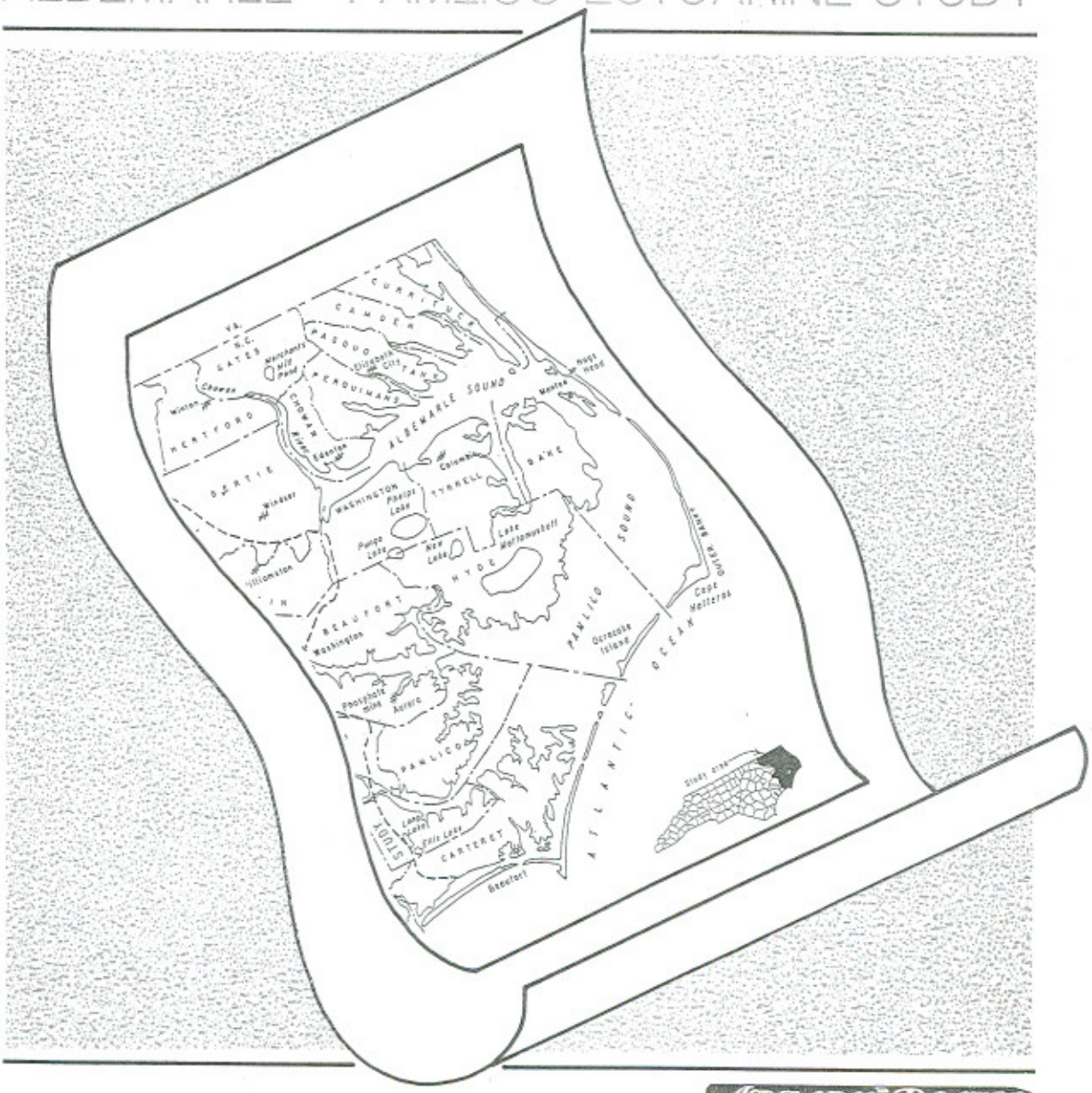
November, 1990

Project No. 90-21

ALBEMARLE-PAMLICO ESTUARINE STUDY DATA MANAGEMENT AND ANALYSIS SYSTEM

FUNCTIONAL DESCRIPTION

ALBEMARLE - PAMLICO ESTUARINE STUDY



North Carolina Department of Natural Resources and Community Development

Funding Provided By Environmental Protection Agency National Estuary Program

ALBEMARLE-PAMLICO

ALBEMARLE-PAMLICO ESTUARINE STUDY

DATA MANAGEMENT AND ANALYSIS SYSTEM

FUNCTIONAL DESCRIPTION

PREPARED BY:

STATE CENTER FOR GEOGRAPHIC INFORMATION & ANALYSIS (CGIA)

PREPARED FOR:

STATE OF NORTH CAROLINA
DEPARTMENT OF ENVIRONMENT, HEALTH, AND NATURAL RESOURCES
A/P STUDY PROGRAM OFFICE

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EXECUTIVE SUMMARY

The State Center for Geographic Information & Analysis (CGIA), formerly Land Resources Information Service (LRIS), conducted a data needs assessment for the Albemarle-Pamlico Estuarine (A/P) Study in the fall of 1988. The purpose of the data needs assessment was to define the data requirements for the A/P Study Database and to identify the software functions necessary to maintain the system and enable users to access, manipulate, and report on the data. The data needs have been described previously in the Data Requirements Document. The software needs are presented in a conceptual way in this document, the Functional Description.

The data needs assessment consisted of a multi-step process to obtain the characteristics of existing and future software and data needs. This process started with identification of organizations that are potential users of the database. Interviews were scheduled and completed with representatives of each organization during the September-November 1988 timeframe. Over 50 interviews were conducted involving over 100 people. Software needs were assembled from notes taken during the interviews, completed questionnaires, and documentation provided by the interviewees. Based upon the information collected in the interviews, generic software functions were identified that would enable users to access the data in the A/P Database.

The purpose of the Functional Description is to provide a conceptual view of the five components of the A/P Study Data Management and Analysis System. These components are: hardware, software, data, people, and procedures. Interactions between the five components result in a set of functions that need to be supported through the A/P System. These functions fall into the broad categories of system management and maintenance, data extraction and management, data creation and editing, data manipulation and summarization, and data analysis and display. Complete descriptions of these functions, and the system as a whole, are provided in the Functional Description. From this conceptual beginning, the A/P System will be further defined in the subsequent System/Subsystem Specifications. Software code and system use procedures will be written from those specifications. Guidelines for purchasing user hardware will also be a product of the specifications.

There are four primary user groups that will be accessing the A/P System. These groups are: resource managers, the research community, local government, and private citizens and organizations. The Functional Description discusses the mission of each group. A collection of applications software tailored to A/P users will support the user groups in accomplishing tasks on the A/P System. The Functional

Description defines the general methods by which the user accesses the A/P System including user interfaces, hardware environments, and communications options.

The A/P System will be developed to support use by all four user groups listed above. This capability will remain in place at the end of the A/P Study. However, at the completion of the Study, the State of North Carolina will be responsible for maintaining the system including the A/P Database. This commitment is vital to the survival of the system in supporting users after the A/P Study ends. Without state support, CGIA will only be able to offer new services to A/P users on a cost recovery basis and the A/P Database will be updated only to the extent that other projects are able to fund those updates.

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SECTION 1

INTRODUCTION

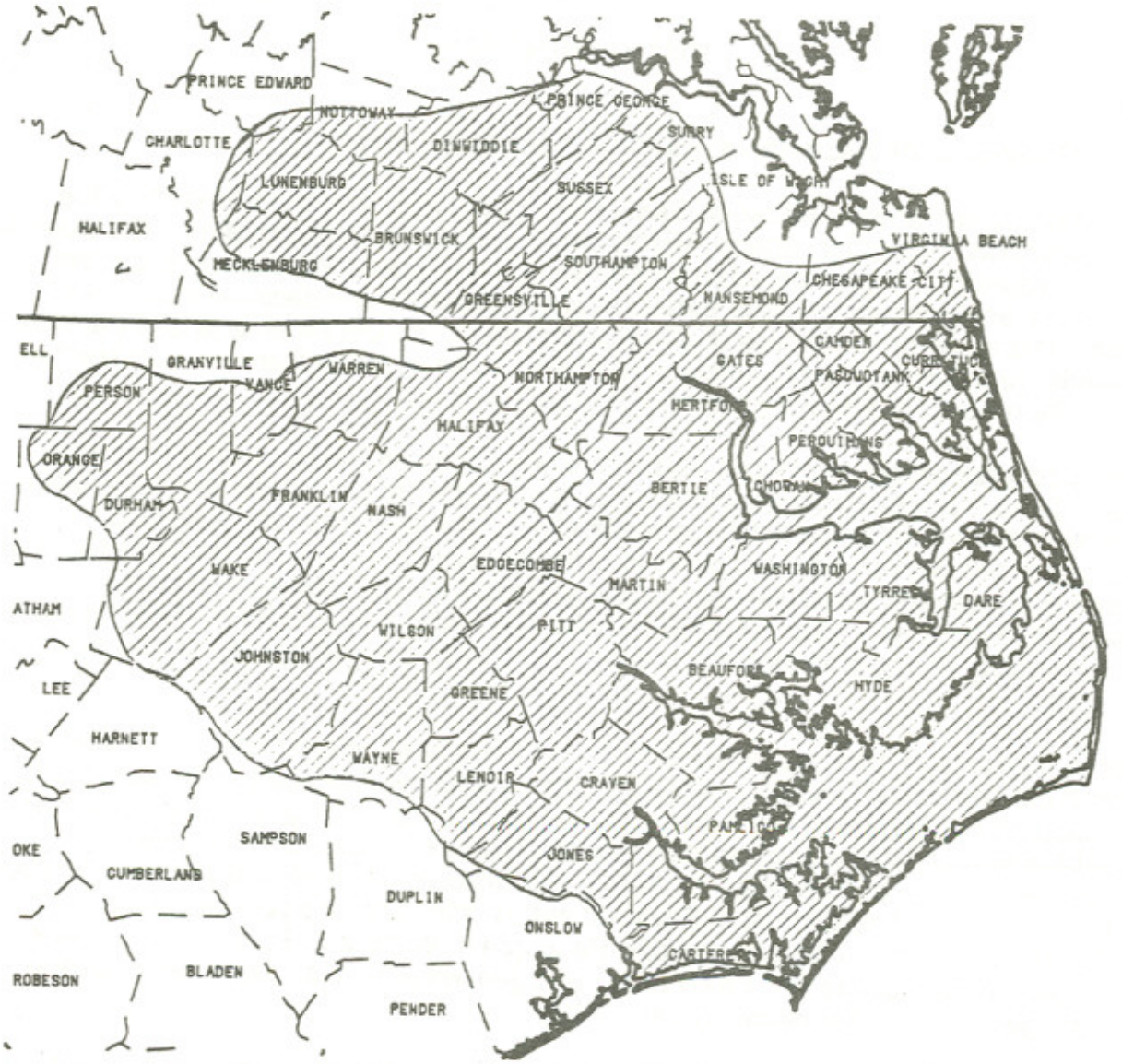
1.1 Overview of Albemarle-Pamlico Estuarine Study

The Albemarle-Pamlico Estuarine Study (A/P Study) is a joint effort funded by the Environmental Protection Agency (EPA) and the State of North Carolina. The purpose of the program is to provide scientific knowledge and public awareness about the estuarine environment to foster better resource management decision making in the area. The study area consists of all lands that drain into the Albemarle and Pamlico Sounds, representing approximately 10 million acres in North Carolina and another two million acres in Virginia as shown in Figure 1.

Scientific knowledge and public awareness are necessary to accomplish rational management decision making in the study area at the federal, state, and local levels. Through the A/P Study, a better understanding of the chemical, physical, and biological properties of the estuaries is being generated. From this understanding will come management strategies for restoring and maintaining the area. Upon completion of the five-year program in 1992, the State of North Carolina will have the responsibility of implementing the management strategies developed during the program.

