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Developing a Geographic Information System for Florida's Aquatic Preserves

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EXECUTIVE SUMMARY

A geographic information system (GIS) is a computer based technology composed of hardware, software and data used to capture, edit, display and, most important, analyze geographic information (Lang 1988). The Rookery Bay National Estuarine Research Reserve first became involved in GIS technology in 1985 when the Reserve was chosen as a site for a Department of Natural Resources demonstration project using Earth Resources Data Analysis Systems (ERDAS) software and LANDSAT satellite images. This report describes how to establish a GIS that can be used to help manage the natural resources of Florida's Aquatic Preserves.

The recommended hardware for aquatic preserve GISes includes a 386 generation computer, RGB high resolution graphics monitor, standard color or black and white monitor, dot matrix printer and color ink jet printer. Their are numerous software systems available. Some controversy exits over which system is most preferred.

The Rookery Bay GIS consists of a base image, overlays and database files. Sixteen overlays have been created for the GIS. Each represents a different piece of information concerning the study area. A database link that allows digital data from dbase files to be displayed in the GIS accesses data from the parameters sampling dates and stations of the Reserve's environmental monitoring program.

Applying GIS information to management problems has provided a link between scientific and land use information that is

revolutionizing our ability to manage coastal areas. The ability to combine different data sets within the GIS allows the user to look at the affects of activities on the land or water, assess the present status of an area and, with sufficient information in the GIS, conduct a basic modeling to simulate conditions that would occur if a change or series of changes is made in an area.

Nine applications of information using the Rookery Bay GIS have been conducted in the past year as part of cooperative efforts between DNR and other governmental agencies. These demonstration projects for other sites have provided management information to the agencies and have served as a valuable learning tool for developing (GIS) applications.

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INTRODUCTION

A geographic information system (GIS) is a computer based technology composed of hardware, software and data used to capture, edit, display and, most important, analyze geographic information (Lang 1988). The first GISes were developed about 20 years ago to manage large collections of natural resource and environmental information (Dangermond 1986). Since their development they have been used in other areas such as utilities mapping, inventory management and land use planning. However, one of their most important functions continues to be in the area of natural resource management.

The Rookery Bay National Estuarine Research Reserve first became involved in Geographic Information System technology in 1985 when the Reserve was chosen as a site for a Department of Natural Resources (DNR) demonstration project using Earth Resources Data Analysis System (ERDAS) software and LANDSAT satellite images. In the first year hardware and software were installed at the Reserve and staff was trained in the handling and ground truthing of LANDSAT images. In year two, the Reserve developed an environmental monitoring program for use in other aquatic preserve sites (Thoemke and Gyorkos 1988). The work from this year's study links the satellite imaging information with the data collected from monitoring activities, other maps and images and additional land use information to create a Geographic Information System for Rookery Bay.

The need for a system to manage and interpret geographic and land use information and scientific data is of crucial importance

to aquatic preserve and other natural resource managers in Florida. Informed and proper managemnet of our coastal resources is mandatory due to the pressures man has exerted on the land. The fact that Florida's population is growing at nearly 800 people per day; 78% of Florida's 12,000,000 residents live in the states coastal zone; 60,000 acres of estuarine habitat have been lost in Florida to dredge and fill activities; and at least 70% of the commercially and recreationally important fish and shellfish in Florida depend on estuaries illustrates the importance of carefully managing these natural resources.

Many of the state's aquatic preserves are located in the coastal areas of Florida that are presently experiencing these development pressures. Preservation of economically important natural resources such as estuaries appears to be on a collision course with development of these areas. One goal of the aquatic preserve program is to balance the inevitable development with a reasonable plan to preserve the natural functioning of these systems. Managers of aquatic preserves need to know the present status of the systems they manage and the history of the alterations to the estuary and its watershed. They also need to monitor changes in present conditions and be able to model the effect of future impacts on the systems.

To accomplish the complex task of understanding and managing an estuarine system managers need to have a variety of information available in an easily usable form. Information such as water quality data, land uses, drainage patterns and vegetation maps are some of the types of information necessary to

understand and manage the coastal zone. The use of GISes is an excellent means by which to organize, collect and interpret this information in an easy to use fashion.

The results of this study show that a GIS can be developed for aquatic preserve sites in Florida. This report will discuss how to establish a GIS, what types of computer hardware and software are needed and demonstrate, through examples from the Rookery Bay and Ten Thousand Islands areas, how the staff at Rookery Bay developed the GIS for this area.

It was originally intended to develop two separate reports from this work, one to report on the Rookery Bay and Cape Romano Ten Thousand Island Aquatic Preserve GIS and its implications to coastal zone management and the other to describe how to create a GIS. To prevent necessary repetition of information this final report combines both of these tasks into one report.

Based on the information learned from this study we feel that the present structure of regional aquatic preserve offices should have the necessary computer hardware and software to establish a GIS for each region. Presently this could be done with a modest investment of money and staff. The result of establishing GIS systems for aquatic preserves will, over the long term, result in an improved ability to manage these systems which will be reflected in increased efficient use of staff time and resources. This should translate into a savings of money for each regional office without sacrificing the quality of information available. If anything it should enhance the amount of information available to the staff and suggest improved ways for managing these important coastal resources.

