari, the EA model "neglects the role of consumer demand in determination of value, assuming that society's objective is to maximize net energy instead of consumer satisfaction."[9]

Merological Approach [10]

This approach assessed key functions on an individual basis with or without attempts to sum component values. One example of this approach is the Adamus method developed by Adamus and Stockwell in 1983. Under this method a wetland is ranked through the assignment of relative values to different functions, such as flood storage, erosion control, wildlife habitat, recreation, and water purification. The values are based on studies or other documented information. High values given for one or more of the functions are an indication that the wetland is performing a valuable service, thus qualifying it for preservation and/or use regulation.

Replacement Cost (RC) Method

This method estimates the value of a wetland service by using the cost associated with providing the same service through an alternative supply mechanism such as a technological substitute. There are three steps to this model, the first of which involves the estimation of the level of environmental service provided by the wetland. This can require an ecological assessment of the wetland service. The second step is to identify the alternative supply mechanism that could provide the same service at the lowest cost This requires engineering and cost assessments of the different alternative supply mechanisms. The third step is difficult because it requires determination of the public's demand for an alternative service if the wetland service was no longer available.

Damage Cost (DC) Method

This method estimates the costs of business and property damages resulting from the elimination of a wetland and the services that it performs. There are a number of steps involved in estimating the dollar amount associated with these losses. The first step is to perform an ecological assessment of the service level to determine how the elimination of the service would physically impact the environment. The next step involves the estimation of the potential physical property damage on an annual basis, or over some designated period of time The third step is to translate the damage into dollars. Finally, an investigation of alternative supply mechanisms must be undertaken to determine if a substitute mechanism could provide the wetland service at a lower cost. The replacement cost method can be used to perform this step.

Aesthetics and Recreational Opportunities

The methodologies used to determine the valuation of wetlands based on the aesthetics and recreational opportunities measure the public's willingness-to-pay for these features. The travel-cost and hedonic methods use data on market expenditures for goods to indirectly estimate the net benefits of these goods. The contingent technique estimates consumers' net willingness-to-pay through the use of survey techniques.

Travel Cost (TC) Method

The TC method is the oldest technique used for an estimation of the value of recreations benefits. The basic premise of this method is that the value or pubic demand of a recreational area, such as a wetland, is reflected in travel and other costs associated with visiting the site.

There re two models that fall under the TC method.

Single Site Model or Site Specific Model

This is the simplest version of the TC method. It plots the rate of site visitation against the costs of the visitation to determine the consumer demand for the recreational opportunities of that site. Thus it assumes that the only costs associated with visiting the site are the travel and time costs Concentric zones are drawn around the site and a survey of visitors is conducted to determine the origin of the visitors Based on this information a visitation rate is calculated, and a demand curve is generated to determine a price-participation relationship.

Population Specific Model

This model is similar to the single site model, but takes more variables into consideration. The Population Specific Model requires larger population samples and is generally more expensive to perform and more complex mathematically.

Hedonic Price Approach

The hedonic group of valuation methods is based on the concept that consumers derive pleasure from the attributes of a commodity that they pay for. Thus, the value placed on this commodity by the consumer is the sum of the value of the attributes. Property value (PV) analysis is a common hedonic technique. This method uses property values to estimate the value of environmental amenities or attributes. For example, it can be used to value water quality or aesthetic beauty associated with land adjacent to wetlands. There are two steps to this approach. In the first step, a regression analysis is completed. The dependent variable is the property value and the independent variables are quality and quantity measurements of different property characteristics, in addition to household socioeconomic characteristics. These parameters indicate the individual's marginal willingness-to-pay for each of the characteristics. The second step of the process involves using the implicit price of a characteristic to create a demand relationship. This demand relationship can then be utilized in estimating a use value measure.

Another hedonic method is known as the household production function approach. This approach reveals information regarding the amount a household actually paid for the pleasure derived from a natural resource. This is called revealed preference information because the household preferences are revealed through the purchases made by that household and through the activities in which the household engages. Thus, the value attributable to a natural resource is equal to a part of the total amount spent by a household on an activity associated with that natural resource. For examples, a fishing trip in a wetland involves fishing equipment, travel costs, and other associated costs. The value attributable to the wetland used for the fishing trip is equal to part of the associated total expenditure.

Hedonic Price Approach Analysis of the Impact of Maryland's Critical Area Act on Real Estate Values

An example of the effect of wetland protection on land values can be found in a study of the impact of Maryland's Critical Area Act (1984) on the real estate market. The law was formulated by Maryland policymakers as a growth management system to support efforts to improve water quality in the Chesapeake Bay. Although not designed specifically to protect wetlands, the critical area program, with its broad objectives of habitat and water quality improvement, contains a number of protective features for tidal and non-tidal wetlands. Beaton and Pollock studied the change in land values of four of the affected counties on the Chesapeake Bay over a six-year period before and after the law was implemented. The findings revealed that following the passage of the law, vacant land values did not decline, residential values grew significantly, and the value of waterfront Critical Areas grew more rapidly than upland properties.

The Critical Areas Act established a program to create buffer zones and limit development within 1,000 feet of the critical area of tidal water or tidal wetlands in Maryland's portion of the Chesapeake Bay. The act directs local governments to map and classify their critical areas into three categories based on the density of existing land uses: Intense Development Areas, Limited Development Areas, and Resource Conservation Areas.

For their assessment, Beaton and Pollock chose a hedonic price approach to measure the change in property values around the Chesapeake Bay as a result of Maryland's Critical Areas Act. Hedonic price theory forms the logical basis for separating the increment or decrement to value derived from a given land-use control from the other attributes that give value to the parcel. Real estate is sold as a bundle of attributes. The attributes include physical characteristics such as lot size, structure size and quality, as well as the legal right to change the current use. The sales price recorded for a parcel reflects the buyer's valuation of the total bundle. The hedonic price theory assigns an implicit price to each attribute by regressing the variables representing each desired attribute on the bundle's total selling price. It is necessary to group observations in such a fashion that unique locational attributes can be entered into the equation.

The database constructed for the analysis contains two important dimensions: observations on the real estate markets both before and after the growth controls are put in place; and data on an area possessing competitive markets with and without the growth controls. The latter is used as a control group for comparison. The data set identifies parcels by their Critical Area Status. It contains information on the size of the parcel, use category, improvement size, quality and age of improvement when built, and waterfront status. It also includes information on accessibility, measured as the distance from the parcel to the nearest major highway, distance to the county seat, and distance to the nearest metropolitan area's central business district The dependent variable represents the natural logarithm of the parcel's sale price as a function of the variables in the data set.

Hedonic price equations were prepared for four market areas adjacent to the Chesapeake Bay - two counties located on the eastern shore, and two others located on the western shore. The counties were also chosen on the basis of accessibility in terms of distance to the Bay and to major population centers. On each side of the Bay one of the counties is more accessible, while the other is more remote.

The research design used is a before-and-after comparison mode with a control group. The time series, represented by the year of parcel sales, begins with the two years of the initial efforts to implement growth controls along Maryland's Chesapeake Bay. The series' last two years coincide with the Commission's effort to prepare guidelines for both local land use controls and best management practices. The control group contains parcels with portions of the same county as the test parcels but in the non-critical area part of the county. This set of parcels is used to control regional price level variation caused by urban development and swings in the business cycle. They do not control for waterfront amenity in the absence of growth management policies. In addition, separate models were run for residential and vacant parcels in the four counties in order to explain the effects of current and anticipated future permitted uses of the parcel.

The residential model equations explain from 46 to 58 percent of the variation in the dependent variable. The regressions for residential models revealed that the value of parcels increases with the size of the residential parcel, and that these increases were greater in the parcels located in more remote areas. As expected, the physical existence of the waterfront amenity adds value to the property. Waterfront adds more value to parcels located in the two remote counties than it does to the two more accessible ones by a difference of ten to thirty percent. In one county, the non-waterfront Critical Area coefficient is negative. This was found to be reasonable in that terrain near the Bay is flat and in many cases these are swamp areas. Such land has neither the view amenity nor the capacity to pass a percolation test for a development permit. Other descriptive variables in the equations such as the quality of construction, age of dwelling unit, and distance, produced coefficients with the expected signs.

In contrast to the residential models, the vacant land model has a wide disparity in equation statistics among the four counties. The coefficients of determination ranged from 72 percent to 34 percent. The results revel more uncertainty in the models for vacant land price determination than that for residential property. The vacant land in the most developed jurisdictions in the study area had a higher coefficient for land area than the rural open spaces found in the other three counties. The coefficients for distance from the major employment centers have the appropriate negative coefficients.

In the case of residential property, waterfront is also a significant determinant of a vacant parcel's market price, adding from 66 to 100 percent to its value. Critical Area vacant land not located on the waterfront generates negative coefficients with one exception, where the positive coefficient may represent the premium obtained from the view amenity found in that particular county.

Beaton and Pollock concluded that following the passage of the Law, residential property in waterfront Critical Areas grew more rapidly in value than their upland counterpart. However, this phenomenon was observed to occur only within the two most accessible market areas on either side of the Bay; no impact was found in the more remote market areas. For the vacant parcel markets, the results are much the same. Waterfront Critical Area land in the highly accessible counties grew while the remote markets areas had no significant impact flowing out of the Law. In the final analysis the authors accepted the conjecture that Maryland legislature had succeeded in fashioning " a growth management instrument that would not create an immediate and insurmountable political backlash. "However, the period must be viewed as one of delayed market reaction. Therefore, values will probably be relatively lower for vacant land remaining undeveloped after all the growth allocation permits have been assigned.

Contingent Valuation (CV) Methods

The CV approach is a direct valuation approach which gives information on what people are willing to pay for an environmental benefit and/or what they are willing to accept by way of compensation to tolerate an impact. The goal of CV is to elicit valuations which are close to those that would be revealed if an actual market existed. The valuation may be done either through a questionnaire type survey or by experimental techniques in which subjects respond to various stimuli in laboratory conditions. The respondents reveal their willingness to pay or willingness to accept if a market existed for the good in question. A comprehensive contingent valuation analysis would include the contingent market including not just the good itself, but also the institutional context in which it would be provided, and the way in which it would be financed. The major attraction of CV is that is should be applicable to most environmental policy scenarios, many times making it the only technique of benefit estimation. The most difficult aspects of this approach are the design and administration of the survey. Much of the literature on CV has been devoted to discussion about the accuracy and possible biases of the technique.

