FLORIDA KEYS CARRYING CAPACITY STUDY

DRAFT FINAL REPORT

September 2002
First Revision

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1.0 INTRODUCTION

1.1 BACKGROUND AND LEGAL MANDATE

This Final Report of the Florida Keys Carrying Capacity Study (FKCCS) is the culmination of efforts to compile, analyze and interpret existing data regarding the ability of the Florida Keys to withstand all impacts of additional land development activities.

The Florida Keys were designated as an Area of Critical State Concern in 1974. Broad goals of this ruling were "...to conserve and protect the natural, environmental, historical and economic resources, the scenic beauty, and the public facilities within the Area of Critical State Concern." The Area of Critical State Concern designation transferred all local Monroe County review and approval rights to the state land-planning agency, the Florida Department of Community Affairs (DCA).

In 1986, Monroe County approved a new comprehensive plan and corresponding land development regulations. The county developed the plan and regulations in response to the Area of Critical State Concern designation, as well as to comply with State of Florida regulations and to maintain a high quality of life in the region. In 1991, the Monroe County Board of County Commissioners ratified the *Monroe County Year 2010 Comprehensive Plan* (the Plan).

Monroe County revised the Plan in 1993 following several legal challenges initiated by the DCA and other private organizations. Ongoing legal proceedings prompted a 1995 Final Order and Recommendation by a Hearing Officer, which resulted in further revisions and final adoption of the Plan in 1996. During final revisions, the Plan adopted a "carrying capacity approach" to growth management.

The Florida Administrative Commission (FAC) issued an Executive Order in 1996 calling for the preparation of a "carrying capacity analysis" for the Florida Keys. The FKCCS fulfills a portion of the state and local government requirements as outlined in FAC Rules. Sections 28-20.100 and 28-19.100 FAC state:

> *"The [carrying capacity] analysis shall be based upon the findings adopted by the Administration Commission on December 12, 1995, or more recent data that may become available in the course of the study, and shall be based upon the benchmarks of, and all adverse impacts to, the Keys land and water natural systems, in addition to the impacts of nutrients on marine resources. The carrying capacity analysis shall consider aesthetic, socioeconomic (including sustainable tourism), quality of life and community character issues, including the concentration of population, the amount of open space, diversity of habitats, and species richness. The analysis shall reflect the interconnected nature of the Florida Keys' natural systems, but may consider and analyze the carrying capacity of specific islands or groups of islands and specific ecosystems or habitats, including distinct parts of the Keys' marine ecosystem."*

The goal of the FKCCS, excerpted from FAC Rule 28-20.100, reads as follows:

> *"The carrying capacity analysis shall be designed to determine the ability of the Florida Keys ecosystem, and the various segments thereof, to withstand all impacts of additional land development activities."*

Additionally, Rule 28-20.100 establishes that the carrying capacity study will be implemented by "...the adoption of all necessary [comp] plan amendments to establish a rate of growth and a set of development standards that ensure that any and all new development does not exceed the capacity of the county's environment and marine system to accommodate additional impacts. Plan amendments will include a review of the County's Future Land Use Map series and changes to the map series and the "as of right" and "maximum" densities authorized for the plan's future land use categories based upon the natural character of the land and natural resources that would be impacted by the currently authorized land uses, densities and intensities."

Therefore, the FKCCS will provide the state and local jurisdictions with an analytical tool and an evaluation of a series of land development scenarios that will support comprehensive plan amendments and revisions to development standards for the Florida Keys.

DCA and the U.S. Army Corps of Engineers (USACE) jointly sponsored the study. Section 528(b) (3) of the Water Resources Development Act of 1996 authorized the USACE to cooperate with a non-federal sponsor to complete the FKCCS, a critical project under the Everglades and South Florida Restoration Programs. The U.S. Congress passed the Water Resources Development Act of 1996, which included legislation directing the Secretary of the Army, through the USACE, to complete a series of Critical Projects associated with the Central and South Florida Restoration Study. The Critical Project authorization required that the project provide independent, immediate, and substantial benefits to the South Florida ecosystem.

1.2 DEVELOPMENT OF THE FLORIDA KEYS CARRYING CAPACITY STUDY SCOPE OF WORK

The development of the Scope of Work (SOW) for the FKCCS began with a cooperative agreement between the DCA and USACE in August 1996. A Steering Committee (SC) and a Technical Advisory Committee (TAC), charged with developing the SOW, included 38 agencies and three individuals. The SC and TAC included all the agencies represented on the Florida Keys National Marine Sanctuary (FKNMS) Water Quality Protection Program (WQPP), as well as area business leaders and intervenors involved in the legal challenges to the Monroe County Comprehensive Plan. Members of the SC and TAC provided knowledge about issues affecting Monroe County.

The TAC met for the first time in September 1996 to define the purpose, goals and objectives, concept and approach, and to review an outline for the FKCCS SOW. Utilizing input from the TAC, the study sponsors developed three drafts of the SOW between September 1996 and October 1997. In March/April 1998, the third draft of the SOW underwent peer review by 18 experts from different disciplines, who represented government agencies, academia, and private industry. Following the peer review, the SOW was finalized in September 1998.

The peer review identified some outstanding issues and uncertainties regarding species, ecosystems, relationship of land development activities and the marine environment, water circulation and water quality modeling, and ecosystem modeling. To keep the FKCCS process moving forward, the study sponsors invited a group of 65 technical experts for a technical workshop series to address the uncertainties and refine the study approach in the following areas:

1.	Conceptual Framework	May 1999
2.	Mobilization Workshop	June 1999
3.	Ecosystems	July 1999
4.	Species of Concern	August 1999
5.	Wastewater	August 1999
6.	Stormwater	September 1999
7.	Water Circulation/Water Quality Modeling	October 1999
8.	Carrying Capacity Analysis Model Framework	November 1999
9.	Scenario Development	January 2000

The workshop reports are included on the FKCCS website at:

http://www.saj.usace.army.mil/dp/index.html

Since engaging a Technical Contractor in late 1999, the FKCCS has focused on establishing predictive relationships between "land development activities" and indicators of carrying capacity in order to determine the ability of the Florida Keys ecosystems to withstand all impacts of additional land development. It has also considered socioeconomic issues, quality of life, amount of open space, diversity of habitats, and species richness. The study has been carried out with the understanding that the state and local governments will use it to assist them in adopting all necessary comprehensive plan amendments to establish a rate of growth and a set of development standards that "ensure that any and all new development does not exceed the capacity of the county's environment and marine system to accommodate additional impacts" (FAC Rule 28-20.100).

In order to address the carrying capacity of the Florida Keys ecosystems and provide support in making countywide comprehensive plan amendments, relationships and results are assessed at the FKNMS scale. Level of effort for the study was apportioned among five key disciplines: terrestrial and marine ecosystems and species, human infrastructure, socio-economics, fiscal, and water issues. Finally, all of the data, relationships, and carrying capacity indicators were integrated using state-of-the-art Geographic Information Systems (GIS) technology in order to build an automated computer model.

With few exceptions, the study team attempted to establish the relationships between development and the environment based upon the findings adopted by the Administration Commission on December 12, 1995 and other data that became available since then. Data searches revealed a paucity of specific, peer reviewed scientific information to support the establishment of defendable carrying capacity criteria or of clear predictive relationships between land development activities and some of the study parameters. For example, while a voluminous and rapidly growing body of scientific literature addresses the marine environment in the Florida Keys (for a recent review, see Porter and Porter 2002), virtually no study shows undisputable connections between development and water quality, the distribution and health of benthic communities, or fisheries productivity in the FKNMS that would allow for establishing predictive relationships.

Overall, the current peer-reviewed scientific information proved insufficient to develop a comprehensive carrying capacity analysis framework that would allow for undisputable determinations of whether future development scenarios fall within the carrying capacity of the Florida Keys (discussion in NRC 2002). Yet the study and the impact assessment model clearly document several untenable effects of development on the environment in the Florida Keys and will provide solid technical support for decisions on comprehensive plan amendments and development standards in the Keys.

1.3 ORGANIZATION OF THE REPORT

This Final Report of the FKCCS presents the technical basis for the study, including its two main technical tools, the Carrying Capacity/Impact Assessment Model (CCIAM) and the Routine Planning Support Tool (RPST, an Internet application). The report addresses stakeholders input, including comments from the National Research Council.

The FKCCS has greatly benefited from stakeholders comments and observations made throughout the execution of the study. The National Research Council (NRC) provided an independent review of the CCIAM (NRC 2002) commissioned by the USACE and the DCA. The following agencies and organizations also provided written comments on recent FKCCS reports: U.S. Environmental Protection Agency (EPA), Florida Fish and Wildlife Conservation Commission (FWC), Florida Department of Environmental Protection (FDEP), Florida Keys Aqueduct Authority (FKAA), 1,000 Friends of Florida, The Ocean Conservancy and World Wildlife Fund (jointly), the South Florida Water Management District (SFWMD), the Florida Keys Citizens Coalition (FKCC), and the Environmental & Land Use Center, Inc., writing on behalf of five non-governmental organizations (NGOs).

Section 2.0 describes the study methods and process. Section 3.0 describes the CCIAM and the RPST. Section 4.0 discusses the scenario evaluation and results. Finally, Section 5.0 offers conclusions of the study, discusses the implementation, and presents recommendations to further the efforts to date. Additionally, appendices include maps, previous FKCCS reports, acronyms, and a glossary.

3.0 CARRYING CAPACITY/IMPACT ASSESSMENT MODEL

3.1 KEY CONCEPTS AND PROCESSES

The Carrying Capacity/Impact Assessment Model (CCIAM) is a spatially explicit, Geographic Information Systems (GIS) based, automated computer model that evaluates the end-state effects of additional land development activities on the Florida Keys ecosystems, including impacts on socio-economics, fiscal, and human infrastructure. Land development activities modify land use patterns, including the type, location, intensity, and distribution of land uses. Therefore, changes in land use trigger the CCIAM analysis. The user defines alternative scenarios by modifying land use patterns and specifying stormwater and wastewater treatment types. The model recognizes three types of development actions: new development, redevelopment, and restoration. New development considers the conversion of undeveloped areas, whether disturbed or in a natural state, to a developed land use. Redevelopment either converts developed land from one type of use to another or changes the intensity of the land use. Restoration reverts developed land to a "natural" or restored habitat. CCIAM is designed so that all coefficients, databases, and algorithms can be updated when more current data and/or scientific understanding becomes available.

Throughout this report, the following key terms are used frequently. A glossary is found in Appendix E.

- **Modules:** A module is a self-contained analysis unit with distinguishing inputs and outputs that may be derived from, or provided to, other modules. Each of the major categories of assessment (e.g., terrestrial habitats and species) is represented by a module, within which all operations relating to that category are executed.
- **Components:** Modules consist of components, which are discrete subsets of inputs, calculations, and outputs. For example, the Integrated Water Module includes the Stormwater and Wastewater components.
- **Elements:** Elements include algorithms, coefficients, data tables, and other computational aspects within each component. One or more elements may constitute a component.
- **Planning Units:** For the analysis, the Florida Keys were divided into 28 planning units (Table 3.1; Map 1) which approximately correspond to the planning units used in the Monroe County Sanitary Wastewater Master Plan (CH2MHILL 2000):

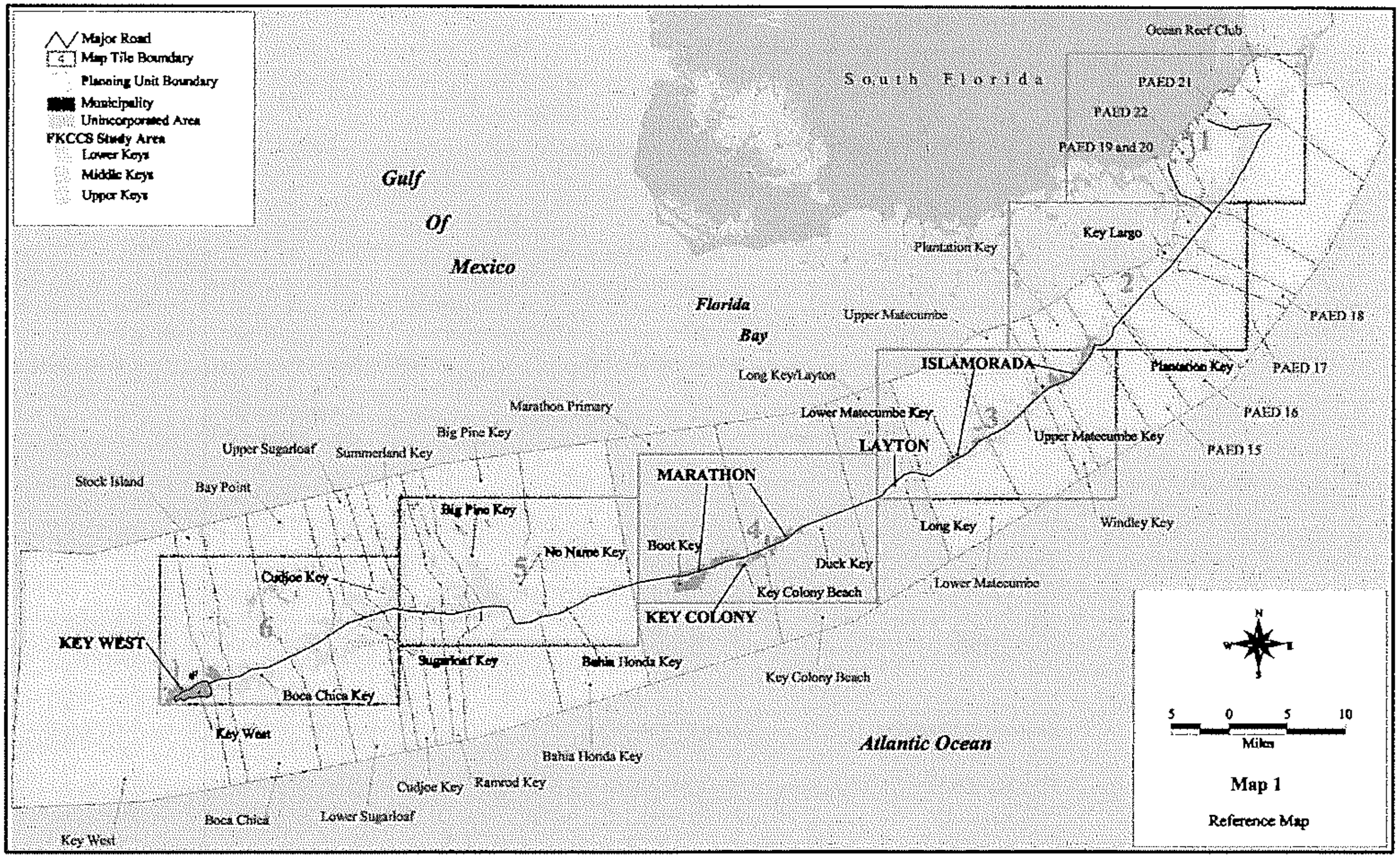

Major Road
Map Tile Boundary
Planning Unit Boundary
Municipality
Unincorporated Area
FKCCS Study Area
Lower Keys
Middle Keys
Upper Keys
Gulf
Of
Mexico
South Florida
Ocean Reef Club
PAED 21
PAED 22
PAED 19 and 20
Key Largo
Plantation Key
Upper Matecumbe
Florida
Bay
PAED 18
PAED 17
PAED 16
PAED 15
Long Key/Layton
ISLAMORADA
Plantation Key
Lower Matecumbe Key
Upper Matecumbe Key
LAYTON
Marathon Primary
Big Pine Key
Upper Sugarloaf
Summerland Key
Stock Island
Bay Point
MARATHON
Big Pine Key
No Name Key
Boot Key
Duck Key
Key Colony Beach
Long Key
Windley Key
Lower Matecumbe
Cudjoe Key
KEY COLONY
KEY WEST
Sugarloaf Key
Bahia Honda Key
Key Colony Beach
Boca Chica Key
Key West
Atlantic Ocean
Bahia Honda Key
Cudjoe Key
Ramrod Key
Boca Chica
Lower Sugarloaf
Key West
N
W
E
S
5
0
5
10
Miles
Map 1
Reference Map

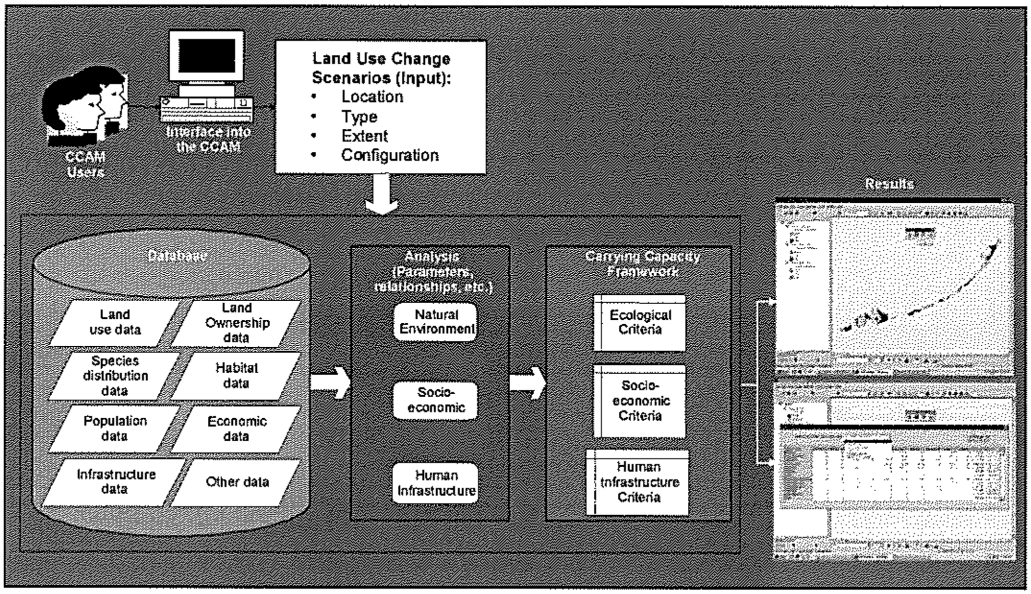
TABLE 3.1
FKCCS PLANNING UNITS

Wastewater Planning Unit Name	
Ocean Reef Club	Marathon Primary
PAED 21 (North Key Largo)	Bahia Honda Key
PAED 22 (Cross Key)	Big Pine Key
PAED 19 and 20 (Garden Cove)	Big/Mid Torch Key
PAED 18 (John Pennecamp State Park)	Little Torch Key
PAED 17 (Rock Harbor)	Ramrod Key
PAED 16 (Rodriguez Key)	Summerland Key
PAED 15 (Tavernier)	Cudjoe Key
Plantation Key	Upper Sugarloaf
Windley Key	Lower Sugarloaf
Upper Matecumbe	Bay Point
Lower Matecumbe	Boca Chica
Long Key/Layton	Stock Island
Key Colony Beach	Key West

The structure and key processes of the CCIAM encompass the following four elements (Figure 3.1):

- **Data:** Datasets were identified, compiled, assimilated, and organized into a series of databases for use in the model. Examples of key data required include land use and land cover, land ownership, population, socio-economics, infrastructure, terrestrial habitat, and species distributions.
- **Scenarios:** Scenarios represent specific sets of land use conditions that the user defines for analysis. Land use conditions are defined in terms of the location, type, extent, and configuration of the land use change.
- **Analysis:** Effects of land use changes on the human infrastructure, socioeconomic conditions, and natural environment within the study area are evaluated. Relationships between land use change and model elements define the analytical basis of the CCIAM.
- **Carrying Capacity Indicators:** Thresholds, limiting factors, and other criteria associated with the ecological, socioeconomic, and human infrastructure categories of the model help evaluate overall carrying capacity. These indicators are used to evaluate results of the analysis and assess whether modeled scenarios are likely to exceed the carrying capacity indicators.

FIGURE 3.1
CCIAM PROCESS



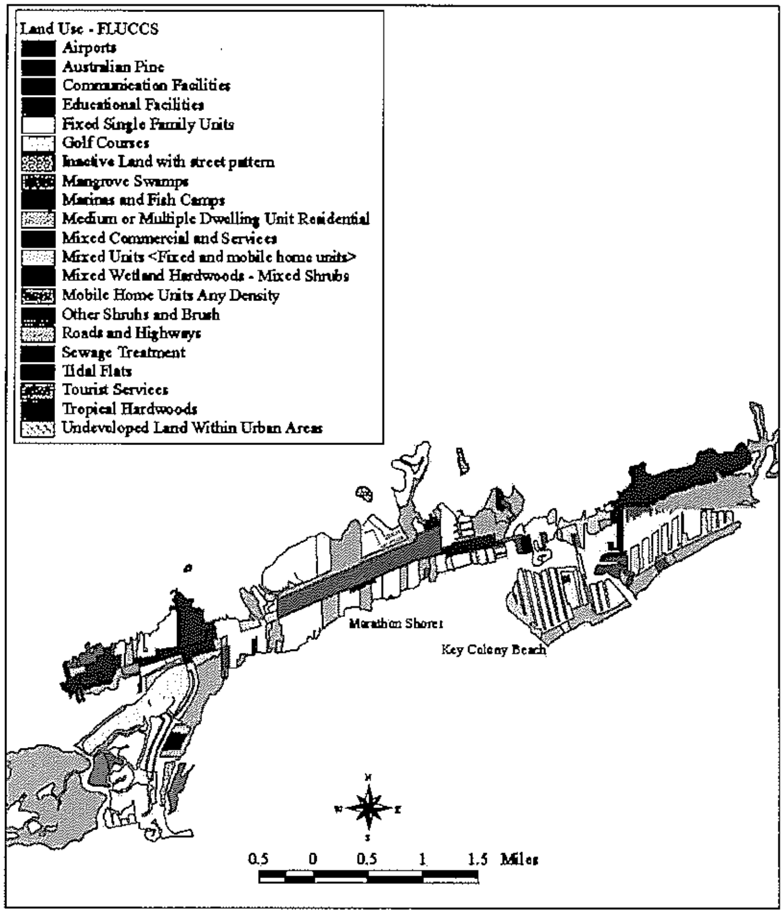
The two primary functional parts of the model are the Scenario Generator and the Analysis Modules. The Scenario Generator is a Graphic User Interface (GUI) and a set of preliminary calculations that create a land use GIS layer from the user-defined scenario. Using these new land use conditions, the Analysis Modules calculate scenario effects on each of the impact assessment variables (IAV). Finally, the Analysis Modules compare resulting IAVs with indicator values and identify conditions that may exceed these indicators.

3.2 DATA SUITABILITY

3.2.1 Land Use/Land Cover Data

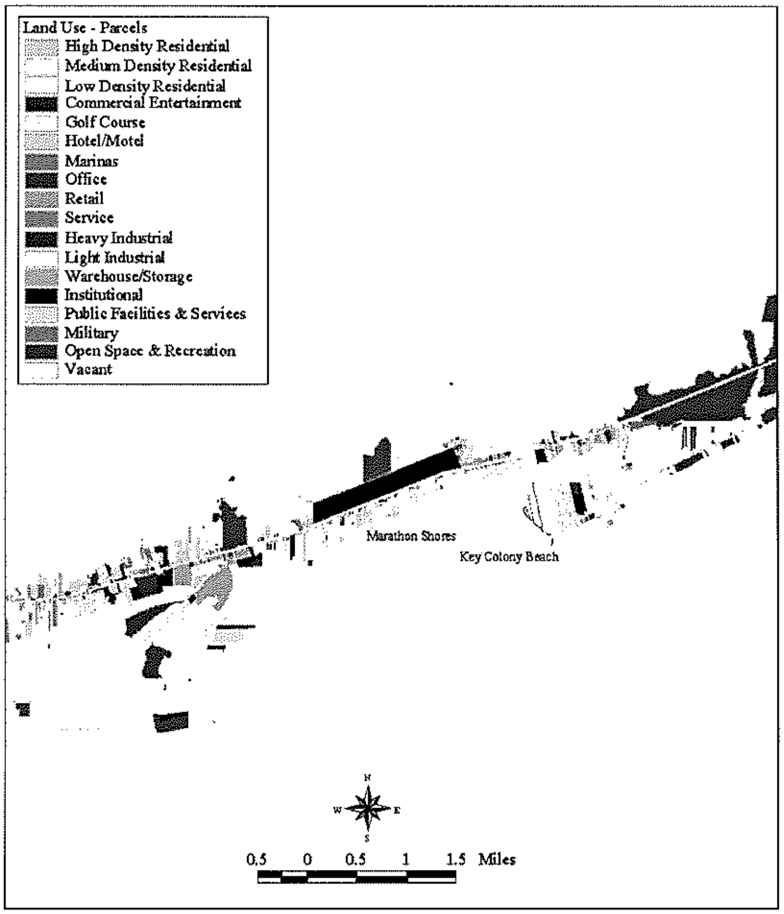
Land use is the fundamental dataset in the model and establishes the initial conditions against which any scenario is defined. Because there are no up-to-date land use maps for Monroe County, three potential sources of land use data were evaluated. First, the Monroe County Growth Management Office provided the Florida Keys Carrying Capacity Study (FKCCS) with a multitude of Digital Exchange Files (DXF). DXF data have no geographic coordinate system and, therefore, could not be translated into a GIS data format for the CCIAM. In addition, there are no attribute fields associated with these DXF data. Second, the South Florida Water Management District (SFWMD) maintains a 1995 land use and land cover map that applies the Florida Land Use, Cover, and Forms Classification System (FLUCFCS) (Figure 3.2). The FLUCFCS is widely used in Florida for planning and environmental applications. For this study, however, the FLUCFCS was insufficient, as it omits information such as vacancy or land ownership.

FIGURE 3.2
EXAMPLE FLUCFCS LAND USE DATA IN THE FLORIDA KEYS



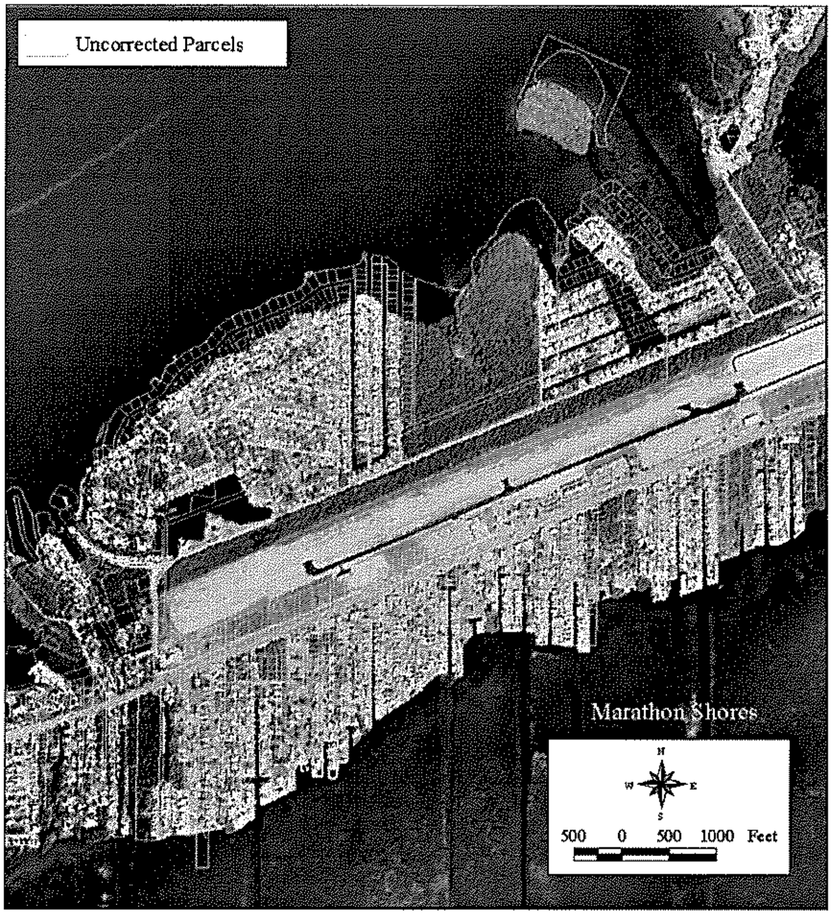
Third, the parcel GIS layer from the Monroe County Property Appraiser's Office is a parcel-by-parcel map of the Florida Keys (Figure 3.3). Its associated Tax Roll database includes numerous fields of information about each parcel, including ownership, development status, taxable value, and sale price, among others. The combination of a spatial coverage linked to a detailed database made the parcel dataset more appropriate for the study than the FLUCFCS map. However, the parcel GIS layer and the Tax Roll were developed to serve specific purposes related to maintaining official taxing and property records. These purposes are quite different from those of the FKCCS. In particular, the spatial data and the tabular data were not designed to provide land use or zoning information, nor are the data required to be accurately geo-referenced in order to serve their purpose for the Property Appraiser. Therefore, the study team faced several challenges in order to effectively use the parcel database and the Tax Roll in this study.

FIGURE 3.3
EXAMPLE LAND USE FROM THE PARCEL DATASET



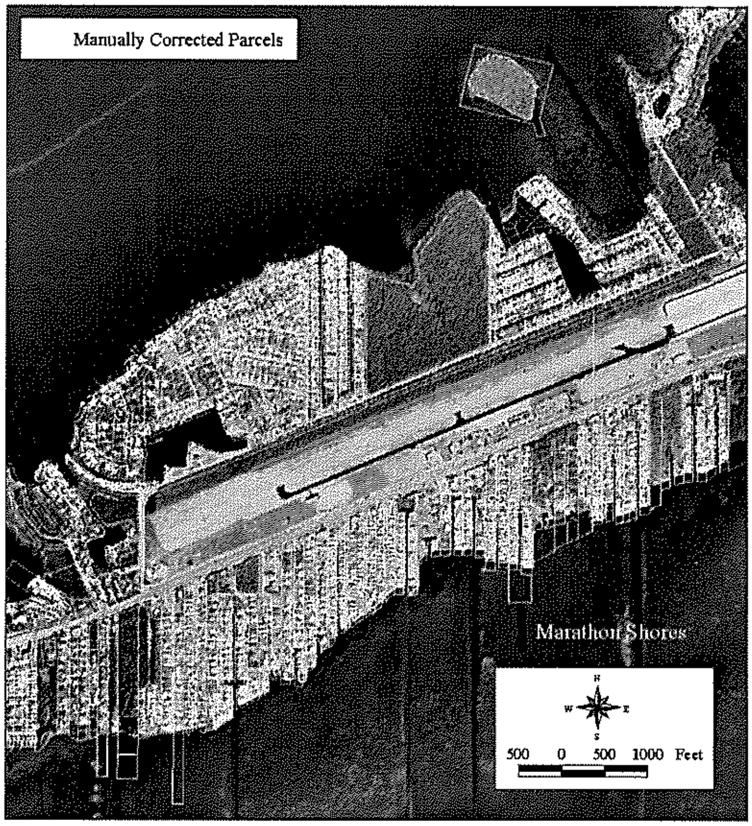
For example, when overlaid on other spatial data, such as Digital Ortho Quarter Quadrangle (DOQQ) aerial photography, the Monroe County parcel GIS layer is "shifted" (Figure 3.4).

FIGURE 3.4
PARCELS PRIOR TO MANUAL CORRECTION



Technically, the data exhibits rotations, skews, and shifts throughout the Florida Keys. The spatial discrepancy increases from the Lower to the Upper Keys and with increasing distance from U.S. 1. The Study Team and the Florida Marine Research Institute (FMRI) developed a simple method to manually shift the parcels to achieve a "best fit" using the 1995 DOQQ as a visual reference (Figure 3.5). While this method is not appropriate for cadastral mapping, it provided sufficient accuracy for a regional planning model such as the CCIAM.

FIGURE 3.5
PARCELS AFTER MANUAL CORRECTION OF SPATIAL SHIFT



The Property Appraiser's Office downloaded a portion of their Tax Roll dataset for use in the FKCCS. The resulting DBASE file contains 54 columns or "fields" of data for each of the approximately 70,000 parcels in the Florida Keys. For example, the property code (PC) field can take one of 99 values that represent land use for that property.

Two other fields, termed "LL1" and "LL2," show one of 297 possible values, which denote environmentally sensitive areas, a wide variety of commercial uses, or unique residential characteristics. The study team allocated a considerable amount of effort to understand the characteristics, limitations, and appropriate use of these fields, including numerous interactions with FMRI and the Property Appraiser's Office. Ultimately, the values from the PC field were used to define the land use categories used throughout the model (Table 3.2).