Large amounts of data are produced through the gathering of scientific knowledge about the study area and likewise large data volumes will be used in the process of developing management strategies. The A/P Study data management program was established early in the study to deal with the data from researchers as well as resource managers. The State Center for Geographic Information & Analysis (CGIA), an agency of the Department of Environment, Health, and Natural Resources (DEHNR) and formerly known as Land Resources Information Service (LRIS), was selected to manage the A/P Study data management program. CGIA operates the state's geographic information system (GIS).

The GIS was identified as the tool for accomplishing data management. A GIS is a hardware and software system used for compilation, storage, analysis, and display of geographic data referenced by x,y-coordinate pairs. With the GIS as an integrating tool, one of the goals of the A/P Study data management program is to minimize duplication of hardware, software, and data while providing for effective interfaces between other computer systems. In practice, this goal means that the A/P Study data management program will not attempt to duplicate the storage of large databases that have established procedures for data acquisition and maintenance. Rather, A/P Study data management funds will be used to develop software interfaces to the databases so that data can be obtained in an effective manner when necessary. A final goal of the data management program is to provide users with both local and remote access



Scale 1: 2,000,000

FIGURE 1 Albemarle - Pamlico Estuarine Study Area

to the A/P Study Data Management and Analysis System. Users include resource managers at the federal, state, and local levels; researchers working in the A/P Study area; and private citizens or other organizations who have an interest in the study area.

1.2 Purpose and Content of the Functional Description

The purpose of the Functional Description is to provide an overview of the five components of the A/P Data Management and Analysis System, referred to from here on as the A/P System: hardware, software, data, people, and procedures. It describes the applications software functions that will be developed to provide users with the ability to manage, manipulate, analyze, and display data related to the A/P Study area. User policies and procedures for using the A/P System will be described in a later document, the Users Manual.

The remainder of this document is divided into four sections, each describing a different aspect of the A/P System:

- Section 2 describes the three primary groups that will be using the A/P System. These groups include: resource managers, the research community, and other potential users including private citizens. This section discusses the mission of each group and how the A/P System is relevant to accomplishment of that mission.

- Section 3 provides an overview of the A/P System with descriptions of the five principle components of the system necessary for the system to operate smoothly now and in the future. These components include the system's hardware, software, data, procedures, and personnel.

- Section 4 provides a description of the applications software functions that will enable users to perform data entry, editing, extraction, management, manipulation, summarization, analysis, and reporting functions.

- Section 5 provides descriptions of the various user interfaces, hardware environments, and communications options that will be available to access the A/P System.

1.3 Overview of A/P Study System Documentation

The A/P Study data management program will produce various documents to progressively define the database and software necessary to support the needs of resource managers and researchers involved in the A/P Study. The Functional Description is the second in a series of design documents produced for the A/P Study. The set of documents are:

- Data Requirements Document

- Functional Description
- System/Subsystem Specification
- Database Specification
- Users Manual

The Data Requirements Document defines the data needs expressed by potential users of the system. The Functional Description provides a conceptual view of the software functionality of the A/P System. These two documents serve as the foundation upon which the System/Subsystem Specification and the Database Specification, respectively, are developed. The System/Subsystem Specification defines the software structure in more detail by expanding the Functional Description into a structured design. The Database Specification serves a similar purpose for the Data Requirements Document in that logical data definitions are transformed into a detailed, physical design of the A/P Study Database. A data dictionary is designed in conjunction with the Database Specification. It includes detailed information for all cartographic data layers and tabular data sets. All attributes for every data layer and data set are defined. The data dictionary is an appendix to the Database Specification. The Users Manual is then developed to guide the user toward taking full advantage of the software tools and data included in the design of the total A/P System.

SECTION 2

SYSTEM BACKGROUND

2.1 Introduction

The goal of the A/P System is to provide natural resource managers and researchers with information and management support to directly aid in addressing the issues of the region. The objectives of the A/P Study data management program include:

- to catalog and assess the literature and data about the region;
- to establish institutional and electronic mechanisms for accessing, integrating, and analyzing pertinent automated data;
- to provide resources for automating data developed by the Study or required by the Study; and
- to develop data reporting and tracking systems that regularly summarize the conditions of the estuarine area.

2.2 User Groups

To help identify the data and software needed in the A/P System, a list of potential users was compiled prior to conducting a data needs assessment. Four primary user groups were identified: resource managers, the research community, local governments, and private citizens and organizations. Resource managers includes various state and federal government agencies with management responsibilities within the A/P Study area. The research community includes university and laboratory researchers with a research interest in A/P Study related issues. Local government users are those county, city, and town governing bodies that have management responsibilities to maintain a healthy environment for their citizens. Private citizens and organizations include the general public, environmental groups, and industry who could benefit from using the data contained in the A/P System upon its implementation. The following four sections discuss each of these user groups in more detail.

2.2.1 Resource Managers

Natural resource managers at the state and federal levels have the responsibility for protecting the natural resources of the State of North Carolina through effective

management practices. These responsibilities include assessing resource use and trends, monitoring compliance with existing laws and regulations, and developing new laws and regulations to further protect the environment. The software needed to support their needs includes the ability to manage, query, model, and display spatial data related to the natural resources in the watersheds of the estuaries. Detailed characteristics of each resource management organization are given in the following paragraphs.

2.2.1.1 State Government Agencies

2.2.1.1.1 Department of Environment, Health, and Natural Resources (Policy Committee and Technical Committee)

The North Carolina Department of Environment, Health, and Natural Resources (DEHNR) is the lead state agency for the Albemarle-Pamlico Estuarine Study and administers the state cost share funds for the study.

2.2.1.1.1.1 Division of Coastal Management (Technical Committee, Third Year Technical Project)

The Division is responsible for implementing a plan for the protection, preservation, orderly development, and management of the coastal area of North Carolina. The Division provides staff support to the Coastal Resources Commission, which administers the Coastal Area Management Act (CAMA). The Division processes major development permits; prepares guidelines for a local land use planning program in the CAMA counties; administers grants to local government for planning, permitting, and beach access programs; and acquires and manages coastal and estuarine reserves as natural areas for research, education, and preservation.

2.2.1.1.1.2 Division of Environmental Health

This Division is concerned with activities relevant to environmental health issues. Staff from the Environmental Health Services Section (Shellfish Sanitation Branch) and the Public Water Supply Section were interviewed.

The Shellfish Sanitation Branch is responsible for protecting the public health of the consumers of oysters, clams, scallops, and crustacean meat. The program personnel conduct sanitary surveys of shellfish growing waters to determine which areas are safe for harvest of shellfish for raw consumption by humans and inspect shellfish, scallop, and crustacean processing plants to certify compliance with sanitary requirements.

The Public Water Supply Section is the lead state office in implementing and enforcing state laws and Commission of Health Services rules pertaining to the surveillance, operation, and maintenance of public water supplies. The Public Water Supply Section is also responsible for implementing the federal Safe Drinking Water Act.

2.2.1.1.1.3 Division of Environmental Management (Technical Committee)

The Division is responsible for comprehensive planning and management of the state's air, surface water, and groundwater resources. The Division issues permits to control sources of pollution; monitors compliance at permitted facilities; evaluates ambient environmental quality; and pursues enforcement actions for violations of environmental regulations.

Interviews were conducted with representatives of the Air Quality Section, Water Quality Section, and Groundwater Section.

2.2.1.1.1.4 Division of Forest Resources (Technical Committee)

The Division has an active role in planning and administering all activities related to maintaining, protecting, and improving the forest resources of the state. Specific activities include management assistance to private landowners, reforestation services, forest fire prevention and suppression, and insect and disease control programs.

2.2.1.1.1.5 Division of Land Resources

The purpose of the Division is to protect and conserve the state's land, minerals, and related resources through the effective implementation and management of programs related to sedimentation pollution control, mined land reclamation, dam safety, land records management, geodetic survey, resources inventory and analysis, and mineral resources conservation and development.

2.2.1.1.1.6 Division of Marine Fisheries (Technical Committee, First and Second Year Technical Projects)

The Division is responsible for the maintenance, utilization, and development of all marine and estuarine fisheries resources. This work includes the enforcement of rules governing coastal fisheries; scientific endeavors leading to the development of information on which regulatory and developmental decisions will be based; and developmental activities intended to improve the cultivation and harvesting of shell and finfish.

2.2.1.1.1.7 Division of Parks and Recreation (Second and Third Year Technical Projects)

The Division administers the state park system which includes state parks, state natural areas, state recreation areas, state trails, state lakes, and natural and scenic rivers. The park system functions to preserve unique examples of archaeological, biologic, geologic, scenic, and recreational resources.

2.2.1.1.1.8 Division of Soil and Water Conservation (Technical Committee, First, Second, and Third Year Technical Projects)

The Division administers a comprehensive, statewide program for conserving the state's soil and water resources, principally in cooperation with the agricultural community.

2.2.1.1.1.9 Division of Solid Waste Management

The Division is responsible for programs to identify solid and hazardous waste sites in the state. One of the programs, the Superfund Program, is responsible for identifying and cleaning up uncontrolled hazardous waste sites. This program is conducted in cooperation with the Environmental Protection Agency. The Superfund Program also evaluates uncontrolled hazardous waste sites that do not fall under the jurisdiction of the federal government.

2.2.1.1.1.10 Division of Water Resources

The Division manages programs for planning, technical assistance, and financial assistance for river basin management, water supply, water conservation, navigation, stream clearance, flood control, beach protection, aquatic weed control, hydroelectric power, and recreational uses of water.

2.2.1.1.1.11 Wildlife Resources Commission (Technical Committee)

The Wildlife Resources Commission administers programs in waterfowl management, non-game and endangered species management, inland fisheries, and wetlands wildlife management.

2.2.1.1.2 Other State Government Agencies

2.2.1.1.2.1 Office of the Governor, Office of State Budget, State Data Center

In its capacity as a depository for data products from the federal Bureau of the Census and the Bureau of Economic Analysis, and as an administratively mandated registrar for state government data series, the State Data Center is the point of entry for a variety of statistical information available from state and federal agencies. The State Data Center disseminates decennial, economic, and agricultural census information, acts as a data clearinghouse, and publishes statistical compendia for the state and its counties.

2.2.1.1.2.2 Department of Cultural Resources, Division of Archives and History, Archaeology and Historic Preservation Section

The Archaeology and Historic Preservation Section conducts a statewide program to identify, examine, and protect and /or preserve the state's historical and archaeological resources.

2.2.1.1.2.3 Department of Transportation

The Department of Transportation is responsible for the design, construction, and maintenance of state highways and roads. Responsibilities include the review of Section 401 and Section 404 permits and the development and implementation of wetlands destruction mitigation plans for its highway projects.

2.2.1.1.2.4 Department of Agriculture (Technical Committee)

The Department of Agriculture's Division of Statistics is responsible for the generation, storage, and dissemination of agricultural output data for the State of North Carolina.

2.2.1.1.2.5 Department of Economic and Community Development, Division of Community Assistance

The Division provides aid to North Carolina's counties and municipalities in the areas of community development, land use, public management, and economic development.

2.2.1.2 Federal Government Agencies

2.2.1.2.1 Environmental Protection Agency (Policy Committee and Technical Committee)

The Environmental Protection Agency (EPA) is the lead federal agency for the A/P Study and administers the federal cost share funds for the Study. The EPA designated the Albemarle-Pamlico Sounds as a National Estuary Program under the Water Quality Act of 1987. The Act authorizes the Administrator of the EPA to convene management conferences to develop Comprehensive Conservation and Management Plans (CCMP) for estuaries of national significance.