SETTING UP A GIS

HARDWARE

There is no industry standard hardware for a GIS. However, certain considerations should be taken into account when setting up a GIS. For applications that can be used in the field offices of the aquatic preserve the best available computer at this time appears to be a 386 generation computer such as the Compaq 386. The computer should have a clock speed of 20-25 megahertz and have a minimum 160 megabyte storage system. Establishing a GIS on a less sophisticated computer will work. An AT generation machine can be used. The major shortcoming is the increased processing time due to the slower clock speed.

A GIS system requires two monitors. A standard color or black and white monitor is necessary to display and enter commands and data. An RGB high resolution graphics monitor is necessary to display the satellite images and overlays. A graphics board such as Number Nine Revolution or Ventura 1024 is necessary to drive the RGB monitor.

Two printers are necessary for the GIS system. The first is a standard dot matrix, daisy wheel or laser printer. A color ink jet printer that can produce the color maps that are part of any GIS system is also required.

Total cost for the hardware ranges from $15,000-20,000 depending upon the type of computer, monitors and printers purchased. This price is based on 1988 dollars and most likely

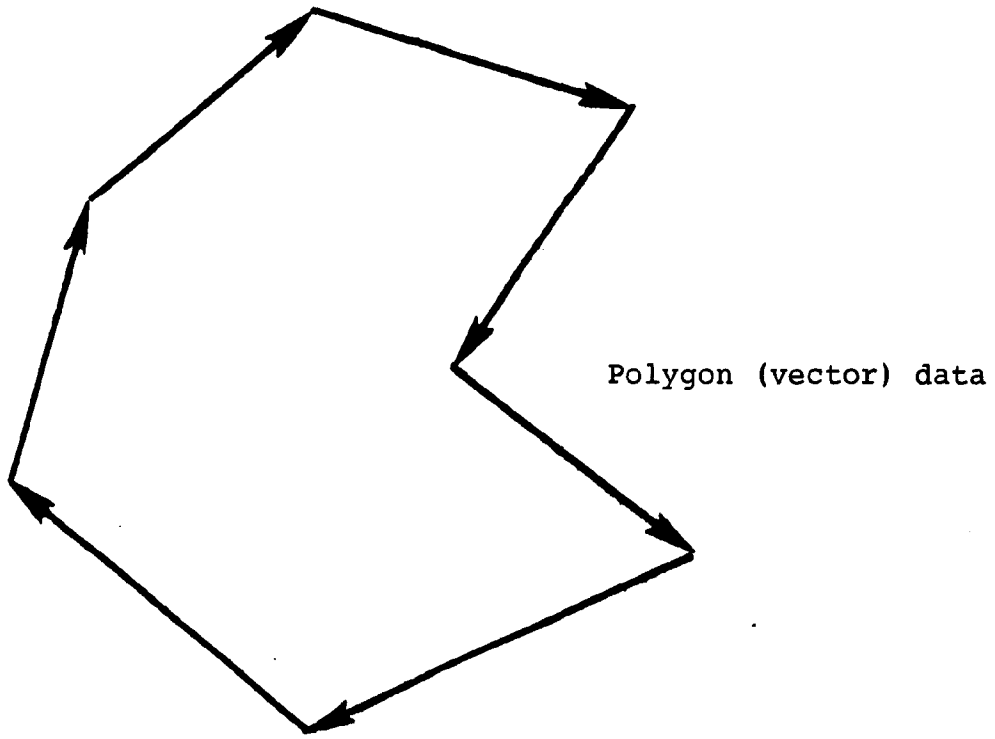
will change as the hardware changes and new equipment is developed.

SOFTWARE

A critical choice in establishing a GIS is the type of software chosen to operate the system. Their are at least 12 companies that produce true GIS software packages (Lang 1988). New companies are forming every year. Regardless of the software purchased, it must be capable of two functions in order to be useful. First the software must be capable of producing cartographic output (i.e. the ability to produce maps and overlays). Second it must have the ability to access and display data base files with the cartographic output.

Processing and display of images and overlays can be accomplished in two ways. An area on a satellite image or map can be described as the area within a polygon that is drawn by a series of vectors or as a series of discrete units of specified size that make up the area (Figure 1). The former is refered to as polygon or vector data and the latter is known as raster data. Among GIS users there is considerable debate as to which system is superior.

The data base link allows digital data to be displayed with the images, maps and overlays. Each software program has its own way of displaying this information on the monitor screen. The information is usually refered to as attributes. For example, the data base link permits the user to integrate water quality data with the drainage canal location overlay to examine the effect of canals on water quality.