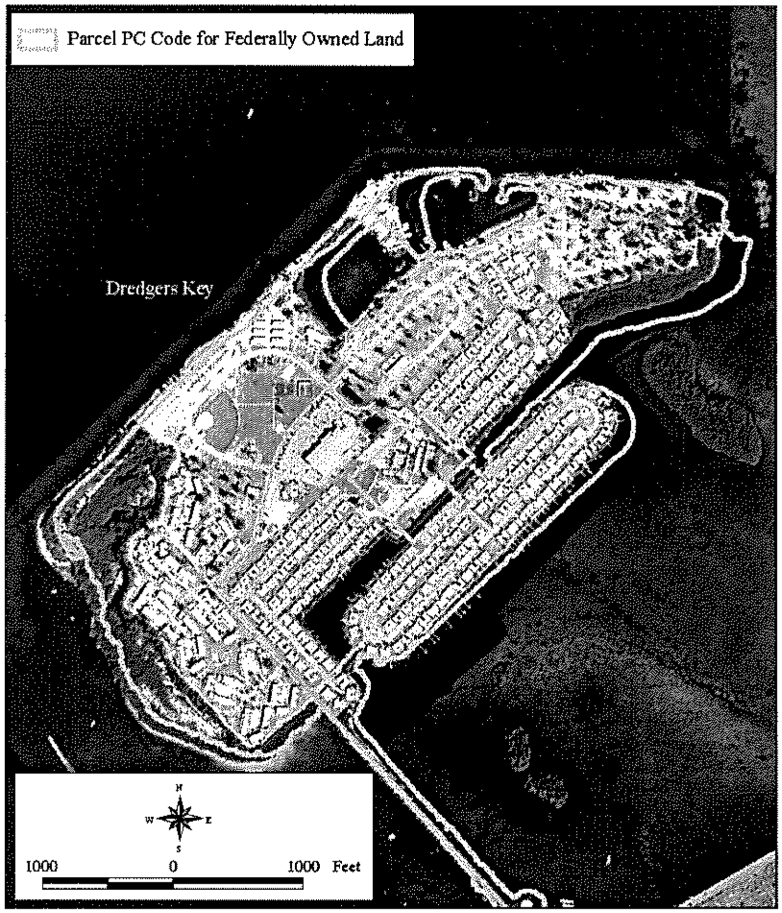
TABLE 3.2
PC CODES UTILIZATION TO DEFINE LAND USE CATEGORIES FOR THE FKCCS

Land Use in the FKCCS	Corresponding PC Values in the Tax Roll
Vacant Land	00, 10, 40, 70
Residential (high, medium, low density)	01, 02, 03, 04, 05, 06, 07, 08, 09, 36
Retail	11, 12, 13, 14, 15, 16
Office	17, 18, 19, 23, 24
Service	21, 22, 25, 26, 28, 29, 30, 61
Marina	27
Commercial Entertainment	31, 32, 33, 34, 35, 37
Golf Course	38
Hotel/Motel	39
Light Industrial	41, 44, 45, 46
Heavy Industrial	42, 43, 47
Warehouse/Storage	48, 49
Public Facilities and Services	83, 84, 85, 91, 94
Institutional	20, 71, 72, 73, 74, 75, 76, 77, 78, 79, 90
Agriculture	69
Open Space and Recreation	80, 82, 86, 87, 88, 89, 92, 99
Military	81
Submerged Lands	95

Similar to land use, no GIS-based zoning data exists for the Florida Keys. The Property Appraiser's Office attempts to assign a zoning category to each parcel in the Tax Roll, but these data do not constitute an official zoning map. However, this information is the best available in the Florida Keys. After additional coordination with the Property Appraiser, the available zoning data was linked to the parcel GIS layer. In addition, numerous inspections of available, recent aerial photography (First American Realty Solutions 2001) helped address and clarify obvious discrepancies or missing zoning values.

Model tests showed inconsistencies between the number of dwelling units and population calculated for the current conditions versus those reported by the Census 2000 (reported in the November 2001 draft of the Test CCIAM Report). This discrepancy suggested anomalies in the PC values or in the application of those values to certain land uses. Further evaluation of the Tax Roll and aerial photography revealed that parcels coded as "county" (PC = 86) or "federal" (PC = 88) were categorized as "open space" when, in fact, the parcel had other land uses. For example, Dredgers Key, in Key West, has a PC code of 88 (open space and recreation), but includes over 100 housing units (Figure 3.6). Similarly, the Key West Airport was coded 86 and initially interpreted as "open space." Corrections based on these findings resulted in the calibration of current condition housing units to within 5 percent of the Census 2000 values Keys-wide (48,792 and 51,571, respectively).

FIGURE 3.6
LAND USE AND PROPERTY CODE DISCREPANCY



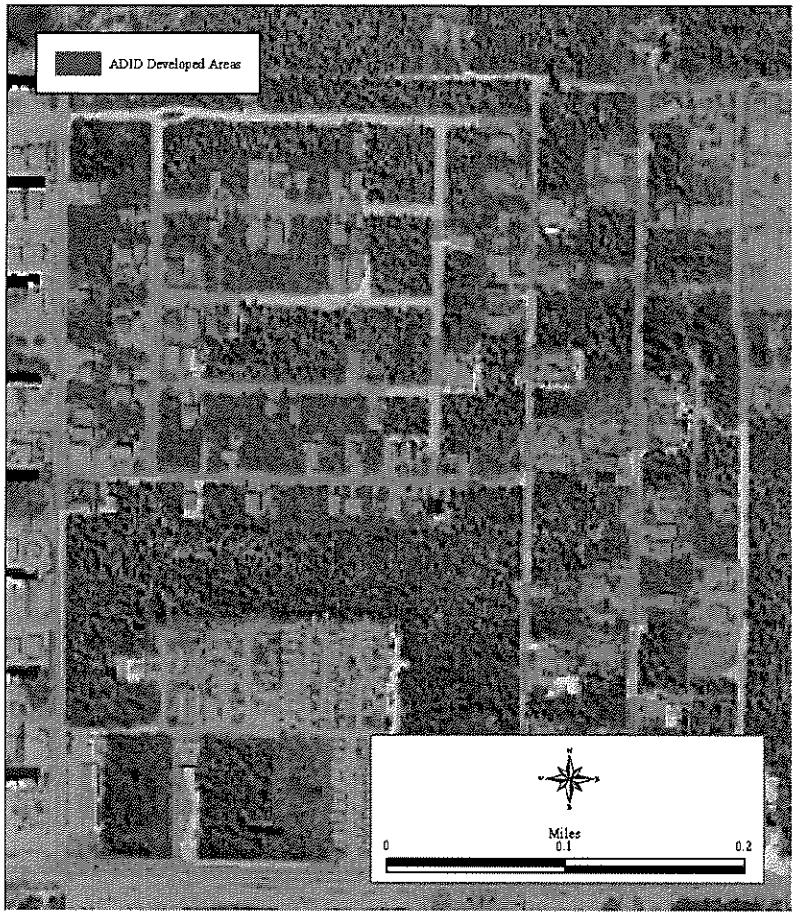
The parcel data and Tax Roll database from the Monroe County Property Appraiser's Office, after adjustments, constituted the land use basis for the study.

3.2.2 Spatial Databases for Terrestrial Habitats and Species

Advanced Identification of Wetlands Map

Several spatial databases regarding terrestrial ecosystems and species are available for the Florida Keys. The Advanced Identification of Wetlands (ADID; FMRI 1995) GIS layer is the best source of spatial terrestrial habitat data available. It classifies land cover into 15 types, based on photo-interpretation of 1991 DOQQs. Its main purpose was to identify wetlands in the Keys under the USACE federal criteria for delineation of wetlands (Environmental Laboratory 1987). For this model, the ADID vegetation classification system, resolution, and spatial accuracy are superior to both the statewide FLUCFCS and the Habitat and Land Cover layer of the Florida Fish and Wildlife Conservation Commission (FWC). A limitation of the ADID map for the CCIAM is that some patches mapped as developed encompass smaller undeveloped patches of various habitat types (Figure 3.7).

FIGURE 3.7
APPARENT HABITAT WITHIN ADID DEVELOPED POLYGONS



Exotic Vegetation Map

Kruer et al. (2000) developed an exotic vegetation map of the Florida Keys based on 1996 fieldwork. The map documents nearly 7,000 acres of exotic vegetation. While the area of infestation was confirmed, the GIS spatial data was based on the Property Appraiser parcel coverage. Therefore, the preparation of the map involved "rubbersheeting" the parcel coverage (T. Armstrong letter to FMRI, dated August 25, 2000). Due to the unknown spatial accuracy of the exotic vegetation GIS layer, the layer was not incorporated into the model.

Historic Habitat Map

A map of the historic distribution of habitats in the Florida Keys, developed for the FKCCS under Delivery Order 7, provided a benchmark to evaluate the effect of development on the extent and distribution of habitat types in the Florida Keys. The mapping approach used for this study is similar to that of Strong and Bancroft (1994). The primary sources of information used to interpret historic vegetation include three aerial photograph series, ranging from 1945 to 1959, which are the earliest available for the entire study area. Other sources included field visits, other historic maps, topography, and soils. The low resolution of the historic photography limited the number of community types identified in the historic map. Therefore, the fifteen ADID categories were aggregated into eight categories, including five vegetation types (hammocks, pinelands, freshwater wetlands, saltwater wetlands, and beach berm) as well as developed land, exotics, and open water. The FKCCS included a second mapping effort to extrapolate vegetation types beyond the 1945 map to pre-development conditions using the same eight categories.

Species Richness Map

A species richness map was developed for the FKCCS using a combination of sources (Table 3.3). Species included in the species richness map met the following criteria:

1. Currently listed by federal or state agencies as an endangered (E), threatened (T), or imperiled species (S2) or species of special concern (SSC) in Monroe County by the federal (F) or state (S) governments. The S2 designation includes species imperiled in Florida because of vulnerability to rarity (6 to 20 records of occurrence or less than 3,000 individuals) or because of vulnerability to extinction due to some natural or man-made factor.

2. There is an existing potential habitat model for the species, for which at least a "Fair" model accuracy rating was given in the Habitat Conservation Needs of Rare and Imperiled Wildlife in Florida (FWC GAP II; Cox and Kautz 2000). The "Fair" model rating indicates that the potential habitat model is sufficiently accurate to allow an assessment of habitat (Cox and Kautz 2000).

3. Species for which other existing potential habitat models were readily available. These GIS layers were obtained from the U.S. Fish and Wildlife Service (USFWS) and FMRI.

4. The species determined to be suitable based on the previous three criteria were further reviewed and selected to balance the representation of upland and wetland species and habitat. Mr. Randy Kautz of the FWC kindly reviewed the list of selected species. The set of species includes an almost equal representation of upland and wetland species.

TABLE 3.3
SPECIES INCLUDED IN THE SPECIES RICHNESS MAP[1]

Taxonomic Class	Scientific Name	Common Name	Model Source
Reptiles	*Alligator mississippiensis*	American alligator	Cox and Kautz 2000
	Malaclemys terrapin rhizophorarum	Mangrove terrapin	Cox and Kautz 2000
	Drymarchon corais couperi	Eastern indigo snake	Cox and Kautz 2000
	Kinosternon baurii	Lower Keys striped mud turtle	USFWS
	Crocodylus acutus	American crocodile	USFWS
	Chelonia mydas (nesting habitat)	Green sea turtle	FMRI ESI
Birds	*Pelecanus occidentalis*	Brown pelican	Cox and Kautz 2000
	Plegadis falcinellus	Glossy ibis	Cox and Kautz 2000
	Pandion haliaetus	Osprey	Cox and Kautz 2000
	Dendroica discolor paludicola	Florida prairie warbler	Cox and Kautz 2000
	Columba leucocephala	White-crowned pigeon	FMRI/ESI
Mammals	*Oryzomys paustris natator*	Silver rice rat	USFWS
	Sylvilagus palustris hefneri	Lower Keys marsh rabbit	USFWS
	Odocoileus virginianus clavium	Florida Key deer	USFWS
	Neotoma floridana smalli	Key Largo woodrat	USFWS
	Peromyscus gossypinus allapaticola	Key Largo cotton mouse	USFWS
Vascular Plant	*Pilosocereus robinii*	Key tree cactus	USFWS

1 Models were rerun, using the ADID as the base habitat layer, for the American alligator, mangrove terrapin, Eastern indigo snake, brown pelican, glossy ibis, osprey, and Florida prairie warbler.

For 10 of the 17 species, the USFWS or FMRI developed the habitat models used in the CCIAM. For the other 7 species, the Technical Contractor developed new potential habitat maps using the FWC GAP II model methods. The models were re-run substituting the ADID for the FWC Habitat and Land Cover layer. Given the higher resolution of the ADID layer, the size of grid cells was reduced from 100 x 100 meters in the GAP II models to 30 x 30 feet for the FKCCS. Some of the model criteria were varied slightly to incorporate Keys-specific habitat considerations into the regionally developed model methods. An overlay of the 17 habitat models provides a measure of species richness in which the value of each 30 x 30 foot cell is the total number of species whose potential habitat are located in that cell. Although the maximum value possible for the species richness layer is seventeen, the maximum number of species found in a given cell in the study area was ten.

Additionally, species-specific spatial data was also used to address species impacts for the Key deer, Lower Keys marsh rabbit, and silver rice rat (Section 4.0).

3.2.3 Other Spatial Databases Used in the Study

Numerous state, federal, and local agencies and organizations provided datasets for potential use in this study. The FMRI was the primary database contractor for the study. Spatial datasets were reviewed to determine their suitability for inclusion according to the following criteria:

- Spatial coverage of data;
- Resolution of the data and concurrence with map accuracy standards for that level of resolution;
- Completeness of data;
- Vintage of data;
- Accuracy of data set attribution;
- Accuracy in polygon closure, edge mapping, and other topology parameters;
- Completeness of documentation or metadata;
- Degree of spatial error and ability to match to other data sets;
- Ability to be analyzed with other data sets;
- Accuracy and documentation of data acquisition methods; and
- Projection parameters.

Two important factors determining data suitability are spatial accuracy and applicability to the needs of the CCIAM. In several cases, a particular dataset contained critical information not available from another source, but was in an incompatible format or contained discrepancies or was incomplete. If data limitations did not represent a fatal flaw, necessary steps were performed to bring the dataset to an acceptable state for use in this study.

The following spatial databases were incorporated into the study:

- Monroe County parcel GIS layer and associated Tax Roll database from the Monroe County Property Appraiser.
- Planning units and other spatial data from the Monroe County Sanitary Wastewater and Stormwater Master Plans (CH2MHILL 2000, CDM 2000).
- The FMRI ADID dataset, which provided terrestrial habitat distribution data.
- Habitat distribution within the FMRI benthic communities' dataset.
- Terrestrial and marine species distribution from the USFWS, the FWC, and FMRI.

3.2.4 Non-Spatial Data

The CCIAM utilizes over 60 look-up tables, which hold factors, coefficients, or initial conditions. These include Census data, government expenditures, effluent characteristics, event mean concentrations (EMCs), species-specific habitat requirements, and traffic data, among others.

The FKCCS benefited from recently completed or ongoing studies, some of which were provided as part of in-kind contribution to the study from the State of Florida. Because each of these studies had been accepted as final, the Technical Contractor did not attempt to verify the data, methods, results, or conclusions of the studies. Studies included the Monroe County Stormwater Master Plan, the Monroe County Sanitary Wastewater Master Plan, the Monroe County Population Estimates and Forecasts 1990 to 2015, the Monroe County Canal Study (ongoing), the Regional Habitat Conservation Plan for Big Pine and No Name Keys (ongoing), the 2001 and 2002 Monroe County Public Facilities Capacity Assessment, and the Monroe County 2002 U.S. 1 Arterial Travel Time and Delay Study, among others.

3.3 INFORMATION TECHNOLOGY

The CCIAM is implemented as a customized ArcInfo 8.1 map document (MXD). This MXD houses the Visual Basic for Applications (VBA) code that automates the analysis, result reporting, and graphical user interface. ArcInfo 8.1 is the latest GIS technology and is widely used in both Florida and the United States. Agencies such as the FWC, Monroe County Property Appraiser's Office, and the DCA employ ArcInfo.

CCIAM testing and refining activities generated over 50 gigabytes of data. The final model including the 7 scenarios consists of approximately 25 gigabytes of data. Some datasets are large, both in number of records and fields (attributes) in the associated tables. For example, there are approximately 70,000 records in the parcel dataset, 13,500 in the benthic communities' dataset, and 9,700 in the ADID dataset. In addition, there are 54 attributes associated with the parcel dataset and most analyses in the CCIAM add at least one field (column) to several different tables. The CCIAM relies on several personal geodatabases and ArcInfo workspaces to manage, access, and generate data. Personal geodatabases employ Component Object Model (COM) technology and are implemented as Microsoft Access 2000 databases. ArcInfo workspaces are unique to the grid and coverage formats of the GIS software vendor, Environmental Systems Research Institute (ESRI).

Study team programmers used VBA to manipulate ArcObjects and execute structured query language (SQL) statements that, in turn, automate all analytical processes in the model. All code is documented both within the code itself and in technical manuals. Additional VBA code displays and operates the GUI as forms within ArcInfo 8.1. Finally, VBA code was also written to display results as maps, charts, and tables from within the GIS software package.

Data compiled and resulting from the FKCCS will be delivered to the general public and local planners via the Internet. Arc Internet Map Server (ArcIMS) is currently available as an "off the shelf" software package for the delivery of GIS information via the Internet. The study team built a Routine Planning Support Tool using ArcIMS as the technology solution. Minor customizations, using Java Script, were made to the "out of the box" solution to enhance the application. The Internet application will supplement the model, provide wide access to the CCIAM information base, and allow for data downloads.

3.4 SCENARIO GENERATOR

In the context of community planning, the term "scenario" is often used interchangeably with the term "vision." A vision, however, typically provides only general direction, usually articulating values and goals of the community for its future. In the CCIAM, scenarios may be interpreted as the land use result of alternative policies. Each scenario involves a particular combination of variables – although the simulation can be replicated any number of times using different combinations of variables.

Users can describe and input alternative scenarios according to the location, type, extent, and configuration of additional development activities. The model uses land use change as the currency for scenarios, instead of "additional development," in order to accommodate scenarios that consider reversion of developed areas to undeveloped conditions. The model utilizes modifications to the Wastewater Planning Units (CH2MHILL 2000) as the analysis unit, and, therefore, as the means to determine the location of development. The type, extent, and configuration of land use change may vary within and among analysis units. For example, two different units may experience different types of development, or different areas within a unit may experience different configurations.

The user may choose among three types of development: new development, which results in vacant land being developed; re-development, which changes the character of developed parcels; and restoration, which reverts developed lands to a natural state. Within each type, development may be residential, commercial, industrial, or recreation, among others. The user may also specify the intensity or magnitude of development defined as area or number of units. For example, residential development may be low density or high density. Finally, the distribution of the development defines the spatial configuration of the user-defined scenario.

3.4.1 Graphical User Interface

The CCIAM provides a GUI, which consists of several computer screens that allow users to select among menu options and, in some cases, to input specific values such as number of dwelling units, percent of parcels, or acreage affected. The following are examples of CCIAM GUI screens:

Land Use "Change From" Conditions Screens. These screens allow the user to select the type of land use to be modified (Figure 3.8). Secondary menus allow for selecting a specific set of conditions defining the parcels to be affected. Users may select for parcels that meet all specified criteria (e.g., scarified parcels within 100 feet of U.S. 1) or that meet any of the criteria (e.g., scarified or within 100 feet of U.S. 1; Figure 3.9).

FIGURE 3.8
VACANT LAND CHANGE FROM GUI SCREENS

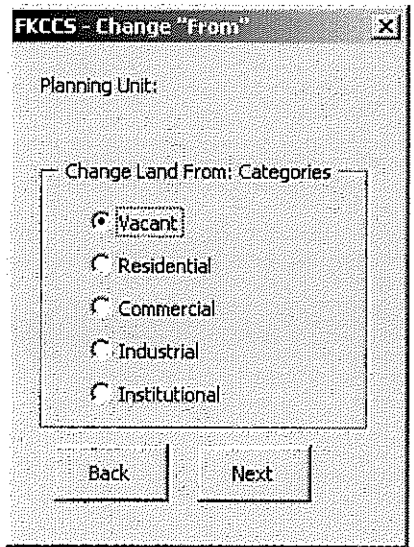
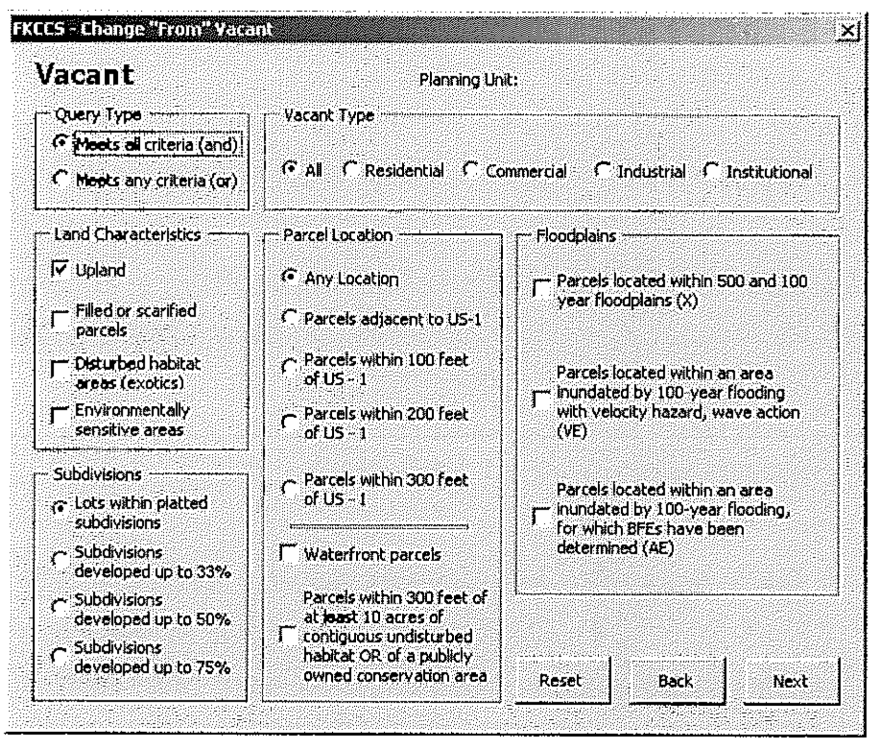
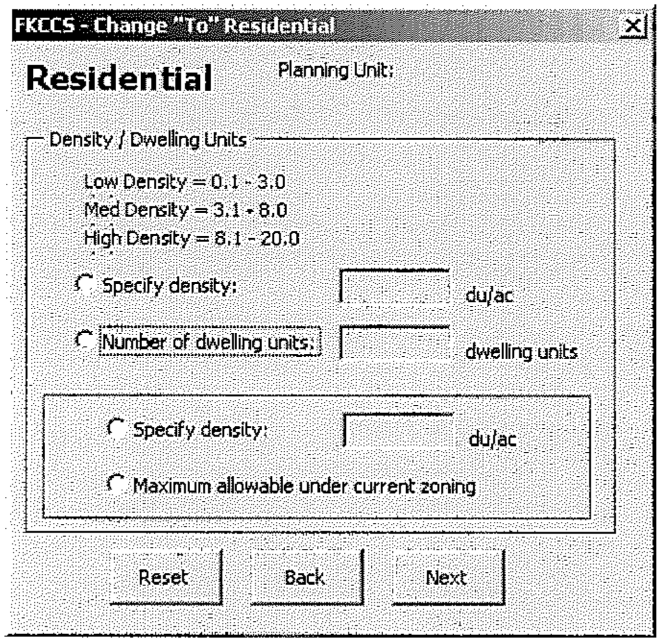


FIGURE 3.9
VACANT LAND CHANGE FROM GUI SCREENS



Land Use "Change To" Conditions Screens. These screens allow the user to define the future land use for the selected areas. This also leads to secondary screens where the user can specify type of activity, density of development, magnitude of change, and percent of parcels affected (Figure 3.10).

FIGURE 3.10
RESIDENTIAL CHANGE TO GUI SCREENS



Other screens provide options for implementing the Stormwater or Wastewater Master Plans, retrofitting, or selecting Best Management Practices (BMPs) for stormwater treatment. Once the user has navigated the CCIAM interface and input criteria for the selected scenario, the scenario is saved and the model creates a new land use GIS layer and associated attributes that represent the future conditions as defined by the user.

3.4.2 Basis for Land Use Change in the Scenario Generator

The scenario choices determine a new spatial pattern of land use, which triggers each of the modules' impact evaluation. Therefore, land use change is the primary basis of the CCIAM. The GUI includes options to allow users to choose a subset of lands for development. For those cases, the model selects specific areas based on a predetermined suitability ranking that reflects common planning standards and regulations in Monroe County. The suitability analysis represents a "pre-processing" activity in the CCIAM (i.e., the analysis was done manually to prepare the data for use in the scenario definition). The following steps were followed to complete the land use and suitability analysis.

Determine the Availability, Suitability, and Development Capacity of Vacant Land

"Vacant lands" were identified in the parcel GIS layer. In conventional land use analysis, the "vacant land" category may provide an adequate measure of future development capacity. However, in the Florida Keys this approach would ignore the existence of stringent regulatory constraints (e.g., zoning, development standards, and environmental protection measures) and socioeconomic aspects (e.g., ownership pattern, location preferences, and cost-related factors such as pre-existing infrastructure), which influence the probability that vacant land will be developed. Therefore, the availability, development suitability, and development capacity of vacant land was evaluated.

The objectives of the vacant lands evaluation were:

- To generate an effective vacant land inventory by excluding unavailable vacant land from the total vacant land inventory. Criteria included ownership (private vs. public), use (conservation and open space), or absolute environmental restrictions (vacant land characterized by wetland vegetation).
- To determine how much of the effective inventory of vacant land is allocated for future development in four main land use categories: residential (PC Code = 00), commercial (PC Code = 10), industrial (PC Code = 40), and institutional (PC Code = 70).
- To identify criteria to rank the intrinsic development suitability of vacant land. The ranking system is based on the assumption that the presence, nature, and extent of certain constraints may make parcels less suitable for development. For example, parcels characterized by hammock vegetation, while usually developable to some extent, tend to rank lower in the development suitability scale because local regulations impose additional constraints to development in those types of parcels. However, the user may override this constraint and specify any degree of development.
- To determine the suitability of available vacant land within each of the above future land use categories. If data were available, specific criteria were applied to be consistent with current policy and the existing regulatory framework. For example, criteria for residential land included location in a legally platted subdivision, availability of infrastructure, high flood base elevation, and absence of natural habitat vegetation cover (i.e., hammock), (Table 3.4). The ADID layer was used in conjunction with the parcels to provide a land use and land cover base map for the study. Floodplain designation was obtained from the Federal Emergency Management Agency (FEMA) Flood Insurance Rate Maps (FIRM). In the case of nonresidential land, this list was modified to incorporate proximity to U.S. 1 as a determinant (Table 3.5). It was assumed that most types of nonresidential development would be attracted first to vacant land that is visually and functionally accessible to U.S. 1. To avoid applying arbitrary distances, physical adjacency of the parcel to the highway was used to define proximity.

- To estimate the development capacity of vacant land selected for conversion in the scenario. Unless otherwise directed by the user for a specific scenario run, the model does this by applying appropriate density and intensity coefficients adopted from local zoning regulations.

TABLE 3.4
SPECIFIC CRITERIA FOR SUITABILITY RANKING OF RESIDENTIAL LAND

	Criteria								
	Platted Subdivision Infill		Infrastructure (Availability of Water Service)		Floodplain Designation			Vegetation Cover (Hammock)	
Ranking	Yes	No	Yes	No	X	AE	VE	Yes	No
Most Suitable	■		■		■				■
	■		■			■			■
Moderately Suitable	■		■				■		■
		■	■		■				■
		■	■			■			■
		■	■				■		■
	■		■		■			■	
	■		■			■		■	
Marginally Suitable	■		■				■	■	
	■			■	■			■	
	■			■		■		■	
	■			■	■				■
	■			■		■			■
	■			■			■		■
	■			■			■	■	
		■	■			■		■	
		■	■				■	■	
Least Suitable		■		■			■		■
	■			■	■			■	
	■			■		■		■	
	■			■			■	■	
		■		■	■			■	
		■		■		■		■	
		■		■			■	■	

Notes:
Floodplain Designation: X = Outside of 100-year and 50-year floodplain.
AE = Area inundated by 100 year flooding.
XE = Area inundated by 100 year flooding with velocity hazard.

TABLE 3.5
SPECIFIC CRITERIA FOR SUITABILITY RANKING OF NONRESIDENTIAL LAND

	Criteria						
	Proximity to U.S. 1		Floodplain Designation			Vegetation Cover (Hammock)	
Ranking	Yes	No	X	AE	VE	Yes	No
Most Suitable	■		■				■
Moderately Suitable	■			■			■
	■				■		■
		■	■				■
		■		■			■
		■			■		■
Marginally Suitable	■		■			■	
		■	■			■	
Least Suitable	■			■		■	
	■				■	■	
		■		■		■	
		■			■	■	

Notes:
Floodplain Designation: X = Outside of 100-year and 50-year floodplain.
AE = Area inundated by 100 year flooding.
VE = Area inundated by 100 year flooding with velocity hazard.

The zoning data provided in the Tax Roll were used to define an appropriate set of density and/or intensity coefficients. For example, vacant parcels zoned as Improved Subdivision, or an equivalent classification, were assumed to yield one dwelling unit per lot. Applicable density and intensity coefficients were multiplied by the total acreage of land in each vacant land subcategory to calculate the potential gross number of dwelling units and/or amount of nonresidential floor area that a scenario will generate.

Determine the Intensity of Existing Development

The intensity of existing development was determined to support scenarios involving conversion of developed land from one use to another or for a change in the intensity of development. The number of existing residential dwelling units, or the amount of existing nonresidential floor area, was divided by the total acreage in each developed land subcategory.

Identify Developed Land Suitable for Redevelopment Activities

Criteria for selection of developed land suitable for redevelopment activities were identified in collaboration with local planners and were based on the assumption that the presence, nature, and extent of certain combinations of conditions may affect the likelihood of redevelopment. These conditions, for which data are available in the Tax Roll, are combined to identify potential redevelopment areas for use in the CCIAM:

- Residential/commercial structures older than 20 years.
- Residential/commercial structures less than 33 percent of the land value.

- Residential structures smaller than 1,200 square feet.
- Commercial structures with a floor area ratio (FAR) of less than 19 percent.
- Waterfront properties.

Once a scenario has been fully defined by the user, the model produces a new GIS layer that represents the new land use pattern. These outputs include:

- Maps illustrating the future land use pattern resulting from the scenario definition.
- Attributes for each land use category including acreage, gross density (in dwelling units/acre) and intensity (in FAR) of development, and number of dwelling units and/or amount of nonresidential floor area generated by the scenario.

The suitability analysis does not identify "vested" development, which exist in areas of the Florida Keys. As the state and local governments explore different development scenarios, vested developments may constitute a scenario. At this time, no detailed listing of vested developments is available at Monroe County.

The selected ranking criteria represent a subset of all potential suitability criteria. The analysis omitted several commonly used factors, including soil type, topography, and quality of adjacent development, because they have lower applicability and impact on the development potential of land in the Florida Keys.

Availability of infrastructure is typically an important development suitability criterion. The Florida Keys Aqueduct Authority (FKAA) provided the only useable data regarding availability of water service. In the future, additional infrastructure data can be incorporated into the model by modifying the selection criteria.

3.5 ANALYSIS MODULES

Scenarios are analyzed in modules (Table 3.6). Inputs and outputs are exchanged among certain modules. For example, population from the socio-economic module and costs of potable water infrastructure from the water module are used as inputs for the fiscal module.

TABLE 3.6
CCIAM ANALYSIS MODULES AND COMPONENTS

CCIAM Module	Module Components
Socioeconomic	Population/Residential; Economic/Nonresidential; Socioeconomic Indicators
Fiscal	Government Expenditures
Infrastructure	Potable Water, Traffic, Hurricane Evacuation
Integrated Water	Wastewater, Stormwater
Terrestrial	Habitat Conversion and Fragmentation Secondary Impacts; Species-Specific Effects
Canals	Pollutant loads and water quality

In summary, the CCIAM evaluates the following effects of land use change:

- **Effects of land use changes on population (Socioeconomic Module):** Changes in land use may result in changes in the population of the study area. This can include changes to the permanent, seasonal, and transient populations.
- **Effects of land use change and subsequent effect of population changes on socioeconomic parameters and government expenditures (Socioeconomic and Fiscal Modules):** Changes in the number and distribution of people result in changes in economic variables, such as employment, income, and demand for services and infrastructure. These in turn affect the government expenditures required to meet population demands.
- **Effects of land use change and subsequent effect of population changes on infrastructure (Infrastructure Module):** Changes in the number and distribution of people also result in changes in the demand for potable water. It also affects traffic patterns, which in turn affects the time required for hurricane evacuation.
- **Effects of land use change on the dynamics of water and the demand for water supply (Integrated Water Module):** Changes in land use and the application of BMPs may result in changes in the impervious surface area, thereby altering stormwater runoff and the volume of water discharged into groundwater and the marine environment. BMPs determine the treatment level for stormwater and affect the pollutant load discharge into the marine environment. Population changes resulting from changes in land use also affect water consumption and the production of wastewater, which ultimately may affect water quality in nearshore waters.
- **Direct and indirect effects of land use change on terrestrial habitats and species (Terrestrial Module):** Conversion of undeveloped land into developed land results in a corresponding decrease in habitat area. This reduction in habitat area results in habitat fragmentation and degradation. In restoration scenarios, developed lands are reverted to natural conditions, increasing habitat area.

3.6 Socioeconomic Module

The socioeconomic module calculates population and other socioeconomic indicators that result from the user-defined development scenario. The module links the number of dwelling units and square footage of nonresidential land uses resulting from the scenario to people and the amount of land necessary to accommodate the specified land uses. In turn, it estimates the businesses' demand for employment and resulting payroll. The Socioeconomic Module produces the following outputs, based on user-specified development scenarios, for each planning unit:

- Population required to support the dwelling units resulting from the development scenario;

- Population ("customers") available and required to support the nonresidential component of the scenario;
- Employees available and required to support the nonresidential component of the scenario;
- Payrolls that will result from development of the nonresidential component of the scenario;
- Taxable value of new development; and
- Construction value of new development.

The basic data input for the Socioeconomic Module is land use. However, other information supports the outputs of the module. The following types of data are used in this module:

Demographic Data. Examples of this information include persons per household, population growth rates during 1990-2000, and ratios of employment per 1,000 square feet of building space for major land use categories.

Demographic coefficients (e.g., persons per household) were calculated and calibrated for each planning unit in the study area using information from the 2000 Census.

Other demographic coefficients address the ratio of employees per 1,000 square feet of gross floor area (GFA) for each of the nonresidential land use categories. The ratio of employees per 1,000 square feet of building space and user-defined area of commercial and industrial development provide an estimate of required employment.

Per capita floor area coefficients were calculated and calibrated for each nonresidential land use category on a countywide basis. Retail market areas and labor sheds of most businesses extend beyond the boundaries of individual planning units, and people will shop or work in locations remote from their homes. These coefficients were developed from the Property Appraiser's database for Monroe County.

Property Values. This information is used to measure several socioeconomic impacts, such as taxable value of new development and construction cost of new development.

In this module, the primary financial coefficient is the taxable value of new development. The taxable values were computed from the current Monroe County Tax Roll. The calculation was completed by summing the GFA and taxable value of each land use category. Then, the total GFA was divided into the total taxable value to compute an average value per square foot of GFA. Due to the high degree of variation, this computation is reported in each planning unit. Added taxable value is a measure of development quality, as well as fiscal resources to the County.