2.2.1.2.2 U.S. Army Corps of Engineers (Technical Committee)

The Corps of Engineers is responsible for planning, design, construction, operation and maintenance of projects for navigation, flood control, water supply for municipalities and industry, recreation and fish and wildlife management, and environmental management. The Corps also serves a regulatory function, reviewing

Section 401 and 404 permit applications for proposed activities in waters of the United States. In this role, the Corps ensures a balance between the public interest in environmental protection for proposed dredging and filling and commercial development .

2.2.1.2.3 Southeast Fisheries Center, National Marine Fisheries Service (Technical Committee, First, Second, and Third Year Technical Projects)

The Southeast Fisheries Center provides scientific and technical information for decision making in conserving marine fishery resources and in conserving the habitat, mammals, and endangered species of the marine environment. The mission of the Southeast Fisheries Center is to understand the biological productivity of estuaries and nearshore ecosystems, the dynamics of coastal fishery resources, and the effects of man on resource productivity in order to enhance recreational and commercial fishery resources along the southeastern coast of the United States.

2.2.1.2.4 U.S. Fish and Wildlife Service (Policy Committee, First Year Technical Project)

The mission of the U.S. Fish and Wildlife Service is to provide the federal leadership to conserve, protect, and enhance fish and wildlife and their habitat for the continuing benefit of the people. The Service facilitates the balanced development of the nation's natural resources by timely and effective provisions of fish and wildlife information and recommendations to assure the natural diversity and continuing survival of fish and wildlife. Within the A/P Study project area, the Service manages nine National Wildlife Refuges.

2.2.1.2.5 U.S. Geological Survey, Water Resources Division (Technical Committee, First, Second, and Third Year Technical Projects)

The U.S. Geological Survey collects, disseminates, and evaluates information on water availability, quantity, and quality to help guide the development, management, and use of the nation's water resources.

2.2.1.2.6 National Park Service

The National Park Service administers for the American people an extensive system of over 300 national parks, monuments, historic sites, and recreation areas. The Service administers these areas for the enjoyment and education of citizens, to protect the natural environment of the areas, and to assist states, local governments, and citizen groups in the development of park areas, protection of the natural environment, and the preservation of historic properties.

2.2.2 Research Community

2.2.2.1 University Programs

Several laboratories and research facilities play a significant role in examining issues related to the estuarine environment. These facilities are affiliated with various North Carolina universities and include:

- Duke University Marine Laboratory (Policy Committee)
- East Carolina University
- North Carolina State University
- UNC Institute of Marine Sciences (Policy Committee)
- University of North Carolina at Chapel Hill
- University of North Carolina Sea Grant College Program (Technical Committee, Second Year Technical Project)
- Water Resources Research Institute (Technical Committee)

Representatives from each of the facilities were interviewed during the data needs assessment.

2.2.2.2 Researchers with A/P Study Technical Projects

Dr. David Adams, North Carolina State University, "Environmental Management Plan for Currituck Sound" (Third Year)

Dr. Mark Brinson, East Carolina University, "Ecological Functions and Value of Fringe Swamps" (First Year)

Dr. Graham Davis, East Carolina University, "Distribution and Management Potential for Submerged Aquatic Vegetation" (First Year)

Dr. Thomas Hoban, North Carolina State University, "Public Attitudes/Water Quality and Management Alternatives" (Third Year)

Dr. Edward Kuenzler, University of North Carolina, "Nutrient Reduction By Coastal Swamps" (First, Second, and Third Years)

Dr. Edward Noga, North Carolina State University, "Shell Disease in Blue Crabs Callinectes Sapidus" (Second and Third Years)

Dr. Sonia Ortega and Dr. John Sutherland, Duke University Marine Laboratory, "Environmental Determination of Oyster Success in the Pamlico Sound" (First Year)

Dr. Hans Paerl, UNC Institute of Marine Sciences, "Potential for Eutrophication and Nuisance Algal Blooms" (First, Second, and Third Years)

Dr. Ray Palmquist and Dr. Kerry Smith, North Carolina State University, "Value of Recreational Fishing on the Albemarle and Pamlico Estuaries" (First Year)

Dr. Leonard Pietrafesa, North Carolina State University, "Albemarle-Pamlico Sound Coupling Study" (Second Year)

Dr. Stanley Riggs, East Carolina University, "Heavy Metal and Organic-Rich Mud Pollutants" (First, Second, and Third Years)

Dr. Roger Rulifson, East Carolina University, "Abundance and Viability of Striped Bass Eggs Spawned in the Roanoke River 1989", "Food and Feeding of Larval Fishes in the Lower Roanoke River and Western Albemarle Sound" "Water Quality as a Function of Discharge from the Roanoke Rapids Reservoir During Hydropower Generation" (Second Year)

Dr. Wayne Skaggs, North Carolina State University, "Effects of Water Management and Land Use Practices on Hydrology and Water Quality" (Second Year)

Dr. Paul Tschetter, East Carolina University, "Characterization of Baseline Demographic Trends in Permanent and Temporary Populations" (First Year)

Dr. John Wells, UNC Institute of Marine Sciences, "Scoping Study of Distribution, Composition, and Dynamics of Water Column and Bottom Sediments" (First Year)

Many other researchers from federal and state agencies had conducted or are currently conducting research in the A/P Study area.

2.2.2.3 Other Researchers

Dr. Wendell Gilliam, North Carolina State University
Dr. Siamak Khorram, North Carolina State University
Dr. Curt Richardson, Duke University

2.2.3 Local Governments

Local governments represent the governing bodies that are closest to the estuarine environment and are potentially subject to the greatest consequences resulting from a lack of protection of that environment. Local officials including county, city, and town planners and administrators have the responsibility of protecting the quality of life of their citizens. Damage to the estuaries in and around these local areas could significantly affect not only the natural environment but the economic well being of local communities. For this reason, local governments must play a role in the management planning of the A/P Study area.

2.2.4 Private Citizens and Organizations

There are a variety of potential users of the A/P Study Data Management and Analysis System who do not fall into the resource management, research community, and local government categories outlined above. The users in this group include private citizens, environmental groups, and private industry who have an interest in the region based upon personal reasons, lobbying activities on behalf of environmental issues, or business activities. The A/P Study Data Management and Analysis System will be made available for use by these groups as well.

2.3 Existing Methods and Procedures

As described in Section 2.2, a wide variety of personnel from federal, state, and local agencies use and/or create data that are related to the management of the Albemarle-Pamlico Estuaries. Over the years, a great deal of information and data has accumulated about the estuarine area. With the formation of the Albemarle-Pamlico Estuarine Study the amount of data and information related to the estuaries increases daily. A primary objective of the A/P data management program is to enable resource managers and researchers to improve the management of the region using the most up-to-date, accurate, and complete information available.

Resource managers, researchers, and other concerned organizations primarily rely upon three forms of data associated with the estuaries: bibliographic materials containing information and research results; spatial data depicting natural and cultural resources in the watersheds of the estuaries; and attribute data which provides descriptive information about these resources. Some of the problems identified with the current methods used to create, maintain, and use bibliographic materials, spatial, and attribute data are given below.

- There is no comprehensive listing of the bibliographic materials, maps, and attribute data that is available for the estuarine systems. This data is currently developed and maintained by a number of individuals and agencies, and can be found in a variety of locations across the state. At best, the lack of a comprehensive listing means that resource managers and researchers do not have the benefit of existing data to support their efforts. At worst, the lack of a comprehensive listing results in the expensive duplication of efforts.

- There is no centralized, standard map series that resource managers can use to get information about the estuaries. Typically, the maps that are used by resource managers vary in terms of projection, scale, resolution, currency, format, and location. As a result, the "same" maps often depict quite different information. Consequently, management decisions are made in an atmosphere of imprecise, and sometimes, conflicting information, which is ultimately reflected in the management of the estuaries.

- There is no centralized source of attribute data that resource managers can use to obtain information about the estuaries. There are vast quantities of attribute data related to the estuaries, but these data vary in terms of format, resolution, and sampling intensity. The data reside on a variety of federal, state, university, and private computers throughout the state. Furthermore, the attribute data are often maintained separately from maps of the natural resources in the estuaries. In addition to not being able to view the attribute data on the maps, this results in information conflicts between the maps and attribute data. These conflicts are ultimately reflected in the management of the estuaries.

- The lack of standardized map formats inhibits the ability of users to exchange, share, and integrate the information available from maps. For example, the ability to develop composite maps by combining the information from two or more other maps is hampered by differences in scale, accuracy, resolution, projection, and currency.

- There is a continuing need for up-to-date cartographic and attribute data. The natural environment changes on a daily basis. The process of drafting, updating, and distributing up-to-date maps is a difficult, time consuming, and expensive proposition. Cartographic data are updated on an infrequent basis and the information portrayed quickly becomes obsolete. Even when updates are made, new versions of the data tend to trickle down to users. Meanwhile, those users are making resource decisions based upon obsolete and/or inconsistent information.

- Resource managers and researchers often cannot find maps which depict the natural resource features that they are interested in at the scale, projection, resolution, currency, and format that they need. This forces them to either adapt the maps they have to their purpose, or go through an expensive redrafting effort.

- Similarly, resource managers often cannot find maps which depict only the attribute data they need. Often, no one map contains all the information that a resource manager needs. At other times, the maps available contain more information than is needed. This increases the difficulty of making decisions and conveying those decisions to the public.

- The ability of natural resource managers to use the database is complicated by the quantity of the data that is available and the inability to easily find and extract the data that are needed. The need to find and extract information primarily takes two forms. One form is to locate a feature on the map and then see all the data that describes the feature. The second form is to search for all the natural resources that meet user defined criteria and then display the features.

- Paper maps are not readily suitable for modeling efforts because the information they portray exists in a format that computers can neither read nor manipulate. The development and implementation of sound regulations related to the use of the estuaries is dependent on the ability to prove that a use is impacting the resource in a harmful way. The complexity of natural resource systems is such that the only

feasible way of demonstrating that certain uses have an adverse impact is through the use of computer modeling. When the resources in question have a spatial component such as the location, area, distance, or proximity, information that can be extracted from data layers can play an important role in models designed to determine the relationships between uses and problems in the estuaries.

- Researchers and natural resource managers are often forced to display data in tables instead of maps because of the time and costs associated with drafting new maps. Some of the drawbacks of presenting research results in this manner are that tables are hard to interpret, make it difficult to see trends, and do not portray the spatial relationships in the data.

2.4 New Methods and Procedures

To correct the problems identified in Section 2.3, the most commonly used cartographic and attribute data that contain information related to the estuaries will be entered or tied into the A/P host computer. Once in the computer, the GIS will enable users to capture, store, manage, analyze, and display both cartographic and attribute data. Specialized software will be developed to enable users to perform these functions in a simple manner. Interagency agreements will be developed to keep the cartographic and attribute data up-to-date. Some of the capabilities which the A/P System will provide to users include the following:

- Identify all the books, journal articles, and cartographic and attribute data that contain information related to the estuarine systems.

- Access and use a centralized set of cartographic and attribute data which meet strict quality standards and are kept up-to-date.

- Locate cartographic and attribute data of interest and extract the data from the centralized database.

- Create standard and customized maps which depict only the requisite natural resource features, labeled with helpful information, and presented using the desired scale, projection, resolution, currency, and format.

- Create standard and customized reports which depict only the requisite attribute data and in the desired format.

- Use specialized GIS functions to create buffers around cartographic features and to form new data layers by overlaying two or more existing data layers.

- Find and report on cartographic and attribute information that meets certain criteria by performing queries on the database.

- Develop models that incorporate spatial information and relationships such as distance, location, and proximity.

SECTION 3

SYSTEM DESCRIPTION

3.1 System Overview

The A/P System consists of five major components: hardware, software, data, procedures, and people as shown in Figure 2. A brief description of each of these components is provided in the following sections.