Valuation Transfers — The Activity Day Method

This method uses unit values developed at other sites for goods to infer the value of similar goods at the study site. The simple transfer may use an activity day value, such as the value of a user day of fishing, developed t another site and apply it to the study site to determine the value of fishing there. A more complicated transfer would involve applying a valuation model created from a travel cost study to the resource good and user characteristics of the site being studied. Recreational day values are based on several site-specific factors: site quality factors for recreational activities, locational factors, and socioeconomic and other characteristics of the user populations.

In the real estate market, wetlands are considered to have little value in that they are expensive to develop due to extensive government regulations and their physical characteristics. However, there are real estate transactions that involve the valuation of wetlands. There are three methods that are used to perform this evaluation: direct sales comparison, alternatives to direct sales comparison, and land price analysis model.

District Sales Comparison [11]

This approach is also known as the market data approach. In this approach, property is appraised by comparing it to the sales of similar property. However, there is a scarcity of sales data relating to wetlands, particularly in regards to parcels of property that are completely wetlands. This lack of data and the government regulations imposed on wetlands have resulted in low marketability of wetlands.

Alternatives to Direct Sales Comparison [12]

There are three different methods that can be used in the appraisal of a wetland in the absence of comparative sales. The first method involves an examination of upland property in the vicinity of the wetlands. The value of the property can then be adjusted after determining the factors that affect the property value of the wetlands. These factors include inaccessibility and regulations. Another method involves the research of sales involving parcels consisting of both upland and wetland properties. The value of the wetland portion is estimated by subtracting the upland property value from the sales price of the total parcel. A third method is the subdivision or development procedure of valuation. This is used to appraise undevelopable waterfront property.

Land Price Analysis Model [13]

In the Land Price Analysis Model, the sales price of a land parcel is determined in part by the benefits it reaps from some wetland service. Land parcels near natural wetlands offer open space and recreational opportunities, as well as aesthetic values. Thus, these locational advantages can increase the market price of the property. This is determined by the consumer's willingness-to-pay for the advantages offered by the wetlands.

Other Methods for the Valuation of Wetlands

Option and Intrinsic Value of Wetlands

There are many models for the valuation of wetland goods and services. However, there is a theory that people are willing to pay for the preservation of natural resources, such as wetlands, even though they may or may not actually use these natural resources. This nonuse or intrinsic value is broken down into two types, existence value and option value. Existence value is the value that the present generation places on the existence and conservation of a wetland. The value of the wetland is not necessarily in its use, because the people that value its existence realize that they may never use it. The option value of a wetland is the value that a person gives a wetland "in order to retain the option of using it later."[14] There is a risk premium involved in that the individuals are willing to face the uncertainty of future supply and demand. These economic concepts are relatively new and the contingent valuation method is the only technique currently available for measuring the intrinsic value of wetlands.

Wetland Mitigation Banks and Wetland Valuation

Another method for wetlands valuation has developed out of the process of wetlands mitigation banking. This is the newest tool in wetlands protection. As a valuation process, mitigation banking requires agencies, developers and mitigation bankers to determine how much an acre of wetlands is worth. Since the 1980s, the concept has developed as a method that adds flexibility to the federal dredge and fill permitting process. Mitigation banking requires the establishment of a mitigation project prior to the permitted impacts on a wetland. This bank allows the developer to purchase wetland acres to offset projected wetland losses. Its best attribute is that is economically feasible and at the same time environmentally sound. It provides developers with a convenient method for complying with stringent wetlands protection laws while avoiding the postage-stamp effect of preserving isolated patches of wetlands.[15] Through mitigation banking, mitigation projects can be consolidated on l acre tracts or land providing greater assurance of long-term sustainability because of their size, connection with other natural systems, and the requirement of a management plan.[16]

Wetlands are now being recognized for the numerous environmental services and amenities they provide such as wildlife habitat, flood protection, aquifer recharge, and water pollution removal. They are even being appreciated for their aesthetic qualities.[17] Since the 1970s, Florida's Development of Regional Impact (DRI) review process has required wetlands protection and mitigation for large projects and developments. The permitting process for dredge and fill projects with wetland impacts requires review by several state and federal agencies, and requires developers to avoid wetland impacts. When impacts are unavoidable they should be minimized or mitigated. Therefore, mitigation i considered a last option when there is proof that the impact in unavoidable. An agency may also consider mitigation when the long term survival of a wetland is threatened due to its isolation from other natural systems.

Mitigation can be required in the form of in-like wetlands restoration, enhancement, or creation. Mitigation can be done onsite or offsite, preferably within the same watershed so that the functions being lost are replaced where they are needed most. The permitting agency determines the ratio of mitigation based on the quality of the wetlands being destroyed and the type of mitigation proposed. One to one ratios may be acceptable if the wetland destroyed is highly degraded. Greater ratio are required in the case of rare or high quality wetlands. Other qualities examined in the permitting process are proximity to hydrologic features, proximity to other preserved natural areas, type of vegetate communities found on site, and the presence of endangered or threaten species, or species of special concern. Mitigation by restoration and enhancement are preferred by permitting agencies and environmentalists because they can provide higher rates of success. There is still very little known about how wetlands work, so agencies are more hesitant when permitting for wetland creation.[18]

In 1991, the Florida Department of Environmental Regulation and the state's water management districts studied the effectiveness of permitted mitigation.[19] The general conclusion was the same: wetland mitigation was losing ground to noncompliance due to insufficient monitoring, need for management, and the environmental isolation of small patches of habitats lacking proper hydrologic connection and proximity to other patches to ensure viability. Mitigation banking was introduced into the state's regulation scheme through the Florida Environmental Reorganization Act of 1993 in an effort to "minimize mitigation uncertainty and provide greater assurance of mitigation success."[20] This is achieved by consolidating multiple mitigation projects into larger contiguous areas which can be effectively managed in the long term with an adequate financial base.

The process of mitigation banking is designed to give the permitting system a head start. Before a permit allowing the damage or destruction of a wetland is issued, a public or private entity established a bank by improving or creating a wetland. The banker then receives credit for it from the appropriate regulatory authority. When the original wetland is impacted by development, the permit applicant can draw from this wetland bank to fulfill all or part of the mitigation requirements. A certain number of bank credits are available on an annual basis. This ensures that increases; in habitat value at the bank site precede or occur concurrently with adverse project impacts.[21] Also, banking mitigation prior to wetland impacts often encourages higher quality work since approval of subsequent projects are tied to the success of the bank.[22]

Developers are also advocating the use of mitigation banks because of the flexibility they add to wetlands permitting. They claim that banks provide high value, low cost wetlands for mitigation, while supporting the creation of large wetland areas that have higher success rates and are easier to monitor than smaller projects.[23] The system also allows them to share some of the responsibility of mitigation success with other responsible parties, including mitigation bankers and environmental professionals.

Some water management districts are already in the process of evaluating and permitting mitigation banks following the guidelines established in Florida's Mitigation Banking Rule. The terms for the applicant include legal or equitable interest in the proposed property, a description of the conditions of the property along with a mitigation plan for its improvement, and financial responsibility for the permitting, implementation, and long-term management of the property.

The actual valuation process for the wetlands takes place in the exchange of proposed losses for mitigation. This exchange does not occur on an acre per acre basis A mitigation ratio per acre is valuated through the dredge and fill permitting process, while the value of the mitigation bank credit is determined through the mitigation bank permitting process. The first valuation is based on the functions and values being lost, and the second valuation is based on the ones being gained. Finally, the price of each credit is determined by the costs involved in establishing and maintaining the mitigation bank with an added profit margin determined by how much the market will accept.[24] The market price depends on how much a developer is willing to pay for the permitting time saved, for sharing the responsibility for mitigation success, and for reducing the risks involved.

An interesting example of wetlands mitigating banking in Florida is being developed in Pembroke Pines, Broward County.[25] Appropriately named, the Florida Wetlandsbank is improving a 350-acre tract of wetlands and uplands belonging to the City. Permits have been obtained from the Army Corps of Engineers (COE) and from the county. The process of obtaining a permit from the South Florida Water Management District is ongoing.[26] Once the credits are sold, meaning the mitigation project is totally established, the bank dissolves and the land turns over to the city in the form of a fully established natural park for passive recreation. Essentially, the park will cost the city nothing. Wetlandsbank provides developers with wetlands for mitigation, permitting agencies with the assurance of successful mitigation, residents with access to a natural park, and habitat for displaced wildlife.

REFERENCES

Adams, Lowell W. and Louise E. Dove, *Urban Wetlands for Stormwater Control and Wildlife*

Enhancement, National Institute for urban Wildlife, Columbia, MD, 1984, pp.10-11.

Bell, Frederick, *Application of Wetland Valuation Theory to Florida Fisheries*, Sea Grant, 1989.

Beaton, Patrick W. and Marcus Pollock, "Economic Impact of Growth Management Policies Surrounding the Chesapeake Bay," *Land Economics*, Vol. 68, No. 4, pp.434-453.

Blum, Michael C., "The Clinton Wetlands Plan: No Net Gain in Wetlands Protection," *Journal of Land use and Environmental Law*, Volume 9, 1994, pp.203-242.

Brumback, Barbara C., Sheri L.R. Coven, Jill Heglie, and N.E. Stroud, *Upland Habitat Compensation,* FAU/FIU Joint Center for Environmental and Urban Problems, Ft. Lauderdale, FL, 1989.

Cowdery, Kathryn, Gale Winter, Karl Scheuerman, and J. Christopher Lombardo, The Valuation of Wetlands, *Journal of Land Use and Environmental Law*, 1, 1, 1985.

Florida Department of Environmental Regulation, *Report on the Effectiveness of Permitted Mitigation,* FDER, Tallahassee, FL, 1991.