Construction Costs. An estimate of per-unit construction costs is used to calculate the value of new development established in the scenario. Data from *Means Square-Foot Construction Costs*, a nationally recognized estimating manual, was used to estimate these coefficients. This is a standard reference for preparing pre-design estimates of construction costs by architects, builders, and feasibility analysts. The basic values were adjusted by the manual's cost index to reflect averages in the region.

Wage Rates. Average annual wage rates per employee were extracted from the current edition of *County Business Patterns*, an annual publication of the U.S. Department of Commerce. These wage rates were equated to the land use categories used in the module. *County Business Patterns* was used because of its uniformity of data collection throughout the nation, as well as its long history of publication.

The fundamental assumption of this module is that future growth in the Florida Keys will likely proceed in a stable manner, without significant deviations from recent historical trends. This assumption is supported by the low rate of population growth from 1990 to 2000 (2 percent), and the consistency of Monroe County's program to limit growth since 1992. Other important assumptions are as follows:

- Demographic characteristics, especially those that strongly affect land use demand, will remain relatively unchanged during the study time frame of 20 years. The slow rate of population growth documented by results of the U.S. Census Bureau counts in 1990 and 2000 indicate that overall countywide averages have not changed significantly over the past ten years. In addition, the future growth rates projected by Monroe County and the Florida Bureau of Business Research (BEBR) at the University of Florida are comparable to that exhibited during recent history. These small projected growth rates will have limited influence on overall population characteristics that drive land use demand.
- Because of the limited population growth expected in the future, the ratios between population size and land use area will remain essentially constant over the study time frame. These ratios include average household size and per capita measures of major land use groups, such as square feet of retail, office, and industrial space.

3.7 FISCAL MODULE

The Fiscal Module of the CCIAM estimates the potential cost of user-defined development scenarios and the resulting impact on government expenditures. The primary indicators of a governmental entity's fiscal condition are revenues, expenditures, operating position, debt structure, unfunded liabilities, and the condition of capital facilities, infrastructure, and community need. The module uses annual government expenditures per capita as the primary indicator of the fiscal impact of development. The essential underlying assumption for this approach is that local governments will set *ad valorem* tax millage rates at levels necessary to meet expenditures. Therefore, a scenario that results in a higher per capita government expenditure indicates pressure on government to increase revenue, including increasing taxes.

The module's base conditions reflect the current level of expenditures of government jurisdictions that have revenue-generating authority to levy *ad valorem* taxes (City of Marathon; Islamorada, Village of Islands; City of Key Colony Beach; City of Key West; City of Layton; Monroe County; Florida Keys Mosquito Control; SFWMD; Monroe County Housing Authority; Monroe County School Board; and the Lower Florida Keys Hospital District).

Expenditures are derived from a combination of operating costs and debt service costs. The annual governmental expenditure figure for each local government jurisdiction was summed from the categories in their annual operating budget, including public schools. Annualized fixed capital costs were included under the debt service category. The annual operating expenditure amount (everything other than debt service) and annual fixed capital (debt service) expenditure amount for each governmental jurisdiction was calculated from these data. Per capita expenditure was obtained by dividing the annual operating and fixed capital expenditure by the functional population for current conditions.

In addition, expenditures are also projected and adjusted for unfunded liabilities for current needs. Unfunded liabilities include known expenditures, currently beyond funded levels of government budgets, necessary to address current deficiencies (e.g., actions necessary to comply with the Wastewater and Stormwater Master Plans).

Under a user-defined scenario, the model adjusts current expenditures to account for unfunded liabilities and all expenditures associated with the scenario. This establishes the baseline for all liabilities rather than just those accounted for in current governmental budgets. This also allows a comparison of the effects of currently unfunded liabilities and the effects of the scenario conditions. The unfunded liabilities used in this analysis include school deficiencies, and capital costs for stormwater, wastewater, and potable water treatment. The module also addresses land acquisition and road improvements for the scenarios analyzed in the FKCCS.

The CCIAM uses GIS to overlay the boundaries of the planning areas and the governmental jurisdictions to determine the amount of each governmental jurisdiction within each planning area. The planning area was expressed as a percentage of the governmental jurisdiction on an acreage basis. Total expenditures across each planning area were calculated by summing the total expenditure of each governmental jurisdiction within the planning area. The endpoint of this module is an estimate of government expenditures for user-defined scenarios. Results allow the evaluation of potential tax rate costs for individual citizens within jurisdictions or wastewater planning units, and the evaluation of total costs for each governmental jurisdiction.

This module interfaces directly with the Socioeconomic Module and the Integrated Water Module, receiving inputs from both of those modules in terms of population and per capita costs of water supply and treatment respectively.

Data for this module was identified and acquired from the local governments in Monroe County; local government annual financial reports provided to the Florida Department of Banking and Finance, Bureau of Accounting for the 1998-1999 and 1999-2000 fiscal years; and fiscal indicators included in the International City Managers Association Fiscal Impact Analysis Manual. This module uses the following inputs:

Population Estimates. The functional population estimate is taken from the socio-economic component of the model.

Government Jurisdiction Expenditures Data. Each local government jurisdiction's total annual expenditures for the 1999-2000 Fiscal Year, taken from the Annual Local Government Financial Report provided to the Florida Department of Banking and Finance, Bureau of Accounting was summarized and provides initial conditions.

Government Jurisdiction Expenditures Not Presently Funded. These are projected expenditures necessary to meet current government commitments. They include additional space for the Monroe County School System (Monroe County 2001), and the implementation of the provisions of the Wastewater (CH2MHILL 2000) and Stormwater (CDM 2000) Master Plans. These unfunded liabilities are added to current expenditures.

Wastewater Planning Area/Government Jurisdiction Relationship. This includes a GIS layer of the wastewater planning areas included within each government jurisdiction.

Fixed Capital Costs/Annual Debt Service Expenditures Conversion Tables. These tables project bond financing of fixed capital facilities for a 20-year term at 5.5 percent financing including bond transaction costs, thereby resulting in the annual debt service expenditure that would be incurred by the appropriate government jurisdiction.

3.8 HUMAN INFRASTRUCTURE

3.8.1 Potable Water

The Potable Water Component develops an estimate of daily potable water demand for each scenario and then compares the estimate against the allowable groundwater withdrawal of FKAA's current consumptive water use permit and the existing potable water infrastructure. The comparison determines whether the existing water system has adequate supply and treatment capacity to meet the required water demand. The Potable Water Component addresses the following four elements:

Allocation of Current Potable Water Demands to Existing Equivalent Dwelling Units. Efforts initiated by the Monroe County Sanitary Wastewater Master Plan to allocate the existing total number of equivalent dwelling units (EDUs) to specific developed land parcels were completed in this study in order to spatially assess existing and future potable water demands. Additionally, representative daily demands were calculated based upon FKAA water use records for each planning unit.

Estimation of Potable Water Demand. Daily potable water demand is calculated for each scenario using land use categories, converted to EDUs, and current specific water consumption rates computed for each planning unit. Computations are aggregated to the level of the 28 wastewater planning units (including Key West), adjusted at the planning unit level for functional populations, and then summed to produce the estimated total potable water requirement for the entire study area.

Adequacy of the Permitted Supply. The component compares the controlling constraints, such as the permitted groundwater withdrawal rate established for the water supply source and the treatment facility capacity, against the estimated potable water demand of a scenario. The component estimates potable water demand from consumers and then multiplies total demand times 1.16 to account for waters loses and unmetered uses (U.S. Geological Survey (USGS) 2002). The resulting number is compared to the permitted withdrawal volume.

Adequacy of the Existing Conveyance Facilities. Transmission pipeline throughput requirements are calculated based upon the potable water demand of a scenario and an assumed maximum average daily velocity of 7 feet per second in the transmission main segments. The component compares the capacity constraints established for each FKAA aqueduct segment against the estimated cumulative potable water demands calculated for each of the planning scenarios.

3.8.2 Traffic Component

The traffic component includes two independent tools to assess the effect of development on traffic in the Florida Keys. First, it applies a regression equation to relate acres of residential and tourist-related land uses and median traffic speed on U.S. 1, by planning unit, throughout the Florida Keys. Using the parcel database, the acreage of different land uses was summarized. A regression analysis revealed a statistically significant correlation ($p < 0.01$) between the density of tourist-related commercial and residential land uses per mile of U.S. 1 and the observed median speed along U.S. 1:

Median Speed = -0.016*((residential acres + tourist-related acres)/miles of U.S. 1) + 49.97

The regression, while statistically significant, explains only about 30 percent of the variance in median speed among planning units. Undoubtedly, other factors affect median speed. Further examination of available information points to the effects of traffic lights and road capacity. For example, Key Deer Boulevard is a two-lane road with a traffic light and shows the lowest median speed. For any user-defined scenario, therefore, the resulting median speed can be estimated as a function of land use by applying the regression equation above; the median speed is directly related to the level of service (LOS). The regression equation is used in the CCIAM to estimate the resulting median speed as a function of land use in the user-defined scenario.

Second, every year Monroe County estimates capacity for additional residential development based on the reserve traffic volume for U.S. 1. A formula developed by the U.S. 1 Task Force relates reserve volume with residential capacity, as follows (Monroe County 2001):

Residential Capacity = Reserve Volume /(Trip Generation Rate * % Impact on U.S. 1)

In 2001, the reserve volume was 44,513 daily trips, for a residential capacity of 6,955 units (Monroe County 2001). In 2002, the reserve volume decreased to 38,949 daily trips and, consequently, the estimated residential capacity also decreased to 6,086.

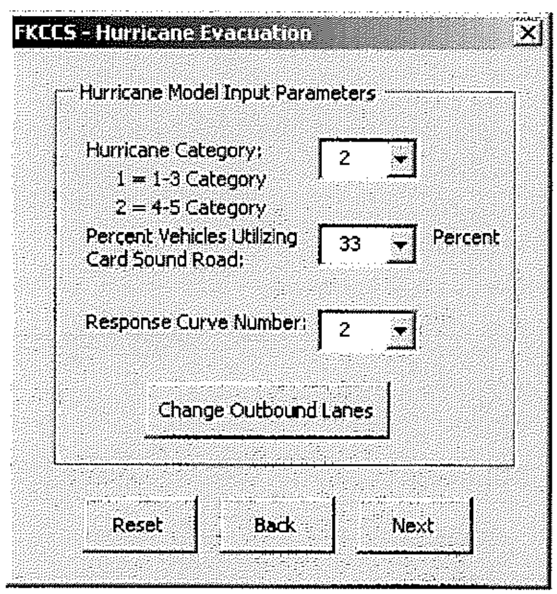
Therefore, the number of additional housing units generated in a user-defined scenario is compared with the residential capacity to determine if it surpasses the trip capacity of U.S. 1.

3.8.3 Hurricane Evacuation

The CCIAM adopted the recently completed *Florida Keys Hurricane Evacuation Study* (FKHES) produced for the Florida Department of Transportation (FDOT) (Miller Consulting Inc. 2001), which estimates the time required to evacuate the Florida Keys up to Florida City in the event of a hurricane. The objectives of the FKHES were to create a documented public domain computer model to improve the traffic analysis subsystem and to automate the traffic assignment system. A special advisory team was assembled to discuss and agree upon all input variables required to run the model.

The FKHES is a Microsoft Excel model that is executed in the CCIAM using VBA. The number of dwelling units produced in each CCIAM scenario is input into the FKHES. The FKHES was not altered in any manner, other than to increase or decrease the number of dwelling units and other input parameters resulting from a land use scenario. Tabular outputs from the FKHES are available in conjunction with the outputs resulting directly from the CCIAM. The CCIAM output removes 52 minutes from the FKHES, in order to report clearance time to Florida City, instead of Florida International University.

FIGURE 3.11
EXAMPLE CCIAM GUI SCREEN FOR HURRICANE EVACUATION



3.9 INTEGRATED WATER MODULE

The Integrated Water Module addresses the volume, fate, and pollutant loads from stormwater and wastewater. The stormwater component utilizes land use from the contributing drainage areas and associated pollutant loading rates to estimate pollutant loads generated within each watershed. It also calculates pollutant load reductions attributable to stormwater BMPs, and calculates the net pollutant loads discharged to the receiving surface water and groundwater systems.

The wastewater component utilizes permanent and functional populations, local wastewater generation rates, local wastewater characteristics, and point source discharge data from the contributing wastesheds to estimate pollutant loads generated within each wasteshed. It also calculates the levels of load reduction attributable to treatment systems, and calculates the net pollutant loads of the effluent discharged to the receiving groundwater systems.

The groundwater component simulates groundwater system interactions, including groundwater flows and pollutant transport in the subsurface environment underlying each of the modeled islands in the Florida Keys and estimates groundwater discharges to the nearshore waters.

3.9.1 Stormwater Component

The Stormwater Component calculates gross pollutant loads and BMP-based reductions, and then routes the resulting net pollutant load discharges to either the groundwater system or the nearshore waters. The component includes the following elements:

Delineation of Watersheds. Watersheds, smaller drainage areas within each planning unit, were delineated primarily using the network of local roadways and canals as boundaries.

Computation of EMC Values. The EPA has designated a number of Florida communities as Municipal Separate Storm Sewer Systems (MS4s), and subsequently required them to collect stormwater discharge characterization data. Because of the absence of stormwater discharge monitoring data in the Florida Keys, EMC data from representative Florida communities were used to calculate the pollutant and nutrient loads in the study area. Constituents incorporated into the Stormwater Component include total nitrogen (TN), TP, 5-day biochemical oxygen demand (BOD), and total suspended solids (TSS).

Runoff Volumes. The Stormwater Component develops an area-weighted runoff coefficient for each delineated watershed using the aggregated land use data for the watershed, a look-up table that maps specific land uses into generalized classes of land use, and a data table of runoff characteristics for generalized land use classes. Runoff volumes are computed for each watershed using the area-weighted runoff coefficient from the aggregate land use data and rainfall volume.

Runoff Pollutant Loads. Pollutant loads are calculated with a simple washoff model, commonly used in most Florida MS4s, that utilizes the EMC database for generalized land uses in the study area. Pollutant loads are calculated for each watershed using the watershed's runoff volume and area-weighted EMC values for the selected pollutants.

Stormwater BMPs. Few structural BMPs exist in the Florida Keys and virtually no performance data has been collected on existing BMPs. The array of current stormwater BMPs was evaluated based upon their potential suitability in the study area. A look-up table of treatment performance by specific BMP was developed based upon literature values and values from the Stormwater Management Master Plan adopted by Monroe County.

Pollutant Load Reductions due to BMPs. Stormwater BMPs, selected by the user, form the basis for calculating the reduction of discharged pollutant loads. Pollutant load reductions are calculated for each catchment on the basis of the user-specified extent of BMP coverage (drainage areas served) and the default removal rate from a data table of potential BMPs.

Allocation of Discharged Pollutant Loads. The final step involves allocating the net discharged pollutant volumes and loads by receiving waters. Significant portions of stormwater runoff percolate into the surficial region of the localized groundwater systems due to the highly porous soils in the Keys. Allocation of the discharged stormwater volumes and pollutants is based upon the governing transport mechanism. Initial loss to the Groundwater Component due to percolation/infiltration is based upon the nature of the soils and the treatment mechanisms of the implemented BMPs. The remainder of the discharge, occurring due to direct runoff, is allocated to the nearshore waters.

The outputs of the stormwater component are:

- Estimated stormwater runoff volume generated by each catchment.
- Estimated pollutant load in the stormwater runoff from each catchment.
- Estimated pollutant load removed from stormwater runoff in each catchment attributable to the implemented BMPs.
- Estimated net runoff volume discharged into the Groundwater Component via percolation/infiltration from each catchment.
- Estimated pollutant load discharged into the Groundwater Component via percolation/infiltration from each catchment attributable to the implemented BMPs.
- Estimated net runoff volume discharged into the nearshore via surface runoff from each catchment.
- Estimated pollutant load discharged into the nearshore waters via surface runoff from each catchment attributable to the implemented BMPs.

3.9.2 Wastewater Component

The Wastewater Component utilizes the water use estimates from the Potable Water Component (Human Infrastructure Module), parcel ownerships, GIS mapping and datasets, raw wastewater characteristics, treated wastewater effluent characteristics per treatment method, and discharge/disposal method data from the contributing wastesheds. These data are used to estimate pollutant loads discharged to groundwater systems and then discharged to the nearshore water.

The Wastewater Component operates in an extensive parcel-based geo-spatial data set that locates and characterizes the existing onsite systems and wastewater treatment facilities within the study area. It utilizes the same watersheds as in the Stormwater Component. Calculation elements address 1) wastewater volumes to be treated by specific treatment methods, 2) pollutant loads associated with each treatment method, and 3) aggregation of the effluent volume and pollutant loads for each wasteshed by disposal method.

Estimation of Wastewater Volumes by Treatment Method. For each scenario, the Wastewater Component calculates the 1) daily wastewater volumes at the parcel level given each parcel's number of EDUs, 2) existing wastewater generation rates, 3) and the specified treatment method associated with each parcel. Computations of wastewater volumes are initially executed at the parcel level and then aggregated at the wasteshed level by specific treatment types. This analysis uses the revised database from the Monroe County Sanitary Wastewater Master Plan. These wasteshed characteristics are further aggregated to the level of the 28 Wastewater Planning Areas and then summed to produce the estimated total wastewater generated, by specific treatment type, for the entire study area for the given scenario.

Estimation of Pollutant Loads Associated with Each Treatment Method. Pollutant loads are estimated at the wasteshed level for the aggregated flows being treated by either onsite wastewater technology or wastewater treatment plants. Computations of wastewater pollutant loads are executed at the wasteshed level for each treatment technology, then aggregated to the level of the 28 planning areas, and then summed to produce the estimated total wastewater pollutant load for the entire study area for each scenario. The CCIAM applies effluent characteristics established by the Florida Department of Environmental Protection (FDEP) during the Monroe County nutrient credit evaluation undertaken by the DCA, Department of Health, and FDEP in April 1999 (Table 3.7). These characteristics are the default in the CCIAM pursuant to FDEP and EPA recommendations.

TABLE 3.7
EFFLUENT CHARACTERISTICS BY TREATMENT METHOD, PER FDEP AND EPA

Treatment Method	BOD (mg/l)	TSS (mg/l)	Total N (mg/l)	Total P (mg/l)
None (Raw Sewage) and Cesspits	200	200	35	6
Substandard (Unpermitted) On-Site Treatment and Disposal Systems	140	85	32	6
Approved On-Site Treatment and Disposal Systems	10	10	25	5
Secondary Treatment	20	20	25	5
Best Available Technology, Including On-Site Treatment and Disposal Systems with Nutrient Removal	10	10	10	1
Advance Waste Treatment	5	5	3	1

Aggregation of Effluent Volumes and Pollutant Loads by Disposal Method. Effluent pollutant loads from each onsite wastewater treatment system and wastewater treatment plant are aggregated by respective disposal methods. Computations of effluent pollutant loads are executed at the wasteshed level by specific treatment technologies and then accumulated at the planning unit level by disposal method.

The wastewater module produces the following outputs:

- Total daily pollutant load of specific modeled pollutants, discharged to the groundwater system in a given wasteshed.
- Total daily wastewater effluent volume discharged to the groundwater system in a given wasteshed.
- Total daily pollutant load of specific modeled pollutants, discharged to the deep well disposal systems, in a given wasteshed.
- Total daily wastewater effluent volume of wastewater discharged to deep well disposal systems, in a given wasteshed.

3.9.3 Groundwater Component

The Groundwater Component calculates the discharged groundwater volumes and pollutant loads generated by infiltrated stormwaters and wastewater treatment system effluents. The calculation assumes additional treatment is provided by flow through the limestone underlying the Florida Keys. The four elements of this component calculate the gross loads to the groundwater system: the in-aquifer treatment, the transport through the aquifer, and the eventual discharge load and location at the shoreline.

Gross Pollutant Loads. The watersheds and wastesheds previously discussed in the Wastewater and Stormwater Components are also used for volume and load accounting in this component. The shallow groundwater pollutant mass loadings are allocated to specific wastesheds depending on the point of origin for TN, TP, BOD, and TSS. Pollutant loads and volumes entering each wasteshed in the Groundwater Component are passed as aggregated values for effluents from on-site disposal systems and wastewater treatment plants from the Wastewater Component. Similarly, stormwater volumes and loads from percolated stormwater runoff are also passed as aggregated values from the Stormwater Component.

Pollutant Treatment. Existing literature and data indicate that pollutant load reductions due to in-aquifer treatment mechanisms are not time-dependent. Rather, pollutant mass introduced to the groundwater will be reduced by a constant percentage at a fixed distance from the source and then remain relatively unchanged thereafter. Pollutant reductions in the groundwater system for the simulation period, based upon the conceptual construct of the groundwater aquifer, are calculated as one-time, fixed percentage reductions that are pulled from a look-up table containing groundwater system reduction values based upon reported literature values for the Keys.

Volumetric and Pollutant Transport. Hydraulic transport rates are not calculated in the Groundwater Component since pollutant treatment is not dependent upon time. Hydraulic transport rates reported in the literature and field observations indicate that effluents from on-site disposal systems and percolated stormwater runoff are very quickly transported to the surface waters. Therefore, given the conceptual construct of the groundwater aquifer system, pollutant transport to the nearshore waters is treated as an instantaneous, steady state process without any time-phased delays or storage of flows.

Discharge Location. The volumes and net pollutant loads calculated for each wasteshed are transported to the shoreline based upon the idealized hydraulic transport of groundwater along the path of least resistance. The shallow groundwater loads simulated in the Groundwater Component for each wasteshed are totaled and assumed to enter the marine environment.

The outputs of this component are:

- Total daily groundwater volume discharged from a given catchment to nearshore waters.
- Total daily pollutant load of specific modeled pollutants discharged from a given catchment to nearshore waters.

3.10 CANAL IMPACT ASSESSMENT MODULE

The Canal Impact Assessment Module (CIAM) applies a tidal flush modeling approach to examine the effects of pollutant loads on water quality in dead-end canals (see Appendix C for full description of the module). There are approximately 480 canals in the Florida Keys. The Technical Contractor developed and applied the module to 10 representative canals. EPA (Dr. Bill Kruczynski), FDEP (Mr. Gus Rios), Monroe County (Mr. George Garrett), and the Government Study Team assisted in selecting the canals.

For each of the 10 canals, the Technical Contractor defined the contributing watershed and divided the canals into segments. For each canal segment, the flushing model incorporates the incoming loads and tidal cycles in order to estimate a resulting pollutant concentration. The module is intended to address the differential effects of land use and stormwater and wastewater treatment scenarios on the resulting water quality along canals.

The CIAM operates as an Excel spreadsheet model, linked to the CCIAM through VBA code. Stormwater and wastewater loads from the Integrated Water Module are input into the CIAM spreadsheet. Outputs are transferred to the CCIAM for display.

3.11 TERRESTRIAL MODULE

The CCIAM measures direct and indirect impacts from land development scenarios on terrestrial habitats and species (Table 3.8). Direct loss of habitat due to development is the most recognizable and easiest impact to measure. The module evaluates direct land use impacts on terrestrial ecosystems and species by calculating a species richness index, statistics on overall habitat characteristics, and impacts on 11 individual species. Indirect or secondary impacts of development are also calculated for overall habitat characteristics. All analyses in this module are spatially explicit and are performed using GIS processes. The basic inputs for the Terrestrial Module include the user-defined land use scenario, the ADID vegetation map, a species richness map, and species habitat requirements.

TABLE 3.8
TERRESTRIAL MODULE COMPONENTS AND ELEMENTS

Component	Elements
Direct Impacts	
Species Richness	Composite species richness index Areas supporting 17 individual species
Overall Habitat Statistics All Upland Habitats Greater Than 13 Acres	Number of Patches Patch Size (total area, minimum, maximum, mean) Frequency distribution of patch sizes (0-5, 5-10, 10-20, >20 acres) Number of Patches Patch size (total area, mean)
Species-specific habitat statistics	Lower keys marsh rabbit Key deer Silver rice rat Key Largo woodrat Schaus swallowtail butterfly White-crowned pigeon Black-whiskered vireo White-eyed vireo Northern flicker Yellow-billed cuckoo Mangrove cuckoo
Indirect Impacts	
Overall Habitat Statistics All Upland Habitats Greater Than 13 Acres	Number of Patches Patch Size (total area, minimum, maximum, mean) Frequency distribution of patch sizes (0-5, 5-10, 10-20, >20 acres) Number of Patches Patch size (total area, mean)

3.11.1 Direct Impacts

Direct Impacts to Species Richness

This module component estimates the direct impacts of development to habitat availability for seventeen species. This approach provides a surrogate measure of land use effects on species richness by focusing on a subset of the terrestrial species of the Florida Keys for which sufficient data exists. The CCIAM overlays developed areas from the user-defined scenario land use map with the species richness map to calculate impacts for each planning unit. Development effects on the 17 species are expressed 1) as a species richness index and 2) for each individual species. The richness index represents an average of the number of species per cell; developed cells have a value of 0:

$$\text{Species Richness Index for Direct Impacts} = \sum(\text{\# of species per cell})/\text{total \# of cells}$$

Direct habitat impacts for each of the 17 species are reported as acres remaining per planning unit.

Direct Impacts to Habitat

Land use change affects the number and size of habitat patches as well as the overall amount of available habitat in terrestrial environments. Patch statistics provide a means to assess the direct habitat displacement or restoration due to land use change. Outputs, calculated as summary statistics for each habitat type, include the number of patches, patch size (total area, minimum, maximum, mean), and frequency distribution of patch sizes. Together, these statistics provide a measure of habitat loss and fragmentation. The number of patches less than 5 acres, 5 to 10 acres, 10 to 20 acres, and greater than 20 acres are calculated for each habitat type. For example, an increase in the number of small patches of hammock with a loss of total hammock acreage indicates that habitat has been reduced and fragmented; therefore, the hammocks may not be able to maintain ecosystem integrity or support the life history requirements of some species. Statistics calculated and reported for each of the 15 ADID habitat categories, as well as for upland habitat types that exceed 13 acres in size include: number of patches, patch size (total area, minimum, maximum, mean), and frequency distribution of patch sizes.

Direct Impacts to Species-Specific Habitat

In addition to the species richness analysis, GIS overlay techniques are used to analyze the direct impacts of development on habitat for 11 terrestrial species for which more detailed habitat models are available: Key deer, Lower Keys marsh rabbit, silver rice rat, Key Largo woodrat, Schaus swallowtail butterfly, white-crowned pigeon, black-whiskered vireo, white-eyed vireo, northern flicker, yellow-billed cuckoo, and mangrove cuckoo. For each user-defined scenario, the CCIAM evaluates the effects of direct habitat conversion on each of the species.

The CCIAM incorporates habitat maps developed from extensive research performed in other studies for the Key deer, Lower Keys marsh rabbit, and the silver rice rat. The Population Viability Analysis (PVA) for the Florida Key deer produced a habitat suitability map, which is used in the CCIAM to evaluate impacts to this species. The map shows three types of areas, or "tiers" (Figure 3.12). Development in Tiers 2 and 3 is of lower consequence to the Key deer. Development in Tier 1 results in significant impacts. Thus, a scenario is reported to exceed thresholds if any new development occurs within Tier 1. Throughout the range of the species, outside of Big Pine and No Name Keys, any habitat loss outside subdivisions is also considered to surpass a carrying capacity indicator.

The Lower Keys marsh rabbit is highly endangered, with a high probability of extinction in considerably less than 100 years (Forys and Humphrey 1999). The CCIAM assesses encroachment on marsh rabbit habitat as determined in the USFWS GIS habitat layer. The model is constructed such that no further loss of the marsh rabbit is allowed under any scenario. A scenario is reported to exceed thresholds if new development occurs on or within 500 meters of marsh rabbit habitat.

FIGURE 3.12
HABITAT SUITABILITY FOR KEY DEER

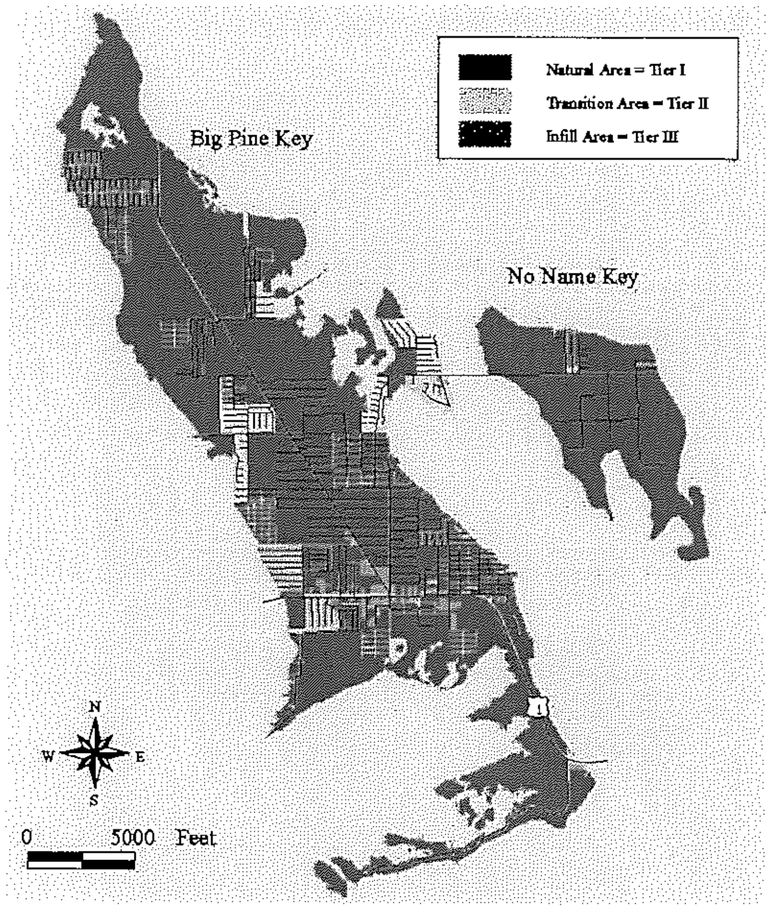


TABLE 3.9
WHITE-CROWNED PIGEON HABITAT REQUIREMENTS[1]

Parameter	Threshold
Nesting areas – habitat	Mangroves
Immature – dispersal habitat	Hammock patch of at least 12 ac
Immature – dispersal distance	6.8 miles
Mature – habitat	Hammock patches of at least 2 ac

[1] Strong and Bancroft, 1994.

The other nine species are incorporated in the CCIAM by assessing either encroachment into existing habitat (silver rice rat, Key Largo woodrat, Schaus swallowtail butterfly), specific habitat requirements (white-crowned pigeon, Table 3.10), or minimum patch size requirements (forest-nesting birds, Table 3.10).

TABLE 3.10
HAMMOCK PATCH SIZE REQUIREMENTS FOR FOREST INTERIOR BIRDS[1]

Parameter	Threshold
Black-whiskered vireo	0.2 ac
White-eyed vireo	2.3 ac
Northern flicker	3.5 ac
Yellow-billed cuckoo	7.5 ac
Mangrove cuckoo	12.8 ac

[1] Bancroft et al., 1995.

3.11.2 Indirect Impacts

A variety of indirect and secondary impacts from adjacent developed land uses affect habitat quality. These effects include noise, domestic predators, light pollution, runoff, and invasion of exotic plants, among others. There is ample evidence that indirect and secondary impacts do occur, and that they decrease with increasing distance from development. The available data, however, is less precise regarding 1) the specific biological consequences of these impacts, 2) the differential response of species, 3) the rate at which effects decrease with distance, or 4) differential land use effects (Table 3.11).

Most studies show indirect impacts to habitat between 200 to 500 feet away from development, depending on development type and intensity. The CCIAM assumes that indirect impacts occur up to 500 feet around developed areas without attempting to quantify the magnitude of the impact. Habitat parameters calculated for indirect impacts are the same as those calculated for direct impacts. For all ADID vegetation types and upland habitat greater than 13 acres, summary statistics calculated include: number of patches, patch size (total area, minimum, maximum, mean), and frequency distribution of patch sizes. The statistics are reported for those areas not affected by the 500-foot buffer, and therefore, represent habitat in which neither direct nor indirect impacts occur.