3.1.1 Hardware

The software and databases of the A/P System reside on a powerful centralized computer operated by the State Center for Geographic Information & Analysis (CGIA). This state-of-the-art computer system is specially designed to handle vast amounts of cartographic data. The system has large amounts of disk storage space, very fast processing speeds, and supports a variety of peripheral devices including workstations, graphic terminals, alphanumeric terminals, printers, plotters, tape drives, digitizers, and a color film recorder. Table 1 is a detailed listing of the components of the CGIA computer system.

To access the large number of external databases that contain data about the estuaries, connections will be developed with EPA's National Computer Center (NCC), and the state's mainframe at State Information Processing Services (SIPS). If required, connections to other computer systems will also be developed. Furthermore, the A/P host computer will be configured to provide access for remote users.

Users will be able to access the A/P host computer using a wide variety of local and remote terminals, microcomputers, or workstations. The various user hardware environments that will be supported for use with the A/P System, their capabilities, and their hardware/software needs are presented in Section 5 of this document.

3.1.2 Software

There are three types of software in the A/P System. These are operating system software, commercial applications software, and custom applications software to be specially developed for A/P System users. Each type is described below. The overall structure of the A/P System software is illustrated in Figure 3.

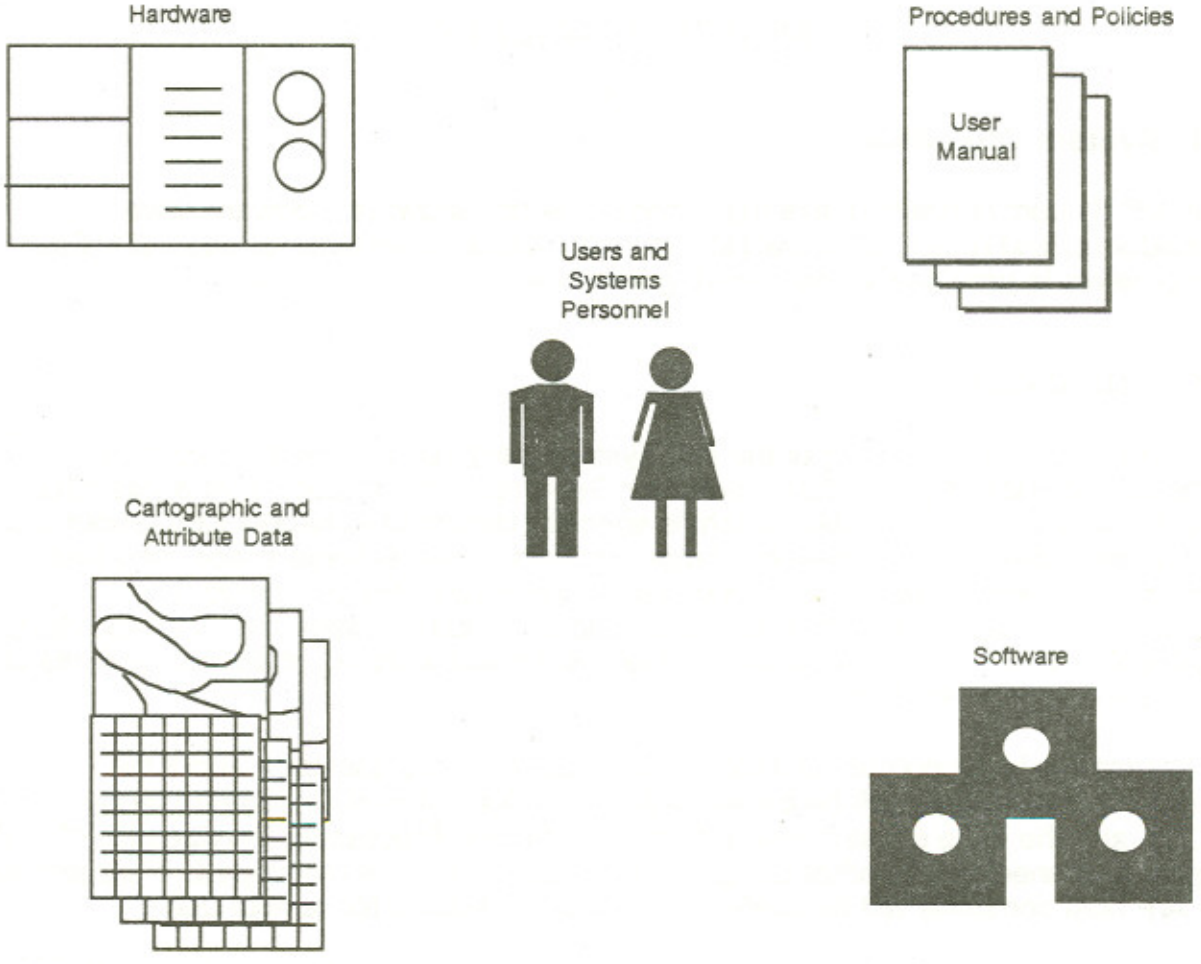


FIGURE 2 Five Major Components of the A/P System

TABLE 1 CGIA Hardware and Software Capabilities

HARDWARE

- Sun 4/390 File Server with:
    - 32 megabytes of memory
    - 2 gigabytes of disk storage
    - 800/1600/6250 bpi tape drive
    - 32 asynchronous data ports
    - floating point processor
- Sun SPARCstation 1 workstations with:
    - 8 or 12 megabytes of memory
    - 2 x 104-megabyte disks
    - 327-megabyte disk (on 4 of 6 workstations)
    - 19-inch color monitor
    - 150-megabyte, 1/4-inch cartridge tape backup unit
    - Graphics accelerator
- Peripherals including:
    - Calcomp 1044 and 1077 pen plotters
    - Calcomp 9100 digitizing tables
    - Altek DATATAB digitizing table
    - Tektronix color graphics terminals
    - Matrix 6000 camera (color film recorder)
    - Wyse (model 85) alphanumeric terminals
    - Data Products 600 lpm line printer

SOFTWARE

- System software including:
    - SunOS (Unix operating system)
    - Sun FORTRAN programming language compiler
    - Sun C programming language compiler
    - SNA 3270 communications (connection to the state's IBM mainframe)
- Applications software including:
    - ESRI's ARC/INFO geographic information system software
    - ESRI's TIN software (three-dimensional modeling)
    - ESRI's NETWORK (routing) software
    - Dynamic Graphics' Interactive Surface Modeling (ISM) software
    - ERDAS image processing software

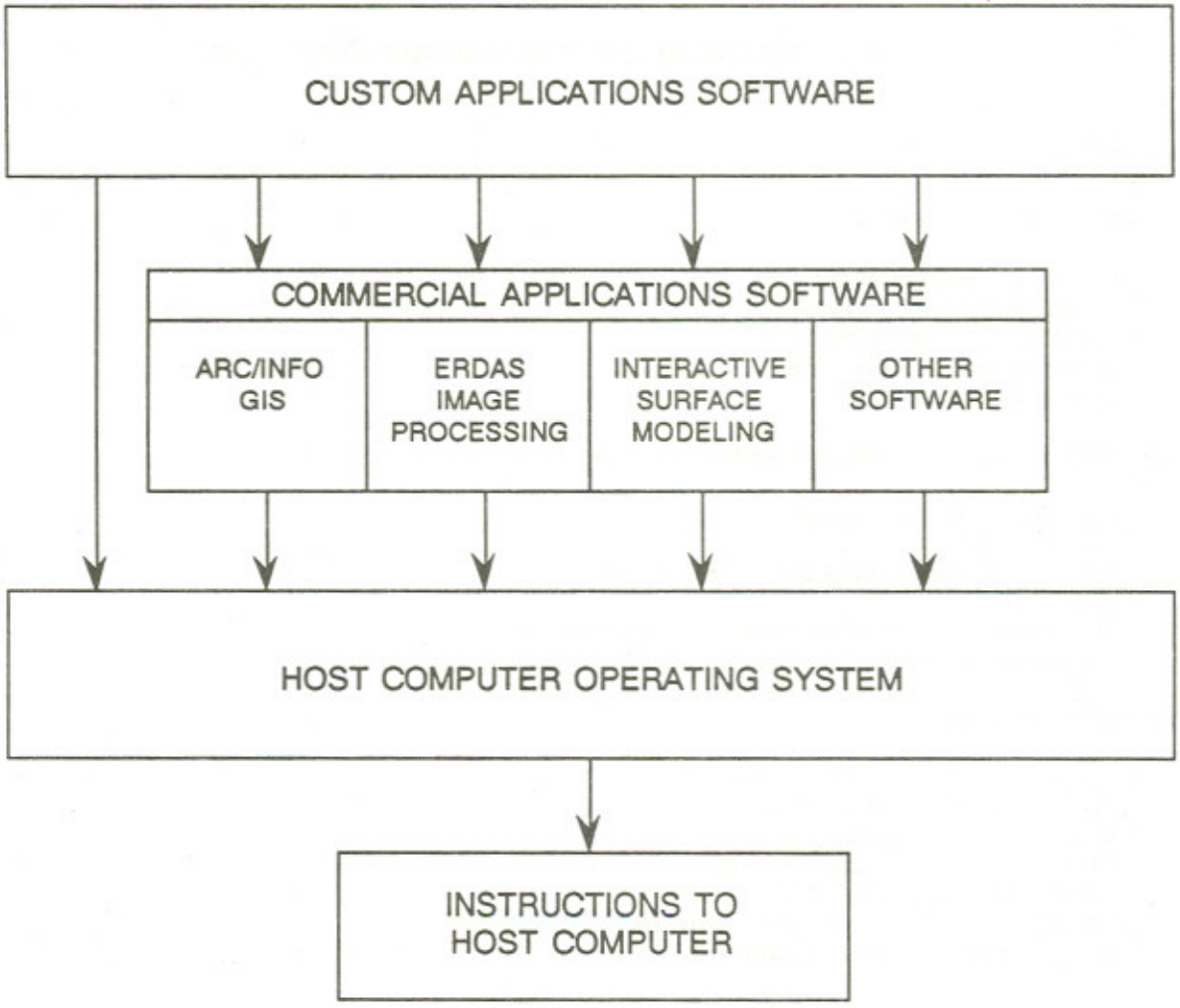


FIGURE 3 Software Relationships in the A/P System

3.1.2.1 Operating System

The Sun File Server and workstation hardware performs tasks under the SunOS operating system. SunOS is based on the converged Berkeley 4.2 BSD and AT&T System V versions of the UNIX operating system. Operating system software translates commands provided by the support software, applications software, and users, into commands understood by the host computer. SunOS software on the A/P host computer provides thousands of commands for performing operations such as creating, editing, and managing files; maintaining the system; communicating with other users; performing tape backups; and others.

3.1.2.2 Commercial Applications Software

Commercial applications software consists of programs that provide geoprocessing and database management capabilities in the A/P System. Commercial software that is available on the A/P host computer includes ARC/INFO, ERDAS, and ISM.

ARC/INFO, is a widely used GIS software package developed by Environmental Systems Research Institute. It consists of a number of separate software modules including ARC, INFO, ARCEDIT, ARCPLOT, NETWORK, TIN, and AML. Together, these packages provide a variety of capabilities for managing and manipulating cartographic and attribute data. ARC is the central program and provides capabilities for managing, exchanging, and manipulating cartographic data. INFO is a relational database management system and fourth generation programming language that provides a wide variety of capabilities for managing, manipulating, and displaying attribute data. ARCEDIT is an interactive graphics editor that provides capabilities for entering and editing cartographic data. ARCPLOT provides a wide variety of functions for querying and displaying both cartographic and attribute data. NETWORK provides functions for manipulating, analyzing, and displaying geographic phenomena such as stream networks. TIN provides capabilities related to the analysis and display of three-dimensional surface models such as contouring, viewsheds, cross-sections, and point elevations. ARC Macro Language (AML) is a fourth generation programming language which enables the commands in the ARC/INFO software to be embedded in programs and then executed.