King, William, Michael Hay, and John Charbonneau, *Valuation of Riparian Habitats*, Paper presented at the National Symposium on Strategies for Protection and Management of Floodplain Wetlands and Other Riparian Ecosystems, Callaway Gardens, Georgia, December 1978 , pp.11-13.

King, David A., Jody L. White, and William W. Shaw, "Influence of Urban Wildlife Habitats on the Value of Residential Properties." In *Wildlife Conservation in Metropolitan Environments*, National Institute for Urban Wildlife, Columbia, MD, 1990.

Kusler, J.A., *Our National Wetland Heritage: A Protection Guidebook*, New York: Environmental Law Institute, 1983.

Loftin, Jan P., “Discovering the Value of Wetlands”, *Florida Water,* Fall, 1992, pp.16-23.

Miller, Robert H. and Richard P. Hopen, “Wetlands Mitigation Banking - Trend or Fad?” *Florida Engineering Society Journal*, October, 1993, pp.15-17. Mitigation Banking Rule, Florida Administrative Code 17-342-1994.

Odum, Eugene P., Wetland Values on Retrospect, *Freshwater Wetlands and Wildlife*, CONF-8603101, DOE Symposium Series No 61, R.R. Sharitz and J. W. Gibbons (eds.), USDOE Office of Scientific and Technical Information, Oak Ridge, Tenn., 1989.

Reenstierna, Eric, The Appraisal of Wetlands, *The Real Estate Appraiser and Analyst*, 46, 3, 1980 .

Salvesen, David, *Wetlands-Mitigating and Regulating Development Impacts*, Urban Land Institute, Washington, D.C., 1994.

Scodari, Paul F., *Wetlands Protection: The Role of Economics*, Washington, D.C. Environmental Law Institute, 1990.

Short, Cathleen, *Mitigation Banking*, Biological Report 88(41), U.S. Dept. of the Interior, Fish and Wildlife Service, Washington, D.C., 1988.

————, “Wetland Creation and Restoration Efforts Associated with Mitigation Banks”, in *Proceedings of the 15th Annual Conference of Wetlands Restoration and Creation*, Hillsborough Community College, Tampa, FL, 1988.

ENDNOTES

1 Scodari, Paul F., *Wetlands Protection; The Role of Economics*, Washington, D.C., Environmental Law Institute, 1990, p.22

2 Ibid., p.3

3 Cowdery, Kathryn, Gale Winter, Karl Scheuerman, and J. Christopher Lombardo, The Valuation of Wetlands. *Journal of Land Use and Environmental Law*, 1, 1, 1985, p.13

4 Scodari, 1990, p.29

5 Bell, Frederick, *Application of Wetland Valuation Theory to Florida Fisheries*, Sea Grant, 1989, p.19

6 Ibid., p.21

7 Bell, p.30

8 Bell, 1989, p.24

9 Scodari, 1990, p.42

10 Odum, Eugene P., Wetland Values in Retrospect, *Freshwater Wetlands and Wildlife*, CONF-8603101, DOE Symposium Series No. 61, R.R. Sharitz and J.W. Gibbons (eds), USDOE Office of Scientific and Technical Information, Oak Ridge, TN, 1989, p.2

11 Cowdery, 1985, p.8 and Reenstierna, 1980, p.7

12 Cowdery, 1985, p.9

13 Bell, 1989, p.27

14 King, et al, 1978, p.163

15 Salvesen, David, *Wetlands-Mitigating and Regulating Development Impacts*, Urban Land Institute, Washington, D.C., 1994, p.132-139

16 Salvesen, op. cit; Michael C. Blum, "The Clinton Wetlands Plan; No Net Gain in Wetlands Protection," *Journal of Land use and Environmental Law*, Volume 9, 1994, pp.203-242; Barbara C. Brumback, Sheri L.R. Coven, Jill Jeglie, and N.E. Stroud, *Upland Habitat Compensation*, FAU/FIU Joint Center for Environmental and Urban Problems, Ft. Lauderdale, FL, 1989, pp.30-33; Jan. P. Loftin, "Discovering the Value of Wetlands," *Florida Water*, Fall, 1992, pp.16-23; Cathleen Short, *Mitigation Banking*, Biological Report 88 (41), U.S. Dept. of the Interior, Fish and Wildlife Service, Washington, D.C., 1988(a); and Cathleen Short, "Wetland Creation and Restoration Efforts Associated with Mitigation Banks," in *Proceedings of the 15th Annual Conference of Wetlands Restoration and Creation*, Hillsborough Community College, Tampa, FL, 1988(b)

17 A study was developed in Columbia, Maryland to determine peoples' attitudes toward different types of stormwater control basins and the wildlife resource associated with these facilities. Over 600 homeowners were surveyed In response to the question, "Do you think wetlands add to the beauty, diversity, and quality of the human living environment?" 94% answered positively. Lowell W. Adams and Louise E. Dove, *Urban Wetlands for Stormwater Control and Wildlife Enhancement*, National Institute for Urban Wildlife, Columbia, MD, 1984, pp.10-11.

King, White, and Shaw estimated the influence of proximity to wildlife habitat on the value of single family residential properties in Tucson, Arizona. The study found that natural open space and some kinds of wildlife habitats, which includes wetlands, have a positive influence on residential properties. David A. King, Jody L. White, and William W. Shaw, "Influence of Urban Wildlife Habitats on the Value of Residential Properties," in *Wildlife Conservation in Metropolitan Environments*, National Institute for Urban Wildlife, Columbia, MD 1990

[18] To evaluate the effectiveness of creating wetlands as mitigation, the Florida Department of Environmental Regulation (now a part of the DEP) examined 119 wetland creation sites required by 63 permits. The study found a high rate of non compliance: only 4 of the 63 permits were found to be in full compliance. Non-compliance ranged from minor non-submittal of reports to major deviations from the permitted mitigation design. Ecological success was defined as whether the site is, or appears likely to become, a functional wetland of the intended type of mitigation wetland. The study recommended, based on the high rate of non-compliance, the primary focus should be on avoiding and minimizing effects of permitted activities on wetlands, and that the applicants should be held responsible for the long-term success of mitigation projects. Florida Department of Environmental Regulation, Report on the Effectiveness of Permitted Mitigation, FDER, Tallahassee, FL, 1991

[19] See Florida Department of Environmental Regulation, Report on the Effectiveness of Permitted Mitigation, FDER, Tallahassee, FL, 1991; Kevin L. Erwin, op. cit., 1991

[20] Mitigation Banking Rule, Florida Administrative Code, 17-342, 1994

[21] Short, op. cit., 1988(a) and 1988(b)

[22] Ibid.; and Loftin, op. cit.

[23] Blum, op. cit.

[24] Brumback, et al, op. cit., p.35; and personal communication with Lou Lawton, CEO, Wetlandsbank, October 11, 1994

[25] Robert H. Miller and Richard P Hopen, "Wetlands Mitigation Banking - Trend or Fad?," *Florida Engineering Society Journal*, October, 1993, pp.15-17

[26] Personal communication with Anita Bain, South Florida Water Management Disrict

CARRYING CAPACITY OF SOUTH DADE COUNTY

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INTRODUCTION

Questions concerning sustainability, carrying capacity, and the welfare of developing regions center on the role of natural resources, or what economists term "natural capital", in economies. Economists are beginning to take a hard look at resource depletion and loss of environmental quality and their effect on economic productivity and net capital formation, suggesting that when taken into account, many otherwise growing economies may in fact be declining, since declining levels of natural capital threaten long term economic sustainability. Increasingly there is a call for factoring into economic production functions the contributions of environmental systems and the negative consequences of resource depletion. Carrying capacity and the welfare of growing populations in developing regions may be tied, ultimately, to natural resources instead of capital formation. This section investigates the resource base of the economy of south Dade and its relationship to sustainability and carrying capacity.

Sustainable Development

The inflow of renewable resources power the natural and agricultural systems and recycle and feedback pathways provide limited resources and energies from the larger economy. Resources are "harvested" from natural and agricultural systems, and either consumed locally, or exported. The proceeds from exported goods are used to purchase imported fuels, goods, and services. Degraded lands and "waste-by-products" are often slow to recycle to productive uses.

Sustainability can be defined from at least three different perspectives : (1) sustainable development of natural systems; (2) sustainable yields from agricultural systems;and (3) sustainable use of resources (supply and use of water) at the regional scale.

In a larger sense, since all systems are embedded within bigger systems, and, in some measure influence lessor systems (i.e. a farm is driven by larger economic forces and in turn influences what crops and management techniques are used at the field level) truly sustainable development should satisfy stainability criteria at all levels simultaneously.

All sytems of production (agriculture, communiyt or region) should strive to at least balance that which is "harvested" with the inflows of energy and resources that drive those processes. If there is net negative balance, in other words if there are more outflows than inflows, the enterprise is not sustainable. In the long run, the greater the deficit, the shorter the time horizon before production/development ceases.

A Definition of Carrying Capacity

Carrying capacity for human populations is the population size that can be sustained at some consumptive level for a given period of time. With a given amount of resources the population level can vary depending on per capita resource consumption. Since resources are not infinite in their availability (both temporally and spatially), increasing local carrying capacity becomes an issue of increasing resource availability. In most economies this means increasing the rates of resource extraction and imports of resources that are in short supply. The rub is that to increase imports, often exports must be increased and therefore even greater rates of resource extraction result. Thus the imports on the one hand may increase carrying capacity in the short run, but the exports, ultimately, decrease carrying capacity in the long run. Clearly the balance between short run increases in carrying capacity and long term decreases has been tipped in favor of the short run as populations and "standards of living" have increased in most nations throughout the developed and developing world. The following question begs to be answered...can these short run increases in carrying capacity be sustained in the long run, in light of the fact that natural capital is being depleted at ever increasing rates?

Determining Carrying Capacity

One theory for determining carrying capacity is that the scale or intensity of development[1] in relation to existing conditions may be critical in predicting its effect and ultimately its sustainability (Odum et al. 1987; Odum and Arding 1991). If a development's intensity is much greater than that which is characteristic of the surrounding landscape, on average, the development has greater capacity to disrupt existing social, economic, and ecologic patterns (Brown 1980). If it is similar in intensity it is more easily integrated into existing patterns. For example, because of the differences between a heavily urbanized area and an undeveloped wilderness area, the appropriate intensity of development in each environment is much different. At the regional scale, the appropriate scale of urbanization is the level that is characteristic of the economy within which the region is embedded.