TABLE 3.11
EFFECTS OF DEVELOPMENT ON ADJACENT HABITATS

Effect Distance	Effect	Reference
Microclimate and Edge Effects		
98	Climatic structural edge influences into a forest (west side).	Ranney et al., 1981
300	Negative impacts on wildlife species from edge effects.	Brown and Schaefer, 1987
450	Changes in air temperature and relative humidity.	Ledwith, 1996
16,404	Edge effects within a reserve boundary.	Janzen, 1986
Surface Water Quality		
35	Less than this is not enough to sustain long-term protection of aquatic resources.	Tjaden and Weber, 1997
35-100	Most common minimum buffer widths for use in water quality and habitat maintenance.	
45	Buffers equal to or greater than this have proven effective in reducing some pesticide contamination of streamflow.	Palone and Todd, 1997
49-66	Minimum buffer for low slopes.	Karr and Schlosser, 1977
75-200	Suggested buffer width for flood control.	Tjaden and Weber, 1997
75	Wetland buffer to minimize sedimentation from coarse sand.	Brown et al., 1990
200	Wetland buffer to minimize sedimentation from fine sand.	
200	Buffer for development adjacent to Aquatic Preserves.	JEA et al., 2000
300	The zone most influential to surface water quality.	Brown et al., 1990 Florida Division of Forestry, 1979
450	Wetland buffer to minimize sedimentation from silt.	Brown et al., 1990
Air Quality and Urban Glow		
492	Minimum recommended distance from beach for lights mounted higher than 16 ft.	Witherington and Martin, 2000
Noise and Vibration		
246	Distance from roadway centerline range for which the acceptable noise range for single-family residential uses is 60 to 65 dB(A), 60 to 70 dB(A) for schools, and less than 70 dB(A) for parks.	City of Monterey Park, 2001
1,640	Area within which breeding bird densities of 3 grassland bird species were significantly reduced adjacent to quiet rural roads.	Van der Zande et al., 1980
Habitat		
15	Minimum width to prevent secondary impacts to habitat functions of wetlands.	St. John's River Water Management District, 1999
25	Average width to prevent secondary impacts to habitat functions of wetlands.	
30	Insufficient to protect wetlands.	Miller and Gunsalus, 1997
100	Minimum width necessary to avoid significantly impacting riparian environments.	Ledwith, 1996
300	Sufficient to protect wetland functions from upland development, i.e. 50 percent of wetland-dependent wildlife and water quality from erosion of sands.	Castelle et al., 1994 Miller and Gunsalus, 1997 JEA et al., 2000
	Generally accepted minimum width for wildlife.	Connecticut River Joint Commissions, 2000

TABLE 3.11
(CONTINUED)
EFFECTS OF DEVELOPMENT ON ADJACENT HABITATS

Effect Distance	Effect	Reference
Habitat (Continued)		
322	Buffer to protect saltwater and freshwater marshes in East Central Florida.	Brown et al., 1990
322-732	To protect wetland resources.	
550	Buffer to protect hammock and forested wetlands in East Central Florida.	
Wildlife		
50	Buffer landward from wetlands jurisdictional line to allow semi-aquatic species area to nest/over winter.	Brown and Schaeffer, 1987
164	To support several interior bird species.	Tassone, 1981
164-197	To support hairy and pileated woodpeckers.	
207-584	Recommended setback for 15 species of breeding colonial birds.	Rodgers and Smith, 1995
220-413	Recommended buffer for 16 species of water birds.	Rodgers and Smith, 1997
240	Minimum distance from humans tolerated by snowy egrets.	Klein, 1989
322	Wildlife in salt marsh habitats.	Brown and Orell, 1995
322-550	Wetland-dependent wildlife species in freshwater riverine systems.	
328	Buffer for neotropical migrant birds.	Triquet et al., 1990
328	Width of buffer strips to protect intrinsic wildlife value.	Tassone, 1981
492-574	Buffer for protection of 90-95 percent of bird species.	Spackman and Hughes, 1995
536	Buffer zone for wetland wildlife.	Brown and Schaeffer, 1987
750	Distance of no human activity around bald eagle's nest.	USFWS, 1999
750-1500	Distance of no buildings proximate to bald eagle's nest.	
984-1968	Nest predation into a forest.	Wilcove et al., 1986
Feral Animals		
112 ha	Home range for female cats.	Warner, 1985
228 ha	Home range for male cats.	
4 acres	Home range for dogs.	Beck, 1973
Other		
75	Set-back of septic systems (regulations in VT and NH).	Connecticut River Joint Commissions, 2000

3.12 CARRYING CAPACITY INDICATORS

In the CCIAM, carrying capacity indicators include thresholds, criteria, levels, or standards, which, if exceeded, would result in a significant level of impact or damage to a resource or element. In some cases this level of impact may be sufficient to impair the sustainability of the resource. In the CCIAM, three types of indicators or thresholds have been used to address the carrying capacity limit of a resource (Table 3.12):

TABLE 3.12
CARRYING CAPACITY INDICATORS FOR THE FKCCS

Indicator	Value or definition	Type*	Comments
Population demand for nonresidential uses	Demand is higher than the available nonresidential uses	III	Population demand for retail, services and other nonresidential uses, increases development demand. The user may input further development in the scenario and run model again.
Business demand for employees	Demand is higher than the available local labor force	III	If the business demand for employees surpasses the available local labor force, pressure builds to increase commuting employees.
Per capita government expenditures	Increase in the per capita expenditures as a result of the scenario	III	An increase in per capita government expenditures means that the government will have to seek increased revenues to match increased expenditures. Therefore, it indicates pressure to increase taxes.
LOS of U.S. 1	Median speed. U.S. I wide, the threshold speed of 45 mph. Required speed may be different for different segments.	I	Current regulations require the Monroe County maintain an adequate LOS. A failure to maintain the required LOS results in a building moratorium.
Hurricane evacuation clearance time	24 hours – the time required to evacuate the Keys in case of an impending hurricane.	I	Current regulations required that the Keys population evacuate in 24 hours.
Permitted volume of water supply	Daily average: 15.83 MGD Maximum day: 19.19 MGD	I	Per SFWMD permit which expires December 2005.
Minimum patch size for upland Keys forests	13 acres	II	Keys hammocks smaller than 5.9 ha. are considered "all edge," with forest interiors lacking the buffering effects of edge vegetation (Strong and Bancroft 1994).
Lower Keys marsh rabbit habitat	Species is in danger of extinction	II	Species is currently in danger of extinction, mainly due to habitat loss (Forys and Humphrey 1994). Only habitat restoration would be beneficial for the Lower Keys marsh rabbit.
Key deer habitat	Habitat quality classification – Tier 2 and 3.	II	Recent studies (Lopez 2001) have determined habitat needs for Key deer.
Patch size requirement for forest-nesting birds in the Florida Keys	Minimum patch size: Black-whiskered vireo: 0.5 acres; White-eyed vireo: 5 acres; Northern flickers: 7.5 acres; Yellow-billed cuckoo: 16 acres; Mangrove cuckoo: 12.8.	II	Documented in Bancroft et al. (1995), who studied 27 Upper Keys forests ranging in size from 0.5 to 217 acres.
White-crowned pigeon habitat	Fledglings hatch in mangroves but require large (12 acres) hammock patches within 72 hours.	II	Documented in Strong and Bancroft (1994), who studied post-fledging dispersal of white-crowned pigeons in the Florida Keys.

*I = Regulatory, II = Scientific, III = Social (see Section 2.2.1 for further description).

I. Government mandated thresholds are based on quantitative standards mandated by local, state, or federal agencies (e.g., permitted volume of water supply).

II. Environmental thresholds are based on a tolerance range or limit for a resource or species, beyond which it is not sustainable (e.g., Lower Keys marsh rabbit habitat). These thresholds are established in the scientific literature or through consultation with technical experts.

III. Socioeconomic thresholds are based upon a tolerance range for a given socioeconomic measure, which, if exceeded, would degrade quality of life in the Florida Keys (e.g., population demand for nonresidential uses).

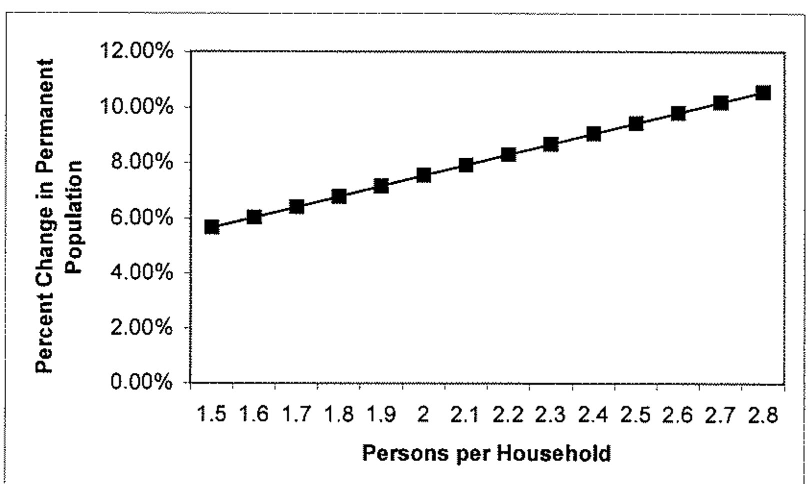
Lack of relevant available data on some topic areas, discussed extensively in previous FKCCS reports, limited the success of attempts to establish carrying capacity thresholds for all environmental parameters. However, carrying capacity indicators exist for several parameters (Table 3.12). Some of these indicators are regulatory and, while currently binding, may be subject to change. Others are documented in the peer-reviewed scientific literature. Together, the carrying capacity indicators provide a framework to explore carrying capacity issues in the Florida Keys.

3.13 SENSITIVITY ANALYSIS

During the development of the CCIAM, the Technical Contractor carried out sensitivity analysis on the model to determine how it reacted to changes in input variables and look-up parameters and coefficients. Sensitivity analyses focused on modules based on numerical calculations, such as Socioeconomics, Fiscal, and Hurricane Evacuation.

All numerical model relationships are linear, resulting from direct multiplication of factors. For example, permanent population is calculated as a multiple of dwelling units. The number of persons per household has varied by less than 0.2 between the 1990 and 2000 Censuses. Changes in the persons per household ratio would affect the magnitude in the percent population change in future scenarios. For example, assume an initial population of 79,589 (per Census 2000) and the construction of 3,000 permanent housing units. The percent permanent population growth would change by 3.8 percent per each additional person per household (Figure 3.13).

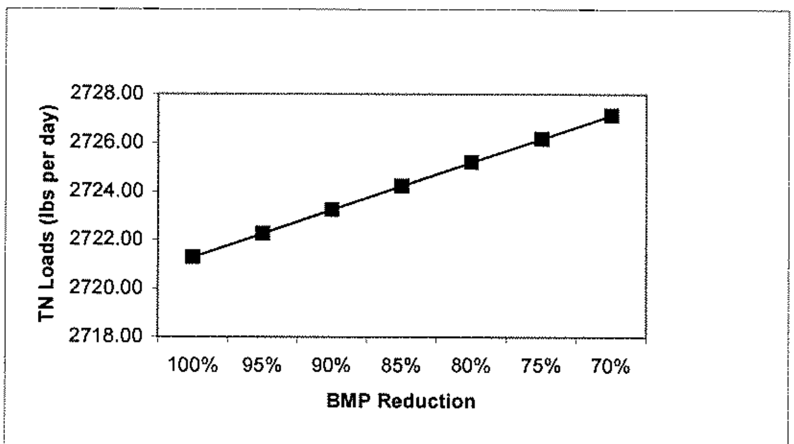
FIGURE 3.13. EFFECT OF PERSONS PER HOUSEHOLD ON PERMANENT POPULATION CHANGE



In the Human Infrastructure Module, median speed on U.S. 1 is estimated using a regression equation, $y = -0.016x + 49.97$, where x is the sum of acres of residential and tourist land uses divided by the length of U.S. 1 in the planning unit, and y is the resulting median speed. In this case, the number of acres of residential and tourist land uses combined, per mile of U.S. 1 in a given planning unit, would have to change by 62.5 acres in order for the median speed to change by 1 mph. None of the scenarios evaluated results in large increases in the acreage of residential or tourist land uses.

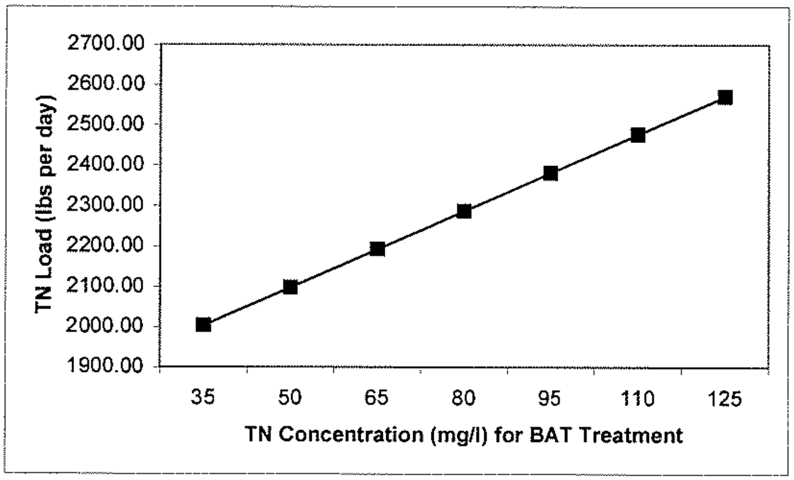
The Stormwater and Wastewater Components of the Integrated Water Module include a series of multiplications (e.g., number of dwelling units times wastewater volume times pollutant concentration times treatment reduction) and additions (e.g., summed over wastesheds, planning units, and entire Keys). Stormwater loads, when summed over the entire study area vary little in response to changes in BMP efficiency. For example, TN loads from stormwater vary only by 1.95 lbs/day with a 10% percent change in BMP efficiency.

FIGURE 3.14. EFFECT OF BMP EFFICIENCY ON TOTAL TN LOADS



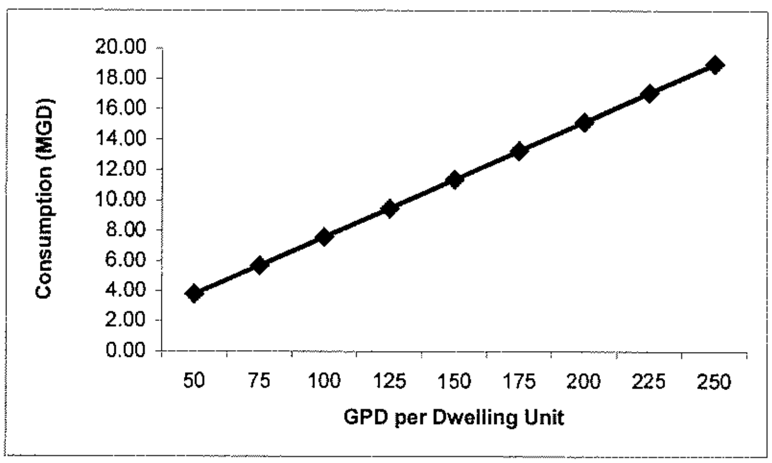
The Wastewater Component is sensitive to changes in effluent characteristics. For example, a change of 15 mg/l of TN for Best Available Technology (BAT) results in almost 100 lbs/day of TN load (Figure 3.15).

FIGURE 3.15. EFFECT OF EFFLUENT CHARACTERISTICS ON WASTEWATER LOADS.



Finally, the Potable Water Component indicates that daily water consumption per dwelling unit has a strong effect on total daily consumption over the entire study area. For example, a reduction of 1 gpd/du (du = dwelling unit) could save approximately 0.8 MGD over the entire Florida Keys (Figure 3.16).

FIGURE 3.16. EFFECT OF WATER CONSUMPTION PER DWELLING UNIT ON TOTAL WATER CONSUMPTION IN THE FLORIDA KEYS.

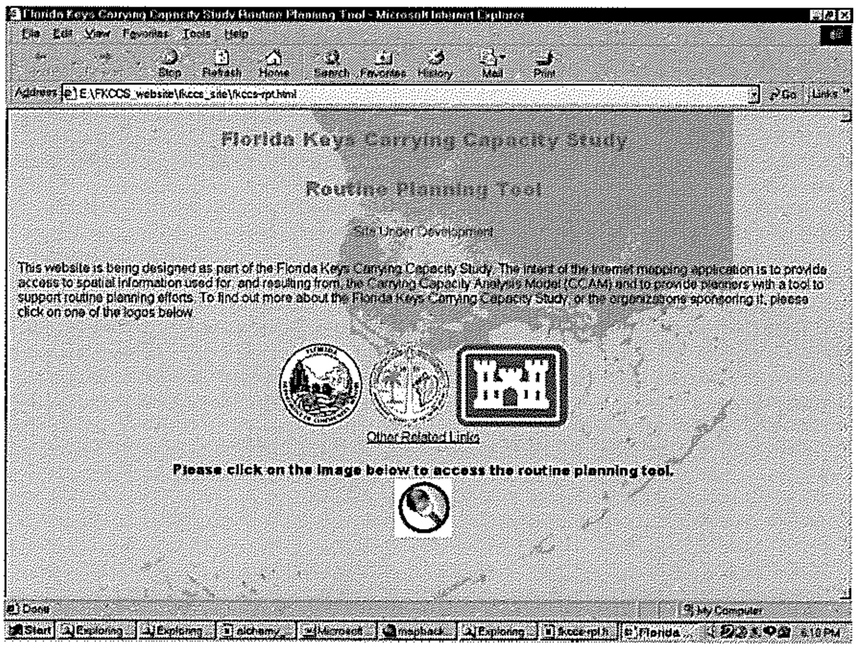


Sensitivity analyses suggest that, overall the CCIAM's sensitivity to changes in model parameters is small and consistent across modules and components. Furthermore, the effect of parameters on model outputs can be easily evaluated and understood, which helps model users understand the limitations and strengths of the model.

3.14 ROUTINE PLANNING SUPPORT TOOL

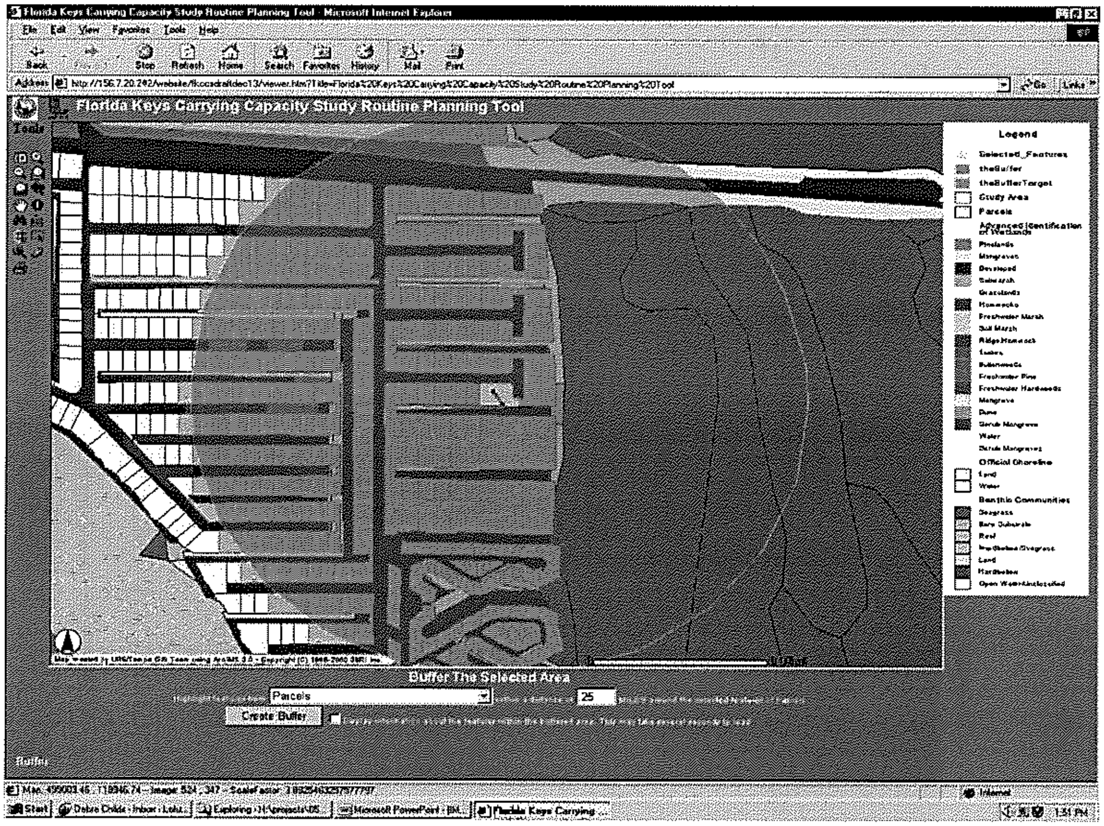
A by-product of the FKCCS, the RPST is an Internet application, which will allow users to view and query FKCCS data and results, including maps (Figure 3.13).

FIGURE 3.13
RPST HOME PAGE



The RPST will assist local planners in their daily activities. Planners will be able to access the web site using their web browser and access data, such as parcel information, habitat characteristics or presence or absence of species habitat, among others. A key application of this Internet tool will be assisting in making permitting decisions. For example, when reviewing a permit application for development, planners will be able to zoom-in to the subject parcel (Figure 3.14) and perform queries regarding characteristics of the parcels, such as habitat present on the parcel or anticipated wetland impacts. The RPST is a significant value-added benefit of the FKCCS.

FIGURE 3.14
EXAMPLE PARCEL-SPECIFIC QUERIES USING THE RPST



4.0 SCENARIO EVALUATION AND RESULTS

4.1 SCENARIOS

The evaluation of scenarios for the Florida Keys Carrying Capacity Study (FKCCS) involved both the interpretation of existing information and the analysis of future scenario conditions using the Carrying Capacity/Impact Assessment Model (CCIAM). The Government Study Team formulated six scenarios, which represent potential futures for the Florida Keys. In addition, the study addressed current conditions primarily through the interpretation of existing information, as well as by executing model analyses.

The first scenario, termed "Smart Growth," provided by the local planners, was translated for input into the CCIAM. The scenario represents a moderate development scheme, in which future growth and development are intended to redevelop blighted commercial and residential areas, reduce sprawl, and direct future growth to appropriate infill areas. The Smart Growth Scenario, as provided by the Local Planners Working Group, is transcribed below:

> *"A Smart Growth initiative will be implemented in Monroe County to preserve the natural environment, redevelop blighted commercial and residential areas, remove barriers to innovative design concepts, reduce sprawl and direct future growth to appropriate infill areas.*
>
> *All Conservation and Recreational Lands (CARLs) and any adjacent habitat areas will be closed to future development and purchased in an accelerated acquisition program. In sparsely developed areas, any land within 1,000 feet of the CARL/Habitat areas will also be designated for purchase.*
>
> *Infill will only be permitted on suitable parcel subdivisions, which are at least 50 percent developed. A maximum of 3,000 scarified lots in these subdivisions will be permitted in a lottery system over the next 20 years. Scattered lands within subdivisions that contain habitat or "redflag" wetlands will be purchased and a conservation easement placed on the lots to prevent future development. Ocean Reef and other subdivisions, which are vested will continue to build out on lots with habitat, but red flag wetland lots will not be filled and developed.*
>
> *In the Urban Residential District and the Suburban Commercial District in Key Largo/Tavernier, and from Stock Island to Big Coppit an additional 500 multi-family, affordable housing units will be developed on scarified lands at a density of 15 to 20 units per acre. Redevelopment of trailer parks and other substandard housing throughout the Keys will be at the existing density, above base flood, and with sanitary sewer.*
>
> *Twenty-five percent of the existing commercial stock will be redeveloped, resulting in improved stormwater management and landscaping. Infill sites for commercial development will be within 200 feet of existing commercially developed areas. A total of 700,000 square feet of commercial will be permitted over the next 20 years either in expansion of existing uses or in infill sites.*

Institutional uses will be deducted from the 700,000 square feet, although they will not have to compete for square footage.

Fifty percent of the existing Industrial and Marine Industrial sites will be cleaned up and redeveloped with stormwater management and landscaping. Future uses will be of a lighter industrial nature. All County owned buildings would be landscaped and retrofitted for stormwater management.

Two additional parks of 5-10 acres each will be developed in the Lower Keys: one on Big Pine Key and one on Sugarloaf Key.

With full implementation of the Overseas Heritage Trail and the Scenic Highway program, the entire U.S. 1 alignment will be landscaped. The stormwater management plan will be implemented on State and County roadways and for all new development. The sewer master plan will be fully implemented with the removal of all cesspits. An active program of water conservation will be instituted for existing development; the building code will assure new development conserves water."

To exemplify the interpretation of scenarios in terms of model parameters, the choices made on the CCIAM Graphic User Interface (GUI) for the Smart Growth Scenario are summarized below (Table 4.1).

TABLE 4.1
CCIAM GUI CHOICES FOR SMART GROWTH SCENARIO

Vacant Land
Keys-Wide Except Ocean Reef
• Change vacant land parcels proposed for conservation by CARL and adjacent (300 ft distance) habitat to "Open Space." • Change sparsely developed (<25 percent) subdivision Vacant Land lots containing habitat polygons within 1,000 feet of CARL to Open Space. • Change 3,000 scarified Vacant Land parcels, in moderately or densely developed (≥ 75 percent) subdivisions, with no wetland or habitat polygons to Residential at the existing density level of the subdivision. Apply default stormwater and wastewater treatment parameters. • Change Vacant Land and/or Commercial land within 200 feet of existing Commercial land to Commercial, with existing zoning to produce 700,000 square feet of commercial GFA.
Ocean Reef (Ocean Reef/PAED 21 (North Key Largo) Planning Area):
• Change all vacant land parcels with "red flag" wetlands to open space. • Change all other vacant land parcels to developed at the existing zoning and density for the area. Apply default stormwater treatment; apply existing wastewater treatment.
• Key Largo/Tavernier and Stock Island to Big Coppitt (PAED 15 (Tavernier), PAED 16 (Rodriguez Key), PAED 17 (Rock Harbor), PAED 18 (John Pennecamp State Park), PAED 19 and 20 (Garden Cove), PAED 21 (North Key Largo), Stock Island, and Boca Chica Planning Areas):
• Change scarified vacant land parcels zoned Urban Residential (UR) and Suburban Commercial (SC) to provide 500 multifamily units at a density of 15 units per acre (HDR classification). Apply default stormwater and wastewater treatment.

TABLE 4.1 (CONTINUED)
CCIAM GUI CHOICES FOR SMART GROWTH SCENARIO

Redevelopment
Keys-Wide
• Query for Trailer Parks and "substandard lots" (residential, <5,000 ft^2 parcel, structure < 1,200 ft^2 and >25 years old); "Change From" existing residential density to same residential density, but apply base flood elevation and current zoning restriction. Apply default wastewater and stormwater treatment. • Query for "blighted" commercial parcels (<19 percent FAR, structure assessed value < 33 percent of land value, structure < 1,200 ft^2 and >20 years old); "Change From" existing commercial density, but apply default stormwater and wastewater treatment for 25 percent of the parcels. • Query for "blighted" industrial/marine industrial parcels (<19 percent FAR, structure assessed value < 33 percent of land value, structure < 1,200 ft2 and >20 years old); Change from existing industrial to light industrial land use, and apply default stormwater and wastewater treatment for 50 percent of the parcels.
Retrofitting
• Apply default stormwater and wastewater treatment to all county-owned lands parcels. • Query for all parcels with "cesspit" as wastewater treatment. "Change from" wastewater treatment to default wastewater treatment. • Apply default stormwater treatment default to all "Road" parcels on U.S. 1.
• Water Conservation
• Apply current building code water conservation defaults for parcels changed from Vacant Land to Residential, Commercial, or Industrial, and all redeveloped parcels.

The Government Study team provided the following five additional scenarios:

Scenario 1: Assume same amount of growth as in the Smart Growth scenario; assume necessary hurricane evacuation improvements (i.e., as recommended by Miller 2001) and potable water improvements (i.e., desalination plant).

The Hurricane Evacuation Study (Miller 2001) recommended the following structural improvements to U.S. 1:

- One additional northbound lane on U.S. 1 in Florida City.
- A three-lane on-ramp from U.S. 1 to northbound Florida's Turnpike.
- One additional northbound lane with a fixed barrier in the median on the 18-mile stretch of U.S. 1.
- One additional northbound lane between milemarkers (MM) 90 and 106.6.
- A continuous three-lane section between MM 54.5 and MM 90.

- One northbound lane through the signalized intersection of U.S. 1 and Wilder Road in Big Pine Key.
- Redesign the intersection of Card Sound Road (C.R. 905A) and County Road 905 to provide a gentle northbound to westbound curve.
- One additional northbound lane from MM 47.6 to MM 48.

Scenario 2: Same as Scenario 1 but, in addition, assume preservation of all habitat areas and restore areas adjacent to existing similar habitat to create habitats of sufficient size and connectivity to be of ecological use to plants and animals.

In the analysis, the Technical Contractor interpreted "preservation" as the acquisition of vacant land for preservation. Potential restoration areas that would increase patch size and connectivity were evaluated.

Scenario 3: Same as Scenario 1 but assume an additional 500,000 annual visitors.

The additional annual visitors were added to the transient population. Assuming that visitors stay in the Florida Keys an average of 5.2 days, the annual number represents an additional 7,142 people on any given day. This amount was added to the functional population.

Scenario 4: Same as Scenario 2 but assume 1/3, 1/3, 1/3 cost sharing for land acquisition, road improvements, and sewer improvements between local, state and federal governments.

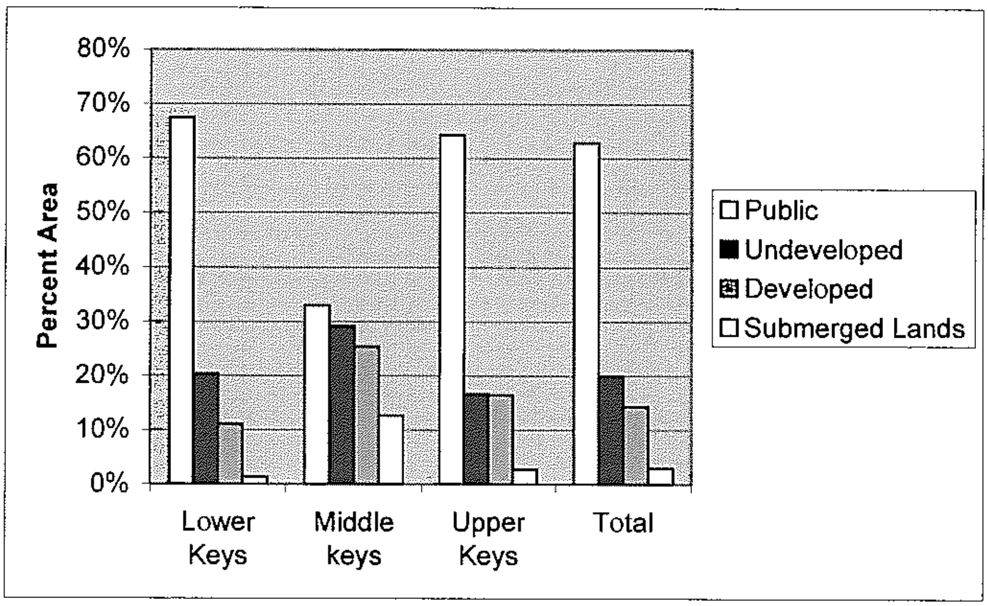
Scenario 5: Scenario 5 calls for a development pattern different from Smart Growth, with the following elements:

- 5,100 additional units over next 20 years (255 units/year x 20 years).
- 2,000 of those units are concentrated in Marathon in an infill pattern (i.e., Grassy Key).
- Full implementation of wastewater and stormwater improvements in Marathon as recommended in master plans.
- Sewering of three hot spots in Upper Keys, sewering of Bay Point, and sewering of Stock Island.
- For Key West, assume complete implementation of stormwater improvements and only redevelopment.
- Development throughout remaining area of Keys as with Smart Growth Scenario but with preservation and restoration as described in Scenario 2.
- Necessary potable water and hurricane evacuation improvements, and
- 1/3, 1/3, 1/3 cost sharing for land acquisition, sewering, and hurricane improvements between local, state, and federal governments.

4.2 LAND USE AND DEVELOPMENT SUITABILITY

Nearly 15 percent of the land area in the Florida Keys is developed (Figure 4.1), and over 60 percent is undeveloped and in public ownership, much of it under conservation. The pattern is similar in the Upper and Lower Keys. The Middle Keys show less public lands and more development. While the majority of the private lands are vacant (Figure 4.2), over 50 percent of the private vacant lands are deemed unsuitable for development (Figure 4.3) based on the developability criteria used in the FKCCS (Section 3.4.2). Approximately 22,600 privately owned parcels remain undeveloped; over 15,000 of them are unsuitable for development. The suitability analysis performed for the FKCCS indicates that less than 10 percent of the acreage of private vacant lands is suitable or moderately suitable for development (Figures 4.4 and 4.5).

FIGURE 4.1
OWNERSHIP AND DEVELOPMENT STATUS OF LANDS IN THE FLORIDA KEYS



The effects of the suitability analysis are reflected in the implementation of the scenarios in the CCIAM. For example, the Smart Growth Scenario calls for 3,000 additional units on subdivisions that are at least 50 percent developed. The scenario also describes other criteria. The CCIAM applied development suitability criteria and generated 2,803 additional units, underscoring the limited availability of suitable land for development in the Florida Keys. Similarly, the CCIAM generated 1,551 additional units in Marathon when it ran Scenario 5.