ISM is a surface modeling software package with the capability to create a gridded surface from scattered data points and perform contouring, surface, and subsurface analysis on that gridded surface. Products include viewsheds, cross-sections, and three-dimensional surface models. Software routines are available to allow transfer of ISM data files to ARC/INFO and vice versa.

ERDAS is a state-of-the-art image processing system that provides a wide range of capabilities for manipulating, analyzing, and displaying raster (i.e., grid cell-based) images obtained from remote sensing platforms such as satellites. A special feature of

ERDAS is the ability to display a raster image simultaneously with vector data created in ARC/INFO.

Communications packages that facilitate the transfer of data between different types of computers will need to be obtained to support the interface between the A/P System and the user community.

3.1.2.3 Custom Applications Software

Custom applications software consists of programs in the A/P System that will be specially written to provide a user friendly interface to the operating system and commercial applications software. Most of this software can be developed using the AML capability of ARC/INFO.

To minimize the complexity of using the commercial software and accessing the A/P Database, the hundreds of commands needed to produce a product or perform a function will be embedded into AML programs that can then be easily executed by users. The custom application software functions that will be developed as part of the A/P System are more fully described in Section 4 of this document.

3.1.3 Data

There are two primary types of data in the A/P System. These are cartographic data and attribute data. These two types of data are combined in the A/P Database to form data layers. Figure 4 shows this hierarchy of database terms. Cartographic data consist of collections of points, lines, or polygons used to represent map features such as roads, elevations, streams, or county boundaries. Attribute data consist of collections of codes, numbers, and text that provide descriptive information and are stored as tables of columns and rows. The cartographic and attribute data are related to each other by a unique identification number for each map feature such that attribute data can be displayed on a map or used for modeling activities, and cartographic data (such as distances, locations, and areas) can be displayed in reports. Figure 5 illustrates this relationship between cartographic and attribute data.

The cartographic and attribute data will reside in a centralized database. Users of the A/P System will extract copies of the data from the centralized database into their own workspaces. Users will perform analyses on this copy of a portion of the A/P Database. This overall database concept is illustrated in Figure 6. The centralized database and user workspace concepts will enable all users to access and share data without corrupting the master data.

To enable users to generate reports and maps, as well as manipulate and change the cartographic and attribute data to meet their own needs, each user will be assigned a workspace. From these workspaces, users will be able to generate reports and maps, as well as extract cartographic and attribute data from the centralize database and

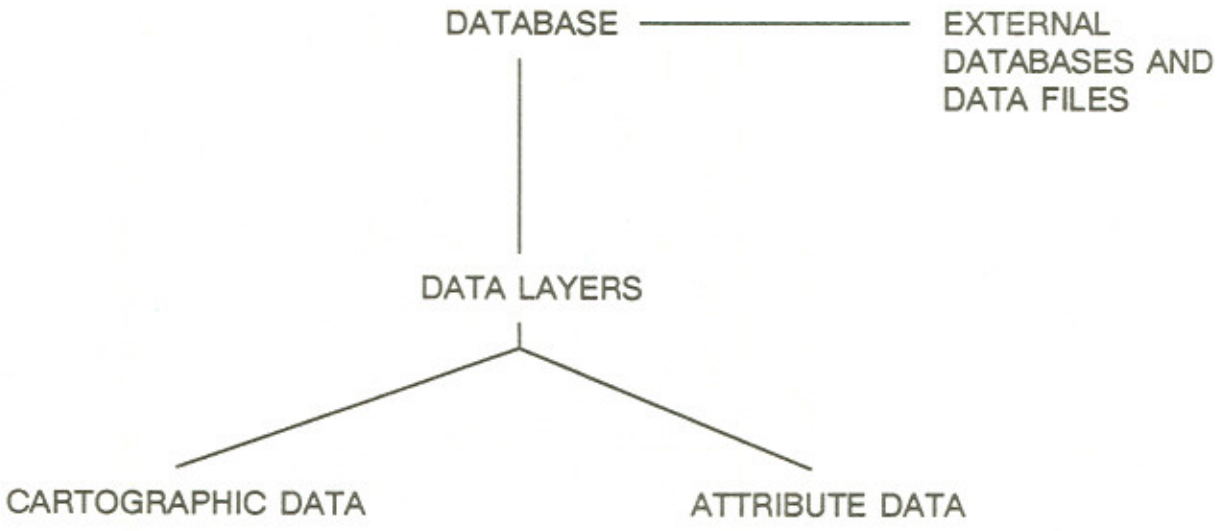


FIGURE 4 Hierarchy of Database Terms

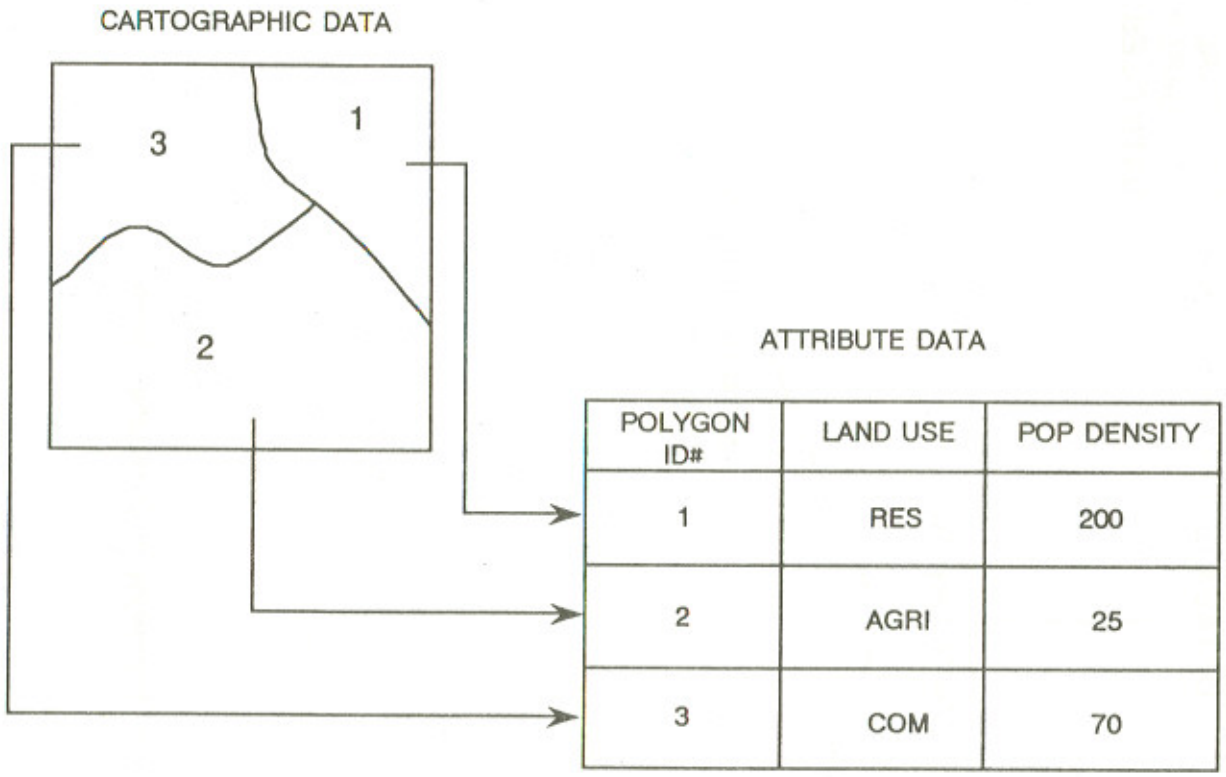


FIGURE 5 Relationship between Cartographic and Attribute Data

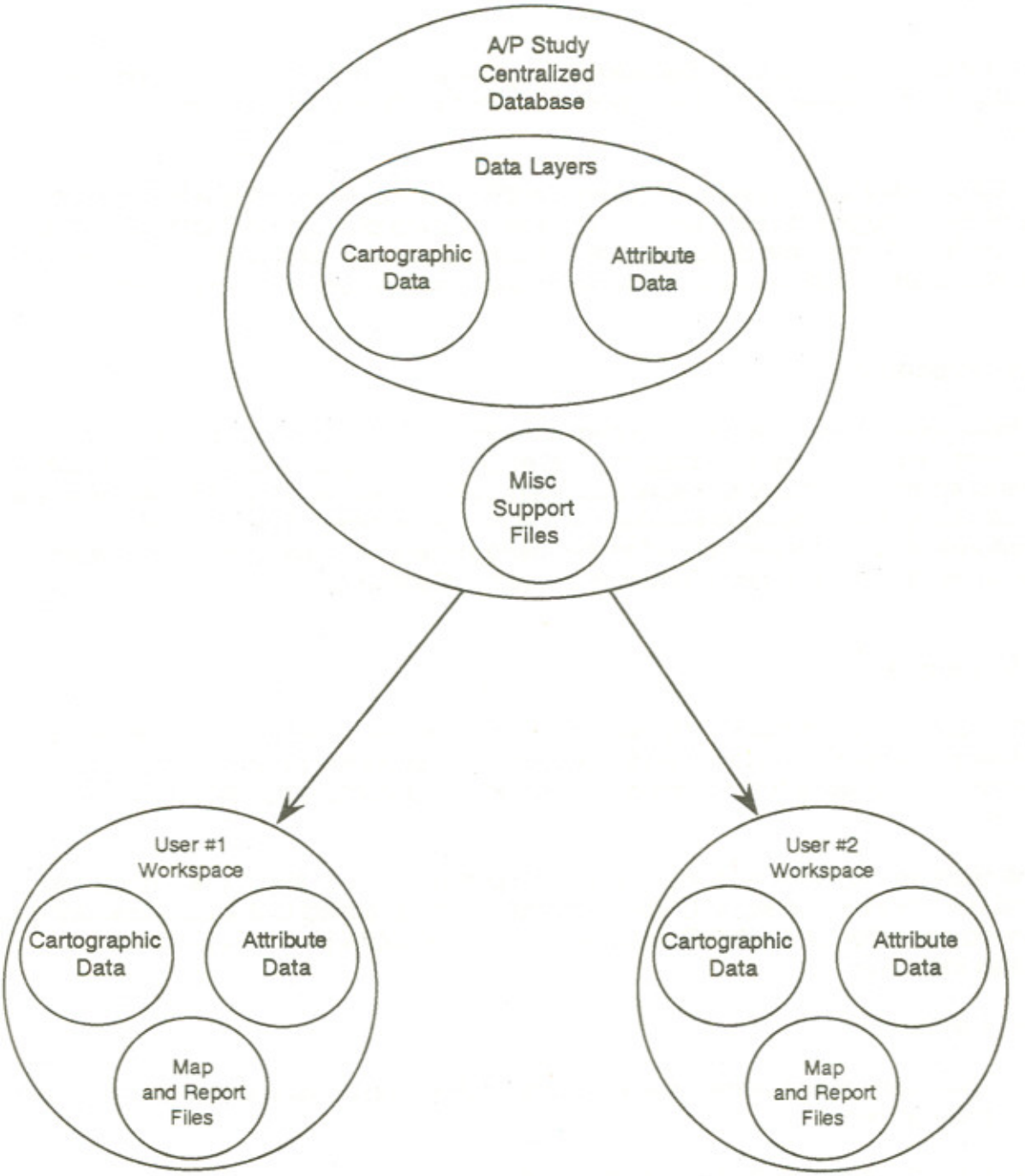


FIGURE 6 Conceptual Database Structure

place it into their workspace. Because they generally contain a subset of the data available for the whole study area, extracts from data layers are referred to as coverages.

Over 60 different data layers have been identified for inclusion in the A/P Database. Lists of the cartographic data and the attribute data are provided in Tables 2 and 3, respectively. A complete description of the data layers and data sets is provided in the Data Requirements Document, available through the A/P Study Program Office.