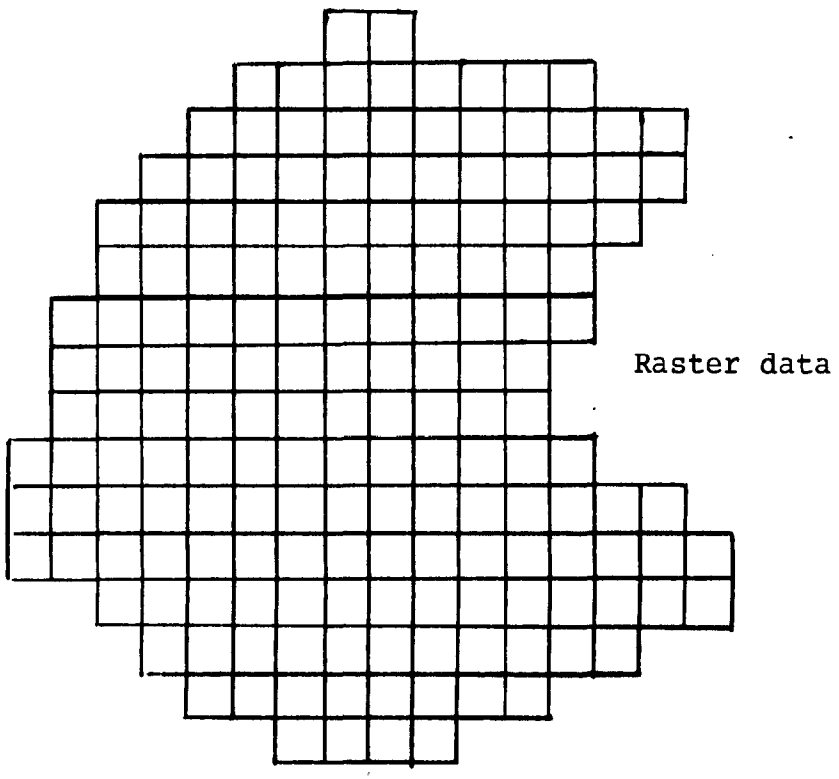


Fig. 1 Generalized illustration of the differences by which an area can be drawn using polygon and raster data processing systems.

The Rookery Bay GIS is a raster data system. It uses ERDAS software to work with the LANDSAT images and to create the overlays. The ability to link data base files is accomplished with Earth Resource Laboratory Software (ELAS) modified for the personal computer. ELAS was originally a mainframe software system developed by NASA as a complete GIS program. It is somewhat difficult to use due to the extensive use of acronyms and abbreviations in the commands.

Many GIS applications use ARC/INFO software. This is a polygon data based system with a data based program link. Raster data can be converted to polygon data and used by ARC/INFO. We have ordered the ARC/INFO starter kit. Combining the features of raster and polygon data systems, we plan to enhance the current Rookery Bay GIS, provide converted raster to polygon data to other GISes and be able to accept polygon data for the Rookery Bay GIS from other sources.

New software systems are constantly being produced. We are aware of at least one system, ATLAS, developed by Delta Data Corporation. This system is capable running both raster and vector data in combination with a data based management system. Essentially it combines the elements of ERDAS, ELAS, ARC/INFO and a database management system in one package. New systems such as ATLAS should be examined for use as the software system for aquatic preservess GIS programs.

DATA ACQUISITION

Aquatic preserves that have established a monitoring program should have conducted a detailed survey of available literature and data on their systems prior to initiating a monitoring

program (Thoemke and Gyorkos 1988). The results of this literature review should have revealed data sets which exist for the study area. The first step in establishing a geographic information system is to input these data as well as data collected by the aquatic preserve staff into overlays and database files. Information such as water quality, road locations, present land use, biological resource data and other informational data available from government and private sources will form the basis of the overlays for GIS. Depending upon the GIS software chosen either a series of base maps or satellite images will serve as the basis for the GIS. A base map is generated from topographic maps, aerial photograph or satellite images. The work conducted in this study show that satellite images provide the most accurate base maps for a study area.

Aerial photographs have a problem when piecing together the many photographs of a large region. The photographs do not accurately line up from scene to scene. We believe this is due to fluctuating altitude and tilt of the photographing aircraft as it flies over an area. Topographic maps have an accuracy problem due to the fact they are generated from aerial photographs. Because of the problems encountered in dealing with aerial photographs and topographic maps the use of satellite images is the prefered method for creating base maps for the GIS.

DATA ENTRY

Once data sets and images have been identified they should be entered into the GIS. This can be done by the direct input of data in a digital form, through the use of a digitizing table for

maps and other photographs or by video digitizing. The procedures and recommended methods for data entry will vary depending upon the type of GIS system chosen for the program and the money available to purchase equipment or services.

THE ROOKERY BAY GIS

The Rookery Bay GIS consists of a base image, overlays and database files. The base image is an uncoded LANDSAT image from April 10, 1986. This scene was taken at 10:00 a.m. during an ebb tide. The uncoded image has 256 classes and has a pixel size of point .22 acre (30 m x 30 m). The base image comes from bands 2, 3 and 4 of the 7 banded LANDSAT data. Bands 2, 3 and 4 are the green (0.52 - 0.60um), red (0.63 -0.69um) and infared (0.76 - 0.90um). Data from bands 3, 4 and 5 (band 5 is infared in the range of 1.55 - 1.75um) was used to create many of the overlays for the base map. The study area for which data have been collected or analyzed is approximately 700,000 acres. This includes both Aquatic Preserves, The Research Reserve and the watersheds that supply fresh water to these areas (Figure 2).

Sixteen overlays have been created for the GIS. Each overlay represents a different piece of information concerning the area. An annotated table of the title of the overlay, its source and a brief description of the information contained is provided in Table 1.

The database link that allows digital data from dBase files to be displayed in the GIS was accomplished using ELAS software.