FIGURE 4.2
SUMMARY OF LAND USE DISTRIBUTION IN THE FLORIDA KEYS

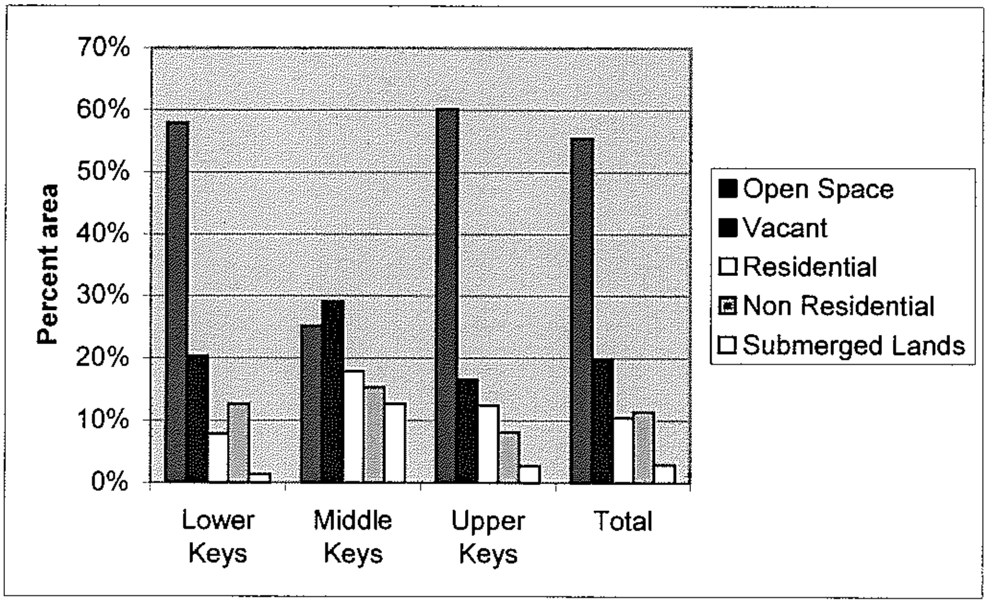


FIGURE 4.3
DISTRIBUTION OF LANDS UNSUITABLE FOR DEVELOPMENT

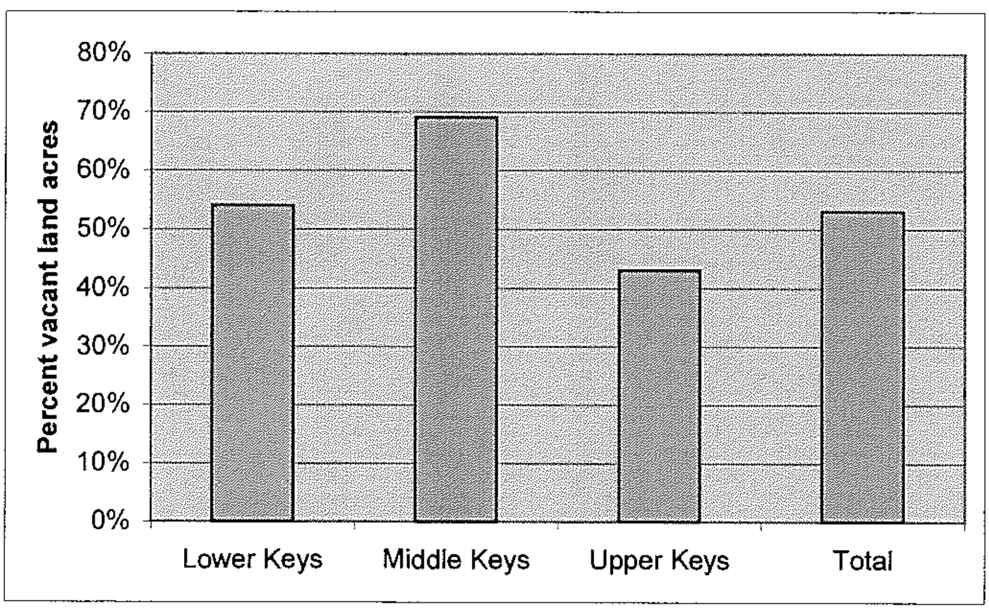


FIGURE 4.4
DEVELOPMENT SUITABILITY OF VACANT RESIDENTIAL LANDS

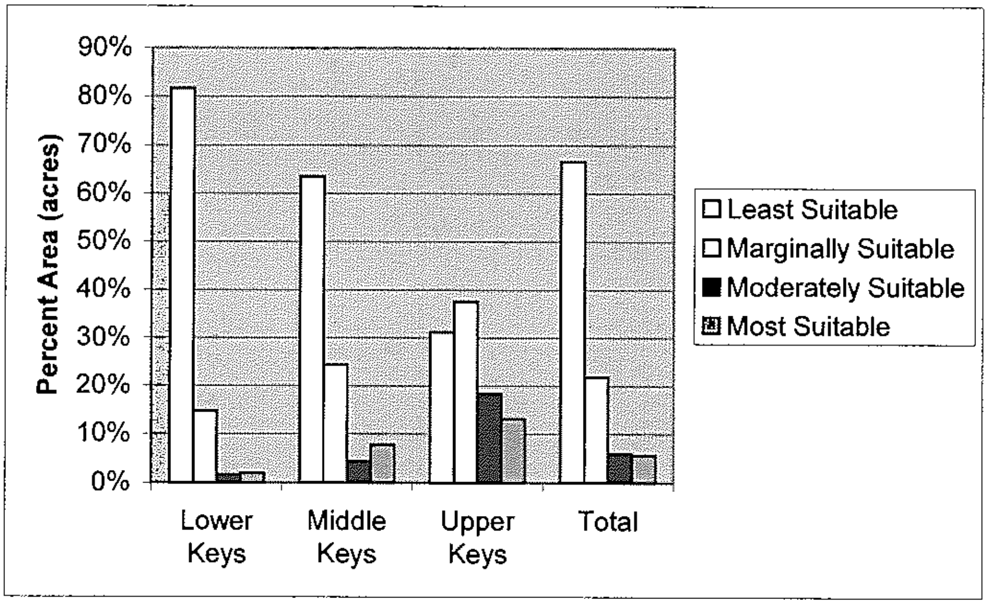
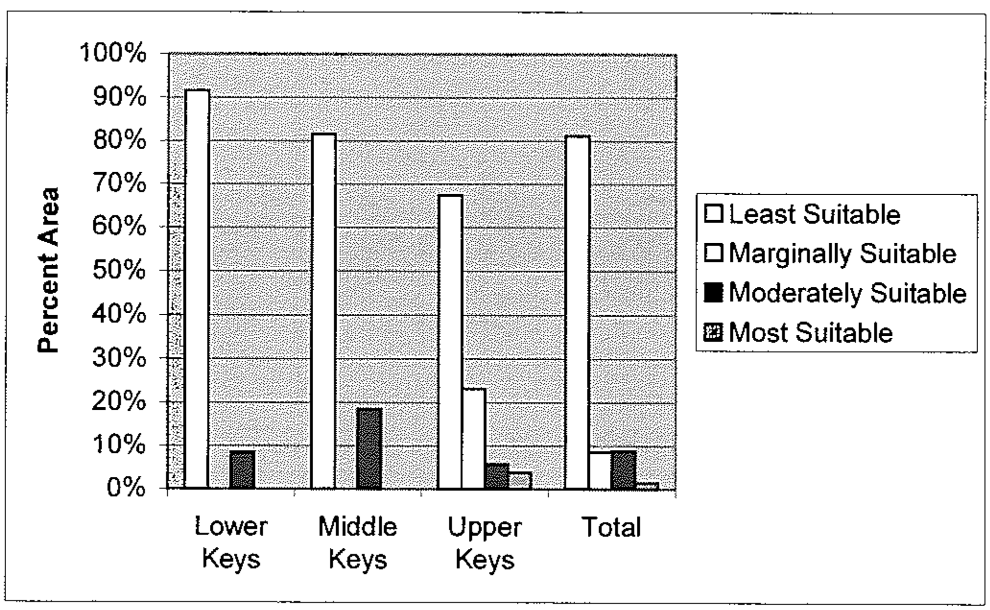


FIGURE 4.5
DEVELOPMENT SUITABILITY OF VACANT NON-RESIDENTIAL LANDS



4.3 SOCIOECONOMIC AND FISCAL ANALYSIS

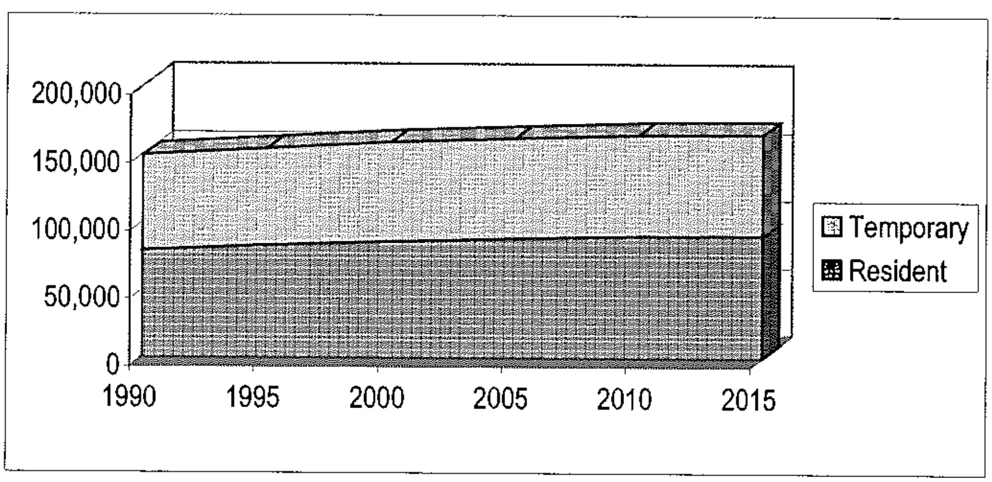
4.3.1 Socioeconomic Impacts

Housing and Population

The permanent population of the Florida Keys in 2000 was 79,589 and the total number of dwelling units was 51,617 (U.S. Census Bureau 2002). Population growth in the Keys slowed significantly in the 1990s, largely because of the implementation of the Rate of Growth Ordinance (ROGO). Between 1970 and 1980, the permanent population of the Florida Keys increased by 20.2 percent; between 1980 and 1990, the permanent population increased by 23.5 percent. In contrast, between 1990 and 2000, the permanent population increased only by 2 percent.

In addition to the permanent population, the Florida Keys host a seasonal population (those who stay in the Keys between 30 and 180 days) and a transient population (those who stay up to 30 days). Monroe County (Monroe County 2001) applies the concept of "functional" population to evaluate facilities demand. The functional population is defined as the number of people likely to be in the Florida Keys on any given evening, and includes the permanent, seasonal, and transient populations. The proportion of temporary population (transient and seasonal combined) relative to permanent population has fluctuated little since 1990 (Figure 4.6), and averages 86 percent of the permanent population.

FIGURE 4.6
TRENDS OF RESIDENT AND TEMPORARY POPULATION



For 2000, the Census Bureau reports 51,617 total housing units. Future scenarios represent 2,803 (Smart Growth) and 4,355 (Scenario 5) additional housing units in 20 years, for a growth of 5.4 and 8.4 percent, respectively. Correspondingly, permanent population growth in the scenarios is less than 10 percent in 20 years (Table 4.2). The Smart Growth Scenario would add

4,049 permanent residents to the Florida Keys; Scenario 5 results in 6,656 additional permanent residents. The additional 500,000 visitors contemplated in Scenario 3 add 7,142 persons to the transient population, therefore increasing the functional population as well.

TABLE 4.2
PROJECTED ADDITIONAL POPULATION[1]

	Smart Growth	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Permanent	4,049	4,049	4,049	4,049	4,049	6,656
Functional	7,531	7,531	7,531	14,674	7,531	12,380
Temporary	3,483	3,483	3,483	10,625	3,483	5,726
Seasonal	1,299	1,299	1,299	1,299	1,299	2,133
Transient	2,184	2,184	2,184	9,326	2,184	3,593

[1] Current permanent population: 79,589 (per Census 2000).

Employment and Payrolls

Total employment in the Florida Keys increased by 18.14 percent from 1990 to 1997, while resident population increased by 2.0 percent from 1990 to 2000. Tourist-oriented businesses, such as food establishments, miscellaneous goods (souvenirs and specialty items), hotels/motels, and amusement services, accounted for 34.8 percent of the county's total employment growth.

The Monroe County Comprehensive Development Plan limits new non-residential growth to 239 square feet per each new housing unit. The amount of non-residential growth in the Smart Growth scenario (700,000 square feet) roughly corresponds to the increase in the number of housing units based on the CompPlan relationship. Employment under Smart Growth scenario is, therefore, projected to grow at the same rate as the employee population, and the ratio of employees available to employees required remains nearly 1 (Table 4.3). Scenario 5 results in more permanent residents than Smart Growth, but it does not add non-residential uses; therefore, there is an increase, although small, of employees available with respect to employees required.

TABLE 4.3
EMPLOYMENT AND PAYROLLS[1,2]

	Smart Growth	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Employees						
Available	33,903	33,903	33,903	33,903	33,903	35,050
Required	34,363	34,363	34,363	34,363	34,363	34,363
Ratio	0.99	0.99	0.99	0.99	0.99	1.02
Payroll						
Total Payroll (in $ millions)	656.3	656.3	656.3	656.3	656.3	656.3

[1] Current condition employees: 32,508 ("required").

[2] Current payroll: $623.1 million.

Total annual payrolls in Monroe County grew by 49 percent during the 1990 to 1997 period. The U.S. Department of Housing and Urban Development estimated a 2000 median household income for Monroe County at $44,600. Personal income resulting from wages and salaries (labor income) has markedly declined since 1971 (Florida Bureau of Business Research (BEBR) 2000). Personal income resulting from investments (dividends, interest, and rent) increased from 18.9 percent in 1971 to 40.9 percent in 2001. This shift suggests that a larger number of households do not rely on weekly paychecks for their income.

Payrolls are projected to increase less that 10 percent, in line with the projected population growth in the scenarios (Table 4.3).

Cost and Taxable Value of New Construction

Annual housing construction peaked in the mid-1970s and again in the mid-1980s, but has since fallen and leveled off in the mid-1990s (Figure 4.7). In contrast, the price of new houses has steadily increased in the 1990s (Figure 4.8).

FIGURE 4.7
MONROE COUNTY HOUSING CONSTRUCTION TRENDS

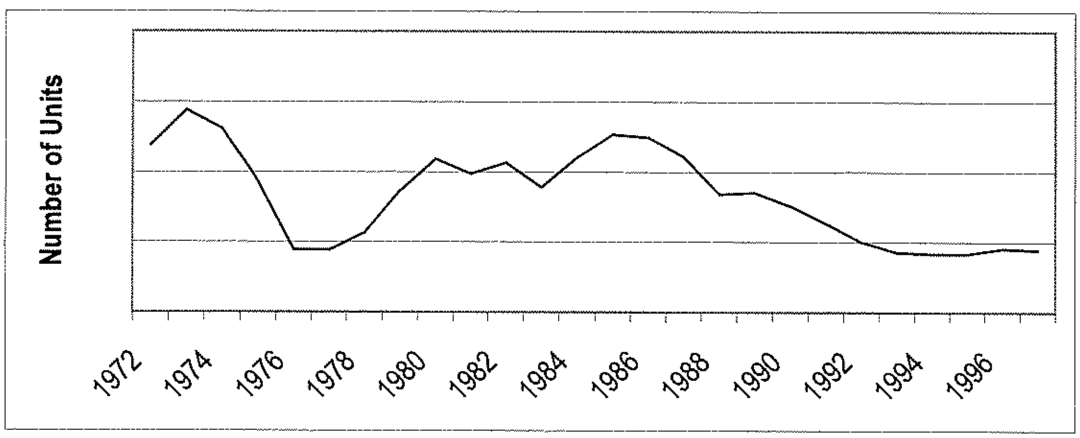
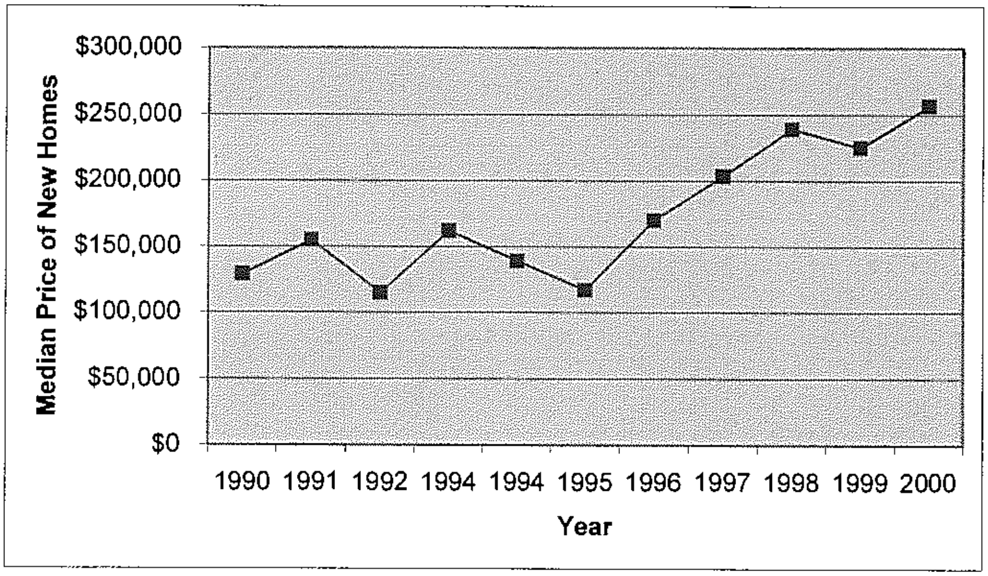


FIGURE 4.8
MEDIAN NEW HOME PRICE IN MONROE COUNTY



Cost of new construction contemplated in the scenarios would exceed $500 million, and would create $800 million in taxable value. Scenario 5, results in higher cost of construction and taxable value (Table 4.4).

TABLE 4.4
COST AND TAXABLE VALUE OF NEW CONSTRUCTION
(IN MILLIONS OF DOLLARS)

	Smart Growth	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Cost	536.6	536.6	536.6	536.6	536.6	805.7
Taxable Value	840.9	840.9	840.9	840.9	840.9	1,276.8

Tourism

Tourism is the most important sector of the economy in the Florida Keys. The most consistent source of estimates of tourist activity is the *Florida Visitor Study*, conducted each year by the State of Florida. In 1998 (most recent report available), an estimated 48.7 million tourists visited the state, of which 1,266,000 (2.6 percent) vacationed in the Florida Keys.

The National Oceanic and Atmospheric Administration (NOAA) conducted a study of visitors to the Florida Keys based on a sample survey during June 1995 to May 1996 (Leeworthy 1996). The purpose of the study was to determine activities and economic value of visitors to the

Florida Keys. Over three million people visited the Keys during the study period, of which 2.5 million visited for recreation purposes (Table 4.5). Over 40 percent of the 2.5 million visitors made it to Key West, whereas 27 percent visited the Upper Keys, 21 percent the Middle Keys, and 9 percent visited the Lower Keys.

TABLE 4.5
VISITORS TO THE FLORIDA KEYS 1995-1996

Category	Total Persons	Person-Days
Recreating Visitors	2,540,488	13,298,387
Non-Recreating Visitors	517,093	2,974,738
All Visitors	3,057,581	16,273,125

This survey also investigated the expenditure patterns of the visitors over this 12-month period. The average expenditure per person per day was $108.98, similar to the value reported in the *Florida Visitor Study* for 1998 ($117.80). The NOAA study shows that 70 percent of visitors' expenditures cover lodging, food and beverage, and transportation. Boating, fishing, and diving activities account for 12 percent of the expenditures (Table 4.6)

TABLE 4.6
AVERAGE VISITOR EXPENDITURES BY PERSON PER DAY

Expenditure Category	Amount
Lodging	$36.31
Food and Beverage	$29.76
Transportation	$10.56
Boating	$5.69
Fishing	$3.30
Diving	$3.46
Sightseeing	$4.16
Other Activity	$1.57
Miscellaneous	$12.53
Services	$1.64
Total Expenditure	$108.98

Source: *Visitor Profiles: Florida Keys & Key West*; NOAA.

While the economic impact of tourism on the Florida Keys is very significant, the land use impact is focused on relatively few activities, and the total demand in acres or floor space is limited. Hotels/motels and restaurants are also important indicators of tourist activity

(Table 4.7). From 1989 to 1998, the number of hotels increased from 17 to 25 and the total number of rooms increased by nearly 800. During the same period, the number of motels increased from 157 to 174 and the total number of rooms increased by more than 400. The number of restaurants decreased, but their total seating capacity and average size increased.

TABLE 4.7
TOURIST-RELATED BUSINESSES IN MONROE COUNTY

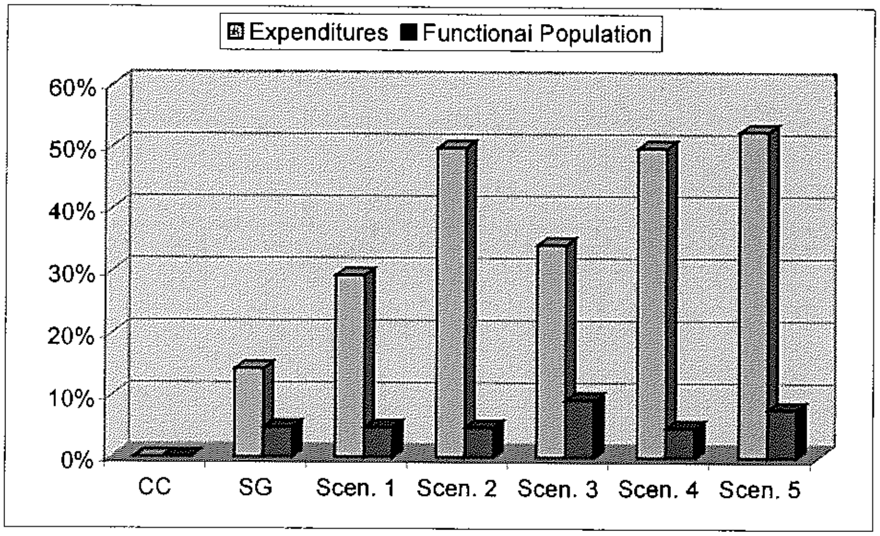
Facilities	1989	1998
Hotels		
Number of Establishments	17	25
Number of Rooms	1,455	2,238
Motels		
Number of Establishments	157	174
Number of Rooms	5,647	6,068
Restaurants		
Number of Establishments	553	524
Seating Capacity	35,591	42,357

The addition of over 7,000 transient persons to the functional population would create a demand for additional tourist-related facilities. Currently, the ratio of transient population to hotel rooms is 0.0197. Should that ratio hold in the future, the additional transient population would require approximately 141 additional hotel rooms.

4.3.2 Fiscal Impacts

Annual government expenditures increase between 13 percent and 51 percent, depending on the scenario (Figure 4.9). In contrast, functional population would grow by less than 10 percent over 20 years in all scenarios

FIGURE 4.9
PERCENT INCREASE IN TOTAL ANNUAL GOVERNMENT EXPENDITURES VERSUS 20-YEAR INCREASE IN FUNCTIONAL POPULATION WITH RESPECT TO CURRENT CONDITION



Therefore, the results show a sharp increase in per capita government expenditures, which would obligate government to increase revenue. Revenue to cover the increased expenditure may be obtained in many ways, such as cost-sharing arrangements with state and federal agencies, bond issues, and tax increases.

Scenarios 1 through 5 included large expenditures (Table 4.8). For example, improvements to U.S. 1 for hurricane evacuation would cost approximately $72 million, assuming a cost of $1.2 million per mile of improvement. Land acquisition for preservation, calculated as the sum of the taxable value of the parcels in the tax roll, would cost approximately $469 million.

TABLE 4.8
ESTIMATED CAPITAL COST OF SCENARIO IMPROVEMENTS

	Scenario 1	Scenario 2	Scenario 3	Scenario 4*	Scenario 5*
U.S. 1 Improvements	$0	$71,800,000	$0	$23,933,333	$29,933,333
Wastewater	$268,966,789	$268,966,789	$268,966,789	$89,655,596	$93,160,537
Stormwater	$191,299,900	$191,299,900	$191,299,900	$63,766,633	$59,706,633
Land Acquisition	$23,802,643	$469,285,169	$23,802,643	$156,428,390	$148,149,505
Restoration	$0	$670,000,000	$0	$223,333,333	$223,333,333
Total	$484,069,332	$1,671,351,858	$484,069,335	$557,117,285	$554,283,341

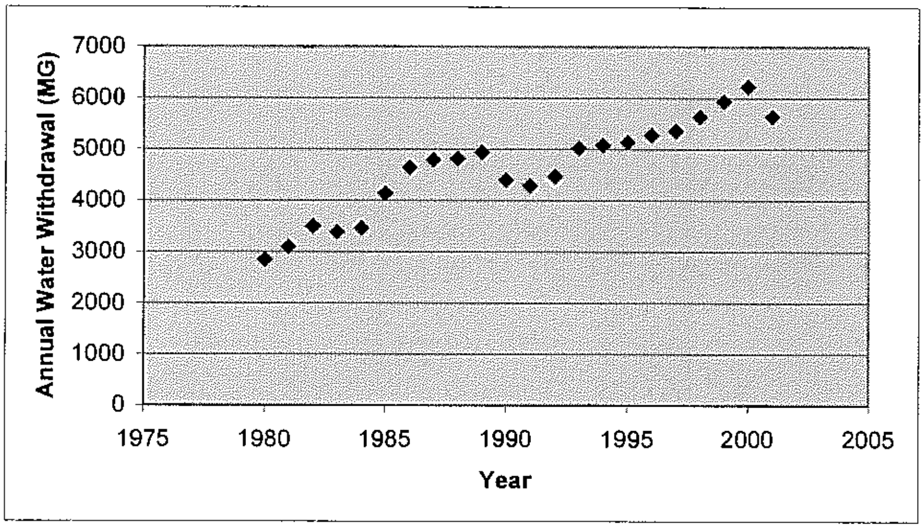
* Cost are divided by 3 to represent shared burden between Federal, state, and local governments.

4.4 INFRASTRUCTURE

4.4.1 Potable Water Supply Impacts

There are no significant water supplies within the Florida Keys. The Florida Keys Aqueduct Authority (FKAA) supplies virtually all of the potable water used in the study area from a wellfield located in southern Miami-Dade County. Key data reviewed with respect to the potable water system include recent consumption records, permitted capacities, plans for expansion, the cost of delivered water, and the operational capabilities of the primary facilities. The facilities include an existing wellfield, water treatment, pumping and transmission facilities, as well as emergency desalination facilities located within the Keys. Annual withdrawals have steadily increased since 1980 (Figure 4.10) and permitted capacity was exceeded in 1999 and 2000 (Monroe County 2001).

FIGURE 4.10
ANNUAL WATER WITHDRAWAL (MG), 1980-2000



The Smart Growth Scenario results in a 0.7 million gallons per day (mgd) increase in withdrawal which, if added to the annual withdrawal recorded in 2000 (6,228 MG; Monroe County 2001) would result in an average of 17.8 mgd, well beyond permitted capacity. Scenario 5 would result in approximately a 1.0 mgd increase in withdrawal. Assuming a per capita daily use of 100 gallons, Scenario 3 could generate 1.4 mgd due to the increase in visitors.

TABLE 4.9
ADDITIONAL POTABLE WATER DEMAND
(IN MILLION OF GALLONS PER DAY)

	Smart Growth	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Demand	0.7	0.7	0.7	1.4	0.7	1.0

Ongoing FKAA regulatory initiatives may help reduce water use. For example, the FKAA recently adopted a formal resolution requesting all municipalities and unincorporated Monroe County to adopt mandatory water conservation and irrigation ordinances in accordance with the South Florida Water Management District's (SFWMD) permit allocation manual. Draft ordinances are being provided (FKAA letter to Ann Lazar, Florida Department of Community Affairs (DCA), February 27, 2002). Scenarios 1 to 5 assume the construction and operation of a desalination plant. A desalination plant contemplated in Scenarios 1-5 would provide sufficient water to meet projected demands.

The 22 mgd capacity of FKAA's existing water treatment plant is sufficient to meet the projected potable water demands for Smart Growth and Scenarios 1-5 for the average day, maximum month day, and maximum day conditions. The anticipated growth under Smart Growth will consume a significant portion of the residual capacity of the existing water treatment system under maximum day conditions. However, the FKAA's water plant expansion program, currently under construction, will increase treatment capacity to 25 mgd, which will provide additional treatment capacity and redundancy for the system.

Comparison of the projected average day demands against the reported capacity of the FKAA pipeline in each segment indicated that the existing pipeline is adequate to handle the scenario potable water conveyance. The projected cumulative maximum day flow in each of the planning units typically required less than 60 percent of the rated aqueduct segment capacity. The highest use of aqueduct capacity occurs at the northern end of the Keys, in the Key Largo Area (Ocean Reef Club + PAED 21 (North Key Largo) + PAED 22 (Cross Key)), where the potable water supply first enters the study area.

4.4.2 Traffic Impacts

Traffic volumes and level of service (LOS) on U.S. 1 are estimated every year based on survey work performed at peak season, between late February and early March (URS 2002). Traffic volume, although with year-to-year fluctuations, has tended to increase slowly since 1993 (Figure 4.10). Median speed, which determines LOS, fluctuates from year to year, with seemingly little connection to changes in land use. For example, while no development has occurred in Big Pine and No Name Keys in the last three years, median speed changed –2.9 mph from 2000 to 2001 and +2.5 mph from 2001 to 2002 (Table 4.10). Traffic volume decreased in both periods (Figure 4.11).

FIGURE 4.11
TRAFFIC VOLUME AT SELECTED LOCATIONS IN THE FLORIDA KEYS

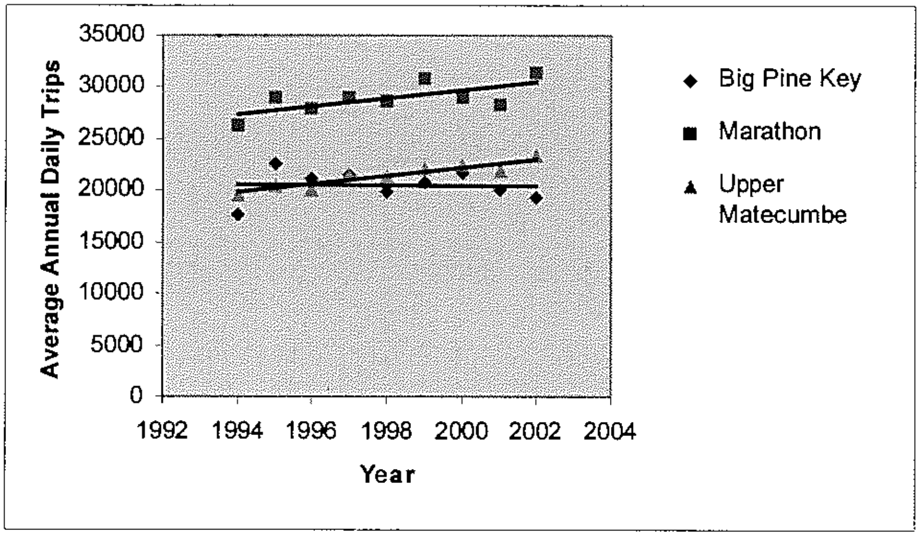


TABLE 4.10
VARIATION IN MEDIAN SPEEDS ON U.S. 1

U.S. 1 Segment	2000-2001	2001-2002
Stock Island	4.1	-1.3
Boca Chica	1.2	-2.5
Big Coppitt	1.7	-2.9
Saddlebunch	-0.5	-1.7
Sugarloaf	-0.2	-1.3
Cudjoe	-1.1	0.6
Summerland	-0.4	0.6
Ramrod	0.4	-0.2
Torch	0.5	-0.9
Big Pine	-2.9	2.5
Bahia Honda	1.7	-1.5
7-Mile Bridge	0.8	-0.9
Marathon	-0.5	-1.8
Grassy	0.5	-0.6
Duck	1.6	-1.1
Long	1.9	-1.9
Lower Matecumbe	0.6	0.2
Tea Table	-0.3	0.0
Upper Matecumbe	0.0	0.0
Windley	0.0	1.6
Plantation	3.5	-0.2
Tavernier	0.9	-1.1
Largo	0.7	0.7
Cross	1.2	2.3

Source: 2002 Arterial and Travel Time/Delay Study, URS Greiner, Inc.

The regression equation that relates acres of residential and tourist-related land uses with median speed predicts a decrease of 1 mph per 62.5 acres/mile of U.S. 1 of new development in the planning unit. Projected changes in land use acreages result in changes in median speed, which are within annual fluctuation. LOS on U.S. 1 will likely continue to fluctuate in the next 20 years, with a tendency to deteriorate. An additional northbound lane on portions of U.S. 1, as proposed, is not intended to improve the LOS on U.S. 1. However, should the additional lane be used continuously as a turn or scramble lane, northbound flow could improve.

The number of additional of housing units is lower than the residential capacity in all future scenarios, suggesting that U.S. 1 may accommodate the additional trips. However, not all segments of U.S. 1 have reserve capacity and the effect of development on the entire U.S. 1 length may be affected by the distribution of development among segments.

4.4.3 Hurricane Evacuation Impacts

Clearance time to Florida City ranges from 24:14 under current conditions to 20:32 in Scenario 1. Under Smart Growth, which does not include improvements to U.S. 1, the clearance time increases by 28 min with respect to current conditions. Under Scenario 5, which includes more dwelling units than Scenario 1, as well as U.S. 1 improvements, the clearance time is 20:56. All runs included a Category 1-3 hurricane.

4.5 Pollutant Loads

4.5.1 Stormwater Loads

Due to the historic lack of flooding in the Florida Keys related to rainfall, little quantitative data exists on the relationship between rainfall and runoff. Few engineered drainage systems have been developed in the Keys, as the soils are highly porous soils and drainage areas are near receiving waters. Similarly, until recent years, there were virtually no stormwater treatment systems in the Keys and stormwater pollutant loads were generally discharged directly to receiving waters.

Stormwater flows and pollutant loads were computed for the seven scenarios using the projected land uses, event mean concentration (EMC) values, and selected load reductions attributable to Best Management Practices (BMPs). The stormwater treatment strategies recommended in the Stormwater Management Master Plan were applied to new development and redevelopment at the parcel level, as well as the retrofitting strategies for identified problem areas. Extensive use of BMPs is required under the Smart Growth strategies, which resulted in implementation of stormwater BMPs that serve 7,086 acres of the Florida Keys. Total loads are only slightly higher in Smart Growth and Scenarios 1-5 than in current conditions (Table 4.11).

TABLE 4.11
STORMWATER LOADS
(IN LBS. PER DAY)

	Current Conditions	Smart Growth	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
TN	1,333	1,355	1,368	1,368	1,368	1,368	1,377
TP	169	167	169	169	169	169	170

Note: Includes SW-Surface, SW-Ground, and U.S. 1.

4.5.2 Wastewater

With the exception of the Key West Wastewater Treatment Plant (10 mgd), there are no large centralized wastewater collection and treatment systems in the Florida Keys. There are small wastewater treatment plants in Key Colony Beach and Ocean Reef Club (0.34 mgd and 0.55 mgd, respectively). Wastewater treatment for existing residential and commercial/industrial wastewater flows is provided by a wide variety of systems ranging from simple cesspits to small on-site package plants.

Wastewater effluent pollutant loads were computed for the seven scenarios using the total number of EDUs and the effluent characteristics from the U.S. Environmental Protection Agency (EPA)/Florida Department of Environmental Protection (FDEP). The effects of an improvement in treatment technology are significant (Table 4.12). Total nitrogen (TN) and total phosphorous (TP) loads are reduced by 69 percent and 73 percent respectively in Smart Growth and Scenarios 1-4, which considered complete implementation of the Wastewater Master Plan. In Scenario 5, in which only a few hot spots were upgraded to treatment plants, the total loads increased significantly, although they are still lower than under current conditions.

TABLE 4.12
WASTEWATER LOADS
(IN LBS. PER DAY)

	Current Conditions	Smart Growth	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
TN	2,429	762	762	762	762	762	1,952
TP	238	66	66	66	66	66	198

4.5.3 Pollutant Loads and Water Quality in Canals

A growing body of literature documents the deterioration of water quality in dead-end canals in the Florida Keys (reviewed in Kruczynski and and McManus 2002). The Canal Module explores the effects of stormwater and wastewater pollutant loads and tidal flushing on water quality in dead-end canals. The model was applied to 10 canals, which represent the diversity of lengths, associated land uses, number of turns and splits, and location of canals in the Florida Keys (Table 4.13).