3.1.4 Procedures

The fourth component of the A/P System consists of written policies, procedures, guidelines, and manuals for designing, developing, managing and using the system. Procedures are necessary to insure that users can access the data and that the system runs smoothly and is being maintained in the proper manner. The policies, procedures, and guidelines related to the management and use of the A/P System will be documented in the Users Manual described in Section 1.3.

3.1.5 People

The fifth component of the A/P System consists of people. This includes the people who design, develop, and maintain the system, as well as the people who use it. CGIA is primarily responsible for the design, development, and management of the A/P System.

As the state agency with responsibility for computerizing data about the natural and cultural resources in the state, CGIA performs activities related to the development and continued operation of the A/P Database. In this role, CGIA performs a number of activities including:

- staffing;
- operations management such as data backup and restore and system security enforcement;
- equipment and software maintenance;
- system performance monitoring;
- database implementation including analysis, design, and automation;
- procurement of hardware, software, and data processing supplies;
- contracting services such as the development of specifications and Requests for Bids (RFB);

TABLE 2 List of Data Layers

1 State Boundary
2 A/P Study Area Boundary
3 County Boundaries
4 Subbasins
5 Quad-County-Subbasin Boundaries
6 Hydrography
7 Land Use and Land Cover
8 Point Source Dischargers
9 Wetlands and Deep Water Habitats
10 Ambient Water Quality Monitoring Sites
11 Natural Heritage Inventory
12 1980 Census Boundaries
13 Surface Water Intakes
14 Submerged Aquatic Vegetation
15 Superfund Sites
16 1990 Census Boundaries
17 Coastal Reserves
18 Fisheries Biological Monitoring Sites
19 Oyster Cultch Plant Sites
20 Game Lands
21 Heavy Metal and Organic-Rich Mud Pollutants Sample Sites
22 Citizen Water Quality Monitoring Sites
23 Mussel Distribution
24 Bottom Sediment Sample Locations
25 Federal Land Ownership
26 Nursery Areas (Primary and Secondary)
27 Shellfish Evaluation Areas
28 Oyster Producing Areas
29 Outstanding Resource Waters
30 1970 Census Boundaries
31 Artificial Reefs
32 CAMA Major Development Permits
33 General Soils
34 Transportation
35 State Park Boundaries
36 Stream-Gaging Stations
37 Marinas

TABLE 2 List of Data Layers (Continued)

38 Peat Lands
39 Anadromous Fish Areas
40 Public Water Supplies (Groundwater Intakes)
41 Solid Waste Facilities
42 Aquifers
43 Detailed Soils
44 Municipal Boundaries
45 Pollution Incidents
46 Ambient Air Monitoring Sites
47 Air Quality Permits
48 Air Emissions Inventory
49 Water Quality Sample Project Locations
50 Mining Permits
51 Lease Blocks
52 Geology
53 Geodetic Control Points
54 Sea Turtle Population
55 Ocean Fishing Pier Licenses
56 Military Air Space
57 Fishing Water Jurisdictions
58 Historic and Archaeological Sites, Buildings, and Structures
59 Water Quality Monitoring Sites (Groundwater)
60 Water Level Monitoring Sites (Groundwater)
61 Dam Inventory
62 Elevation
63 Watersheds
64 Bathymetry

TABLE 3 List of Attribute Data

1 1970 Census Data
2 1980 Census Data
3 1990 Census Data
4 Agricultural Output Statistics
5 Air Emissions Inventory Data
6 Air Quality Permits Data
7 Ambient Air Monitoring Data
8 Ambient Water Quality Monitoring Data
9 Anadromous Fish Data
10 Big Game Kill Reports Data
11 Boat Registrations Data
12 Boating Access Areas Data
13 Bottom Sediment Sample Data
14 Building Permits Data
15 CAMA Major Development Permits Data
16 Census of Agriculture
17 Census of Manufactures/Mineral Industries
18 Census of Wholesale and Retail Trade
19 Citizen Water Quality Monitoring Data
20 Commercial Landings Data
21 County Business Patterns Data
22 Dam Inventory Data
23 Detailed Soils Data
24 Fish Processing Operations Data
25 Fisheries Biological Monitoring Data
26 Furbearer Harvest Data
27 General Soils Data
28 Hazardous Waste Facilities Data
29 Heavy Metal and Organic-Rich Mud Pollutants Data
30 Historic and Archaeological Data
31 Marinas Data
32 Mechanical Harvest of Clams Permits Data
33 Mining Permits Data
34 Municipal Data
35 Mussel Distribution Data
36 Natural Heritage Inventory Data

TABLE 3 List of Attribute Data (Continued)

37	Ocean Fishing Pier Licenses Data
38	Operating Unit Survey Data
39	Outdoor Recreation Facility Inventory Data
40	Oyster Cultch Plant Data
41	Oyster, Scallop, and Clam Licenses Data
42	Pollution Incidents Data
43	Population Estimates/Projections Data
44	Pound Net Registrations Data
45	Public Water Supplies Data (Groundwater Intakes)
46	Recreational Fishery Statistics
47	Sea Turtle Population Data
48	Seafood Dealer Licenses Data
49	Solid Waste Facilities Data
50	State Parks Data
51	Stream-Gaging Data
52	Striped Bass Reproduction Monitoring Data
53	Superfund Data
54	Surface Water Intakes Data
55	Tourism Expenditures and Employment Data
56	Vessel Licenses/Permits Data
57	Water Level Monitoring Data (Groundwater)
58	Water Quality Data Analysis
59	Water Quality Monitoring Data (Groundwater)
60	Water Quality Sample Project Data

- bid evaluations, coordination of installations, and acceptance testing;
- vendor liaison including hardware and software problem determination and resolution;
- liaison with other computer installations and agencies managing data relevant to the A/P Study; and
- documentation of the data management procedures, standards, and software that are developed as part of the A/P System.

Among the special responsibilities of CGIA for the A/P Study are development of a comprehensive data management plan; design, development, and documentation of custom applications software; coordination of the cataloging of data and literature; coordination and performance of user training and assistance; and preparation of progress reports.

Potential users of the system include a number of individuals from a wide variety of agencies and organizations at the local, state, and federal levels as identified in Section 2.2. To ensure that these people are able to use the system in an effective manner, training courses, user manuals, and technical support will be provided by CGIA.

3.2 Inputs-Outputs

There are primarily three types of inputs to the A/P System. These are attribute data, cartographic data, and user responses. Cartographic data consist of a collection of points, lines, or polygons used to represent map features such as roads, streams, or county boundaries. Landsat satellite imagery depicting land use/land cover classifications is also available from the A/P Database. This data will be converted from a raster, pixel format to a vector format represented as polygons. This is an example of cartographic data derived from a non-map source. Attribute data consist of a collection of codes, numbers, and text that provides descriptive information and are stored as a table of columns and rows. User inputs consist primarily of selecting commands, selecting data layers to work with, and providing information for labeling reports.

Outputs from the A/P System will include reports, statistical graphs, and maps. Users will be able to preview or display data at a terminal, send them to a plotter or printer, or archive them on a magnetic tape.

Reports are documents that display data from one or more attribute data sets. All tabular reports will be a maximum of 80 characters wide. This width will enable reports to be viewed on the terminal or printed on standard office paper. When the

number of columns in a report exceeds the width of the page, the columns will be wrapped to a second page.

Statistical graphs are documents that display attribute data in the form of a bar chart, line graph, or scatter diagram. Users will be able to create these graphs in black and white to make them suitable for photocopying, or use a variety of colors for display or plotting. The exact number of colors will be limited only by the user's hardware configuration.

Maps are documents that display one or more data layers plus supporting information such as a title, scale bar, north arrow, and legend. When producing maps, users will be able to choose from any number and combination of data layers. For example, the user may choose to display land use/land cover, roads, and streams on one map. Users will also be able to display only those features that meet certain criteria. For example, the user may elect to display only those land use areas that fall into the category of "forest". In either case, users will be able to produce maps in color or black and white (to make them suitable for non-color reproduction). Users will be able to produce map displays with a multitude of colors. The number of colors available will depend on the user's display hardware. Hardcopy plots of those maps will be limited only by the pen colors available for the plotters at CGIA. Some 50 different patterns will be available to users for shading polygon data to produce either color or black and white maps. A variety of map sizes and map scales will be supported.

3.3 System Security

To protect the system from unauthorized access and to support system management needs, a password system will be implemented to grant users access to the system. Each user will be assigned a level of access rights to the various databases, personal workspaces, and software capabilities in the system. Access restrictions or limitations will be defined for each data layer, including cartographic and attribute data.

SECTION 4

DETAILED FUNCTIONAL REQUIREMENTS

The purpose of Section 4 is to describe the functional requirements of the A/P System. Functional requirements are the major capabilities that the system will contain to satisfy the needs of the user community. Most of the requirements will be met by the operating system of the host computer and the commercial applications software, both described in Section 3.1.2. The remaining requirements will be satisfied by custom applications software, specifically designed and implemented for the A/P System.

4.1 General Requirements

During the course of the A/P Study data needs assessment, general requirements for the applications software were collected and analyzed. The most important design goals and requirements for software in the A/P System are listed below.

1. The system should be developed using state-of-the-art methodologies and procedures for systems design, analysis, and programming.

2. Emphasis should be placed on the development of generic (multi-purpose) data and software that has the potential for satisfying the needs of the greatest number of users before resources are allocated to the development of non-generic (single-purpose) data or software.

3. The system should be developed to minimize the duplication of hardware, software, and data whenever possible.

4. The system must enable users to extract, edit, manage, manipulate, analyze, model, and display both cartographic and attribute data. (Users will be prohibited from altering the A/P Database. Updates or other modifications to the database will be made by CGIA.)

5. The system must be flexible to accommodate future changes in hardware, software, data, procedures, and personnel.

6. The system must be flexible to accommodate use by a wide variety of potential users including urban and regional planners, resource managers, technicians, and scientists.

7. The system should be simple and easy to use for users with little prior computer or GIS experience, but also powerful and flexible for those users with extensive computer and/or GIS experience.

8. The system should be accessible by local and remote users using a variety of hardware and software.

9. The system should protect users from accidently destroying or modifying data, but enable them to modify data in their local workspaces to meet their own needs.

10. The system should be as interactive as possible and thereby enable users to obtain answers to their questions in real time.

11. The system should be reliable and procedures should be developed to maintain it beyond the life of the A/P Study.

12. The system should be developed and usable in a cost effective manner and be self-supporting at the conclusion of the A/P Study.

As described in Section 3.1.2, the system consists of three types of software: the host operating system, commercial applications software, and custom applications software. Custom applications software needs to be written for the A/P System to provide a user friendly interface to the host operating system and commercial applications software.

4.2 System Functions

The applications software needed to maintain and use the A/P Database can be divided into three broad areas: system management functions, application-general functions, and application-specific functions. Implementation of these functions will be accomplished primarily through commercial applications software with some custom application software development required in certain cases. System management functions consist of the capabilities needed to create, manage, and maintain the databases and software in the A/P System. Application-general functions consist of common capabilities that the vast majority of users will need to create, edit, manage, manipulate, model, analyze, and display the cartographic and attribute data in the A/P Database. Application-specific functions are special purpose software capabilities designed to meet well defined, frequent needs of specific users. All three categories of functions, and the capabilities they provide, are discussed in the remainder of Section 4.2.

4.2.1 System Management Functions

System management functions are needed to create, manage, and maintain the databases and software in the A/P System in a consistent and reliable manner. System management functions include database interfaces, database management, data archiving and restore functions, and software development tools. System

management capabilities will be utilized by system personnel at CGIA to maintain an ongoing, operational system and will be largely invisible to users. A majority of the system management capabilities are provided through the host operating system (SunOS) and ARC/INFO.