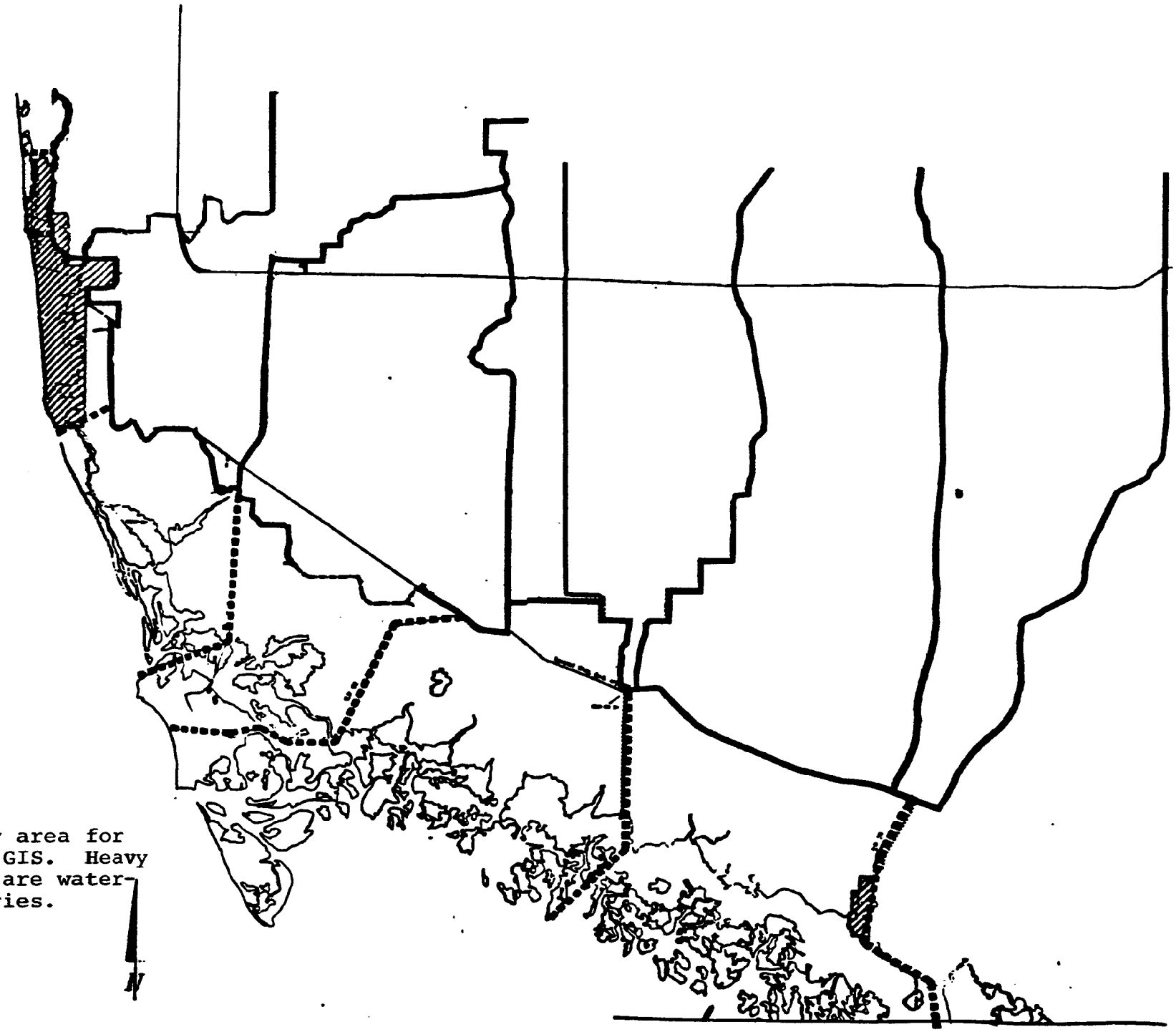


Fig 2. Study area for Rookery Bay GIS. Heavy black lines are water-shed boundaries.

Table 1. Rookery Bay GIS overlays

OVERLAY TITLE	SOURCE	DESCRIPTION
Rookery Bay National Estuarine Research Reserve Vegetation	Landsat Bands 3,4,5	A sixteen class vegetation map of the Research Reserve
Rookery Bay Aquatic Preserve Vegetation	Landsat Bands 3,4,5	Sixteen class vegetation map of the Rookery Bay Aquatic Preserve
Cape Romano-Ten Thousand Island Aquatic Preserve Vegeatation	Landsat Bands 3,4,5	Sixteen class vegatation map of Cape Romano/Ten Thousand Islands Aquatic Preserve
PUD/DRI	Collier County Gov.	Shows approved and proposed planned unit developments (PUD) and development of regional impact (DRI) projects in the study area.
Commercial Property	Collier County Gov.	Shows commercially zoned property in study area. Parcels of this catagory are included in appendix 1.
Roads	Collier County DOT	This is a five class overlay road map: four lane highways, two lane primary roads, two lane secondary, dirt limited access and airports.
Survey Information	Collier County DOT	These are the township section and range lines within the study area.
Boundaries	DNR documents	Boundaries of the Research Reserve and Aquatic Preserves.
Water Quality	Rookery Bay	These are the station locations for all water quality sampling programs that are being conducted in the Research Reserves and Aquatic Preserve.
Watersheds	Collier County Water Management	These are the watershed areas recognized by the county for the study area.
Canals/Weirs	Water Control Structure Index Collier County Gov.	These are the drainage canals and water control structures within the study area.
Sewage Plants	Collier County Dept. of Environmental Pollution Control	These are the package sewage treatment plants located in study area.
1928 Photos	NOAA-NOS National Cartographic Section	These are 1928 aerial photos of Rookery Bay and vicinity. These are video digitized overlays showing the general topographic features of the study area in 1928.
1958 Topographic Maps	U.S. Geological Survey	These are digitized images of the standard topographic quadrangles for this area.
Soils	1928 U.S Dept of Agricultural Soil Survey	This is an overlay showing the various soil types as described from the only soil survey available for Collier County.
Database Files	Various research projects.	These are the database file containing all of the data collected on water quality, benthic invertibrate, creel survey and other data collected withing Rookery Bay and the Ten Thousand Islands area. Each parameter with this database file can be converted to an overlay for use in the GIS. Depending upon how the data are combined over time and space their are many possib overlays that can be create fro[redacted]se [redacted]sets[redacted]

Data from the parameters, sampling dates and stations described in Appendix 1 can be shown as overlays on any of the other overlays and/or the base image. There are a wide variety of ways in which to display these data. For instance phosphorous levels at each of the water quality stations could be shown as overlays from each sampling date or yearly averages could be calculated and those data could be displayed in one overlay.