Large-scale developments and those with greater intensity than the surroundings can be integrated into the local economy and environment if there is sufficient regional area to balance its effect. Much like the ecological concept of carrying capacity, where differing environments require different aerial extent of photosynthetic production for support of a given biomass of animals, environmental carrying capacity for human populations and their economies depends on the area of "support" over which development can be integrated. As the intensity of development increases (and therefore its consumption of resources and environmental impacts increase), the area of natural undeveloped environment required for its support must increase. All other things being equal, the more intensely an area is developed, the greater the area of environment necessary to balance it. Thus, if planned in advance, the spacing between urban centers should increase as their intensity increases. The methodology described in this section uses EMergy analysis to evaluate intensity of urban development and the support base of the local environment and then uses a ratio of purchased, nonrenewable EMergy to the resident renewable EMergy of the environmental support base as a means of determining carrying capacity.

CARRYING CAPACITY AND ECONOMIC COMPETITIVENESS

EMergy Investment Ratio

Given in Figure 5.2 is a diagram illustrating the use of nonrenewable and renewable EMergies in a regional economy. The interaction of indigenous EMergies (both renewable [I] and nonrenewable [N] with purchased resources from outside [F]) is the primary process by which humans interface with their environment.

The Investment Ratio (IR) is the ratio of purchased inputs (F) to all EMergies derived from local sources (the sum of I and N) as follows:

$$\mathbf{IR = F/(I+N)} \qquad (1)$$

The name is derived from the fact that it is a ratio of "invested" EMergy to resident EMergy. The Investment Ratio is a dimensionless number; the bigger the Investment Ratio the greater the intensity of development. Regional or statewide IRs are useful for comparing the intensity of individual developments or smaller regions embedded within the larger. The U.S.Investment Ratio is about 8 to 1 and the State of Florida IR is 7.75 to 1, while Dade County's is about 18 to 1. In this analysis we used both the ratio for Florida (calculated previously) and that for Dade County.

Determining Regional Carrying Capacity

Once the annual flux of renewable EMergy per year per unit area of landscape (renewable EMergy density) is known and the nonrenewable EMERGY flux for a region is known , the Investment Ratio can be calculated. Renewable EMergy density is derived from regional a EMERGY analysis calculted previously (Brown et.al, 1995). Using the calculated Investment Ratio for the larger region, the Investment Ratio for a subregion is set equal and then the equation for IR is solved for the nonrenewable EMERGY flux as follows:

$$\mathbf{IR_{(lr)} = IR_{(r)}} \qquad (2)$$

where:

$IR_{(lr)}$ = Investment Ratio of the larger region = known

$IR_{(r)}$ = Investment Ratio of the sub-region = $[F_r] / [I_r + N_r]$

since $I_r + N_r$ is known, the equation is solved as follows:

$$\mathbf{F_r = [IR_{(lr)}][I_r + N_r]} \qquad (3)$$

Once F_r is known , it is added to the quantity $[I_r+N_r]$ yielding the total EMERGY flux for the sub- region. Total population at a given per capita EMERGY use is then determined by dividing total EMERGY flux by EMERGY per capita. EMERGY use per capita is the sum of the emergy used directly or indirectly by the population. This index is a measure of the quality of life in a region that accounts not only for the resources provided by the economy, but also for the ones supplied by the environment. In this sense, it has the advantage of account-ing for resources that improve life quality, but are invisible when the measures of economic income are used. The population that can be supported at the given EMERGY per capita is calculated as follows:

$$\textbf{Population} = (F+N)_r + I_r / \textbf{EMERGY per capita} \qquad (4)$$

An awareness has recently developed that sustainability is a key factor to consider when considering issues of regional development. Yet sustainability remains an elusive concept. It can be argued that sustainable development, in the long run (100 years or more?), is that which can be supported by the renewable flows of EMergy of a region. Development that depends on purchased resources may not ultimately be sustainable since purchased EMergy is composed of nonrenewable flows and subject to fluctuations in world prices. Yet, development that does not allow for the possibility of using purchased resources to amplify a region's environmental basis cannot give an economic return and becomes a moot point. Thus sustainability should reflect the current intensity of development of an economy and match it. In this way, it is no more dependent on limited supplies of nonrenewable EMergies than the economy as a whole. As the economy's use of nonrenewable purchased energies may decline, new development under these circumstances does not draw more of these energies on the average than the rest.

Determinations of sustainability should take into account the relative mix of: (1) an economy's environmental basis (renewable EMergy sources), (2) its use of nonrenewable storages from within, and (3) its purchased goods, resources, and services. These flows drive the economy and ultimately influence what is sustainable by defining an upper boundary to the present mix of purchased EMergy, resources from within, and renewable EMergy flows. The investment ratio is a ratio of purchased EMergy to resident EMergy and when the ratios of development proposals are compared to the ratio for the economy in which they are imbedded, may provide one means of defining sustainable carrying capacity. Development proposals that have investment ratios that are higher than the economy require more purchased EMergy per unit of resident EMergy and therefore are more vulnerable, on the average, to changes in availability of purchased EMergy. Developments with lower ratios than the local economy are less vulnerable, but also yield less, on average.

Evaluations of South Dade's Carrying Capacity

In addition to using the Investment Ratio to determine a sustainable EMERGY intensity for the region, carrying capacity using the sustainable water “crop” was also calculated. For each method, several alternative scenarios were analyzed in order to produce a range of population levels.

Water Crop Method

Water crop is a theoretical amount of water that can be harvested from ground water sources without depleting reserves. Based on best estimates of local recharge, the water crop is that amount of local rainfall that can be withdrawn from the drinking water aquifer without causing draw down. We assumed an average annual rainfall in the region of 60 inches, with 75% evaporation. The receiving area was considered to comprise all of the study area, about 1.6E+9 square meters (395.4E+3 acres), yielding an average of 2.32E+9 cubic meters of water a year (612.94E+9 gallons). With an evapotranspiration and a runoff of 75% and 24% respectively, the remaining 1%, 2.32E+7 cubic meters, was assumed as available for human use. Water use per capita was assumed as 346.8 cubic meters a year (251 gallons a day) (Morin, 1987), including agriculture.

Two water use regimes were analyzed in order to determine their corresponding water crop carrying capacity. Under the first, water available from infiltration of rainfall is used and disposed without any recycling effort. Under the second, the rain water available is reused after treatment in a wetlands system designed for the purpose, and then released to estuaries. This increases local infiltration somewhat (0.4% of rainfall) resulting in a higher water crop.

Investment Ratio Scenarios

Investment ratios of Dade County and Florida were used in combination with the renewable emergy density in the south Dade region and two different emergy use per capita levels to calculate several different population levels. When the IR for Florida (7.75 / 1) was used to calculate carrying capacity of south Dade, a development intensity that is more rural in character was obtained. This is the average of the State as a whole, and reflects the average statewide intensity of land utilization. When the Dade County IR (18 / 1) was used to calculate carrying capacity, a development intensity resulted that reflects the average for Dade County, more urban in character.

If the influences of Latin America continue to grow, and Miami continues to act as a hub for business activity with Latin America, development in the south Dade region may continue to grow. Population levels may eventually match the population densities that are characteristic of the northern portions of the County. Local commerce will expand to match the population levels, and international commerce may expand as well, leading to a relatively dense urban economy with less reliance on production of agricultural products. The Dade county Investment Ratio was used to calculate the population level that would be characteristic of this scenario.

On the other hand, if the Latin American "connection" is not as influential, and there is no growth in the south Florida economy, the population level of the south Dade region may be more sustainable if the region is developed to the intensity if Florida on the average. The economy would be an agriculturally based economy with some local commerce and some tourism activity. In fact, much like the present day economy. The State of Florida Investment Ratio was used to calculate the population level that would be characteristic of this scenario.

A third scenario was calculated as well. This is the lower population level sustainable at cur rent EMERGY per capita consumption, but relying only on the renewable resource base of the region. This scenario represents a lower limit to population carrying capacity based on current EMERGY consumption patterns.

Table 5.1 summarizes the carrying capacity of south Dade based on the Water Crop and Investment Ratio calculations. The sustainable water crop assuming no recycle of treated wastewater locally yielded a population of about 67,000 people. When recycle of treated wastewater is included the sustainable water crop method yielded a population of almost 94,000 people. Carrying capacity using the Investment Ratios of Florida and Dade County was 718,000 and 1.7 million people respectively. The renewable carrying capacity of the region was 82,000 people using Florida's per capita EMERGY consumption and 94,500 using Dade County's per capita EMERGY consumption.

In all, the four population carrying capacities represent differing sustainable population levels under the various scenarios. The lower bound, that which is sustainable on a renewable basis, was calculated to be between about 70,000 and 95,000 people. At higher levels of development intensity, and relying on a continued flux of purchased EMERGY from outside the region, the carrying capacity of south Dade is between 700,000 and 1.7 million people. At these higher levels, water crop calculations suggested that local rainfall/recharge will not be sufficient to supply water needs of the population. Additional outside water sources will need to be transferred from other areas of south Florida to meet the higher demand.

A Proposal for Increasing Carrying Capacity of South Dade

In this analysis a proposal is made to reuse wastewater more effectively and thus increase the development potential of the hurricane impact area in south Dade County. If natural productivity is enhanced and those areas that have been experiencing declines in productivity and are stressed are restored the entire region benefits through better use of resources. Our concept of carrying capacity is based on the ability of a natural system to support economic development, thus if natural areas are restored and enhanced, there is greater support of economic development.

The rebuilding of south Dade County offers a unique opportunity to reestablish wetland sloughs that once drained through the pine ridge connecting the Everglades with Biscayne Bay. During the wet season, waters from inland used to flow through broad sloughs called "finger 'glades" southeastward to Biscayne Bay. The map in Figure 5.3 shows historical land cover (c. 1990) of the south Dade region with the pine ridge actually more resembling a series of islands surrounded by wet prairie. Drainage projects begun in the early part of this century lowered ground water tables and decreased wet season flooding. The map in Figure 5.4 shows present land use and the canal network that is now in place.