Database interfaces are needed to link the A/P Database to large, existing, external databases residing on a variety of university, state, and federal computers. Over 60 sets of attribute data were identified in the data needs assessment for inclusion in the A/P Database. Some of those currently reside on the A/P host computer, while others reside on other computers in a variety of formats. Procedures and software will be developed to obtain selected portions of external databases to fulfill user data requests. The Database Interface function will enable data transfers to be performed by providing data extraction, formatting, and exchange capabilities.

The Cartographic Data Management function will provide systems personnel at CGIA with the procedures necessary to maintain the cartographic data for all data layers. Functions that will be provided include displaying the data contents as well as adding, deleting, and updating the cartographic portion of a data layer within the A/P Database. These features are part of the ARC/INFO GIS software. CGIA will augment this software as necessary with custom software to facilitate ease of use.

The Attribute Data Management function will provide systems personnel at CGIA with the procedures necessary to maintain the attribute data. Functions that will be provided include displaying the data contents as well as adding, deleting, and updating data sets in the database, and adding, deleting, and updating the attribute portion of a data layer within the database. These features already exist in INFO. Modifications will be made as necessary to accommodate A/P System users.

When completed, the A/P Database will contain tremendous amounts of data in the centralized database, as well as in project and personal workspaces. To minimize the storage space required by this data, and enable files that are accidently damaged or deleted to be recovered, the ability to backup and restore data from magnetic tape is needed. The Data Archive and Restore function will provide system personnel with the ability to backup and restore project and personal workspaces, data layers (including cartographic and attribute data), text files, and various other data files in the system. This capability is already available for use by CGIA staff. It will be adapted for A/P System users.

4.2.2 Application-General Functions

Application-general functions consist of commonly used GIS capabilities. These functions will enable users to extract, edit, manage, manipulate, model, analyze, and report on the cartographic and attribute data in the A/P Database. Application-general functions can be thought of as a generic set of tools for manipulating and displaying the spatial data in the A/P Database. Four major groups of application-general functions have been identified. These are: data extraction and management functions,

data creation and editing functions, data manipulation and summarization functions, and data analysis and display functions.

4.2.2.1 Data Extraction and Management Functions

One of the primary objectives of the A/P System is to provide users with bibliographic, cartographic, and attribute data to help them improve the management of the natural resources in the estuarine areas. Data Extraction and Management functions will enable users to locate, access, extract, and manage bibliographic, cartographic, and attribute data in the A/P System. The Bibliography and Data Inventory function will enable users to perform searches for literature, data, and other types of materials containing information about the estuaries. These materials include books, journal articles, proceedings, reports, documentaries, brochures, pamphlets, as well as the maps, attribute data, photographs, and imagery.

To use the data in the A/P Database effectively, users must know something about the data and where it is stored. The Data Dictionary function will aid users by providing general descriptions of each data layer in each database, the relationships between the cartographic and attribute data contained in each layer, and the characteristics of each data layer. For each data layer, information about the cartographic data such as the source, owner, accuracy, resolution, scale, currency, update frequency, geographic and temporal coverage, and a brief description will be provided. Information about the attribute data such as the source, owner, currency, update frequency, geographic and temporal coverage, and a brief description will also be provided.

The A/P Database will eventually consist of data layers containing cartographic and attribute data available for read-only use. To support individual and project needs that involve the manipulation of cartographic and attribute data, users will be able to work with extracts of the centralized database that have been copied into their personal or project workspaces. The Workspace Management function will enable users to manage and modify the many types of data files that will accumulate in their workspaces. Functions that will be provided include creating, selecting, describing, deleting, renaming, copying, displaying, and printing the contents of their workspaces, data layers (i.e., cartographic and attribute data), text files, reports, and plot files.

When completed, the A/P Database will contain over 60 data layers. To prevent accidental deletion or corruption of data, the data layers will be available for read-only use and will not be modifiable by the user. Although the cartographic portion of the database will support the users' needs to perform "query and display", those users that wish to change, manipulate, or perform modeling activities with data layers will need to work with copies of the layers. The Cartographic Data Extraction function will enable users to specify the USGS quad sheet, county, subbasin, or geographic coordinates of the area to be extracted, extract the desired data layer(s) from the database, and then place a copy of the data layer(s) in the user's personal workspace. After performing a

data layer extraction, the user will have the opportunity to obtain copies of the attribute data that are related to the extracted cartographic data using the Attribute Data Extraction function.

The Attribute Data Extraction function will enable users to specify the USGS quad sheet, county, subbasin, or geographic coordinates of the area to be extracted, perform an extraction of the desired attribute data, and then place a copy of the data in the user's personal workspace. After performing the extraction, the user will have the opportunity to obtain copies of the data layers that are related to the extracted attribute data using the Cartographic Data Extraction function.

It is anticipated that most users will interact with the A/P System by logging into their personal or project workspace on the A/P host computer through telecommunications or network software. However, some users may wish to perform local GIS analysis by downloading the data they need from their personal workspace to their personal computer (e.g., an IBM PC, graphics workstation, or other computer running ARC/INFO). The Cartographic Data Exchange function will enable cartographic data to be exchanged between the A/P host computer and other computers using routines in the ARC/INFO software designed specifically for moving cartographic data between different kinds of computers. ARC/INFO also contains the tools to convert data to external formats for other users. A common example of such a format is the USGS Digital Line Graph (DLG) format. Due to the potentially large quantities of data involved, access to the Cartographic Data Exchange function will only be granted to users who have had their data request approved by CGIA.

For users who have a personal computer but not ARC/INFO, the Attribute Data Exchange function will enable attribute data to be downloaded to their computer for more traditional, non-GIS modeling and analysis.

4.2.2.2 Data Creation and Editing Functions

Although the A/P Database will contain vast amounts of cartographic and attribute data that will be useful to many users, it is anticipated that users will need to be able to create, store, and/or edit data in the system that is specific to their needs. Data creation and editing functions will enable users to modify the cartographic and attribute data that they have extracted from data layers in the centralized database and copied to their workspaces, as well as to create new data layers. Some of the functions needed to enable users to create and edit data in the A/P System include: Cartographic Data Editing, Attribute Data Editing, a Data Layer Generator, a Three-Dimensional Surface Generator, and a Contour Generator.

Although users will not be able to modify the data layers that reside in the centralized database, they will be able to modify data layers that have been extracted from the centralized database and copied into their personal workspaces. This will enable them to perform analyses and generate cartographic data specific to their needs. The Cartographic Data Editing function will enable users to select a data layer in their

workspace and modify it using options to display, add, delete, edit, and move the points, lines, and polygons in the data layer. The Attribute Data Editing function will enable users to select an attribute data file in their workspace and modify it using options to list, add, delete, or rename column items in the file, or to display, add, delete, edit, and delete rows of records in the data file. Both Cartographic and Attribute Data Editing functions are standard features of the ARC/INFO GIS software. AML routines have been written at CGIA to streamline data editing tasks for CGIA production staff. Therefore, minimal custom software will be required to implement these features for A/P System users.

As part of their investigations, users will need to subdivide data layers, depict point sample locations, and represent other forms of attribute data. The Data Layer Generator function will enable users to generate grid, point, and vector data layers that are automatically georeferenced to the area that they are interested in. These data layers will then be suitable for further analysis and manipulation in overlay and modeling activities.

Using three dimensions to depict data can often provide insights that are not apparent in two dimensions. The Three-Dimensional Surface Generator function will enable users to produce three-dimensional surfaces depicting the interaction between three different variables (one variable each for the x, y, and z axes). This function will support the generation of three-dimensional surfaces from two types of data. The first type of data is that which is collected on the basis of point samples that already exist as x,y-coordinate pairs. Examples of point sample data are water quality measurements, heavy metal concentrations, and toxin levels. The second type of data consists of three columns of numeric values that are related to each other in some way. Once generated, surfaces from both types of data will be able to be viewed using the Three-Dimensional Surface Display function discussed in Section 4.2.2.4.

Large amounts of data that exist for the estuaries have been collected as point samples. Extrapolating point sample data to the surrounding areas and presenting it in a format that is easy to understand is extremely difficult when the data are presented in tables. However, maps that depict point sample values in the form of contour lines are very useful for extrapolating point data to surrounding areas. The Contour Generator function will accept point data as input and extrapolate and/or interpolate the data to surrounding areas, and produce a new data layer with the point sample values represented as contour lines.

4.2.2.3 Data Manipulation and Summarization Functions

The development of generic data manipulation and summarization functions is difficult because these activities tend to be highly specific. However, some common capabilities needed to manipulate and summarize the cartographic and attribute data in the A/P System can be identified. Some of the functions that will enable users to manipulate and summarize data in the system include Cartographic Data Manipulation and Attribute Data Manipulation.

One of the features that distinguishes a GIS from a computer mapping system is the ability to overlay data layers and thereby generate new information. For example, by overlaying data layers depicting salinity, water depth, and residential development, one could determine the areas in the estuaries that have the most potential as primary nursery areas. The Cartographic Data Manipulation function will enable users to perform overlays and buffers by prompting the user for the names of the data layers, ensuring that the overlay or buffer operation is valid, performing the overlay or buffer operation, and alerting the user when the operation is complete.

In addition to performing query and display, users need to be able to manipulate the attribute data to create new information and support complex analyses. The Attribute Data Manipulation function will enable users to perform simple modeling efforts by applying mathematical operations to any two columns of data and placing the results in a third column. The mathematical operations that will be supported include addition, multiplication, division, subtraction, and exponentiation. In some respects, this function will provide capabilities similar to those in a spreadsheet.

Cartographic and attribute data manipulation may result in statistical summary information. ARC/INFO GIS software provides for summarization of these data as standard features.

4.2.2.4 Data Analysis and Display Functions

The functions in this category will help resource managers and researchers search for and display the geographic data in the A/P Database. These data could then be presented in a format that best supports their needs and communicates the results of their work. Some of the functions that will enable users to analyze and report on the cartographic and attribute data in the system include Query and Display, Attribute Sort Utility, Report Generator, Map Generator, Statistical Graphics Generator, Three-Dimensional Surface Display, and Map Composition Editor.

Query and display capabilities needed by potential users of the A/P System generally fall into two categories. The first consists of the ability to display all the attribute information that describes a selected feature on a map. The second consists of the ability to graphically display all the map features that meet certain criteria defined by the user. The Query and Display function will fulfill both of these requirements by enabling the user to perform either graphic query and display or attribute query and display. Using graphic query and display, users will be able to point at one or more features on a displayed map and then display all the data about the feature(s). Using attribute query and display, users will be able to enter a number of criteria that will be used to search the attribute data, and then display all the map features that meet those criteria. For both types of query and display, users will be able to save the features that are found as a result of a query for further analysis and manipulation.

There will be about 60 different data layers in the A/P Database as well as specialized layers that users may create in their personal or project workspaces. Although users will be able to produce a map in a standard format for any data layer, in many instances this format may not be suitable to the user. The Map Generator function will enable users to produce customized maps depicting one or more data layers using a standardized set of scales, colors, shade patterns, and formats. The Map Generator will enable users to define the area of interest, select one or more data layers to plot, produce the plot using a scale, map projection, and other format options selected by the user, as well as provide the name and title information for the plot. A Report Generator function will be available for producing summarized attribute data.

One of the objectives of the A/P Study is to be able to track the trends and determine the status of the estuaries. Statistical graphics can be especially useful for displaying status and trend data. For example, one of the most useful tools for trend analysis is the ability to graphically display a variable (such as water quality, arsenic concentrations, or oxygen levels) against time on a simple line graph. The Statistical Graphics Generator function will enable users to display any column of data as a scatter diagram, line graph, bar chart, or pie chart.