GIS APPLICATIONS

The ability to link scientific, planning and geographic information using computer based maps and images has created a new level of scientific and resource management information. Examining the relationship between different combinations of overlays can reveal relationships that bear closer scientific investigation. Applying GIS information to management problems has provided a link between scientific data and land use information that is revolutionizing our ability to manage coastal areas.

The results of this work begin to demonstrate ways in which a GIS can be used in coastal zone management issues affecting Rookery Bay and other Florida coastal areas. The ability to combine different data sets within the GIS allows the user to look at the affects of activities on the land or water, assess the present status of an area and, with sufficient information in the GIS, conduct basic modeling to simulate conditions that would occur if a change or series of changes is made in an area. GISes also have the benefit of being easily updated when new

information becomes available or existing database files or image overlays have new information added to them.

The best way to illustrate how a GIS can be used used in coastal zone management problem solving is by example. Suppose a manager would like to know whether or not speed restriction signs for boaters should be posted in an area due to the presence of manatees. In order to make this decision, the manager must have some idea of whether manatees occur in this area, how frequently they are sited, how much boat traffic is in the area, where are the locations of boat channels and marinas and how many manatee deaths have been recorded in the vicinity. A GIS, if it contained appropriate information, would combine and illustrate the data sets needed to make an assessment.

Using a simple base map of the study site, overlays showing the locations of boat channels, marinas, boat use, manatee sightings and sites of manatee deaths are prepared. These overlays are combined in the GIS to develop a picture showing areas where manatees sitings and high boat use areas co-occur. The deaths occurring in relation to boat traffic use patterns may also show particularily dangerous areas that may need special attention. From this combination of data, the manager can determine whether signs are warranted alerting boaters to the presence of manatees or if special restricted speed zone sites should be established.

A second example would be determining how many acres of wetland would be lost when siting a new road. Using a base vegetation map overlay that identifies wetlands, various proposed

or hypothetical alignments of the road could be placed through the study area to find the best alignment that fits the conditions of the road. For instance if the goal is to have the least amount of wetland vegetation disturbed then an alignment could be found that moves the road from upland areas to upland area transiting through only the smallest wetland area. On the other hand if a straight line road is necessary then an alignment that goes through the least amount of wetland vegetation could be chosen. Since the base map would contain different types of wetland and upland habitats using a GIS can help design a road that passes through the least biologically sensitive areas.

These are only two of many possible examples of how the GIS could be used in management applications. The questions that can be answered using a GIS are limited to the data in the GIS. In a self feeding mechanism the GIS can be used to generate questions and if the data are not available the data can be obtained and entered into the GIS to help answer the questions.

APPLICATIONS OF THE ROOKERY BAY GIS

Nine applications of information using the Rookery Bay GIS have been conducted in the past year as a part of cooperative efforts between DNR and other government agencies. These demonstration projects for other sites have provided management information to the agencies and have served as a valuable learning tool for developing applications of the GIS.

1. Assistance was provided to the U.S. Army Corps of Engineers in an enforcement case. The GIS was used to determine the amount of wetland vegetation that was allegedly destroyed on

an interior freshwater wetland in Collier County. Using the 1986 LANDSAT image we compared the vegetation from the study site to the vegetation analysis from a 1984 LANDSAT image. The results indicated that some wetland habitat had been destroyed and converted into impounded agricultural lands.

2. An extensive demonstration project assisted the Collier County Government in the preparation of a vegetation analysis of Collier County. Using the 1986 LANDSAT image and ground truthing information supplied by the county staff, a vegetation map for the county's 1.2 million acres was created. This map was reproduced by the county and is being used as a part of their revised Comprehensive Plan.

3-4. Two internal DNR projects used the Rookery Bay GIS. An internal project at the Reserve involved using the GIS vegetation map to determine the area and extent of scrub oak habitat in the Reserve. This information was used to develop a gopher tortoise research project which is currently underway at the Reserve. The second project involved creating the vegetation map overlays for the Bureau of Aquatic Preserves' Rookery Bay and Cape Romano/Ten Thousand Islands Aquatic Preserves Management Plan.

5. To enhance the vegetation map overlay for the county a detailed study of the proposed Florida Panther National Wildlife refuge was conducted for the U.S. Fish and Wildlife Service. Within the boundaries of the proposed refuge the wetland areas were classified into five major types to be used for panther habitat management.

6. To assist the updated soil survey program being conducted

by the U.S. Department of Agriculture we worked with their field representatives to determine vegetation and soil similarities for the new survey study. This was conducted in the wetland area of Collier County.

7. A small project for the Florida Department of Environmental Regulation was done using the GIS. Vegetation analysis and acreages of soon to be altered lands and altered lands were calculated using the GIS.