The objective of this analysis was to develop a wetland slough system that would allow for effective recycle of reclaimed wastewater and increased flow of Everglades water during the wet season toward the east. The map in Figure 5.5 shows one wetland slough scheme. Reclaimed wastewater from greater Miami would be discharged to the system in its upper northwestern segment and in the wetland area in the vicinity of Homestead. Water flows southwest through the western segment, then southeast to Biscayne Bay.

Tables 5.2 and 5.3 evaluate the emergy in yearly productivity and the emergy associated with structure of the various land uses and land cover of the area that would be converted to wetland slough. The total area is 38,967 hectares (96,287 acres) or about 150 square miles. The single most affected land cover is the classification called Protected Area, which is primarily eastern Everglades. Protected area and "Open Land", together, comprise about 62% of the area affected. When combined with agricultural lands, the area of relatively "undeveloped land" comprises about 90% of the total.

It is important to note that the land use and land cover was compiled from projected land use map by Metro-Dade County Planning, and does not represent the as-built condition. It is our thought that these numbers represent the maximum costs associated with a wetlands slough proposal. The map indicates that about 7,476 acres of low/med residential, 122 acres of med/high residential, and 1,465 acres of business/industrial lands are affected. In addition, about 676 acres of institutional and 26 acres of transportation are affected by the slough system.

The costs associated with conversion of present land uses to wetland can be divided into two areas. First there is the loss associated with loss of yearly productivity. Table 5.2

summarizes these losses. The highest losses are in Business and Low/Med. Residential categories comprising about 81% of the total. The second loss is the structure associated with each land use and land cover type. Table 5.3 summarizes these losses. The highest losses, again, are from Business/Industrial and Low/ Med. Residential, comprising about 33% of the total. Agricultural structure, because of the magnitude of area affected is the third largest emergy loss, about 15% of total losses. If some minor modifications were made to the alignment of the slough system, and actual viable structure were taken into account, instead of assuming that all structure is in place, these costs would be substantially reduced. It is quite apparent from the analysis of the hurricane impacts that much of the structure in the south Dade impact area has been damaged and that a large percentage (about 30%) has been damaged beyond usefulness. Thus losses associated with conversion to a wetland slough given in Tables 5.2 and 5.3 are highest losses and when analyzed in greater detail by determining the actual viability of structure within the slough system alignment, we can expect them to decrease.

Table 5.4 summarizes an emergy benefit cost analysis for the proposed wetland slough system. Total costs result from losses of yearly production and structure associated with land uses and land cover types, that are within the "footprint" of the slough, the sloughs capital costs, and its yearly operation and maintenance costs. The largest costs are associated with operation and maintenance (90.7 E 18 sej/yr) and capital costs (73.9 E 18 sej/yr). Emergy benefits total 1575.9 E 18 sej/yr, and the largest of which is the value of the reclaimed wastewater that is used more effectively through the wetland system. The ratio of value received to costs if the wetland slough system were constructed is about 7.3/1, if no additional development occurs.

Additional development could be supported as a result of the increases in productivity in the landscape and good use of reclaimed wastewater. We have estimated that the "multiplier" effect, or matching effect that natural systems have on the economy is about 8/1, thus if this potential increased development is included in the analysis, the total benefits are about 8 times as high, or 12.606 E 21 sej/yr. In this case, the benefit received for the losses incurred would be almost 60/1.

The effect on the calculated carrying capacity of south Dade should the wetland slough system be constructed and treated wastewater recycled through it was significant. Assuming 345E+6 cubic meters a year (250 MGD), produced by the city is recycled through the system and a volume of 8.62E+7 (25 %), is available for reuse through recharge of local aquifers the water crop carrying capacity population would increase to 342,530 people.

A Proposal for Rebuilding South Dade

We carried the analysis of south Dade one step farther. Using theories of the hierarchical organization of cities in landscapes first enunciated by Chrystaller in 1933 (Brown, 1980), and found to follow a power law distribution by Zipf (1941) and others, we developed hypothetical spatial designs of development for south Dade. Using the calculated population levels from the analysis of carrying capacity to set development density and the wetland slough system as a backdrop, we designed three urban landscapes that represented low, medium, and high development intensity.

The hierarchy of urban centers described by Zipf (1941) and found by Brown (1980) in two regions of Florida, was simulated for south Dade with the simple formula:

$$p=(P/n)/N \qquad (5)$$

where

- p = is the population of each urban center
- P = is the population of the region
- n = is the number of towns in each class of city
- N = is the number of classes of cities used

For all the scenarios calculated the number of classes of cities was set at three, with one central, two secondary and ten third level cities.

The area for each urban center was assigned based on the emergy required by the population of that center. Land uses within each city were aggregated in eight categories defined by their empower density. The categories used were: (1) Business and Industrial; (2) medium -high density residential; (3) transportation (including streets and highways); (4) low- medium residential; (5) institutional; (6) agriculture; (7) parks and protected areas; and (8) natural lands. These land uses are arranged in a decreasing order from high empower levels representing the central business district to low empower of the outskirts of the cities and the rural and natural areas.

The percentage of land for each category was adapted from land use distributions found by Brown (1980) for two regions of Florida, and from Bartholomew (1965) for 53 central cities in the United States. Smaller cities received a higher proportion of low emergy land categories, like agriculture, as they are devoted to concentrate resources from the fields around. Large urban centers concentrate the products from smaller towns, serving as central places, therefore a higher proportion of high emergy land uses, like industrial, commerce and institutional, were concentrated in them.

Figures 5.6 through 5.8 are GIS generated maps of the spatial distribution of cities based on three development intensities. Cities are located along the existing ridge corridor and utilizing the established highway infrastructure. The largest central place is located in the northern portion of the study area closest to greater Miami, near the present day city of Kendal. Other cities are located along the highway infrastructure and at central locations in the surrounding agricultural regions.

In the first scenario (Figure 5.6), representing the population sustainable on renewable EMERGY, the population was about 75,000. The area required for this population was calculated at about 20,000 hectares. The number of city classes was fixed at three, with one central city (25,000 people), two secondary cities (12,500 people each) and ten third class centers (1,250 people each). The medium development scenario (Figure 5.7) represents a sustainable population based on renewable EMERGIES and recycled wastewater from greater Miami. The population in this scenario was about 340,000 people distributed in the three classes of cities as follows: one central city (112,000 people), 2 secondary cities (56,000 people), and 10 third class cities (5,600 people). The final development scenario (Figure 5.8) is based on Investment Ratio calculations and developing the region to levels equal in intensity to the State as a whole. The total population was 1.7 million people distributed in three classes of cities as follows: one central city (567,000 people), 2 secondary cities (283,000 people), and 10 third class cities (28,300 people).

SUMMARY

Questions concerning the impacts of economic development, its costs and benefits and ultimate sustainability, and the carrying capacity of regions for expanded development are relative to the economy in which they are imbedded. The carrying capacity of south Dade County was evaluated using EMergy flows and the EMERGY Investment Ratio and availability of long term storages of water on a sustainable basis. The carrying capacity of the region, using the Investment Ratio was based on setting aside sufficient undeveloped "support area" so that the contributions of environmental resources to the developed economy equaled that which was characteristic of the State economy. Population levels calculated in this manner were between 700,000 and 1.7 million people. In addition, several carrying capacity levels were calculated based on sustainable use of water resources, or "water crop". These suggested that between 70,000 and 90,000 people could be supported without "mining" water resources of the region, and that if treated wastewater were imported from greater Miami, and recycled through constructed wetland sloughs, the sustainable water crop would increase population levels to about 340,000 people.

A range of population levels have been generated using the Investment Ratio and water crop methods. The range has an almost 30 fold difference between the lowest and highest values. Our intention was to suggest that carrying capacity is a dynamic concept, depending on resource availability. With little or no resources available from outside sources, the carrying capacity in south Dade is probably more on the order of 70,000 people. With moderate availability of outside resources, the carrying capacity is probably on the order of 350,000 people. And under full development to intensities characteristic of Dade county, the population level would be over 1.7 million people. Which scenario is appropriate for south Dade, depends on global and national economies, and the degree to which the area is integrated into them.

The use of EMergy flows as a means of evaluating the carrying capacity of regional economies may lend insight into the complex questions surrounding the increased integration of regional economies with outside economies and whether over development is beneficial and sustainable in the long run. The proposed methods of quantitative evaluation are tendered more as a means of helping guide public policy decisions than as the means to once and for all predict ultimate carrying capacity. The intensity to which a region develops, and thus the number of people that are sustainable within it are serious questions that communities should be wrestling with. The age of unlimited resource availability is behind us, requiring more accurate awareness of what over development may mean in the long run.

REFERENCES CITED

Arding, J., and M. T. Brown, *Collected and Recalculated Transformities: A Working Paper*, Gainesville, FL: Center for Wetlands, Univ. of FL, 1991, p.73.

Brown, M.T., *Energy Basis for Hierarchies in Urban and Regional Landscapes*, Ph. D. Dissertation, Department of Environmental Engineering Sciences, University of Florida, Gainesville, FL, 1980.

Brown, M.T., H.T. Odum, G. McGrane, R.D. Woithe, S. Lopez, and S. Bastianoni, *EMergy Evaluation of Energy Policies for Florida*, Report to the Florida Energy Office, Center for Environmental Policy, Department of Environmental Engineering Sciences, Univ. of Florida, Gainesville, 1995.

Florida Department of Commerce, *Florida County Comparisons*, Florida Department of Commerce, Tallahassee, FL, 1991.

Florida Legislature Division of Economic & Demographic Research, *Florida Monthly Economic Report*, February 1990 - January 1991 issues, Florida Legislature Division of Economic & Demographic Research, Tallahassee, FL, 1990-1991.

Metro-Dade County Planning Department, Proposed Land Use Elements (Support Components): *Metro-Dade County Comprehensive Development Master Plan for 2000 and 2010*, Metro-Dade County Planning Department, Miami, FL, 1988.

Metro-Dade County Planning Department, *Hurricane Andrew in Florida*, Metro-Dade County Planning Department, Miami, FL.