TABLE 4.13
CHARACTERISTICS OF SELECTED CANALS

Canal ID	# of Seg.	Total Length of Seg. (ft)	Canal Splits	Longest Distance (ft)	Nearshore Water Quality[1] TN (mg/l)	Nearshore Water Quality[1] TP (mg/l)
50 Key Largo	16	2,250	3	1,590	0.334	0.009
69 Rock Harbor	27	4,930	2	1,920	0.429	0.009
70 Rock Harbor	12	1,330	0	1,330	0.419	0.009
117 Plantation Key	14	1,923	0	1,923	0.344	0.009
152 Lower Matecumbe Key	30	6,214	2	3,244	0.197	0.007
204 Marathon	6	795	0	795	0.213	0.010
208 Marathon	12	1,083	0	1,083	0.213	0.010
246 Marathon	8	1,150	1	1,030	0.245	0.009
288 Big Pine Key	12	1,314	0	1,314	0.303	0.010
339 Little Torch Key	44	6,185	6	2,580	0.301	0.010

[1] Estimated by interpolating existing water quality data. It estimates concentrations at 250 feet offshore from the mouth of the canal.

For each canal, the model was run to evaluate current conditions and the Smart Growth scenario. The main difference between the runs is that, under Smart Growth, wastewater is assumed to be transported to a treatment plant and disposed away from the canal.

In the two scenarios, stormwater loads remain essentially unchanged. In contrast, wastewater loads are dramatically lower under the Smart Growth scenario (Table 4.14). The average reduction in stormwater pollutants was only about 1 percent on average; for wastewater pollutants, the average reduction was about 90 percent. Wastewater contribution to total TN and TP loads is about 80 percent under current conditions, but only about 10 percent under Smart Growth.

In all cases, model results show pollutant concentrations increase with distance from the canal mouth (Appendix C), and are higher than in the open, nearshore waters. Under current conditions, average concentrations (mg/l) ranged from 0.51 to 2.53 for TN and 0.02 to 0.25 for TP (Table 4.15). Under the Smart Growth scenario, average concentrations (mg/l) ranged from 0.24 to 0.57 for TN and 0.01 to 0.06 for TP. The pollutant discharge from the canal (during ebb tide), which can be interpreted as a point source discharge, ranged from 2.98 to 38.34 pounds/day of TN and 0.21 to 1.25 pounds/day of TP under current conditions and from 1.80 to 34.36 pounds/day of TN and 0.10 to 0.85 pounds of TP under Smart Growth.

TABLE 4.14
POLLUTANT LOADS INTO CANALS

Canal	Daily SW Load			Daily WW Load		
	TN (lbs)	TP (lbs)	Flow (cft)	TN (lbs)	TP (lbs)	Flow (cft)
50 Key Largo						
Current Conditions Scenario:	0.19	0.04	2,125	1.09	0.11	698
Smart Growth Scenario:	0.18	0.03	2,314	0.60	0.03	966
Percent Change:	-6%	-5%	9%	-45%	-72%	39%
69 Rock Harbor						
Current Conditions Scenario:	0.38	0.08	4,655	2.68	0.27	1,714
Smart Growth Scenario:	0.38	0.08	4,666	0.00	0.00	0
Percent Change:	0%	0%	0%	-100%	-100%	-100%
70 Rock Harbor						
Current Conditions Scenario:	0.14	0.02	1,362	1.07	0.11	683
Smart Growth Scenario:	0.14	0.02	1,391	0.00	0.00	0
Percent Change:	-1%	-1%	2%	-100%	-100%	-100%
117 Plantation Key						
Current Conditions Scenario:	0.49	0.09	4,582	3.38	0.33	2,024
Smart Growth Scenario:	0.48	0.09	4,715	0.00	0.00	0
Percent Change:	-2%	-1%	3%	-100%	-100%	-100%
152 Lower Matecumbe Key						
Current Conditions Scenario:	0.37	0.07	5,489	3.03	0.30	1,931
Smart Growth Scenario:	0.37	0.07	5,489	0.00	0.00	0
Percent Change:	0%	0%	0%	-100%	-100%	-100%
204 Marathon						
Current Conditions Scenario:	0.12	0.02	1,150	0.83	0.08	469
Smart Growth Scenario:	0.12	0.02	1,166	0.00	0.00	0
Percent Change:	-1%	-1%	1%	-100%	-100%	-100%
208 Marathon						
Current Conditions Scenario:	0.11	0.02	1,025	0.82	0.08	463
Smart Growth Scenario:	0.11	0.02	1,025	0.00	0.00	0
Percent Change:	0%	0%	0%	-100%	-100%	-100%
246 Marathon						
Current Conditions Scenario:	0.16	0.03	1,515	0.56	0.05	282
Smart Growth Scenario:	0.16	0.03	1,515	0.18	0.01	282
Percent Change:	0%	0%	0%	-69%	-82%	0%
288 Big Pine Key						
Current Conditions Scenario:	0.11	0.02	1,118	0.57	0.06	365
Smart Growth Scenario:	0.11	0.02	1,133	0.00	0.00	0
Percent Change:	-1%	-1%	1%	-100%	-100%	-100%
339 Little Torch Key						
Current Conditions Scenario:	0.38	0.08	4,439	2.31	0.23	1,512
Smart Growth Scenario:	0.38	0.08	4,439	0.00	0.00	0
Percent Change:	0%	0%	0%	-100%	-100%	-100%
Minimum % Change:	-6.4%	-5.1%	0.0%	-100%	-100%	-100%
Maximum % Change:	0.1%	0.1%	8.9%	-45%	-72%	39%
Average % Change:	-1.1%	-0.9%	1.7%	-91%	-96%	-76%

TABLE 4.15
POLLUTANT CONCENTRATION AND CANAL DISCHARGES

Canal	Average Canal Concentration(mg/l)		Canal Discharge (lbs/day)	
	TN	TP	TN	TSS
50 Key Largo				
Current Conditions Scenario:	0.51	0.030	9.94	133.84
Smart Growth Scenario:	0.45	0.019	9.01	133.50
Percent Change:	-12.4%	-37.3%	-9.3%	-0.3%
69 Rock Harbor				
Current Conditions Scenario:	0.51	0.019	38.34	453.27
Smart Growth Scenario:	0.44	0.011	34.36	451.96
Percent Change:	-14.8%	-40.2%	-10.4%	-0.3%
70 Rock Harbor				
Current Conditions Scenario:	1.28	0.105	5.85	40.77
Smart Growth Scenario:	0.51	0.027	3.00	39.91
Percent Change:	-60.4%	-74.6%	-48.8%	-2.1%
117 Plantation Key				
Current Conditions Scenario:	2.53	0.250	12.76	89.86
Smart Growth Scenario:	0.57	0.059	4.79	77.99
Percent Change:	-77.5%	-76.4%	-62.5%	-13.2%
152 Lower Matecumbe Key				
Current Conditions Scenario:	0.62	0.054	13.2	204.3
Smart Growth Scenario:	0.24	0.016	7.42	202.26
Percent Change:	-62.0%	-71.1%	-43.6%	-1.0%
204 Marathon				
Current Conditions Scenario:	0.55	0.043	3.5	51.6
Smart Growth Scenario:	0.25	0.016	1.85	46.58
Percent Change:	-53.4%	-62.1%	-47.2%	-9.7%
208 Marathon				
Current Conditions Scenario:	0.51	0.040	4.3	73.7
Smart Growth Scenario:	0.25	0.015	2.76	69.80
Percent Change:	-50.8%	-61.4%	-36.2%	-5.2%
246 Marathon				
Current Conditions Scenario:	0.62	0.050	2.98	47.24
Smart Growth Scenario:	0.41	0.028	2.20	42.63
Percent Change:	-33.1%	-44.0%	-26.2%	-9.8%
288 Big Pine Key				
Current Conditions Scenario:	0.86	0.077	3.19	33.11
Smart Growth Scenario:	0.39	0.029	1.80	32.68
Percent Change:	-54.4%	-61.7%	-43.6%	-1.3%
339 Little Torch Key				
Current Conditions Scenario:	0.55	0.040	16.20	226.34
Smart Growth Scenario:	0.33	0.018	12.05	225.07
Percent Change:	-40.3%	-55.2%	-25.6%	-0.6%
Minimum % Change:	-77.5%	-76.4%	-62.5%	-13.2%
Maximum % Change:	-12.4%	-37.3%	-9.3%	-0.3%
Average % Change:	-45.9%	-58.4%	-35.4%	-4.3%

4.6 TERRESTRIAL ECOSYSTEMS AND SPECIES

4.6.1 Habitat Loss and Fragmentation

Since the 1800s, development in the Florida Keys has occurred primarily in upland areas, resulting in the loss of almost half of the upland habitats, from 20,038 acres in pre-development times to 10,353 acres in 1995. Along with habitat loss, upland habitats have been severely fragmented into numerous, smaller patches (Figures 4.12 and 4.13). This is in sharp contrast with pre-colonial conditions, where the average patch size was over 100 acres.

FIGURE 4.12
NUMBER OF UPLAND PATCHES IN THE FLORIDA KEYS, 1800 – 1995

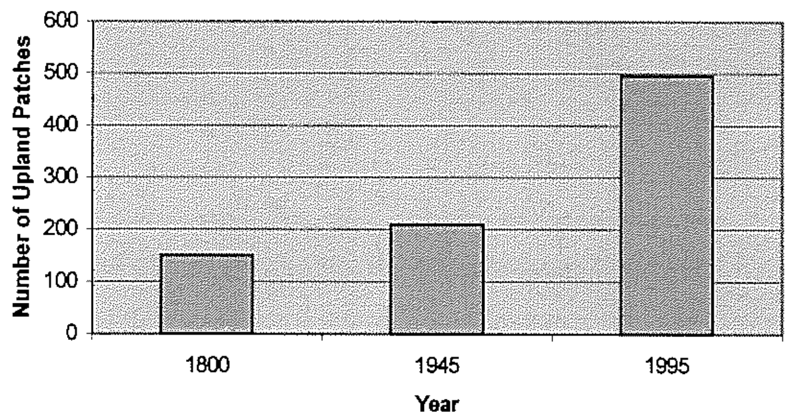
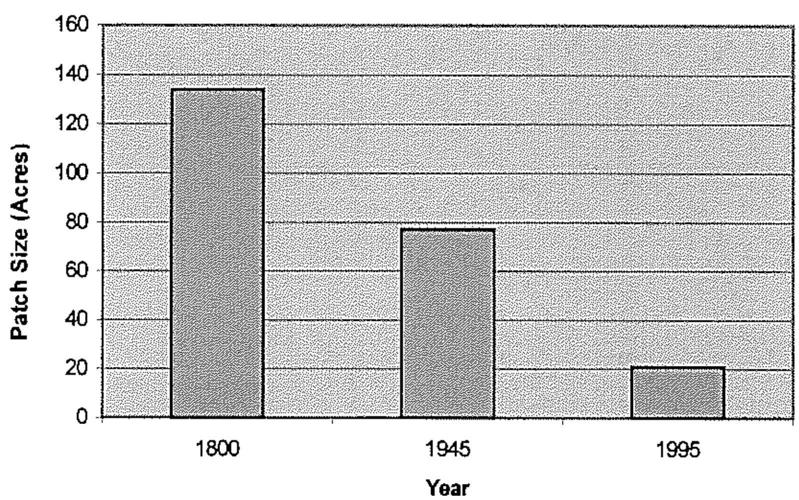


FIGURE 4.13
AVERAGE SIZE OF UPLAND PATCHES IN THE FLORIDA KEYS, 1800 – 1995



Under both current conditions and Smart Growth, approximately 80 percent of all upland habitat patches are less than five acres (Figures 4.14 and 4.15). The frequency of small patches is lowest in the Lower Keys and highest in the Upper Keys. In all scenarios, including current conditions, nearly 90 percent of all the remaining upland occurs as patches of less than 10 acres. Keys hammocks, smaller than 13 acres, are considered "all edge," with forest interiors lacking the buffering effects of edge vegetation (Strong and Bancroft 1994).

FIGURE 4.14
DISTRIBUTION OF UPLAND PATCH SIZES IN THE FLORIDA KEYS – CURRENT CONDITIONS

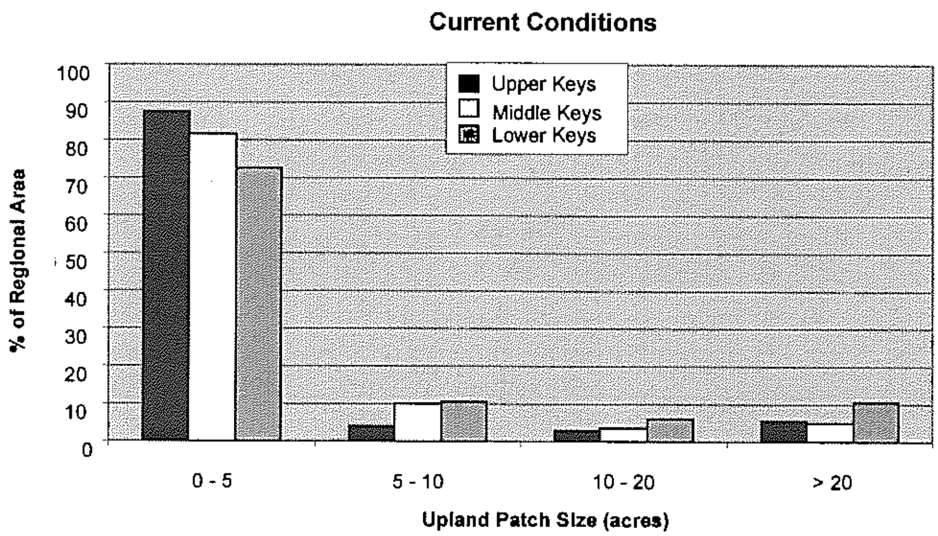
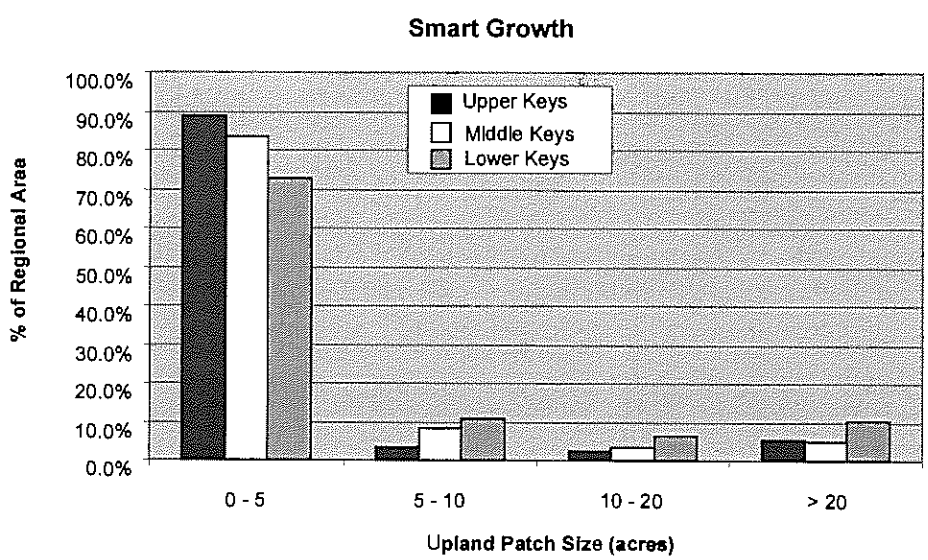


FIGURE 4.15
DISTRIBUTION OF UPLAND PATCH SIZES IN THE FLORIDA KEYS – SMART GROWTH



4.6.2 Species Richness

Species richness, here approximated by the potential occurrence of up to 17 species of concern in 30 x 30 foot cells, is highest in the Lower Keys and lowest in the Middle Keys (see examples in Figures 4.16 and 4.17). The overlay analysis results in a maximum of 10 species per cell in the richest areas. Throughout the Florida Keys, low species richness cells account for the majority of the area. Additional adverse species richness effects are negligible (fourth decimal place) in Smart Growth and Scenarios 1-5 with respect to current conditions; however, virtually any encroachment of development into open areas affects one or more species of concern.

FIGURE 4.16
SPECIES RICHNESS IN THE FLORIDA KEYS – HIGH SPECIES RICHNESS AREA

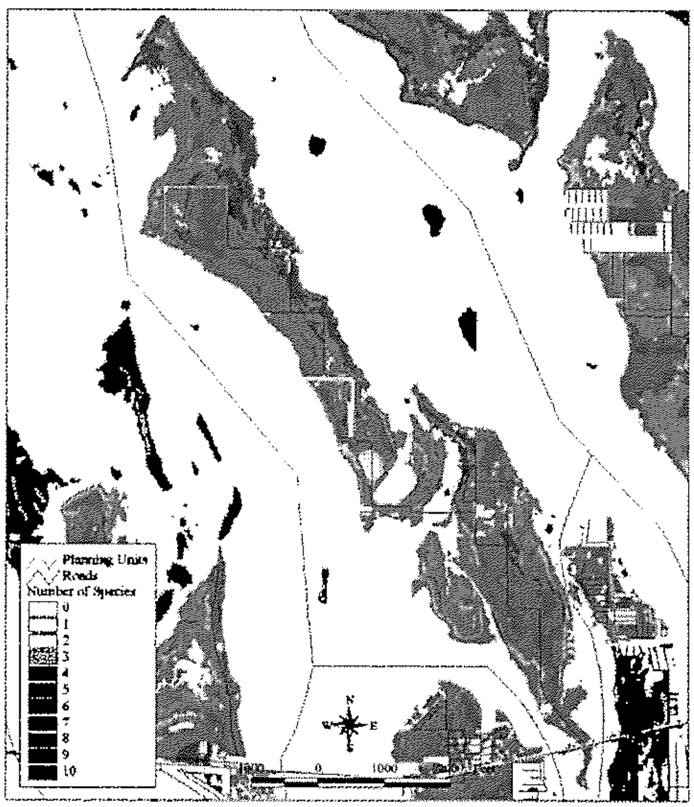
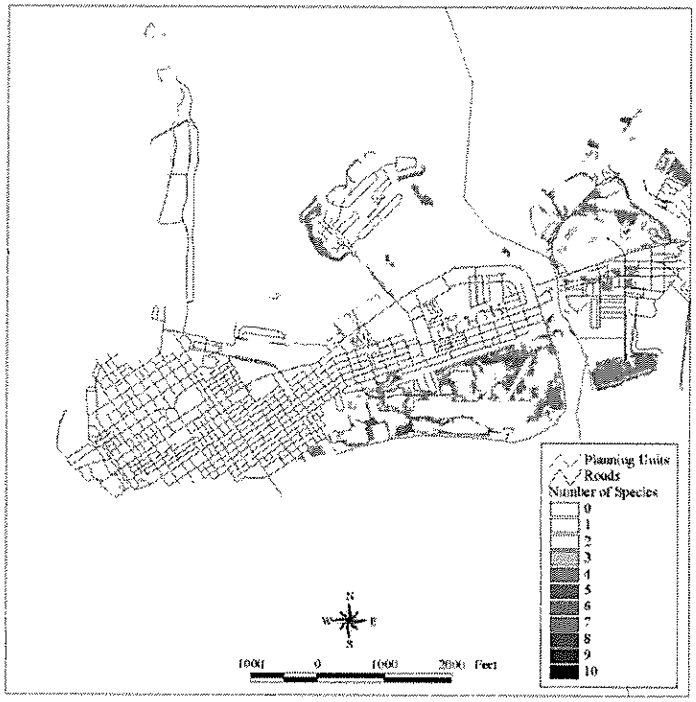


FIGURE 4.17
SPECIES RICHNESS IN THE FLORIDA KEYS – LOW SPECIES RICHNESS AREA



4.6.3 Species-Specific Impacts

Key Deer

The most studied terrestrial species in the Florida Keys is the Florida Key deer (*Odocoileus virginianus clavium*), yet existing detailed population studies were over 20 years old (e.g., Silvy 1975). Recent population research revealed that the Key deer population has tripled since the 1970s (Lopez 2001). The Key deer is the subject of an ongoing Habitat Conservation Plan (HCP), which addresses the species in detail. As part of the HCP, URS Corporation and Dr. Roel Lopez (Texas A&M University), on behalf of the Florida Department of Transportation (FDOT), DCA, and Monroe County developed a population viability analysis (PVA) for the Key deer. The PVA model included two main components: a matrix model of population dynamics and a spatial habitat model of carrying capacity and secondary impacts.

Lopez (2001) studied the ecology and population dynamics of the Key deer for three years (1998-2000). As part of the HCP studies, the movement, habitat utilization, and fate of over 150 individual deer were followed for the three years of the study. Quantitative information on mortality and fecundity for deer of different ages was used to create a matrix model, which allows for simulating the fate of the population under different scenarios. In the matrix model, changes in mortality or fecundity result in changes in the way the population fluctuates through time.

Coupled with the matrix model, the habitat preferences of the Key deer, and data on Key deer mortality due to vehicle collisions and other human effects, were used to determine the contribution of different habitats to the carrying capacity (i.e., the number of deer the area can support) and the "harvest" (i.e., contribution to mortality due to human impacts) for Big Pine and No Name Keys.

FIGURE 4.18
KEY DEER PVA MODEL GRID LAYERS

Harvest Grid **Carrying-Capacity Grid**

(Darker shades = higher deer value)

The PVA model evaluated twelve development intensities. In each scenario, the model "chooses" parcels to be developed beginning with those of lowest quality for the Key deer. Risk of extinction increases with development intensity. Risk increases faster as higher-quality parcels become developed. The PVA model also provided an estimate of additional mortality, which represents an estimate of "take" due to the level of development.

Additional development in Smart Growth and Scenarios 1-5 occurs outside high-quality Key deer areas.

Lower Keys Marsh Rabbit

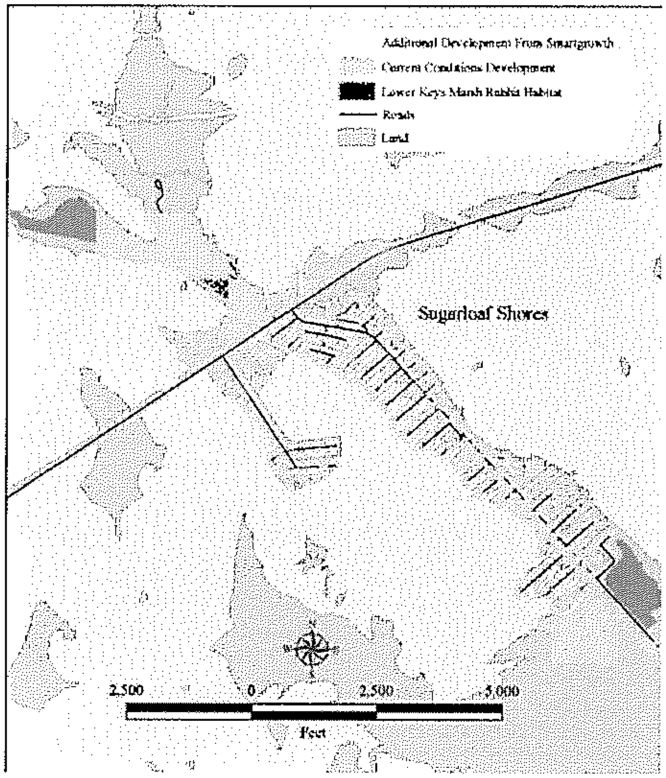
Recent literature documents the population biology and population viability of the endangered Lower Keys marsh rabbit, whose distribution is restricted to the Lower Keys. Forys and Humphrey (1999) developed a PVA for the marsh rabbit in order to estimate the threat of extinction faced by the marsh rabbit and determine the necessity and efficacy of different management strategies. Results of the simulations indicate survival, particularly for adult females, must be increased for the marsh rabbit to persist. Other than development, domestic cats represent the main threat to the Lower Keys marsh rabbit and are the principal cause of mortality. Since the rabbit occurs in small, relatively disjunct populations, has a low population density, and is subject to predation by domestic predators, the species is in danger of extinction.

Smart Growth and Scenarios 1-5 result in small additional habitat loss for the Lower Keys marsh rabbit (Table 4.16, Figure 4.19) with respect to current conditions. In addition to habitat loss, there is an increase in the amount of habitat at risk due to potential secondary effects shown by fewer patches and acres available after including risk.

TABLE 4.16
REMAINING HABITAT: LOWER KEYS MARSH RABBIT

		Number of Patches	Total Area	Mean Patch Size
Direct Impacts	Current Conditions	150	1,125	7.5
	Smart Growth	152	1,124	7.4
	Scenario 5	152	1,124	7.4
Secondary Impacts	Current Conditions	123	798	6.5
	Smart Growth	125	797	6.4
	Scenario 5	125	797	6.4

FIGURE 4.19
EXAMPLE OF SMART GROWTH DEVELOPMENT ENCROACHMENT ON LOWER KEYS MARSH RABBIT HABITAT



Silver Rice Rat

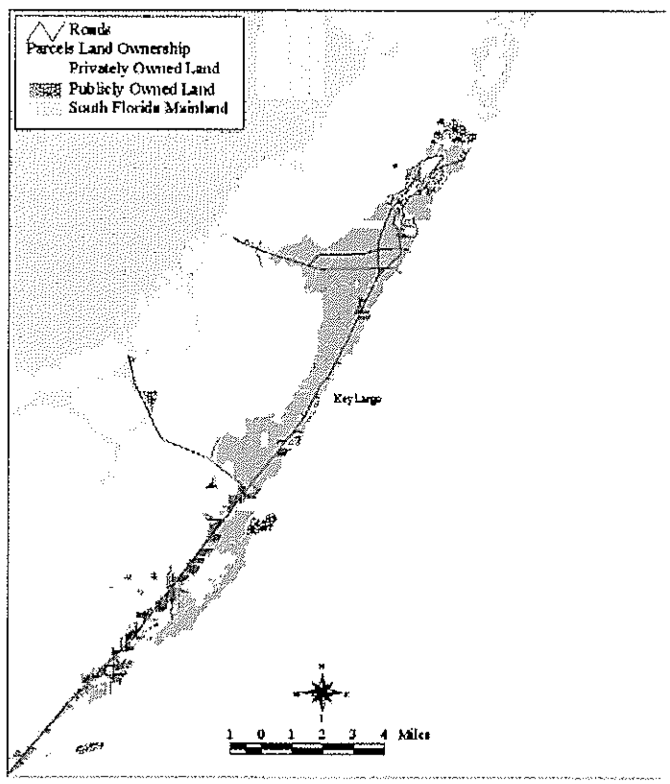
The silver rice rat (*Oryzomys palustris natator*) is a medium-sized, semi-aquatic rat known to occur on 12 islands of the Lower Keys (Forys, et. al. 1996). Viable populations require large, contiguous mangrove and salt marsh habitats for foraging and salt marsh habitats for nesting. Freshwater marshes that lie adjacent to salt marshes are also used along with buttonwood transitional vegetation. The U.S. Fish and Wildlife Service (USFWS) maintains a Geographic Information System (GIS) data layer (provided by Dr. Phil Frank, USFWS), which documents the status of every suitable habitat patch for the silver rice rat. No additional impacts occur under Smart Growth and Scenarios 1-5 with respect to current conditions.

Key Largo Woodrat

The Key Largo woodrat (*Neotoma floridana smalli*) is a small rodent, currently limited to northern Key Largo, but it once ranged over the entire island. The woodrat builds large stick nests for resting, feeding, and breeding. Females are on average much smaller than the males (Hersh 1981). Key Largo woodrats are active climbers (Goodyear 1985) and have overlapping home ranges. They have defined trails and fallen trees are often used to move through the hammocks. The Key Largo woodrat is capable of reproducing all year although winter peaks are evident (Hersh 1981). They are nocturnal omnivores but feed primarily on plant material (Brown 1978). The primary threat to their survival is habitat loss and fragmentation. Natural and increased levels of predation are a threat including raccoons and domestic and feral cats.

The Multi-Species Recovery Plan for South Florida (USFWS 1999) cites 4,445 acres (91 percent) of suitable Key Largo woodrat habitat is in public ownership and, therefore, protected; the remainder is in private ownership (Figure 4.20). Smart Growth and Scenario 5 result in the loss of about 50 acres of Key Largo woodrat habitat.

FIGURE 4.20
LAND OWNERSHIP IN KEY LARGO



Schaus Swallowtail Butterfly

Schaus swallowtail butterfly (*Heraclides aristodemus ponceanus*) is a large blackish-brown and yellow butterfly; antennae are black but males have a yellow knob. Historically they are known from hardwood hammocks from southern Miami to Lower Matecumbe Key in the Middle Keys. Their current range is largely diminished. Two unconfirmed sightings occurred over 20 years ago in the Lower Keys (USFWS 1982, Covell 1976). Males prefer trails and edges of the hammock and females typically fly within the hammocks (Rutkowski 1971). The butterflies are diurnal and short-lived. They have a single annual flight-season from May to June, and there is only one generation per year (Emmel 1985). The Schaus swallowtail butterfly population has been in general decline for many years primarily because of habitat destruction but also from pesticides, road kill, extreme climatic conditions, and collectors.

The vast majority of the Schaus swallowtail butterfly in the Florida Keys is under public ownership and has conservation status. Smart Growth and Scenario 5 result in the additional loss of 26 acres of potential swallowtail habitat.

Other Species Directly Addressed in the CCIAM

The CCIAM incorporates habitat requirements for the white-crowned pigeon (*Columba leucocephala*) and five species of forest-nesting birds. The white-crowned pigeon occurs in several areas of the Florida Keys, and is an important seed disperser in upland forests (Bancroft et al. 1994). White-crowned pigeons nest primarily on mangrove islands (Strong and Bancroft 1994), but must disperse to hardwood hammocks to meet foraging needs. Once they have fledged, young white-crowned pigeons show a strong preference for hardwood hammocks 5.0 hectares or greater within the first 72 hours of fledging (Strong and Bancroft 1994). After this, white-crowned pigeons generally stay within hardwood hammocks, avoiding urban areas (Strong and Bancroft 1994). Viable foraging habitat represents the major limiting factor for the white-crowned pigeon (Strong et al. 1991). Smart Growth and Scenario 5 result in further losses of white-crowned pigeon habitat (Table 4.17)

TABLE 4.17
WHITE-CROWNED PIGEON

	Number of Patches	Total Area (ac)	Mean Patch Size (ac)
Adult White-Crowned Pigeon			
Current Conditions	496	7,080	14.3
Smart Growth	504	7,000	13.9
Scenario 5	504	6,979	13.8
Juvenille White-Crowned Pigeon			
Current Conditions	5,833	44,372	7.6
Smart Growth	5,858	44,251	7.6
Scenario 5	5,857	44,193	7.5

Bancroft et al. (1995) determined the minimum patch size below which five forest-nesting bird species were unlikely to be found. The species studied were the white-eyed vireo (*Vireo griseus*), the black-whiskered vireo (*Vireo altiloquus*), the northern flicker (*Colaptes auratus*), the yellow-billed cuckoo (*Coccyzus americanus*), and the mangrove cuckoo (*Coccyzus monor*). The Smart Growth Scenario resulted in a slight additional habitat loss for the five forest nesting species (Table 4.18).

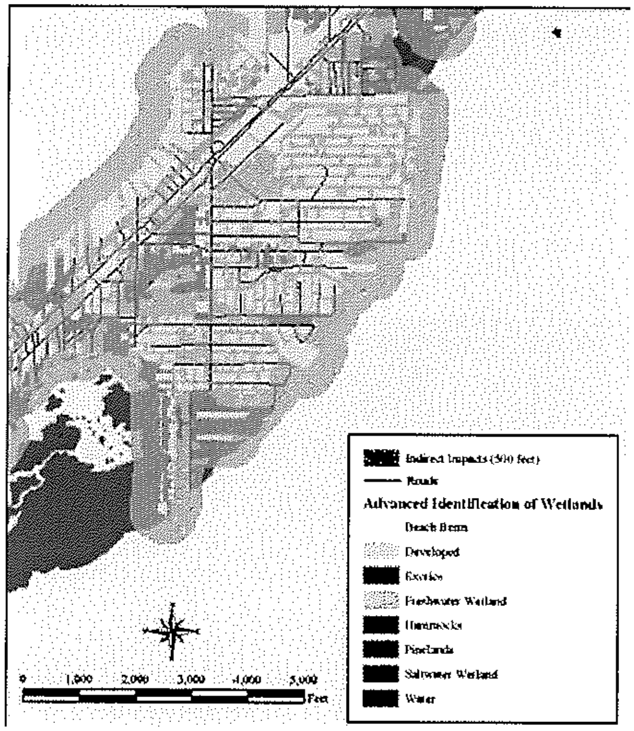
TABLE 4.18
RESULTS OF THE DIRECT IMPACTS TO FOREST INTERIOR BIRD HABITAT

Species	Current Conditions		Smart Growth		Scenario 5	
	Habitat Acreage	Number of Patches	Habitat Acreage	Number of Patches	Habitat Acreage	Number of Patches
Black-whiskered Vireo	7,579	625	7,486	611	7,460	606
White-eyed Vireo	6,778	189	6,703	187	6,683	189
Northern Flicker	6,401	136	6,335	135	6,335	135
Yellow Cuckoo	5,633	74	5,574	73	5,574	73
Mangrove Cuckoo	5,055	50	5,000	49	5,000	49

4.6.4 Secondary Impacts

The secondary effects of development on habitats, such as increased predation pressure due to the introduction of domestic predators, or the effects of increased and sustained noise levels, ripple through the habitat and may affect entire patches of native vegetation. Small patches, which are the rule in the Florida Keys, are often surrounded by development and may receive secondary effects around its entire perimeter. While difficult to quantify, secondary effects are likely to be more significant as patch size decreases. In many areas of the Florida Keys, particularly in the narrower Upper and Middle Keys, indirect effects cover entire patches of habitat (Figure 4.21).

FIGURE 4.21
INDIRECT EFFECTS



Over 37 percent of the remaining habitat after direct effect is within 500 feet from a developed area, leaving approximately 32,000 acres of habitat potentially unaffected by development (Table 4.19).