8. The most extensive program involves the Reserve's participation in a multi-organization project with Research Planning Institute, Inc., the Remote Sensing Institute of the University of South Carolina, NASA's Earth Resource Laboratory and the Rookery Bay Research Reserve. Rookery Bay was chosen as a site for a demonstration project to develop an oil spill response survey because of its extensive database and GIS. Both LANDSAT and SPOT satellite images were taken from Rookery Bay in October 1988. Additional spectral analysis data was collected from a Lear jet at approximately 10,000 feet altitude. Radiometer readings were taken from a helicopter at low altitude and from leaves taken from mangrove tree canopies and forest floor areas. This layered approach to spectral analysis of the system was designed to determine what types of interferences occur as a result of the atmosphere.

Twelve first order magnitude locations were sighted in using a global positioning system (GPS) instrument. These will be used as reference marks for locating ground positions in remote mangrove forest, marsh and upland sites. Most of this work will be repeated again in March 1989. This information will provide

detailed data on the vegetation analysis of this area.

9. The Rookery Bay GIS was used to help the Florida Division of Forestry. They requested a vegetation analysis for the areas surrounding their fire spotting towers to develop future control burn procedures in the county. Vegetation analysis was conducted in a ten mile radius around each of the county's five spotting towers.

In addition to these projects several other agencies and organizations have approached us for information that uses the Rookery Bay GIS. Collier Seminole State Park has requested a vegetation analysis, the Bureau of Aquatic Preserves has asked us to develop a vegetation map for the St. Joe Bay Aquatic Preserve, the U.S. Customs service is interested in locating shoals and sandbars in the Ten Thousand Islands, and the Lee County Nature Center Planetarium would like us to develop an educational display on remote sensing. All of these requests, in addition to the projects described above, are providing new and refined data for the Rookery Bay GIS.

SUMMARY

1. A Geographic Information System is a computer based technology composed of hardware, software and data used to capture, edit, display and, most important, analyze geographic information (Lang 1988).

2. A GIS can help Aquatic Preserve and other natural resource managers develop management strategies. GISes organize existing information and data about an area and present it in an easily usable format. Management problems can be addressed using a combination of overlays and/or database files to examine relationships between parameters.

3. The recommended hardware for a GIS systems includes a 386 generation computer with a clock speed of 20-25mh; a minimum 160 megabyte storage system; two monitors, a standard color or black and white monitor and an RGB high resolution graphics monitor; and two printers, a daisy wheel, dot matrix or laser printer and color ink jet printer.

4. Their are several options in choosing a software system for the GIS. Regardless of your choice, the software must be capable of producing cartographic output (the ability to produce maps and overlays) and it must have the ability to access and display database files with the cartographic output. Data can be handled in either a polygon or raster form. The Rookery Bay GIS uses raster data with the ERDAS and ELAS software systems. A polygon based GIS software, ARC/INFO is used by many sites. Rookery Bay will be adding ARC/INFO to the GIS system in the next year. This

will allow us to work with both vector (polygon) and raster data.

5. The Rookery Bay GIS consists of a base image from the LANDSAT satellite, 16 overlays and a link to dBase 3 Plus files. The overlays include vegetation maps, locations of development and commercial properties, roads, survey information, watershed maps, locations of canals and weirs, sewage plant sites, 1928 aerial photographs, 1950 topographic maps and soils. Database files include extensive information on water quality, benthic invertebrates, creel survey information and bird census data.

6. Nine applications of the Rookery Bay GIS have been conducted in the past year as part of a cooperative effort between DNR and other government agencies. Assistance has been provided to: the U.S. Army Corps of Engineers in an enforcement case; the Collier County government to develop a county vegetation map; DNR for developing vegetation maps for the aquatic preserves and to determine the extent of scrub oak habitat for a gopher tortoise research project at the Reserve; the U.S. Fish and Wildlife service to develop a vegetation map for the Florida Panther National Wildlife Refuge; the U.S. Department of Agriculture to develop an updated soil survey program in wetland areas; the Florida Department of Environmental Regulation to do vegetation analyses of altered lands; develop oil spill response survey in mangrove habitats as part of a multi-organization project; and with the Florida Division of Forestry to do vegetation analysis for fire management.

7. Based on the information learned from the pilot project of developing a GIS for Rookery Bay, we recommend that the Bureau of Aquatic Preserves and other natural resource management areas

consider establishing regional or site specific GISes.

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Database files linked to Rookery Bay GIS

File Name: RB1

Dates: April 30, 1980 to November 30, 1982, monthly

Stations: 1, 2, 3, 4, 5, 6 (See map 1)

Parameters: surface and bottom temp, pH, D.O., salinity, B.O.D., turbidity, suspended solids and mid-depth orthophosphate, nitrite, nitrate, nitrite-nitrate, ammonia, total nitrogen, trichromatic chlorophyll a, chlorophyll a and phaeopigment.

Note: E. coli samples were also collected through December 27, 1982

File Name: TIDAL1

Date: September 23, 1980, April 30, 1981, March 30, 1982, September 15, 1982, samples were collected every two hours for a 12 hour period.

Stations: 2, 3, 4, 5, 6 (See map 1)

Parameters: surface and bottom temp, pH, D.O., salinity, B.O.D., turbidity, suspended solids and mid-depth orthophosphate, nitrite, nitrate, nitrite-nitrate, ammonia, total nitrogen, trichromatic chlorophyll a, chlorophyll a and phaeopigment.