Morin, O.J., *Desalination in South Florida*, 1987.

Odum, H. T., and J. E. Arding, *Emergy Analysis of Shrimp Mariculture in Ecuador*, Gainesville, FL: Center for Wetlands, Univ. of FL, 1991, p.114.

Odum, H. T., M. J. Lavine, F. C. Wang, M. A. Miller, J. F. Alexander, Jr., and T. Butler, Energy Analysis of Environmental Value, *A Manual for Using Energy Analysis for Plant Siting*, (Revised supplement from the final report to the Nuclear Regulatory Commission, NUREG/CR-2443 FINB-6155), Center for Wetlands, University of Florida, Gainesville, 1987, p.97.

Odum, H.T., E.C. Odum, and M.T. Brown, *Environment and Society in Florida*, Center for Environmental Policy, University of Florida, Gainesville, FL, 1993.

ENDNOTES

[1] Intensity may be measured using any quantity (energy, materials, money, or information) per unit time per unit area. If one uses energy per unit time, or power, expressed over a unit area, the intensity is power density (Brown 1980)

Table 5.1 Summary of Carrying Capacity for South Dade County

Method	Carrying Capacity (1000 people)	Total EMERGY Use (E21 sej/yr)	Area of Dev. Land (E3 hectacres)
Water Crop			
1% of Rainfall	67.0	1.8	19.0
1% of rainfall + recycle	93.8	2.5	26.0
1% of rainfall + Miami wastewater	342.5	9.2	76.4
Investment Ratio			
At Florida's IR	718.0	19.6	85.4
At Dade Co.'s IR	1700.0	40.3	85.4
Renewable EMERGY only	82.0	2.2	18.9

Note: See Appendix for Tables and Calculations

Table 5.2 Productivity loss of land uses within the proposed wetland system

Land Use	Area (acres)	Emergy Density (E 12sej/ac/yr)	Empower (E 18sej/yr)
Open Land	14066	33.49	0.47
Protected Area	45285	45.21	2.05
Agriculture	27171	167.44	4.55
Institutional	676	837.20	0.57
Transportation	26	4186.00	0.11
Low/Med Residential	7476	2093.00	15.65
Med/High Residential	122	4353.44	0.53
Bus./Industrial	1465	13395.20	19.62
Total Land Use	96287		43.54

Table 5.3 EMERGY loss associated with structure on land uses within the proposed wetland system

Land Use	Area (acres)	Structure (E 12sej/ac)	EMERGY (E 18sej)
Open Land	14066	4.19	0.06
Protected Area	45285	33.49	1.52
Agriculture	27171	837.20	22.75
Institutional	676	8372.00	5.66
Transportation	26	16744.00	0.44
Low/Med Residential	7476	6279.00	46.94
Med/High Residential	122	10465.44	1.28
Bus./Industrial	1465	50232.20	73.59
Total Land Use	96287		152.23

Table 5.4 EMERGY costs and benefits of reclaimed wastewater wetland system in south Dade

Flow or Storage (units)	Amount	Transformity (sej/unit)	EMERGY (E 18sej)
EMERGY Costs			
Yearly Production			43.54
Structural losses			7.61
Capital Costs (E6 $/yr)	46.2	1.60E+12	73.92
O & M (E6 $/yr)	56.7	1.60E+12	90.72
Total Costs			215.80
EMERGY Benefits			
Created Wetlands	96878	66.98	6.49
Reclaimed Water (J/yr)	1.57E+15	1.00E+06	1569.41
Total Benefits			1575.90

APPENDIX

Tables of ENERGY Evaluations of Carrying Capacity in South Dade

By S. Lopez

Table A.1 Water from rain available for human consumption at three recycling and non-recycling stages.

Note	Item	Annual supply cubic meters	Population
1	Rainfall	2320000000	
2	Evapotransp.	1740000000	
3	Req. runoff	558000000	
4	Available	23200000	
5	Consume per person		347
6	People Sustainable		67032
7	To recycle	18600000	
8	Available	9300000	
9	People Sustainable		93845
10	Miami Sewage	345000000	
11	Available	86200000	
12	People Sustainable		342530

Notes to Table A.1

1 *Rainfall in South Florida*

Annual rainfall: 1.45 meters.

Study area: 1,600,000,000 Square meters.

"(From shoreline to Everglades, south of Tamiami Trail)"

Total annual: 2,320,000,000 Cubic meters.

"(Morin, O.J. 1987 Desalination in South Florida)"

2 *Evapotranspiration*

Percent in decimals: 0.75.

3 *Required runoff to estuaries*

Percent in decimals: 0.24.

5 *Use of water per capita in Florida*

Annual use per capita: 347 Cubic meters.

Average including agriculture.

(The Atlas of Water Resources of Florida,

and O.J. Morin: Desalination in South Florida).

6 *People sustainable*

Water available for humans divided by consumption per capita.

7 *Water available to recycle after human use*

Percent of rainfall in decimals: 0.008.

8 *Water available after Recycling*

Percent of rainfall in decimals: 0.004.

9 *People sustainable*

Water available for humans divided by consumtion per capita..

10 *Water from Miami sewage*

Waste water from Miami: 345,000,000 Cubic meters.

11 *Water available for human use after treatment*

25% after treatment: 86,200,000 Cubic meters.

12 *People sustainable*

Water available for humans divided by consumption per capita.

Table A.2 Carrying capacity on land required for population sustained on local rainfall using three scenarios.
(annual data).

Note	Parameter	Local No. Recycl.	Recycle	Wastewater	
1	Population	67000	93800	343000	Habs.
2	Emergy required	1.8E+21	2.52E+21	9.21E+21	Sej.
3	Renewable	2.06E+20	2.89E+20	1.05E+21	Sej.
4	Non renewable	1.6E+21	2.24E+21	8.16E+21	Sej.
5	Required area	1.90E+08	2.60E+08	7.64E+08	Sq. Meters

Notes to Table A.2

1 *Population*

Populations from Table A.1

a) No recycling 67000.

b) Recycling 93800.

c) Adding Wastewater 343000.

2 *Emergy required* (annual data).

To match the emergy per capita of the state.

Required emergy per capita = 2.69E+16 Sej.

Population levels as indicated.

Emergy required = Population * Emergy per capita.

Emergy Required in a) 1.8E+21 Sej.

Emergy Required in b) 2.52E+21 Sej.

Emergy Required in c) 9.21E+21 Sej.

3 *Renewable emergy required*

Emergy required / (1 + Emergy Investment Ratio)

Investment Ratio of Florida 7.75.

Renewable Emergy in a) 2.06E+20 Sej.

Renewable Emergy in b) 2.89E+20 Sej.

Renewable Emergy in c) 1.05E+21 Sej.

4 *Non-Renewable Emergy*

Non-renewable Emergy = Total Use - renewable emergy.

Non-renewable Emergy a) = 1.6E+21 Sej.

Non-renewable Emergy b) = 2.24E+21 Sej.

Non-renewable Emergy c) = 8.16E+21 Sej.

5 *Required Area to get renewable emergy* (annual data).

Area = Renewable emergy required / renewable emergy per sq. meter.

Renewable emergy per square meter = renewable emergy /area.

Emergy in rainwater = Chemical energy in rain * transformity.

Energy from rain for all impact area = (land area + shelf area) * (rain) * (evapotransp.) * (moles water * gas constant * temp.) * (water dens.) * (Gibbs free energy).

Land area =	1600000000	Sqr. meters.
Shelf area =	45000000	Sqr. meters.
Rainfall =	1.45	meter/ yr.
Evapotranspiration	0.75	% as decimal.
Freshwater concentration	1000000	ppm.
Sea water concentration	965000	ppm.
Moles * R* temperature	139	J/g.
Water density	1000000	g/m3.
Gibbs free energy	4.95	J/g.
Chemical energy in rain	1.48E+16	J/yr.
Transformity	15000	Sej/J.
Emergy from rain	2.22E+20	Sej.

Annual energy in tides = (shelf area) * (# tides/yr) * (mean tidal range)^2 * (fraction of tide absorbed) * (sea water density) * (gravitational constant) * (1.0 E-7 Joules/erg) * (3.15 E+7 s/yr).

1/2 of Continental shelf	233000000	m^2.
Mean tidal range	0.49	m^2.
Number of tides a year	730.	
Tides absorbed	0.1	fraction.
Sea water density	1030000	g/m^3.
Gravitational constant	9.81	m/s^2.
Conversion factors	3.15.	
Annual energy	8.4E+16	Joules.
Transformity of tide	24000	Sej/J.
Emergy in tides	2.02E+21	Sej.
Total renewable emergy	2.24E+21	Sej.
Area of captation	2070000000	Square meters.
Renewable emergy per unit area	1.08E+12	Sej.
Area required for a)	190000000	Square meter.

Emergy added in recycled rainwater (annual):

Volume of water recycled	9300000	Cubic m. per yr.
Water density	1000000	g/m^3.
Gibbs free energy	4.95	Joule/gram.
Energy in water	4.6E+13	Joule.
Transformity of water (river)	1000000	Sej/J.
Emergy in recycled wastewater	4.6E+19	Sej.
Area of rain captation	1600000000	Sq. meter.
Added emergy per square mtr.	2.87E+10	Sej.
Total emergy per square meter	1.11E+12	Sej
Area required for b)	260000000	Square meters.

Emergy added in wastewater from Miami (annual):

Volume of water recycled	86200000	m^3.
Water density	1000000	g/m^3.
Gibbs free energy	4.95	Joule/gram.
Energy in water	4.26E+14	Joule.
Transformity of water (river)	1000000	Sej/Joule.
Emergy in recycled wastewater	4.26E+20	Sej.
Area of rain captation	1600000000	Sq. meter .
Added emergy per square mtr.	2.66E+11	Sej/Sq. meter.
Total emergy per square meter	1.38E+12	Sej.
Area required for c)	764000000	Square meters.

Table A.3 Population, land area and land use for three city classes in South Dade, based on water crop with out recycle.