TABLE 4.19
HABITAT REMAINING

	After Direct Impacts	After Indirect Impacts
Current Conditions	51,652	32,563
Smart Growth	51,490	32,463
Scenario 5	51,382	32,400

4.6.5 Restoration Potential in the Florida Keys

Development has replaced and fragmented natural habitats throughout the Florida Keys, leaving over 90 percent of the remaining upland areas fragmented into patches of 10 acres or less (Figures 4.22 and 4.23). Restoring connectivity and re-creating large patches of continuous habitat would require the conversion of developed lands (Figures 4.24 and 4.25).

FIGURE 4.22
EXAMPLE OF HABITAT LOSS AND FRAGMENTATION IN THE UPPER KEYS

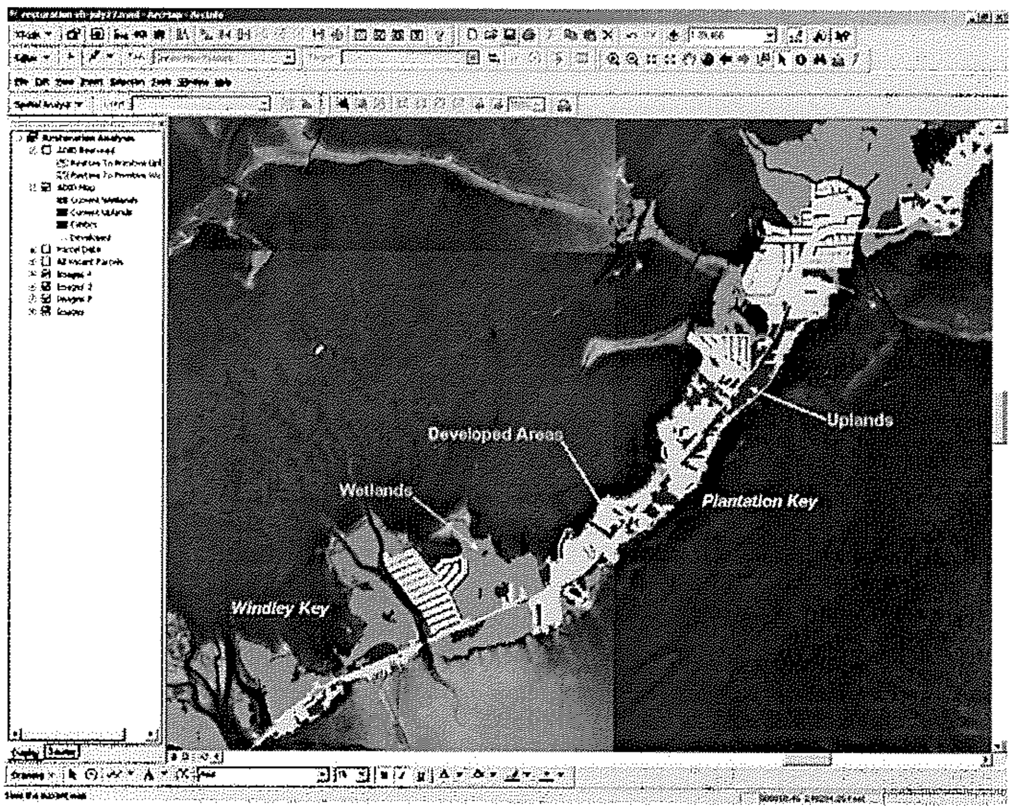
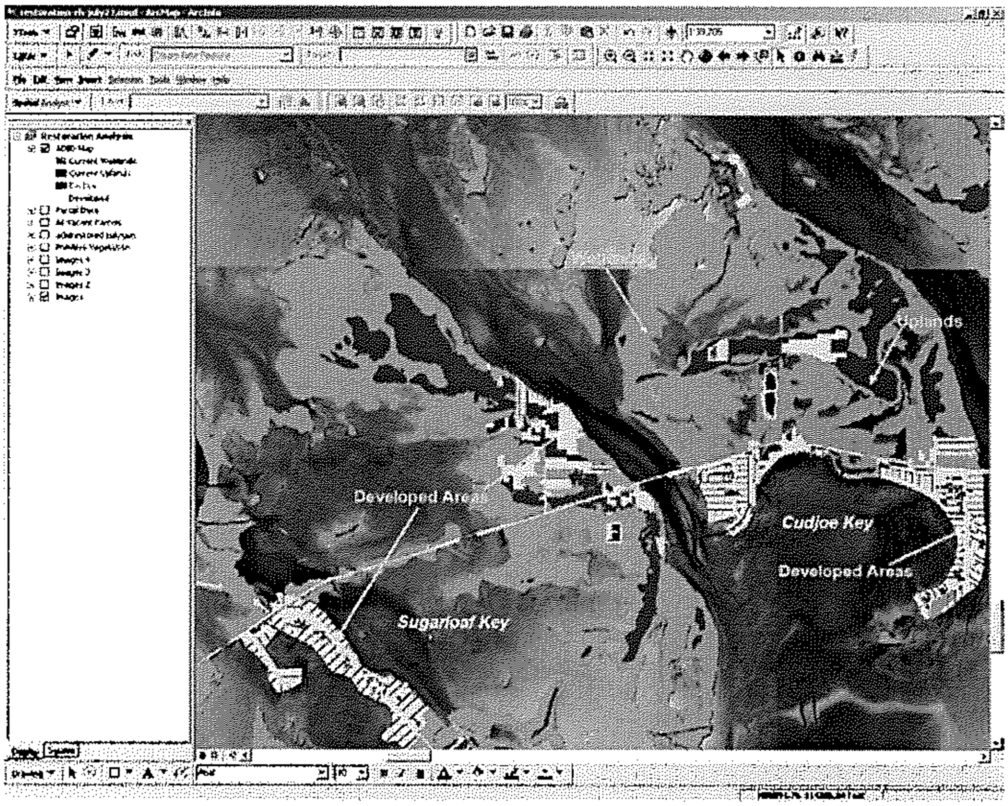


FIGURE 4.23
EXAMPLE OF HABITAT LOSS AND FRAGMENTATION IN THE LOWER KEYS



The Technical Contractor explored the challenges and consequences of restoring habitat through the acquisition and conversion of developed lands using example areas in the Upper Keys and Lower Keys. In pre-development times, upland habitats in the Upper Keys occurred in a long, narrow, continuous patch from northern Key Largo to Tavernier. This long patch was fragmented into many small patches, over 90 percent of which are below the 13-acre threshold. Restoring connectivity in the example area would require the acquisition and conversion of over 3,000 parcels (Figure 4.24), with over 3,200 dwelling units, and a total taxable value of over $520 million.

A similar exercise for the example area in the Lower Keys suggested that restoration would require the acquisition and conversion of over 1,300 developed parcels (Figure 4.25), including over 740 dwelling units, with a total taxable value of nearly $150 million. No attempt was made to estimate other cost involved in such a restoration effort, such as permitting, demolition, re-grading, re-planting, monitoring, and closing costs.

FIGURE 4.24
RESTORATION CHALLENGES IN EXAMPLE AREA IN THE UPPER KEYS

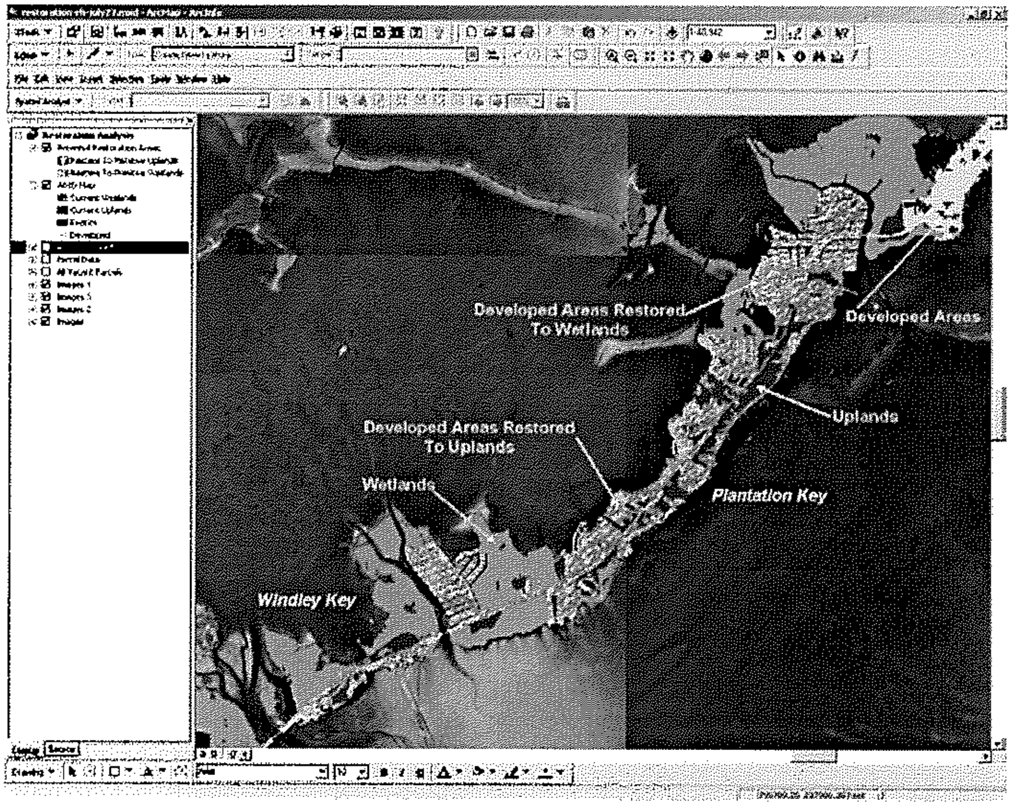
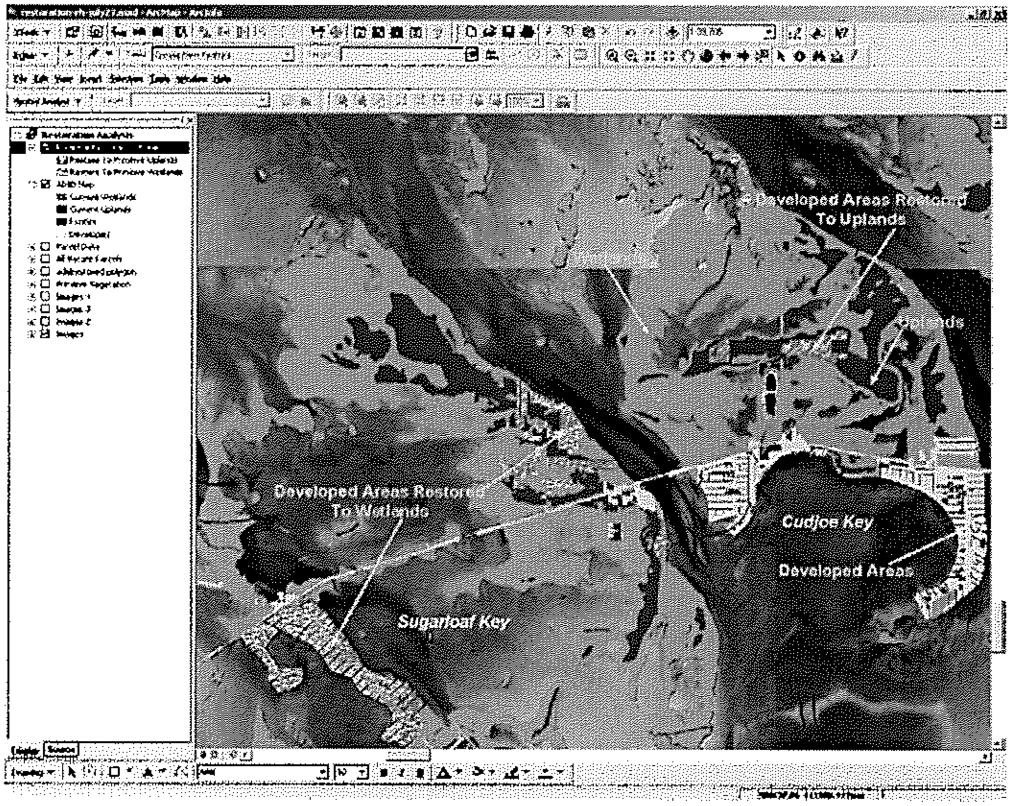


FIGURE 4.25
RESTORATION CHALLENGES IN EXAMPLE AREA IN THE LOWER KEYS



4.7 MARINE ECOSYSTEMS AND SPECIES

The literature search on marine ecosystems and species of the Florida Keys focused on peer-reviewed data on direct impacts caused by human activities on the marine environment, including propeller scarring in seagrass, boat collisions and anchoring impacts of coral, diving and snorkeling impacts, and fishing pressure. The literature search also sought information on the potential effects of nutrient, pollutant, and pathogen discharges from the Florida Keys on the water quality and benthic communities within the Florida Keys National Marine Sanctuary (FKNMS). Despite the existence of an extensive and growing body of literature on the ecological resources and water quality characteristics of the FKNMS (reviewed in Porter and Porter 2002, Sullivan et. al 1996), the available data proved insufficient to establish predictive relationships between land development activities and the impacts listed above. The remainder of this section summarizes current knowledge on water quality, benthic community biological response to nutrients, and direct human impacts to marine resources in the FKNMS.

4.7.1 Water Quality and Benthic Communities of the Florida Keys National Marine Sanctuary

Water Quality in the Florida Keys National Marine Sanctuary

Since 1995, EPA and the State of Florida have been monitoring water quality in the FKNMS. Boyer and Jones (2002) summarized the results of this monitoring program based on sampling from 1995 to 1998. They concluded that, at a Keys-wide scale, the FKNMS exhibited "very good" water quality (Boyer and Jones 2002, page 613). They showed that the Upper Keys generally have lower nutrient concentrations than the Middle or Lower Keys. Concentration of TN generally decreased from inshore to offshore (both bayside and oceanside); the same occurred for TP, with the exception of the Upper Keys, where TP increased offshore, oceanside. Median TP and TN concentrations were 0.17 µm and 10.04 µm respectively, with a median TN:TP ratio of 62.10, indicating a P-limited environment (benthic organisms uptake N and P in relatively constant ratios. A P-limited environment has lower availability of P and benthic organisms may respond rapidly to increases in P). Sampling stations located in channels or passes had significantly higher nutrient concentrations than stations located off land; however, differences were "very small and not likely to be biologically important" (Boyer and Jones, op. cit., page 626).

The Nature Conservancy (TNC) has run a volunteer-based water quality sampling program in canals and other nearshore locations in the Florida Keys since 1994. Keller and Itkin (2002) have reported on the results of this program. Results based on sampling data from November 1996 to October 1997 show that monthly TN values range from 13.6 to 177.0 µm, with the largest annual mean occurring in the Upper Keys, followed by the Lower and Middle Keys. Statistically significant differences occurred only between Upper and Middle Keys values. TN was lower in sampling stations near developed areas (41.3 µm) than in natural shorelines (52.3 µm). Monthly mean values for TP ranged from 0.17 to 5.25 µm. Annual mean was not statistically different between stations with regard to region (Upper, Middle, Lower Keys), shoreline type (developed, undeveloped), side (bayside, oceanside), or season. A significant correlation between TP and Chl a suggested that P-limitation occurs.

Kruczynski and McManus (2002) provide an extensive discussion of water quality issues in the Florida Keys. They reviewed TN and TP data for three canals, and show values between 19.8 and 40.5 µm for TN and between 0.21 and 1.04 for TP; both higher than those observed in open waters. Lapointe et al. (1994) also measured elevated TN and TP levels (>35 µm and >0.45 µm, respectively) at sampling stations that received direct nutrient inputs, including a canal in Big Pine Key.

Water Circulation

Circulation patterns influence water quality. Lee et al. (2002) and Smith and Pitts (2002) recently reviewed the current state of knowledge regarding circulation patterns in the Florida Keys. Circulation patterns in the Keys are complex, as they vary in space and time and exhibit influences from regional current, local gyres, tidal movements, and wind patterns. Smith and Pitts (2002) conclude that there is a clear coupling between the Gulf of Mexico and the Atlantic side of the Keys, mainly through Florida Bay and tidal channels. Despite extensive documentation of circulation patterns, no one has attempted to develop a hydrodynamic model for the Florida Keys. For the FKCCS, diligent attempts to adapt existing models or to develop a simple model led to the conclusion that existing models and data are insufficient.

Pathogens in the Marine Environment

High levels of pathogens in recreational waters can increase human exposure through ingestion and body contact; therefore, increasing the risk of human illness. Total and fecal coliform bacteria are frequently used as indicators for waters polluted by human wastes typically through sewage and stormwater runoff. Additionally, other agencies recommend other indicators for use in marine waters, such as Enterococci. A review of federal, state and local datasets revealed that, while several programs are in place, no long-term data were available to establish a relationship between land development and human pathogens in the marine environment in the Florida Keys. However, mounting evidence suggest that human pathogens enter the marine environment from Florida Keys sources. For example, health officials have closed beaches in the Florida Keys several times in the last few years because of fecal coliform contamination. Recent research has shown viral tracers on coral heads within 100 m from shore (Lips et al. 2002), suggesting a potential connection between sewage and coral communities.

Effects of Nutrients on Benthic Communities

The literature review focused on finding peer-reviewed documentation of the relationship of land development activities and the distribution, extent, and ecological conditions of benthic communities in the Florida Keys. In particular, efforts focused on the documentation of the relationship between water quality and benthic communities. An extensive body of literature explores the effects of pollution on seagrasses, but widespread agreement on the appropriate indicator to study is elusive.

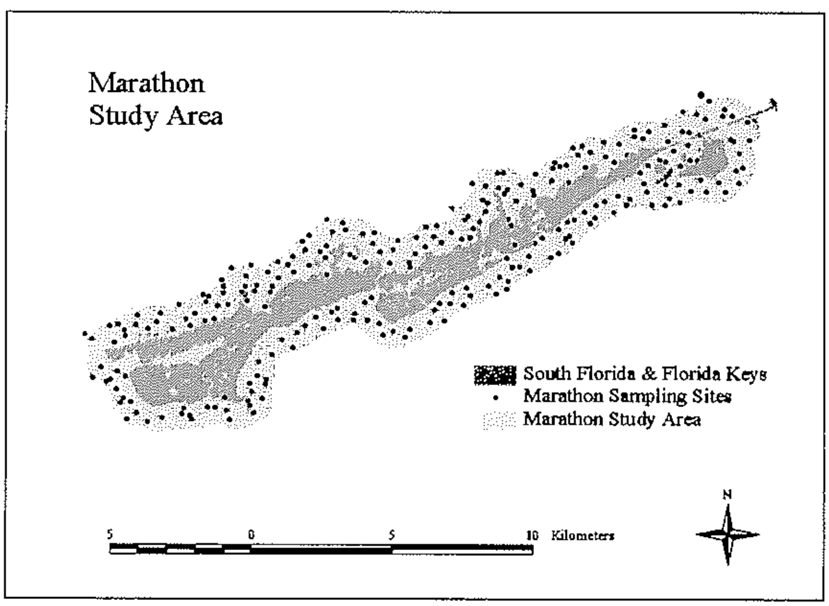
Lapointe et al. (1994) determined that TN and TP concentrations decreased with increasing distance from shore. They measured TN and TP concentrations in the water column as well as seagrass productivity parameters. They concluded that the use of TN and TP pools appears to be the best single nutrient index of eutrophication as this measurement includes all nutrient pools and is also a proxy for water transparency (Lapointe and Clark 1992). The FKCCS explored the connections between TN and TP loads and their contribution to TN and TP concentrations in the marine environment.

The FKCCS included an investigation by Florida International University (FIU) (Jim Fourqurean and Leanne Miller-Rutten, investigators) of nearshore (<1 km from shore) benthic communities of the Florida Keys (Appendix A). The study tried to identify spatial and temporal variations within nearshore benthic communities and their associated nutrient regimes and to determine if these variations may be associated with human land use activity in the Florida Keys. Working hypotheses included:

- **H_1:** Nearshore benthic communities and their associated nutrient regimes exhibit spatial/temporal variation throughout the Florida Keys.
- **H_2:** There is a significant relationship between human land use activity and spatial/temporal variation of nearshore benthic communities and their associated nutrient regimes throughout the Florida Keys.

The project began with the creation of maps of the current distribution and composition of nearshore benthic communities using intensive surveys and recent aerial photographs. Next, historic aerial photographs were used to construct a complete time series of maps at multiple sites within the study area. The nature of changes within nearshore benthic communities at those sites was investigated. Nutrient samples were also collected near the time series sites to characterize the nutrient regimes of nearshore benthic communities (Figure 4.26). Finally, all project data and available countywide land use activity data were incorporated into a GIS database. Database queries and spatial analyses were conducted to explore relationships between land use activities, nearshore nutrient regimes, and nearshore benthic communities in the Florida Keys.

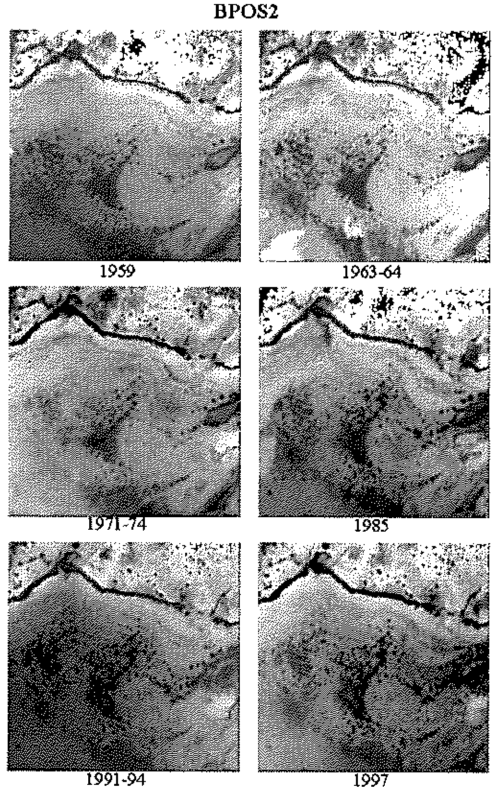
FIGURE 4.26
BENTHIC SAMPLING LOCATIONS NEAR MARATHON



The first working hypothesis, that nearshore benthic communities and their associated nutrient regimes exhibit spatial or temporal variation throughout the Florida Keys, was conclusively proven. Both nearshore benthic communities and their associated nutrient regimes do exhibit spatial variation throughout the Florida Keys. However, nearshore benthic communities exhibited very little temporal variation through the past 40 years, even in the face of tremendous land development in the Florida Keys. FIU's time series analyses of the black and white FDOT aerial photographs reveal very little change in the distribution of nearshore benthic communities in the Florida Keys since 1959 (Figure 4.27). There are no significant differences in the amount of Keys-wide benthic macrophyte cover with respect to time (1959-1997, six time steps), location (oceanside or bayside), or land use (heavily or slightly developed). However, there are clear differences in the magnitude and direction of the minimal changes detected with respect to study area. The mean temporal change at most Key Largo and Marathon sampling sites were positive, reflecting small net increases, while the mean temporal change at most Big Pine and Key West sampling sites were negative, reflecting slight net decreases. The results provided little evidence to support the hypothesis that there is a significant relationship between human land use activity and spatial or temporal variation of nearshore benthic communities and their associated nutrient regimes throughout the Florida Keys.

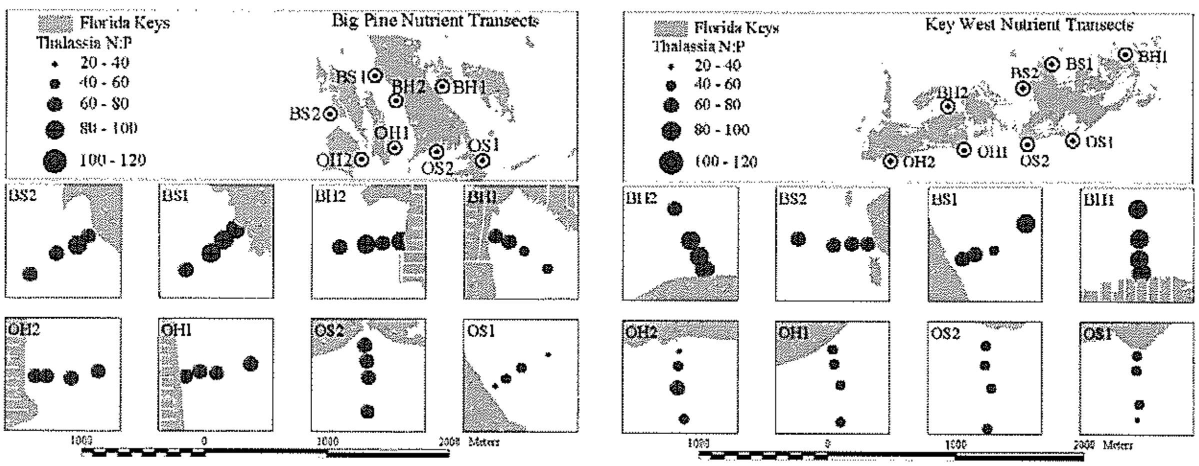
FIGURE 4.27
EXAMPLE TIME SERIES

BPOS2



Results indicate that substrate, not land use, is the most important factor associated with benthic community distribution and composition. Two modeling approaches identified potential relationships between a few individual taxa, taxa groups, nutrient parameters, and land use, but very few of these relationships are significant throughout the Florida Keys. Preliminary analyses of *Thalassia testudinum*, sediment, and epiphyte samples collected at 32 transects did not reveal any significant Keys-wide trends in nutrient parameters with respect to location (oceanside or bayside), distance from shore (50 meters, 100 meters, 250 meters, or 500 meters), or land use (heavily or slightly developed). However, maps of nutrient data revealed potential significant relationships may exist within study areas (Figure 4.28). Further spatial analyses showed no conclusive relationships. N:P were high in the vast majority of samples, corroborating other reports of a P-limited environment.

FIGURE 4.28
THALASSIA N:P RATIOS IN BIG PINE KEY AND KEY WEST



4.7.2 Direct Human Impacts on Marine Resources

Residents and tourists alike use the expansive waters of the FKNMS for boating, snorkeling, diving, and fishing. Each of these activities put people in direct contact with environmental resources and may significantly affect them. The study team's research focused on four types of direct impacts: propeller scarring, boat groundings, snorkeling and diving impacts, and fishing pressure. The main objective was to determine a quantitative and spatial relationship between land development activities, people, and impacts to the resources.

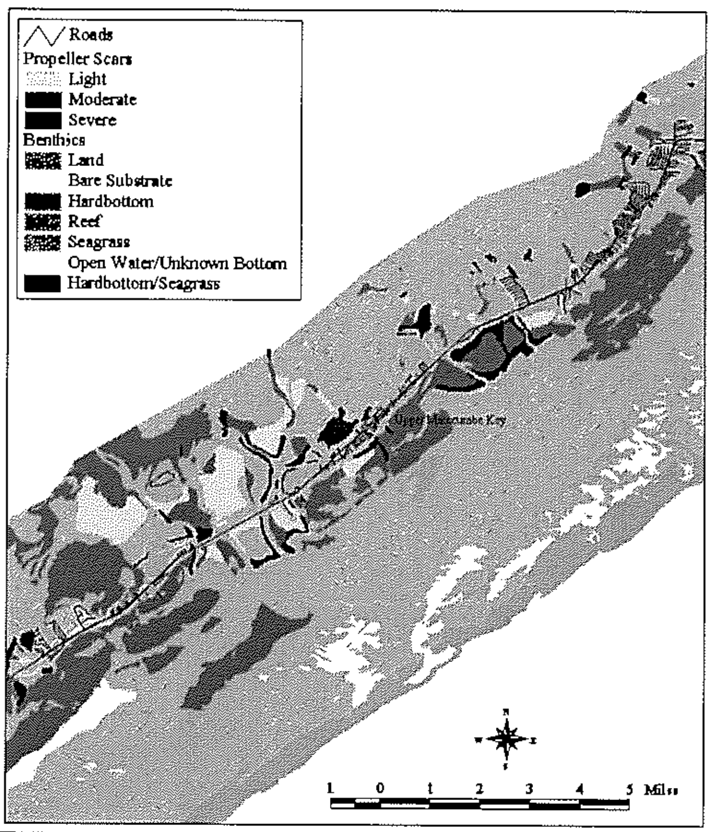
Propeller Scarring in Seagrasses and Boat Groundings on Coral Reefs

Initially, efforts concentrated in quantifying the volumes and sources of boat traffic within the study area. A review of the literature revealed that no comprehensive boat traffic study existed for the Florida Keys (Leeworthy 1998, Stolpe 1998, Matthews and Donovan 1992, FKNMS 1996; Kruer 1993).

Subsequently, the Technical Contractor evaluated aerial survey data for boat usage from both Florida Marine Research Institute (FMRI) and the National Marine Fisheries Service (NMFS). The NMFS Miami Laboratory, in conjunction with the United States Coast Guard Miami Air Station, has monitored vessel activity in the Sanctuary from 1992 to present. FMRI aerial fly-over/surface survey data, collected from June 1992 through August 1993, represents the most rigorous attempt to estimate utilization of the FKNMS to date. However, the FMRI survey includes data for only one year, which prevents any correlation analysis to development in the Florida Keys. In addition, Hurricane Andrew hit south Florida during the FMRI survey period. The NMFS survey data, though collected for nine years, does not measure the total number of boats. Therefore, neither dataset proved appropriate for establishing a connection between population and the number of boats utilizing the FKNMS.

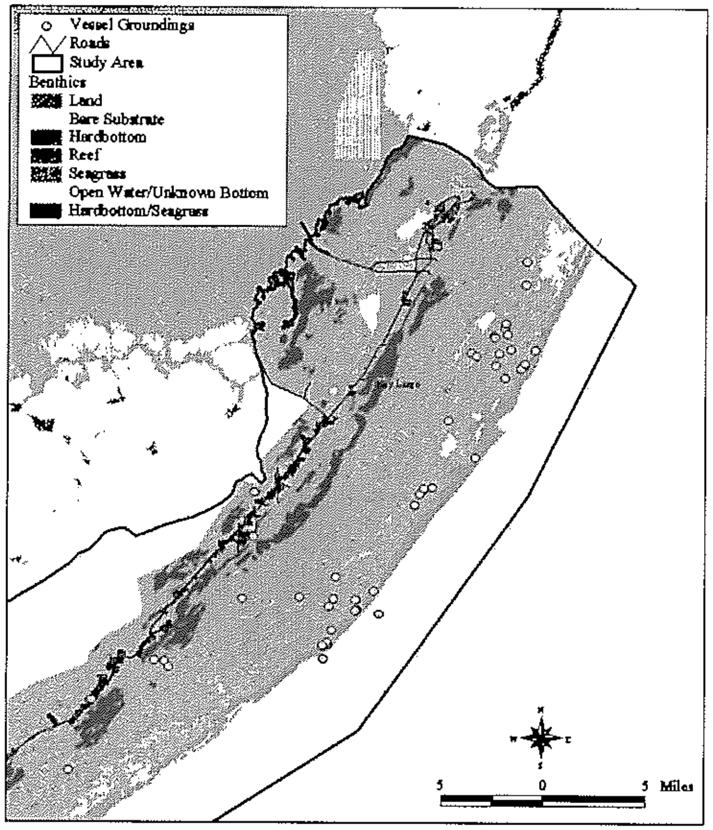
FMRI developed a seagrass scarring map (Sargent et al. 1995, see Figure 4.29) that classifies scars as light, moderate, or severe. Multiple regression analysis showed no significant correlation between the distribution of scars and a series of development surrogates, including development status of the nearest shore, location of marinas and boat ramps, location of navigational aids, and location of channels. The distribution of scarred seagrass areas was correlated with distance from shore (independently of shoreline type) and water depth. The conclusion was that, as expected, seagrass scarring occurs mainly in nearshore, shallow water.

FIGURE 4.29
PROPELLER SCARS MAPPED IN THE UPPER MATECUMBE AREA



In addition, FMRI maintains a spatial boat groundings database (Figure 4.30). As expected, boat groundings occur mainly near reef areas, and are more likely to occur in popular reef destinations.

FIGURE 4.30
FMRI BOAT GROUNDINGS DATA IN THE UPPER KEYS



Snorkeling and Diving Impacts on Coral

Recreational SCUBA diving causes damage to reefs at exponentially increasing rates as diving intensity increases (Hawkins and Roberts 1992). The total dive site area in the Florida Keys is 217 nautical square miles (Kearney and Centaur 1991). A third of the tourists in the Keys participate in scuba diving or snorkeling (Monroe County Tourist Development Council 1997-2001). Nearly 90 percent of the significant dive spots are located in the upper Keys and are popular because of their accessibility and the number of dive operations available.

A Florida study showed divers touched coral heads an average of seven times during a 30-minute interval, while five percent of divers have more than 20 incidents per 30-minute dive (Tagle 1990). Snorkellers generally stand on corals and stir up large amounts of sediment, but they usually have fewer contacts than scuba divers. Scuba divers generally touch corals when pushing off the substrate and when finning. Indicator species considered for diver damage were branching corals as opposed to massive corals (Paryente et al. 1999, Rouphael and Inglis 1995, Hawkins and Roberts 1992). However, sanctuary-wide coral monitoring data exists only for 4 years, rendering identification of long-term changes in coral densities difficult (Jaap et al. 2001). Diver damage to corals is unlikely to have major consequences for local coral populations, but may be substantive enough to affect the aesthetic appeal of the sites (Rouphael and Inglis 1995).

Recreational Fishing

Recreational fishing is an integral part of life in the Florida Keys. The study team spent a considerable amount of effort researching the relationship between development, population, recreational fishing effort and the status of the fisheries. The primary means by which development is likely to impact fisheries in the Florida Keys include direct fishing pressure, production of pollutants affecting fisheries, and destruction of essential habitat. Commercial fisheries were not rigorously considered because commercial fishing pressure is largely independent of residential and tourism development patterns. The number of commercial vessels in the Keys has remained almost constant since the early 1960s (Bohnsack et al. 1994).