File Name: RBBI1

Date: June 5, 1984 to April 10, 1985, biweekly

Stations: 2, 3, 4, 5, 6 (See map 1)

Parameters: surface and bottom temp, pH, D.O., salinity, B.O.D., turbidity, suspended solids and mid-depth orthophosphate, nitrite,

nitrate, nitrite-nitrate, ammonia, total nitrogen, trichromatic chlorophyll a, chlorophyll a and phaeopigment.

File Name: RBWEEK1

Date: January 7, 1986 to November 27, 1987, weekly

Stations: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 (See map 1)

Parameters: surface and bottom temp, pH, D.O., salinity, B.O.D., suspended solids and turbidity.

File Name: RBBI2

Date: April 15, 1987 to September 2 1987, biweekly

Stations: 20 thru 150 (See map 2)

Parameters: surface and bottom temp, pH, D.O., salinity, B.O.D., turbidity, suspended solids and mid-depth orthophosphate, nitrite, nitrate, nitrite-nitrate, ammonia, chlorophyll a, chlorophyll b, chlorophyll c and phaeopigment.

File Name: RBBI3

Date: April 7, 1987 to present, biweekly

Stations: 1 thru 10, 160 thru 180, 190 thru 192, 205 and 206 (See maps 1,2)

Parameters: surface and bottom temp, pH, D.O., salinity, B.O.D., turbidity, suspended solids and mid-depth orthophosphate, nitrite, nitrate, nitrite-nitrate, ammonia, total nitrogen, trichromatic chlorophyll a, chlorophyll a and phaeopigment.

File Name: RBECOLI1

Date: April to present, monthly

Stations: 1 thru 10 and 160 thru 280 (See maps 1,2)

Parameters: E.coli, surface and bottom temp, pH, D.O. and salinity

File Name: RBSONDE1

Date: March 21, 1988 to present, 20 minute readings

Station: 5 (See map 1)

Parameters: mid-depth tempetature, pH, D.O., conductivity, salinity and redox potential

File Name: BIRDS

Date: April 1981 to present, quarterly

Stations: 6 routes are now sampled, 4 routes were originally sampled then a 5th station was added in Feburary, 1983 and a 6th added in November, 1985. The data is kept as one database and accessed accordingly.

Parameters: A group of volunteers are used to census birds along established routes in Rookery Bay National Estuarine Research Reserve.

File Name: CREEL

Date: September 2, 1982 to October 31, 1986 then restart January 1, 1988 to present.

Stations: This is roving creel survey in Rookery Bay.

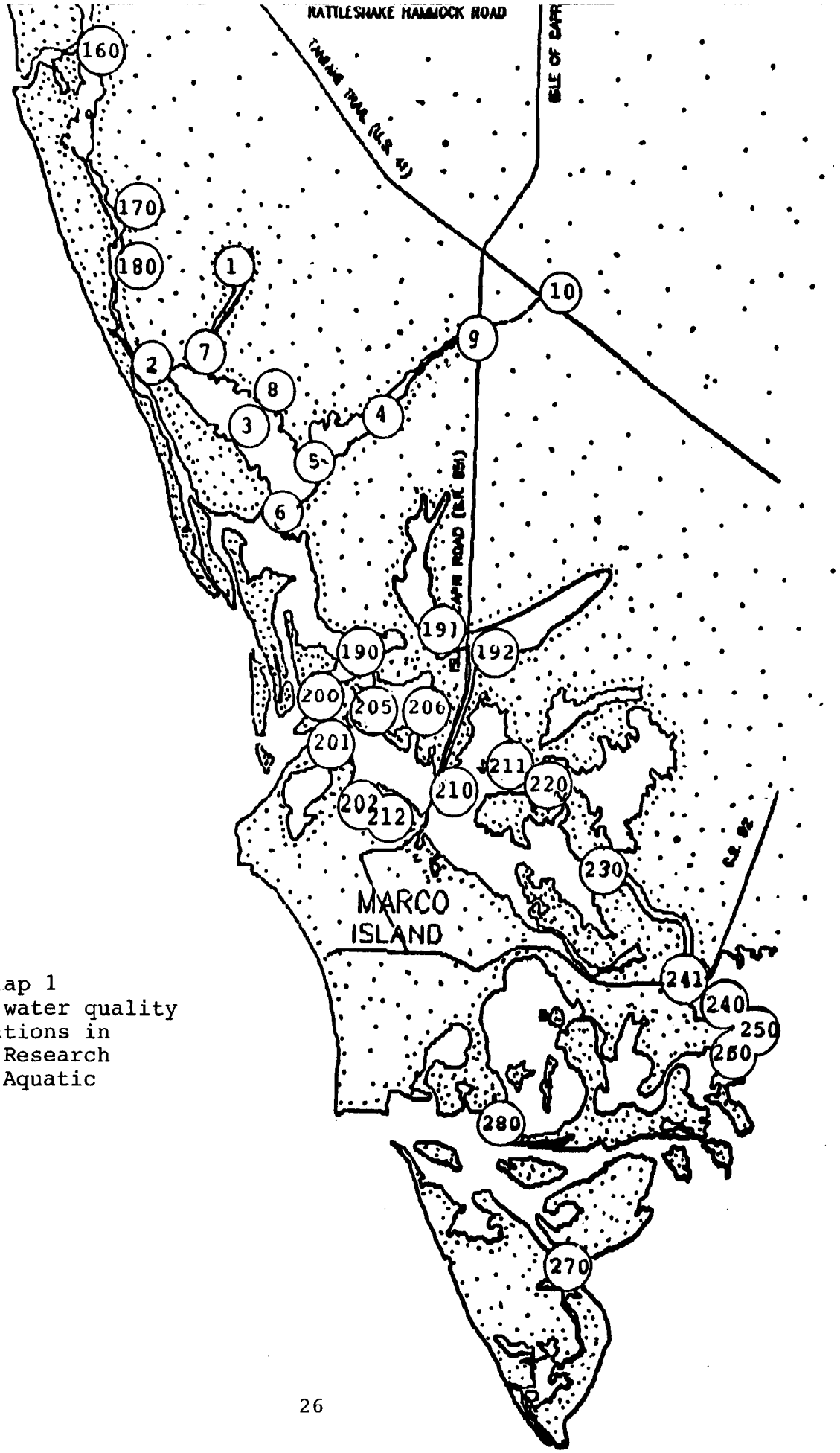
Parameters: Fishermen are surveyed on their catch and preferences for bait, fishing location and desired catch.