Note	Items	Central city	2nd. Towns	3rd. Villages	Region
		Distribution of population and land uses			
1	Required centers	1	2	10	
2	Population	22300	11200	2230	67000
3	Area of each city	63400000	31700000	6340000	190000000
4	Land use areas (Sqr. meters).				
	Open land	1650000	793000	152000	4760000
	Parks	38100000	19000000	3810000	114000000
	Agriculture	19900000	9940000	1990000	59700000
	Institutional	222000	114000	22200	672000
	Low med density	2410000	1250000	258000	7480000
	Transportation	888000	444000	88800	2660000
	Med high density	63400	25400	5080	165000
	Business / Ind.	254000	121000	22800	723000
5	Area of wetlands	2190000	1100000	219000	6580000

Notes to Table A.3

1 *Urban centers*

Number of urban centers per category in hierarchy.

2 *Population*

Estimate population per each urban center. The distribution was made proportionally following the formula: p = (P/n)/N.

Where p is the population of each town; P is the population of the entire region; n is the number of towns of each class; and N is the number of classes of cities used.

3 *Area of each city*

The area for each urban center is determined keeping the population density (people per unit area), of the region: a = p * (P/A).“

Where a is the area of each urban center; p is the population of the center; P is the population of the region; and A is the total area of the region.

4 *Percent of land use*

An average of the land use percentages of Northeast and the original Southeast Florida was used to obtain the proposed distribution.

An estimated increase in the proportion of land used for higher empower "uses was added to the higher class cities, and a higher proportion” of low empower was applied for rural small towns.

Percentages used:

Land uses	Central city	Secondary	Tertiary Town
Open land	0.026	0.025	0.024
Parks	0.6	0.6	0.6
Agriculture	0.3135	0.3135	0.3135
Institutional	0.0035	0.0036	0.0035
Low density residential	0.038	0.0393	0.0406
Transportation	0.014	0.014	0.014
Medium density residential	0.001	0.0008	0.0008
Commercial and industrial	0.004	0.0038	0.0036
TOTAL	1	1	1

(Source: Brown 1980).

5 *Areas of wetlands*

Wetlands areas required for treatment of waste water are included as part of the area assigned to parks.

Wetlands are assumed to be able to process two inches of wastewater a week.

Wetlands area = (Wastewater produced)/(treatment capability).

Wastewater produced a year per capita (.75 of water use per capita)	260	Cubic meters.
Processing capability of wetlands (2 inches a week)	2.65	Meters.

Table A.4 Population, land area and land use for three city classes in South Dade, based on water crop adding Miami waste water.

Note	Items	Distribution of land uses and population			
		Central city	2nd. Towns	3rd. Villages	Region
1	Required centers	1	2	10	
2	Population	114000	57100	11400	343000
3	Area of each city	255000000	127000000	25500000	764000000
4	Land use area (Sqr. meters)				
	Open land	6620000	3310000	662000	19900000
	Parks	153000000	76400000	15300000	459000000
	Agriculture	79900000	39900000	7990000	240000000
	Institutional	917000	446000	89200	2700000
	Low med density	8660000	4590000	968000	27500000
	Transportation	3820000	1780000	357000	11000000
	Med high density	1020000	382000	25500	2040000
	Business / Ind.	1020000	510000	96800	3010000
5	Area of wetlands	11200000	5600000	1120000	33600000

Notes to Table A.4

1 *Urban centers*

Number of urban centers per category in hierarchy.

2 *Population*

Estimate population per each urban center. The distribution was made proportionally following the formula: p = (P/n)/N.

Where p is the population of each town; P is the population of the entire region; n is the number of towns of each class; and N is the number of classes of cities used.

3 *Area of each city*

The area for each urban center is determined keeping the population density (people per unit area), of the region: a = p * (P/A). "

Where a is the area of each urban center; p is the population of the center; P is the population of the region; and A is the total area of the region.

4 *Percent of land use*

An average of the land use percentages of Northeast and the original Southeast Florida was used to obtain the proposed distribution.

An estimated increase in the proportion of land used for higher empower "uses was added to the higher class cities, and a higher proportion" of low empower was applied for rural small towns.

Percentages used: (see Table A.3)

5 *Area of wetlands*: (see Table A.3)

Table A.5 Emergy based carrying capacity in South Dade.

Note	Item Dade	No water recycled At Fla's Ratio	 At Dade's Ratio	Miami wastewater At Fla's Ratio	 At Dade's Ratio
1	Renewable emergy	2.24E+21	2.24E+21	2.67E+21	2.67E+21
2	Non-renewable emergy	1.74E+22	4.03E+22	2.07E+22	4.8E+22
3	Total use	1.96E+22	4.25E+22	2.33E+22	5.06E+22
4	Emergy per person	2.69E+16	2.37E+16	2.69E+16	2.37E+16
5	I.R. carrying capacity	728000	1800000	867000	2140000
6	Renewable carrying capacity	83200	94500	99100	112000

Notes for Table A.5

1 *Renewable emergy*

Renewable emergy available in study area

2.24E+21 Sej.

Emergy from rain, tide and 10 % of minor imputs."

Surplus with emergy of recycled wastewater from Miami

2.67E+21 Sej.

2 *Non Renewable emergy*

Non-renewable = (Renewable emergy)*(emergy investment ratio)

Emergy investment ratio for Florida	7.75	
Emergy investment ratio for Dade County	18	
Non-renewable emergy for a)	1.74E+22	Sej.
Non-renewable emergy for b)	4.03E+22	Sej.
Non-renewable emergy for c)	2.07E+22	Sej.
Non-renewable emergy for d)	4.8E+ 22	Sej.

3 *Total emergy use*

Total use = (renewable emergy)+(non-renewable emergy).

4 *Emergy per person*

Ratio for Florida	2.69E+16	Sej/person.
Ratio for Dade County	2.37E+16	Sej/person.

(Source: Odum et. al. 1993a and Odum et. al. 1993b respectively).

5 *Population*

Total emergy use divided by emergy per person.

6 *Population based on renewable emergy*

Total renewable emergy in the study area divided by the emergy per person of the state and county respectively.

Table A.6 Population, land area and land use for three city classes in South Dade based on carrying capacity without recycling water.
Florida's emergy per capita.

Note	Items	Distribution of land uses and population			
		Central city	2nd. Towns	3rd. Villages	Region
1	Required centers	1	2	10	
2	Population	243000	121000	24300	728000
3	Area of each city	534000000	267000000	53400000	1600000000
4	Land use area (Sqr. meters)				
	Open land	13900000	6950000	1390000	41700000
	Parks	321000000	160000000	32100000	962000000
	Agriculture	167000000	83800000	16800000	503000000
	Institutional	1920000	935000	187000	5660000
	Low med density	18200000	9620000	2030000	57700000
	Transportation	8020000	3740000	748000	23000000
	Med high density	2140000	802000	53400	4270000
	Business / Ind.	2140000	1070000	203000	6310000
5	Area of wetlands	23800000	11900000	2380000	71500000

Notes to Table A.6

1 *Urban centers*

Number of urban centers per category in hierarchy.

2 *Population*

Estimate population per each urban center. The distribution was made proportionally following the formula: p = (P/n)/N.

Where p is the population of each town; P is the population of the entire region; n is the number of towns of each class; and N is the number of classes of cities used.

3 *Area of each city*

The area for each urban center is determined keeping the population density (people per unit area), of the region: a=p*(P/A). "

Where a is the area of each urban center; p is the population of the center; P is the population of the region; and A is the total area of the region.

4 *Percent of land use*

An average of the land use percentajes of Northeast and the original Southeast Florida was used to obtain the proposed distribution.

An estimated increase in the proportion of land used for higher empower "uses was added to the higher class cities, and a higher proportion" of low empower was applied for rural small towns.

(2 inches a week) 2.65 Meters.

Percentages used: (see Table A.3)

5 *Area of wetlands*: (see Table A.3)

Table A.7 Population, land area and land use for three city classes in South Dade based on carrying capacity without recycling water.
Dade's emergy per capita.

Note	Items	Distribution of land uses and population			
		Central city	2nd. Towns	3rd. Village	Region
1	Required centers	1	2	10	
2	Population	598000	299000	59800	1800000
3	Area of each city	534000000	267000000	53400000	1600000000
4	Land use areas (Sqr. meters).				
	Open land	13900000	6950000	1390000	41700000
	Parks	321000000	160000000	32100000	962000000
	Agriculture	167000000	83800000	16800000	503000000
	Institutional	1920000	935000	187000	5660000
	Low med density	18200000	9620000	2030000	57700000
	Transportation	8020000	3740000	748000	23000000
	Med high density	2140000	802000	53400	4270000
	Business / Ind.	2140000	1070000	203000	6310000
5	Area of wetlands	58800000	29400000	5880000	176000000

Notes to Table A.7

1 *Urban centers*

Number of urban centers per category in hierarchy.

2 *Population*

Estimate population per each urban center. The distribution was made proportionally following the formula: p = (P/n)/N.

Where p is the population of each town; P is the population of the entire region; n is the number of towns of each class; and N is the number of classes of cities used.

3 *Area of each city*

The area for each urban center is determined keeping the population density (people per unit area), of the region: a=p*(P/A). "

Where a is the area of each urban center; p is the population of the center; P is the population of the region; and A is the total area of the region.

4 *Percent of land use*

An average of the land use percentajes of Northeast and the original Southeast Florida was used to obtain the proposed distribution.

An estimated increase in the proportion of land used for higher empower "uses was added to the higher class cities, and a higher proportion" of low empower was applied for rural small towns.

Percentages used: (see Table A.3)

5 *Area of wetlands*: (see Table A.3)

Table A.8 Population, land area and land use for three city classes in South Dade based on carrying capacity recycling Miami waste water.
Florida's emergy per capita.

Note	Items	Distribution of land uses and population			
		Central city	2nd. Towns	3rd. Villages	Region
1	Required centers	1	2	10	
2	Population	289000	145000	28900	867000
3	Area of each city	534000000	267000000	53400000	1600000000
4	Land use areas (Sqr. meters)				
	Open land	13900000	6950000	1390000	41700000
	Parks	321000000	160000000	32100000	962000000
	Agriculture	167000000	83800000	16800000	503000000
	Institutional	1920000	935000	187000	5660000
	Low med density	18200000	9620000	2030000	57700000
	Transportation	8020000	3740000	748000	23000000
	Med high density	2140000	802000	53400	4270000
	Business / Ind.	2140000	1070000	203000	6310000
5	Area of wetlands	28400000	14200000	2840000	85100000

Notes to Table A.8

1 *Urban centers*

Number of urban centers per category in hierarchy.