Catch per unit effort (CPUE) commonly provides a measure of stock abundance, but other factors may also influence catch. Bohnsack 1994 point out that "better data are particularly needed for recreational fisheries although the task will be complex considering the number of participants, various modes of fishing (private boat, shore, bridges, guide boats, headboats, charter boats), the various species targeted (e.g., inshore flats, reefs, offshore trolling), and the various goals of individual participants (trophy fish, food, excitement, catch-and-release, 'just catch something')." Further complicating CPUE, are the changes due to a rapidly growing fishing power per vessel (Mace 1997). As a result, "catch per boat day" has a much different meaning than ten or even five years ago, rendering year-to-year comparisons questionable. CPUE evaluation is also complicated by the fact that guided services, including guide, charter, and head boats, are adept at altering fishing targets when CPUE weakens, in order to provide satisfaction to clients. For all these reasons, available CPUE data are difficult to use to predict impacts of land development activities.

Ault et al. (1997) suggested that the Florida Keys reef fish stocks exhibit classic overfishing patterns with more vulnerable species being progressively depleted (citing Munro and Williams 1985 and Russ and Alcala 1989), and that several reef fish stocks are overfished according to NOAA definitions (citing Rosenberg et al. 1996). However, these conclusions do not clarify quantitative relationships between land development and fishing pressure. A recent study by the FKNMS reported higher densities of several fish species occurring in no-take zones of Sanctuary Preservation Areas than in uncontrolled fishing areas, but this information was not quantitatively related to fishing pressure (NOAA 1998).

4.7.3 Quality of Life

Test results of the CCIAM can be contrasted with the ranking of quality of life issues identified through the Public Involvement and Information Program (PIIP). The mean ranks were divided by the smallest rank and values were grouped in categories from 1 to 3.5 (Table 4.20). Water quality and conservation of habitat obtained the highest rank. Water quality would tend to improve with the implementation of the stormwater and wastewater master plans, as indicated in the Smart Growth and Scenarios 1-5. The Smart Growth and Scenarios 1-5 also include the acquisition of lands for conservation, thereby providing for increased conservation.

TABLE 4.20
NORMALIZED RESULTS FROM THE COMMUNITY CHARACTER/ QUALITY OF LIFE ISSUES RANKING

Parameter	Relative Rank
Water Quality Protection/Improvement	1.0
Conservation of Existing Habitat	1.0
Maintain Current Community Character	1.5
Decrease Level of Traffic	1.5
More Land Use and Development Growth Controls	2.0
Affordable Housing	2.0
Improve Safety on U.S. 1	2.0
Strengthen Enforcement of Existing Government Regulations	2.0
Protection of Property Owner's Rights	2.0
Decrease Level of Tourism	2.0
Current Land Use and Development Growth Controls	2.5
Land Recreation Opportunities	2.5
Water Recreation Opportunities	2.5
Current Level of Tourism	2.5
Reduce Government Regulation	3.0
Less Land Use and Development Growth Controls	3.0
Increase Level of Tourism	3.5

5.0 DISCUSSION

5.1 TERRESTRIAL ECOSYSTEMS AND SPECIES

Land development in the Florida Keys has displaced nearly 50 percent of all upland habitats, as well as large areas of saltwater wetlands. Over 90 percent of the remaining uplands are distributed in patches of 10 acres or less. In the Florida Keys, upland patches of less than 13 acres are considered to have lost key ecological functions (Bancroft 1994). Small patches of forests show lower biodiversity, increased vulnerability to invasion by exotic plant and animal species and decreased gene flow within and among populations. Any further encroachment into areas dominated by native vegetation would exacerbate habitat loss and fragmentation. Development in the Florida Keys has surpassed the capacity of upland habitats to withstand further development.

The secondary and indirect effects of development further contribute to habitat loss and fragmentation. Little habitat remains unaffected by development's secondary effects. While difficult to quantify, indirect effects cause significant habitat degradation, especially on small patches of habitat. Any further development in the Florida Keys would exacerbate secondary and indirect impacts to remaining habitat.

Terrestrial habitats in the Florida Keys show a combination of tropical, Caribbean and temperate species that are unique to the U.S., which is exemplified by over 100 species that occur only in the Florida Keys. Habitat loss is likely the most important cause of species depletion in the area, resulting in the protected legal status of dozens of species of plants and animals. Virtually every native area in the Keys is potential habitat for one or more protected species. Two species endemic to the Lower Keys, the Lower Keys marsh rabbit and the silver rice rat, are highly restricted and likely could not withstand further habitat loss without facing extinction. The Key deer, while largely recovered from population numbers as low as 25 in the 1950s, has a restricted range and will continue to face threats to its viability if development occurs in prime habitat. In the Upper Keys, large tracts of uplands are already under government ownership, yet privately owned uplands are also potential habitat for protected species such as the Schaus swallowtail butterfly or the Key Largo woodrat. Throughout the Florida Keys, any further development of native habitats would likely negatively affect one or more protected species. Development in the Florida Keys has surpassed the capacity of several protected species to withstand the effects of further development activities.

Under current regulations, development suitability in the Florida Keys is extremely restricted. Besides privately owned parcels in infill locations or already disturbed areas, the vast majority of private lands face one or more development constraints. The FKCCS developability analysis was conservative in removing wetland parcels – over 50 percent of all private lands were removed largely due to this constraint. Development suitability was low or marginal for most of the remaining lands, due to open space requirements, lack of infrastructure or other factors.

Successful restoration of lands to create large patches of terrestrial habitats and to reestablish connectivity seems improbable. Restoration would require the conversion of large developed areas to native habitat, a goal that would face legal constraints, as well as high costs, uncertain probability of success, and a long timeframe for execution. Continuing and intensifying vacant land acquisition and restoration programs may provide more and faster returns in terms of consolidating protection of habitats in the Florida Keys.

5.2 INFRASTRUCTURE

The six future scenarios evaluated in the study call for a small amount of growth in the next 20 years – less than 10 percent growth in the number of dwelling units and population. Therefore, incremental pressures on infrastructure capacity are also moderate over a 20-year period. However, current conditions and the evaluation of future scenarios suggest that even small amounts of growth in the Florida Keys may place stringent demands on some infrastructure capacity.

The last two annual traffic studies for Monroe County (Monroe County 2001, 2002) have estimated a residential capacity of just over 6,000 units. Large year-to-year fluctuations on both traffic volumes and median speeds, even in the absence of significant development, introduce uncertainty to any future prediction of the levels of traffic on U.S.-1. The amount of growth evaluated in the future scenarios would likely result in changes in traffic within the observed recent fluctuations. In the absence of structural improvement to U.S.-1, the level of service will continue to be close to its state-mandated standard.

Similarly, hurricane evacuation clearance times would continue to increase as population increases, unless measures are taken to improvement evacuation conditions. Improvements to U.S.-1, while resulting in lower clearance times, would add to the government costs, nutrient loadings, and indirect impacts to wildlife and habitats.

Water withdrawals in the Florida Keys doubled from 1980 to 2000; they increased by 50% in the 1990s, even though development was restricted by ROGO. In the absence of effective water conservation or reuse measures, withdrawal is likely to continue to increase in the next 20 years. Permitted capacity has already been exceeded in 1999 and 2000, and model projections suggest that permit violations would continue to occur in the future scenarios. Alternative water supplies would help meet the needs for additional water. Interim measures, such as the continuous operations of two existing reverse osmosis plants (3 MGD) or the expansion of treatment facilities, would help cover demands in the short term. In the long-term, a desalination plant could meet a growing demand for water. Implementation of a desal plant would include choosing an appropriate location, as well as significant capital and maintenance costs.

5.3 SOCIOECONOMIC AND FISCAL

The six future scenarios evaluated in the FKCCS contemplate small increases in permanent population, which are unlikely to affect the overall socioeconomic structure of the Florida Keys.

The increase in the number of visitors contemplated in Scenario 3 would impose additional demands on tourist-related land uses, water supply, and recreation opportunities.

In contrast, the six future scenarios would result in a disproportionate increase in government expenditures with respect to the projected increase in population. Per capita annual expenditures are likely to increase in all the scenarios, creating immediate pressure for government to increase revenue. Tax increases on both the local population and visitors would likely occur.

5.4 MARINE ECOSYSTEMS AND SPECIES

The existing data are insufficient to establish quantitative, predictive relationships between land use or development and the marine environment. However, there is plenty of evidence of human effects on the marine ecosystems and species in the Florida Keys.

Seagrass scars, boat groundings, beach closings, coral collisions, and poor water quality in canals and other confined waters clearly expose the effects of humans on the marine environment. The CCIAM scenario analysis strongly argues for the benefits of wastewater treatment, but other impacts are more related to resource management than to land development. Recreational opportunities in the Florida Keys attract visitors from the Keys and beyond. Once in the Keys the impacts that boaters, fishermen, snorkellers, divers and others may have on the marine resources is largely related to their behavior.

5.5 IMPLEMENTATION OF THE FKCCS

The FKCCS will assist state and local government in making decisions regarding amendments to the Comprehensive Plan to ensure that future development does not exceed the capacity of the county's environment and marine systems to accommodate additional impacts.

The study and the CCIAM provide a comprehensive body of knowledge and an effective analysis tool to explore the carrying capacity consequences of development strategies in the Florida Keys.

The findings of the study suggest four main guidelines for future development in the Florida Keys:

1. Prevent encroachment into native habitat. A wealth of evidence shows that terrestrial habitats and species have been severely affected by development and further impacts would only exacerbate an already untenable condition.

2. Continue and intensify existing programs. Many initiatives to improve environmental conditions and quality of life exist in the Florida Keys. They include land acquisition programs, the wastewater and stormwater master plans, ongoing research and management activities in the Florida Keys National Marine Sanctuary, and restoration efforts throughout the Keys.

3. If further development is to occur, focus on redevelopment and infill. Opportunities for additional growth with small, potentially acceptable, additional environmental impacts may occur in areas ripe for redevelopment or already disturbed.

4. Increase efforts to manage the resources. Habitat management efforts in the Keys could increase to effectively preserve and improve the ecological values of remaining terrestrial ecosystems.

6.0 LITERATURE CITED

Ault, J.S., J.A. Bohnsack, and G.A. Meester. 1997. A retrospective (1979-1996) multispecies assessment of coral reef fish stocks in the Florida Keys. Fishery Bulletin 96(3): 395-414.

Avery, W.M. 1996. Status of naturally occurring and introduced *Halodule wrightii* in Hillsborough Bay. Pp 177-187 *In* Proceedings, Tampa Bay Area Scientific Information Symposium 3, October 21-23, Clearwater, Florida. Tampa Bay National Estuary Program and Tampa Bay Regional Planning Council.

Bancroft, G.T., A.M. Strong, and M. Carrington. 1995. Deforestation and its effects on forest-nesting birds in the Florida Keys. Conservation Biology. 9:835-844.

Bureau of Economic and Business Research. 2000. *Florida Statistical Abstract.* Gainesville, Florida: University of Florida.

Beck, A. 1973. The Ecology of Stray Dogs; A Study of Free-Ranging Urban Animals. York Press. Baltimore, Maryland.

Bohnsack, J.A., D.E. Harper, and D.B. McClellan. 1994. Fisheries trends from Monroe County, Florida. Bulletin of Marine Science 54(3): 982-1018.

Boyer, J.N., J.W. Fourqurean, and R.D. Jones. 1997. Spatial characterization of water quality in Florida Bay and Whitewater Bay by multivariate analyses: zones of similar influence. Estuaries 20(4): 743-758.

Boynton, W.R., J.D. Hagy, L. Murray, C. Stokes, and W.M. Kemp. 1996. A comparative analysis of eutrophication patterns in a temperate coastal lagoon. Estuaries 19(2B): 408-421.

Bricker, S.B. and J.C. Stevenson. 1996. Nutrients in coastal waters: a chronology and synopsis of research. Estuaries 19 (2B): 337-341.

Brown, M.T. and J.M. Schaefer. 1987. Buffer zones for Water, Wetlands, and Wildlife. A Final Report on the Evaluation of the Applicability of Upland Buffers for the Wetlands of the Wekiva Basin. Center for Wetlands, University of Florida. 163 pp.

Brown, M.T., J.M. Schaefer, and K.H. Brandt. 1990. Buffer zones for water, wetlands, and wildlife in the East Central Florida Region. Report prepared for the East Central Florida Regional Planning Council, Winter Park, Florida. (CFW-89-07). University of Florida, Center for Wetlands. Gainesville, Florida.

Brown, M.T. and J. Orell. 1995. Tomoka River and Spruce Creek Riparian Habitat Protection Zone. Final Report for St. John's River Water Management District. University of Florida, Center for Wetlands. Gainesville, Florida. 77 pp.

CH2M HILL. 2000. Monroe County Sanitary Wastewater Master Plan. Marathon, Florida: Monroe County Growth Management Division.

City of Monterey Park, Planning Division. 2001. Draft Environmental Impact Report. http://ci.monterey-park.ca.us/cdd/planning/env_report/index.html.

Covell, C.V., Jr. 1976. The Schaus swallowtail: a threatened subspecies? Insect World Digest 3(59):21-26.

Connecticut River Joint Commissions. 2000. Riparian Buffers for the Connecticut River Watershed. http://www.crjc.org/riparianbuffers.htm. Charleston, New Hampshire.

Cox and Kautz. 2000. Habitat conservation needs of rare and imperiled wildlife in Florida.

Dawes, C.J. and D.A. Tomasko. 1988. Depth distribution of *Thalassia testudinum* in two meadows on the West Coast of Florida; a difference in effect of light availability. Marine Ecology 9(2): 123-130.

den Hartog, C. and P.J.G. Polderman. 1975. Changes in the seagrass populations of the Dutch Waddenzee. Aquatic Botany 1: 141-147.

Dennison, W.C. 1987. Effects of light on seagrass photosynthesis, growth, and depth distribution. Aquatic Botany 27: 15-26.

Dennsion, W.C. 1990. Photosynthetic and growth responses of tropical and temperate seagrasses in relation to Secchi depth, light attenuation, and daily light period. Pp 82-87 *In* Kenworthy, W.J. and D.E. Haunert (eds.) Results and Recommendations of a Workshop Convened to Examine the Capability of Water Quality Criteria, Standards and Monitoring Programs to Protect Seagrasses from Deteriorating Water Transparency. November 7-8, South Florida Water Management District. West Palm Beach, Florida.

Duarte, C.M. 1991. Seagrass depth limits. Aquatic Botany 40: 363-377.

Duarte, C.M. 1995. Submerged aquatic vegetation in relation to different nutrient regimes. Ophelia 41: 87-112.

Durako, M.J. 1995. Indicators of seagrass ecological condition: an assessment based on spatial and temporal changes. Pp 261-266 *In* Dyer, K.R. and R.J. Orth (eds.) Changes in Fluxes in Estuaries: Implications for Science to Management. Olsen and Olsen, Fredensborg, Denmark.

Durako, M.J., J.W. Fourqurean, C.A. Moncreiff, P.R. Carlson, and G. McRae. 1997. Multiscale assessment of the population status of *Thalassia testudinum* (Turtle Grass): a new approach to ecosystem assessment. A Proposal. 13 p. http://www.fiu.edu/~crose01/pages/epa.html.

Emmel, T.C. 1985. Status survey of the Schaus swallowtail in Florida in 1984. Technical report No. 145, Florida Cooperative Fish and Wildlife Research Unit, University of Florida; Gainesville, Florida.

Emmel, T.C. 1995a. Designated species management plan for the reintorduction of the Schaus swallowtail butterfly in the Florida Keys. University of Florida, Gainesville, Florida.

Emmel, T.C. 1995b. Captive propagation and experimental reintroduction of the Schaus swallowtail in the Florida Keys. Interim status report submitted to the U.S. Fish and Wildlife Service, Research Work Order No. 153; Vero Beach and Jacksonville, Florida.

Environmental Laboratory. 1987. U.S. Army Corps of Engineers Wetland Delineation Manual. Technical Report Y-87-1, U.S. Army Engineer Waterways Experiment Station; Vicksburg, Mississippi. (p.77).

First American Realty Solutions. 2001. Aerial and Map Atlas, 36th Edition. Monroe County, Florida. Pp. 1-40.

Florida Division of Forestry. 1979. Silviculture Best Management Practices Manual. Florida Department of Agriculture and Consumer Services, Division of Forestry, Collins Building. Tallahassee, Florida.

Forys, E.A., P.A. Frank, and R.S. Kautz. 1996. Recovery Actions for the Lower Keys marsh rabbit, silver rice rat, and Stock Island tree snail. Unpublished report to Florida Game and Fresh Water Fish Commission, Tallahassee, Florida, Cooperative Agreement No. 1448-0004-94-9164. Tallahassee, Florida.

Forys, E.A. and S.R. Humphrey. 1994. Biology of the Lower Keys marsh rabbit at Navy lands in the Lower Florida Keys. Semi-annual performance report No. 3 in the files of the Florida Game and Freshwater Fish Commission: Tallahassee, Florida.

Forys, E.A. and S.R. Humphrey. 1996. Home range and movements of the Lower Keys marsh rabbit in a highly fragmented habitat. Journal of Mammalogy, 77: 1042:1048.

Forys, E.A. and S.R. Humphrey 1999. Use of population viability analysis to evaluate management option for the endangered lower Keys marsh rabbit. Journal of Wildlife Management, 63:251-260.

Frankovich, T.A. and J.W. Fourqurean. 1997. Seagrass epiphyte loads along a nutrient availability gradient, Florida Bay, U.S.A. Marine Ecology Progress Series 159: 37-50.

Giesen, W.B.J.T., M.M. van Katijk, and C. den Hartog. 1990. Eelgrass condition and turbidity in the Dutch Wadden Sea. Aquatic Botany 37: 71-85.

Hall, M.O., D.A. Tomasko, and F.X. Courtney. 1990. Responses of *Thalassia testudinum* to *in situ* light reduction. Pp 53-58 *In* Kenworthy, W.J. and D.E. Haunert (eds.) Results and Recommendations of a Workshop Convened to Examine the Capability of Water Quality Criteria, Standards and Monitoring Programs to Protect Seagrasses from Deteriorating Water Transparency. November 7-8, South Florida Water Management District. West Palm Beach, Florida.

Hall, M.O., D.A. Tomasko, and F.X. Courtney. 1991. Responses of *Thalassia testudinum* to *in situ* light reduction. Pp. 85-94 *In* Kenworthy, W.J. and D.E. Haunert (eds.) The Light Requirements of Seagrasses. National Oceanic and Atmospheric Administration Technical Memorandum, NMFS-SEFC-287. Washington, D.C.

Hall, M.O., M.J. Durako, J.W. Fourqurean, and J.C. Zieman. 1999. Decadal changes in seagrass distribution and abundance in Florida Bay. Estuaries 22(2B): 445-459.

Hawkins, J.P. and C.M. Roberts. 1992. Can Egypt's Coral Reefs Support Ambitious Plans for Diving Tourism? Pp 1007-1013 *In* Proceedings of the Seventh International Coral Reef Symposium, Volume 2. University of Guam, Marine Laboratory. Mangilao, Guam.

Inter-Governmental Cuba Committee. 2000. Inter-Governmental Cuba Report. Key West, Florida.

Jaap, W.C., J.W. Porter, J. Wheaton, K. Hackett, M. Lybolt, M.K. Callahan, C. Tsokos, and G. Yanev. 2001. U.S. Environmental Protection Agency/ Florida Keys National Marine Sanctuary Coral Reef Monitoring Project Updated Executive Summary 1996-2000. Steering Committee Meeting August 1, 2001.

Janzen, D.H. 1986. The external threat. *In* M.E. Soulé (ed.) Conservation biology: The science of scarcity and diversity. Sinauer Associates, Inc., Sunderland, Massachussetts.

Johansson, J.O.R. 1996. Seagrass in Tampa Bay: historic trends and future expectations. Pp 139-150 *In* Proceedings of the Tampa Bay Area Scientific Information Symposium 3, October 21-23, Clearwater, Florida. Tampa Bay National Estuary Program and Tampa Bay Regional Planning Council.

Karr, J.R. and I.J. Schlosser. 1977. Impact of nearstream vegetation and stream morphology on water quality and stream biota. U.S. Environmental Protection Agency, Environmental Research Lab, Office of Resources and Development. Athens, Georgia.

Kearney and Centaur. 1991. Impacts of Oil and Gas Development on the Recreation and Tourism Off the Florida Straits. U.S. Department of the Interior, Minerals Management Service, Atlantic OCS Division, OCS Study MMS91-0039.

Keller, B.D. and A. Itkin. 2002. Shoreline Nutrients and Chlorophyll *a* in the Florida Keys, 1994-1997: A Preliminary Analysis. *In*: J.W. Porter and K.G. Porter (Eds.), The Everglades, Florida Bay, and coral reefs on the Florida Keys: An ecosystem sourcebook (pp. 649-658). Boca Raton: CRC Press, 2002.

Kenworthy, W.J., M.S. Fonseca, and S.J. DiPiero. 1990. Defining the ecological light compensation point for seagrasses in *Halodule wrightii* and *Syringodium filiforme* from long-term submarine light regime monitoring in the southern Indian River. Pp 67-70 *In* Kenworthy, W.J. and D.E. Haunert (eds.) Results and Recommendations of a Workshop Convened to Examine the Capability of Water Quality Criteria, Standards and Monitoring Programs to Protect Seagrasses from Deteriorating Water Transparency. November 7-8, South Florida Water Management District. West Palm Beach, Florida.

Klein, M.L. 1989. Effects of high levels of human visitation on foraging waterbirds. Journal of Wildlife Management.

Kruczynski, W.L. and F. McManus. 2002. Water quality concerns in the Florida Keys: sources, effects, and solutions. *In*: J.W. Porter and K.G. Porter (Eds.), The Everglades, Florida Bay, and coral reefs on the Florida Keys: An ecosystem sourcebook (pp. 827-881). Boca Raton: CRC Press, 2002.

Kruer, C.R. 1993. Mapping Assessment of Vessel Damage to Shallow Seagrasses in the Florida Keys. A Report to the Florida Department of Natural Resources and the University of South Florida/Florida Institute of Oceanography. F.I.O. Contract # 47-10-123-L3. Summerland Key, Florida.

Kruer, C.R., T. Armstrong, and P. Braisted. 2000. Invasive Exotic Vegetation Mapping in the Florida Keys – 1996. The Florida Keys Invasive Exotics Task Force.

Lapointe, B.E. and M.W. Clark. 1992. Nutrient inputs from the watershed and coastal eutrophication in the Florida Keys. Estuaries 15(4): 465-476.

Lapointe, B.E., D.A. Tomasko, and W.R. Matzie. 1994. Eutrophication and trophic state classification of seagrass communities in the Florida Keys. Bulletin of Marine Science 54(3): 696-717.

Ledwith, T. 1996. The effects of buffer strip width on air temperature and relative humidity in a stream riparian zone. Watershed Management Council Networker, Summer 1996 Volume 6(5).

Lee, T.N., E. Williams, E. Johns, D. Wilson, and N.P. Smith. Transport Processes Linking South Florida Coastal Ecosystems. *In*: J.W. Porter and K.G. Porter (Eds.), The Everglades, Florida Bay, and coral reefs on the Florida Keys: An ecosystem sourcebook (pp.309-342). Boca Raton: CRC Press, 2002.

Leeworthy, V.R. 1998. Review of Florida Marine Research Institute aerial fly-over methods for estimating the number and type of users in the specially protected areas and ecological reserves of the Florida Keys National Marine Sanctuary.

Livingston, R.J. 2000. Eutrophication Processes in Coastal Systems. CRC Press. New York, New York. 327 p.

Lopez, R. R. 2001. Population ecology of Florida Key deer. Ph.D. Dissertation, Texas A&M University, College Station, Texas. 203pp.

Mace, P. 1997. Developing and sustaining would fishery resources: state of science and management. Pp 1-20 *In* Hancock, D.A., D. Smith, A. Grant, and J.P. Beumer (eds.) Developing and sustaining world fisheries resources: the state of science and management, Proceedings of the Second World Fishery Congress. Brisbane, Australia.

Matthews, T. and P. Donovan. 1992. Estimating Utilization of Florida Keys National Marine Sanctuary Using Aerial Surveys. A Proposal. Florida Marine Research Institute and The Nature Conservancy. Marathon, Key West, Florida.

Miller Consulting, Inc. 2001. Florida Keys Hurricane Evacuation Study Final Report. Contract No. C7391. Miami, Florida: FDOT, District 6.

Miller, R.E., Jr. and B.E. Gunsalus. 1997. Wetland Rapid Assessment Procedure. South Florida Water Management District. Technical Publication REG-001.

Monroe County Public Facility Capacity Assessment Report for 2001. Monroe County, Division of Growth Management.

Monroe County Year 2010 Comprehensive Plan, Technical Document. Marathon, Florida: Monroe County Growth Management Division, 1993.

Mueller, R. 2001. Personal Communication. Florida Marine Research Institute, St. Petersburg, Florida.

Munro, J.L. and D.M. Williams. 1985. Assessment and management of coral reef fisheries: biological, environmental, and socio-economic aspects. Pp. 544-578 *In* Proceedings of the Fifth International Coral Reef Congress, Tahiti 4.

National Research Council, Division on Earth and Life Sciences, Ocean Studies Board and Water Science Technology Board, Committee to Review the Florida Keys Carrying Capacity Study, 2002. A Review of the Florida Keys Carrying Capacity Study.

National Oceanic and Atmospheric Administration. 1988. Florida Keys National Marine Sanctuary Zone Performance Report – Year 1. Florida Department of Environmental Protection, and Florida Keys National Marine Sanctuary. http://www.fknms.nos.noaa.gov/ research_monitoring/zpr98.pdf.

Onuf, C. 1990. Light requirements of *Halodule wrightii, Syringodium filiforme,* and *Halophila englemannii* in a heterogeneous and variable environment inferred from long-term monitoring. Pp. 59-66 *In* Kenworthy, W.J. and D.E. Haunert (eds.) Results and Recommendations of a Workshop Convened to Examine the Capability of Water Quality Criteria, Standards and Monitoring Programs to Protect Seagrasses from Deteriorating Water Transparency. November 7-8, South Florida Water Management District. West Palm Beach, Florida.

Orth, R.J. and K.A. Moore. 1983. Chesapeake Bay: an unprecedented decline in submerged aquatic vegetation. Science 222: 51-53.

Palone, R. and A.H. Todd. 1997. Determining Buffer Width. Chapter 6. In: Chesapeake Bay Riparian Handbook: A Guide for Establishing and Maintaining Riparian Forest Buffers. U.S. Forest Service NA-TP-02-97. http://www.chesapeakebay.net/pubs/subcommittee/nsc/ forest/sect06.pdf.

Paryente, M., I. Alleson, and S. Kronick. 1999. A comparative study of SCUBA divers on the coral reefs of Eilat, Isreal: 1996 & 1999. Arava Institute for Environmental Studies. http://www.arava.org/Info_Center/Student_Projects/scuba_divers/scuba_divers.html.

Ranney, J.W., M.C. Bruner, and J.B. Levenson. 1981. The importance of edge in the structure and dynamics of forest islands. Pp: 67-95 *In* R.L. Burgess and D.M. Sharpe (eds.) Forest Island Dynamics in Man-Dominated Landscapes. Springer-Verlag. New York, New York.

Rodgers, J.A. and H.T. Smith. 1995. Set-back distances to protect nesting bird colonies from human disturbances in Florida. Conservation Biology 9:89-99.

Rodgers, J.A. and H.T. Smith. 1997. Buffer zone distances to protect foraging and loafing waterbirds from human disturbances in Florida. Wildlife Society Bulletin 25(1): 139-145.

Rosenberg, A., P. Mace, G. Thompson, G. Darcy, W. Clark, J. Collie, W. Gabriel, P. Goodyear, A. MacCall, R. Methot, J. Powers, V. Restrepo, T. Wainwright, L. Botsford, J. Hoenig, and K. Stokes. 1996. Scientific review of definitions of overfishing in U.S. fishery management plans. National Oceanic and Atmospheric Administration Technical Memorandum NMFS-F/SPO-17. 205 p.

Ross, M.S., J.J. O'Brien, and L.S.L. Sternberg. 1994. Sea level rise and the reduction in pine forests in the Florida Keys. Ecology, 4:144-156.

Rouphael, T. and G. Inglis. 1995. The effects of qualified recreational SCUBA divers on coral reefs. CRC Reef Research Center, Technical Report No. 4. Townsville, Australia. ISBN 1 876054 03 4.

Russ, G.R. and A.C. Alcala. 1989. Effects of intense fishing pressure on an assemblage of coral reef fishes. Marine Ecology Progress Series 56: 13-27.

Rutkowski, F. 1971. Observations on *Papilio aristodemus ponceanus* (Papilionidae). Journal of Lepidopterists' Society 25(2):126-136.

Sand-Jensen, K.A.J. 1977. Effect of epiphytes on eelgrass photosynthesis. Aquatic Botany 3: 55-63.

Short, F.T. 1987. Effects of sediment nutrients on seagrasses: literature review and mesocosm experiment. Aquatic Botany, 27: 41-57.

Silberstein, K., A.W. Chiffings, and A.J. McComb. 1986. The loss of seagrasses in Cockburn Sound, Western Australia. III. The effect of epiphytes on productivity of *Posidonia australis*. Aquatic Botany 24: 355-371.

Silvy, N.J. 1975. Population density, movements and habitat utilization of Key deer, *Odocoileus virginianus clavium*. Ph.D. Dissertation, Southern Illinois University, Carbondale, 152 pp.

Smith, N.P. and P.A. Pitts. 2002. Regional-scale and long-term transportation patterns in the Florida Keys. *In*: J.W. Porter and K.G. Porter (Eds.), The Everglades, Florida Bay, and coral reefs on the Florida Keys: An ecosystem sourcebook (pp. 343-360). Boca Raton: CRC Press, 2002.

Spackman, S.C. and J.W. Hughes. 1995. Assessment of minimum stream corridor width for biological conservation: Species richness and distribution along mid-order streams in Vermont. USA Biological Conservation 71:325-332.

St. John's River Water Management District. 1999. Applicant Handbook: Management and Storage of Surface Waters.

Stevenson, J.C., L.W. Staver, and K.W. Staver. 1993. Water quality associated with survival of submersed aquatic vegetation along an estuarine gradient. Estuaries 16(2): 346-361.

Stolpe, N.E. 1998. National Recreational Boating Patterns. *In* Crawford, R.E., N.E. Stolpe, M.J. Moore (eds.) The Environmental Impacts of Boating; Proceedings of a Workshop held at Woods Hole Oceanographic Institution, Woods Hole Massachussetts, U.S.A., December 7 to 9, 1994. Technical Report WHOI-98-03, Woods Hole Oceanographic Institution. Woods Hole, Massachussetts.

Strong, A.M. and G.T. Bancroft. 1994. Postfledging Dispersal of White-crowned Pigeons: Implementations for Conservation of Deciduous Seasonal Forests in the Florida Keys. Conservation Biology 8:770-779.

Stumpf, R.P., M.L. Frayer, M.J. Durako, and J.C. Brock. 1999. Variations in water clarity and bottom albedo in Florida Bay from 1985 to 1997. Estuaries 22(2B): 431-444.

Sullivan, K.M., M. Chiappone, and C. Lott. 1996. Controversies and conservation issues. Site Characterization for the Florida Keys National Marine Sanctuary and Environs. The Preserver, Zenda, Wisconsin.

Tagle, H. 1990. Impact of recreational divers on coral reefs in the Florida Keys. p 365-373 *In* Proceedings of the Underwater Sciences Tenth Annual Scientific Symposium. University of South Florida. St. Petersberg, Florida.

Tassone, J.F. 1981. Utility of hardwood leave strips for breeding birds in Virginia's central piedmont. MS Thesis. Virginia Polytechnic and Institute and State College. Blacksburg, Virginia. 83 pp.

Tjaden, R.L. and G.M. Weber. 1997. Riparian Buffer Management: Riparian Forest Buffer Design, Establishment and Maintenance. http://www.agnr.umd.edu/ces/pubs/html/fs725/ fs725.html.

Tomasko, D.A. and B.E. Lapointe. 1991. Productivity and biomass of *Thalassia testudinum* as related to water column nutrient availability and epiphyte levels: field observations and experimental studies. Marine Ecology Progress Series 75: 9-17.

Tomasko, D.A., C.J. Dawes, and M.O. Hall. 1996. The effects of anthropogenic nutrient enrichment on Turtle Grass (*Thalassia testudinum*) in Sarasota Bay, Florida. Estuaries 19(2B): 448-456.

Triquet, A.M., G.A. McPeek, and W.C. McComb. 1990. Songbird diversity in clearcuts width and without a riparian buffer strip. Journal of Soil and Water Conservation 45:500-503.

U.S. Census Bureau, American Fact Finder. 2002. http://factfinder.census.gov/servlet/ BasicFactsServlet.

U.S. Fish and Wildlife Service. 1982. Schaus swallowtail butterfly recovery plan. U.S. Fish and Wildlife Service; Atlanta, Georgia.

U.S. Fish and Wildlife Service. 1999. Multi-Species Recovery Plan for the Threatened and Endangered Species of South Florida. http://southeast.fws.gov/wildlife/vbms.html.

Van der Zande, A.N., W.J. der Keurs, and W.J. van der Weijden. 1980. The impacts of roads on the densities of four bird species in an open field habitat: evidence of a long-distance effect. Biological Conservation 18: 299-321.

Warner, R. 1985. Demography and movements of free-ranging cats in rural Illinois. Journal of Wildlife Management. 49:340-346.

Wetzel, R.L. and P.A. Penhale. 1983. Production ecology of seagrass communities in the lower Chesapeake Bay. Marine Technology Society Journal 17: 22-31.

Wilcove, D.S., C.H. McLellan, and A.P.Dobson. 1986. Habitat fragmentation in the temperate zone. *In* M.E. Soulé (ed.) Conservation biology: The science of scarcity and diversity. Sinauer Associates, Inc., Sunderland, Massachussetts.

Witherington, B.E. and R.E. Martin. 2000. Understanding, assessing, and resolving light-pollution problems on sea turtle nesting beaches. 2nd rev. ed. Florida Marine Research Institute Technical Report TR-2. 73 pp.