File Name: BENTHIC

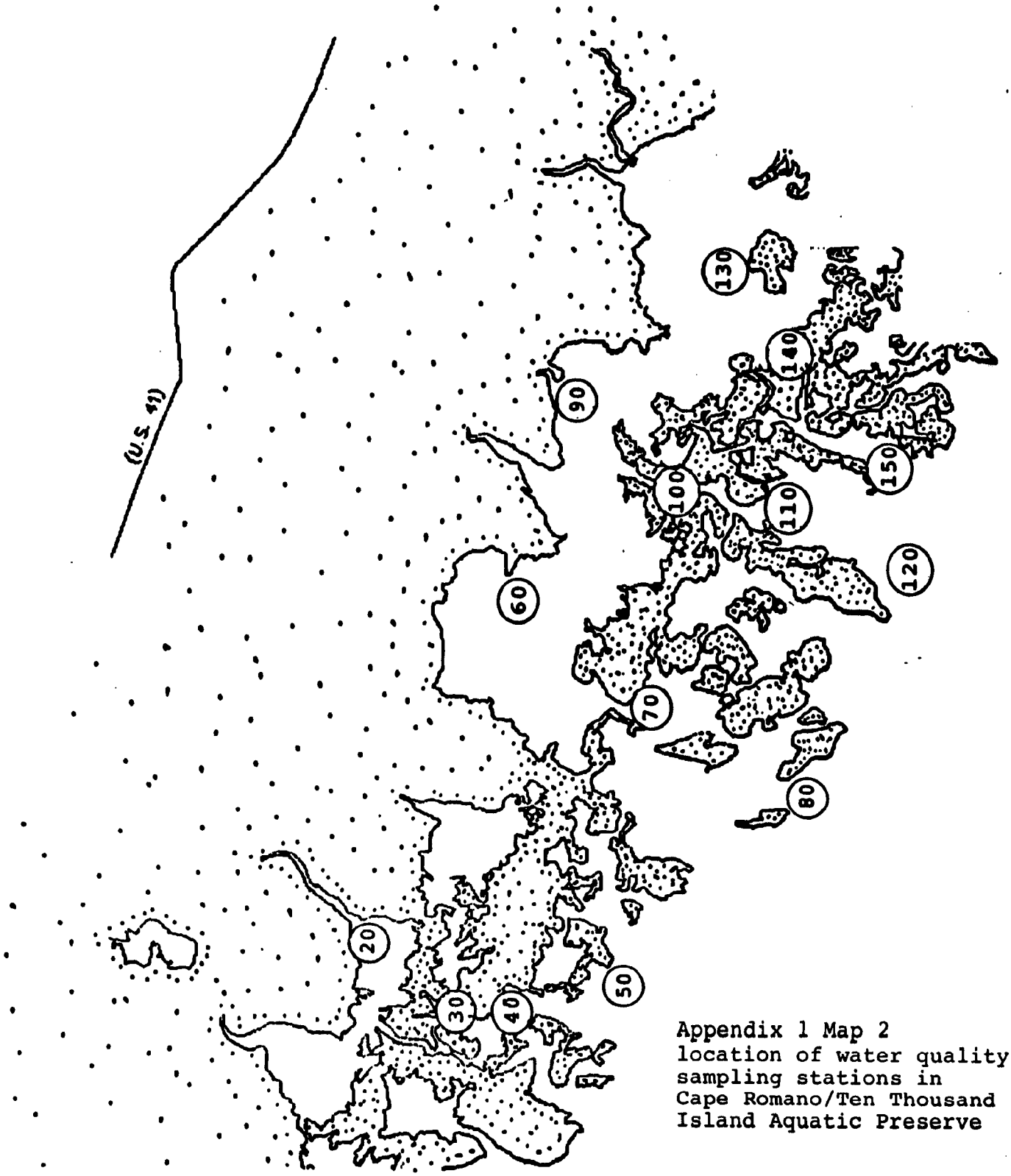
Date: November 30, 1984 to November 9, 1985, monthly.

Stations: Five stations in Rookery Bay.

Parameters: Benthic cores were taken for sediment grain size analysis and species identification, density and distribution.



Appendix 1 Map 1
location of water quality sampling stations in Rookery Bay Research Reserve and Aquatic Preserve.



Appendix 1 Map 2
location of water quality sampling stations in Cape Romano/Ten Thousand Island Aquatic Preserve

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