2 *Population*

Estimate population per each urban center. The distribution was made proportionally following the formula: p = (P/n)/N.

Where p is the population of each town; P is the population of the entire region; n is the number of towns of each class; and N is the number of classes of cities used.

3 *Area of each city*

The area for each urban center is determined keeping the population "density (people per unit area), of the region: a=p*(P/A). "

Where a is the area of each urban center; p is the population of the center; P is the population of the region; and A is the total area of the region.

4 *Percent of land use*

An average of the land use percentajes of Northeast and the original Southeast Florida was used to obtain the proposed distribution.

An estimated increase in the proportion of land used for higher empower "uses was added to the higher class cities, and a higher proportion" of low empower was applied for rural small towns.

(2 inches a week) 2.65 Meters.

Percentages used: (see Table A.3)

5 *Area of wetlands*: (see Table A.3)

Table A.9 Population, land area and land use for three city classes in South Dade based on carrying capacity recycling wastewater of Miami.
Dade county emergy per capita.

Note	Items	Distribution of land uses and populations			
		Central city	2nd. Towns	3rd. Villages	Region
1	Required centers	1	2	10	
2	Population	712000	356000	71200	2140000
3	Area of each city	534000000	267000000	53400000	1600000000
4	Land use areas (Sqr. meters)				
	Open land	14600000	6950000	1390000	42400000
	Parks	321000000	160000000	32100000	962000000
	Agriculture	164000000	83700000	16800000	499000000
	Institutional	2460000	962000	187000	6250000
	Low med density	18700000	9080000	1920000	56100000
	Transportation	9080000	4010000	748000	24600000
	Med high density	2670000	1070000	160000	6410000
	Business / Ind.	2620000	1070000	214000	6890000
5	Area of wetlands	69900000	35000000	6990000	210000000

Notes to Table A.9

1 *Urban centers*

Number of urban centers per category in hierarchy.

2 *Population*

Estimate population per each urban center. The distribution was made proportionally following the formula: p = (P/n)/N.

Where p is the population of each town; P is the population of the entire region; n is the number of towns of each class; and N is the number of classes of cities used.

3 *Area of each city*

The area for each urban center is determined keeping the population " density (people per unit area), of the region: a=p*(P/A). "

Where a is the area of each urban center; p is the population of the center; P is the population of the region; and A is the total area of the region.

4 *Percent of land use*

An average of the land use percentajes of Northeast and the original Southeast Florida was used to obtain the proposed distribution.

An estimated increase in the proportion of land used for higher empower "uses was added to the higher class cities, and a higher proportion" of low empower was applied for rural small towns.

Percentages used: (see Table A.3)

5 *Area of wetlands*: (see Table A.3)

Table A.10 Population, land area and land use for three city classes in South Dade based on carrying capacity without recycling water.
"Renewable carrying capacity, Florida's emergy per capita."

Note	Items	Distribution of land uses and population			
		Central city	2nd. Towns	3rd. Villages	Region
1	Required centers	1	2	10	
2	Population	27700	13900	2770	83200
3	Area of each city	534000000	30500000	6110000	1600000000
4	Land use areas (Sqr. meter).				
	Open land	13900000	763000	147000	16900000
	Parks	321000000	18300000	3660000	394000000
	Agriculture	168000000	9570000	1910000	206000000
	Institutional	1870000	110000	21400	2300000
	Low med density	20300000	1200000	248000	25200000
	Transportation	7480000	427000	85500	9190000
	Med high density	534000	24400	4890	632000
	Business / Ind.	2140000	116000	22000	2590000
5	Area of wetlands	2720000	1360000	272000	8170000

Notes to Table A.10

1 *Urban centers*

Number of urban centers per category in hierarchy

2 *Population*

Estimate population per each urban center. The distribution was made proportionally following the formula: p = (P/n)/N.

Where p is the population of each town; P is the population of the entire region; n is the number of towns of each class; and N is the number of classes of cities used.

3 *Area of each city*

The area for each urban center is determined keeping the population " density (people per unit area), of the region: a=p*(P/A). "

Where a is the area of each urban center; p is the population of the center; P is the population of the region; and A is the total area of the region.

4 *Percent of land use*

An average of the land use percentajes of Northeast and the original Southeast Florida was used to obtain the proposed distribution.

An estimated increase in the proportion of land used for higher empower " uses was added to the higher class cities, and a higher proportion" of low empower was applied for rural small towns.

Percentages used: (see Table A.3)

5 *Area of wetlands*: (see Table A.3)

Table A.11 Population, land area and land use for three city classes in South Dade based on carrying capacity without water recycling.
"Renewable carrying capacity, Dade's emergy per capita."

Note	Items	Dsitribution of land uses and populations			
		Central city	2nd. Towns	3rd. Villages	Region
1	Required centers	1	2	10	
2	Population	31500	15700	3150	94500
3	Area of each city	534000000	267000000	53400000	1600000000
4	Land use areas (Sqr. meter).				
	Open land	13900000	6680000	1280000	40100000
	Parks	321000000	160000000	32100000	962000000
	Agriculture	168000000	83800000	16800000	503000000
	Institutional	1870000	962000	187000	5660000
	Low med density	20300000	10500000	2170000	63000000
	Transportation	7480000	3740000	748000	22400000
	Med high density	534000	214000	42700	1390000
	Business / Ind.	2140000	1020000	192000	6090000
5	Area of wetlands	3090000	1550000	309000	9280000

Notes to Table A.11

1 Urban centers

Number of urban centers per category in hierarchy.

2 Population

Estimate population per each urban center. The distributio was made proportionally following the formula: p = (P/n)/N.

Where p is the population of each town; P is the population of the entire region; n is the number of towns of each class; and N is the number of classes of cities used.

3 Area of each city

The area for each urban center is determined keeping the population " density (people per unit area), of the region: a=p*(P/A). "

Where a is the area of each urban center; p is the population of the center; P is the population of the region; and A is the total area of the region.

4 *Percent of land use*

An average of the land use percentajes of Northeast and the original Southeast Florida was used to obtain the proposed distribution.

An estimated increase in the proportion of land used for higher empower "uses was added to the higher class cities, and a higher proportion" of low empower was applied for rural small towns.

Percentages used: (see Table A.3)

5 *Area of wetlands*: (see Table A.3)

Table A.12 Population, land area and land use for three city classes in South Dade based on carrying capacity recycling wastewater from Miami. "Renewable carrying capacity, Florida's emergy per capita."

Note	Items	Distribution of land uses and population			
		Central city	2nd. Towns	3rd. Villages	Region
1	Required centers	1	2	10	
2	Population	33000	16500	3300	99100
3	Area of each city	534000000	267000000	53400000	1600000000
4	Land use areas (Sqr. meters)				
	Open land	13900000	6680000	1280000	40100000
	Parks	321000000	160000000	32100000	962000000
	Agriculture	168000000	83800000	16800000	503000000
	Institutional	1870000	962000	187000	5660000
	Low med density	20300000	10500000	2170000	63000000
	Transportation	7480000	3740000	748000	22400000
	Med high density	534000	214000	42700	1390000
	Business / Ind.	2140000	1020000	192000	6090000
5	Area of wetlands	3240000	1620000	324000	9730000

Notes to Table A.12

1 *Urban centers*

Number of urban centers per category in hierarchy.

2 *Population*

Estimate population per each urban center. The distributionwas made proportionally following the formula: p = (P/n)/N.

Where p is the population of each town; P is the population of the entire region; n is the number of towns of each class; and N is the number of classes of cities used.

3 *Area of each city*

The area for each urban center is determined keeping the population " density (people per unit area), of the region: a=p*(P/A). "

Where a is the area of each urban center; p is the population of the center; P is the population of the region; and A is the total area of the region.

4 *Percent of land use*

An average of the land use percentajes of Northeast and the original Southeast Florida was used to obtain the proposed distribution.

An estimated increase in the proportion of land used for higher empower "uses was added to the higher class cities, and a higher proportion" of low empower was applied for rural small towns.

Percentages used: (see Table A.3)

5 *Area of wetlands*: (see Table A.3)

Table A.13 Population, land area and land use for three city classes in South Dade based on carrying capacity recycling wastewater from Miami.
"Renewable carrying capacity, Dade's emergy per capita."

Note	Items	Distribution of land uses and population			
		Central city	2nd. Towns	3rd. Villages	Region
1	Required centers	1	2	10	
2	Population	37500	18700	3750	112000
3	Area of each city	534000000	267000000	53400000	1600000000
4	Land use area (Sqr. meter).				
	Open land	13900000	6680000	1280000	40100000
	Parks	321000000	160000000	32100000	962000000
	Agriculture	168000000	83800000	16800000	503000000
	Institutional	1870000	962000	187000	5660000
	Low med density	20300000	10500000	2170000	63000000
	Transportation	7480000	3740000	748000	22400000
	Med high density	534000	214000	42700	1390000
	Business / Ind.	2140000	1020000	192000	6090000

Notes to Table A.13

1 *Urban centers*

Number of urban centers per category in hierarchy.

2 *Population*

Estimate population per each urban center. The distribution was made proportionally following the formula: p = (P/n)/N.

Where p is the population of each town; P is the population of the entire region; n is the number of towns of each class; and N is the number of classes of cities used.

3 *Area of each city*

The area for each urban center is determined keeping the population "density (people per unit area), of the region: a=p*(P/A). "

Where a is the area of each urban center; p is the population of the center; P is the population of the region; and A is the total area of the region.

4 *Percent of land use*

An average of the land use percentajes of Northeast and the original Southeast Florida was used to obtain the proposed distribution.

An estimated increase in the proportion of land used for higher empower "uses was added to the higher class cities, and a higher proportion" of low empower was applied for rural small towns.

Percentages used: (see Table A.3)

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