The Three-Dimensional Surface Display function will enable the three-dimensional surfaces produced by the Three-Dimensional Surface Generator to be viewed in a variety of ways and from a variety of perspectives by the user. These capabilities include the direction the surface is viewed from, the viewer's height, vertical exaggeration, and subsampling distance. In addition, users will be able to obtain data values for points anywhere on the surface, produce two-dimensional profiles of the surface, and save any of the three-dimensional displays as a permanent file for subsequent production as a map. CGIA will use the ISM software package to implement these capabilities.

Although the Map Generator function described above will enable users to develop customized maps within a framework of standard scales, projections, and formats, some users have expressed the need to produce highly customized maps in a non-standard format to meet very specific project applications. The Map Composition Editor will enable users to develop customized, non-standard maps by selecting map features to position and reposition, modify standard map scales and formats, and display a variety of legends, scale bars, and descriptive text.

4.2.2.5 Core Routines

Many of the functions described in Section 4.2 above share a common set of needed capabilities. For example, most functions prompt users for the names of files, check input data against specified data value ranges, and define the geographic extent of the area that is being studied. When implemented as software, these common subfunctions are referred to as "core routines". A thorough identification and analysis of these routines is needed to ensure that computer programming and software maintenance efforts are minimized and that consistency in the user interface is

maintained. As shown in Figure 7, the core routines will form the building blocks upon which the remaining programs in the A/P System will be built. In addition, these routines will be made available to users who want to develop application programs to meet their specific needs.

4.2.3 Application-Specific Functions

Application-specific functions are special purpose software packages designed to meet well defined, frequent needs of specific users such as the Division of Environmental Management. These functions will continually evolve as users become familiar with the contents of the A/P Database and the GIS capabilities present in the ARC/INFO software. As the need for these specialized functions and models becomes apparent, members of the CGIA staff will work with users to identify the following requirements for each function:

- data layers (including cartographic and attribute data)
- external database access
- GIS processing
- non-GIS processing
- output products
- operational needs

Based on this focused requirements analysis, specifications will be developed to implement the application-specific functions through procedures, AML commands, and/or FORTRAN code. This process will be repeated for each new application-specific function or model that is identified.

Examples of application-specific functions that could be developed include a GIS-based environmental permit management system and software procedures to calculate nutrient budgets.

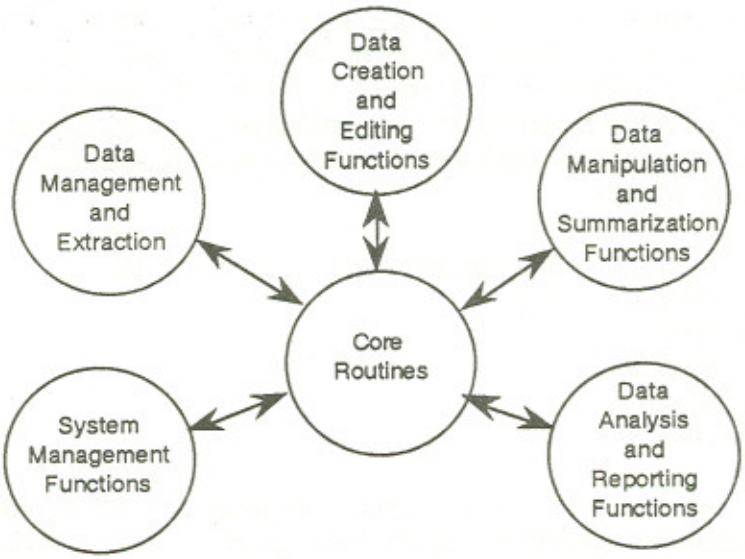


FIGURE 7 A/P System Core Routines

SECTION 5

OPERATING ENVIRONMENT

5.1 General Access Procedures

Users will be able to access the A/P System using a wide variety of user interfaces, hardware, and communication options. The ability to utilize the capabilities in the A/P System will be directly related to the combination of user interface, hardware environment, and communications options that are available to the user. The functionality provided by each of these options is discussed in the sections that follow.

5.2 Interfaces

An interface is a link between the A/P System and the user community. Interfaces can take many different forms. Implementation of the A/P System involves four major types of interfaces broadly categorized as database, human, software, and hardware. The database interface was addressed previously in Section 4.2.1. The human interface refers to interaction between CGIA staff and users to perform projects and fulfill information requests. This is referred to below as the CGIA interface. The software interface is divided into two parts -- an application-general interface and an application-specific interface. This category of interface consists of the full functionality of the A/P System software described in Section 4 and discussed later in this section. The hardware interface is represented in a set of hardware options that will be supported by the A/P System. This interface is discussed in Section 5.3.

5.2.1 CGIA Interface

The CGIA interface is a non-computerized interface to the A/P Database and GIS software. Using this interface, users do not need to know anything about the computers, the A/P Database, or GIS. Rather, users submit requests for data, information, or products directly to CGIA. CGIA provides services of a "project" nature to users of the A/P Database. This is the manner in which CGIA has traditionally operated. These services include basic database query, report and map generation, modeling, and the design and development applications-specific software tailored to individual user needs. The CGIA interface is available now and enables non-technical users to obtain data and products from the A/P Database.

5.2.2 Application-General Interface

The application-general interface will consist of a series of pull-down menus forming a user friendly interface to the functions discussed in Section 4.2. Users will access the capabilities of ARC/INFO through these menus. CGIA staff will only be involved in this interface when users need assistance. To accommodate the large number of potential users of the A/P System with a variety of computer skills and training, several levels of user interface will be offered. An increasing level of interface is indicative of an increasing level of complexity in using the A/P System. As the level of the interface increases, users will have increased flexibility and power to interact with the A/P Database and the GIS software, but each level will be more difficult to use and will require greater GIS knowledge on the part of the user.

At the simplest level, users will have the ability to perform query and display of the data layers and data sets in the centralized database. The next level of user interface will enable users to extract cartographic and attribute data from the centralized database and manipulate it. With increasing levels, users will be able to create new data layers and data sets, write AML and INFO applications software, and use pull-down menus to interact with ARC/INFO software. The most complex level of user interface will allow users to work directly with ARC/INFO commands in the same manner as CGIA staff.

5.2.3 Application-Specific Interface

The application-specific interface will consist of pull-down menus that provide a user friendly interface to those functions discussed in Section 4.2.3. To accommodate the development of application-specific software, a main menu with columns reserved for each division or agency that wants to use the A/P Database will be created. Users will interact directly with the menu to utilize specially developed ARC/INFO capabilities. CGIA staff will be available to assist users in using application-specific software. As applications software is developed for a particular division, section, or agency, it will be installed in the application-specific interface along with password protection, where appropriate.

5.3 User Hardware Environment

Although there is an almost infinite variety of hardware, software, and communications configurations that will enable users to access the A/P Database, these configurations can be grouped into six primary hardware environments. These environments are: non-graphic terminals, graphic terminals, computers emulating non-graphic terminals, computers emulating graphic terminals, computers emulating non-GIS workstations, and computers emulating GIS workstations. The following six sections provide a general description of each of these environments, their capabilities and limitations, as well as the general operating procedures associated with each environment.

Information on specific hardware/software configurations will be made available when the A/P System User Manual is released.

5.3.1 Non-Graphic Terminal Environment

This environment consists of non-graphic terminals connected to the A/P host computer. No local memory or disk storage is included in this user environment. Users will be able to display only attribute data on the A/P host computer, work only with attribute data in their workspaces, use only the attribute applications software, and will not be able to download data for local processing. Users will be able to generate hardcopy printouts on the A/P host computer, or produce local attribute hardcopies if the terminal is attached to a screencopy device such as a graphics printer or plotter.

5.3.2 Graphic Terminal Environment

This environment consists of monochrome and color graphic terminals connected to the A/P host computer. No local memory or disk storage is included in this user environment. Users will be able to display both cartographic and attribute data on the A/P host computer, manipulate and work with the data in their workspaces, and use all of the applications software on the A/P host computer, but will not be able to download data for local processing. Users will be able to generate hardcopy maps and printouts on the A/P host computer, or produce local map and attribute hardcopies if the terminal is attached to a screencopy device such as a graphics printer or plotter.

5.3.3 Non-Graphic Computer Environment

This environment consists of microcomputers, workstations, minicomputers, and mainframes that lack graphic communications software and/or graphic capabilities that prevent them from acting as a graphic terminal to the A/P host computer. Local memory and disk storage are included in this user environment. Users will be able to display and work only with the attribute data on the A/P host computer and use only the attribute applications software. Users will be able to generate hardcopy printouts on the A/P host computer, or produce local attribute hardcopies if the computer is attached to a screencopy device such as a graphics printer or plotter.

5.3.4 Graphic Computer Environment

This environment consists of microcomputers, workstations, minicomputers, and mainframes that have graphic communications software and graphic capabilities that enable them to act as graphic terminals to the A/P host computer. Local memory and disk storage are included in this user environment. Users will be able to display both

the cartographic and attribute data on the A/P host computer, manipulate and work with the data in their workspaces, and use all of the applications software on the A/P host computer, but will not be able to download data for local processing.

5.3.5 Non-GIS Computer Environment

This environment consists of microcomputers, workstations, minicomputers, and mainframes that have graphic communications software and graphic capabilities, but lack GIS software. When the computer is equipped with communications software that supports ASCII file transfers, the computer will effectively act as a non-GIS workstation capable of downloading and processing only attribute data locally. Users with this configuration will be able to work with, manipulate, download, and generate printouts of the attribute data in the A/P Database on either the A/P host computer or their computer, but will be unable to use or work with any of the cartographic data in the A/P Database.

5.3.6 GIS Computer Environment

This environment consists of microcomputers, workstations, minicomputers, and mainframes that have graphic communications software, graphic capabilities, and GIS software. This configuration will enable users to act either as a remote graphic terminal to the A/P host computer or as a stand-alone GIS workstation. When acting as a remote terminal, users will have the capabilities described above for the terminal environment. When acting as a GIS workstation, users will be able to display both cartographic and attribute data, manipulate and work with data in their personal workspaces, use the applications software on the A/P host computer, download data from the host computer, and perform modeling, processing, and report production on their own computer.

5.4 User Communications and Data Transfer Environment

Regardless of the desired user interface or hardware environment, users will be able to communicate and perform data transfer with the A/P host computer using five different options. These options are local access, remote access, network access, diskette transfer, and tape transfer. The functional capabilities offered by each of these options is discussed in the following five sections. Information on specific hardware/software configurations will be made available when the user manuals are released.

5.4.1 Local (Direct) Access

Terminals, microcomputers acting as terminals, microcomputers acting as workstations, and other GIS workstations/computers that are less than 50 feet from the A/P host computer will be supported by running direct lines between the user's hardware and the host computer. Local access will enable users to interactively use the A/P Database, as well as upload and download data. In general, this form of access will provide relatively fast (up to 9600 baud) and reliable communications and data transfer rates.

5.4.2 Remote (Dial-In) Access

Terminals, microcomputers acting as terminals, microcomputers acting as workstations, and other GIS workstations/computers which are greater than 50 feet from the A/P host computer will be able to dial-in to the host computer using modems and communications software. One or more 1-800 numbers will be available to do this. Remote access will enable users to interactively use the A/P Database, as well as upload and download data. This form of access will provide relatively fast (up to 9600 baud) and reliable communications and data transfer rates.

5.4.3 Network Access

Terminals, microcomputers acting as terminals, microcomputers acting as workstations, and other GIS workstations/computers that have access to any of the computer networks that the A/P host computer is linked to (e.g., SNA) will be able to access the A/P Database directly by installing the board(s), software, and cabling necessary to become a node on the network. Network access will enable users to interactively use the database, as well as upload and download data. In general, this form of access will provide the fastest (up to 19,200 baud) and most reliable communications and data transfer rates.

5.4.4 Diskette Transfer

Users with computers that have disk drives will be able to receive data from the A/P host computer on 3.5" or 5.25" diskettes. With this form of access, users will not be linked interactively to the A/P System, but will be able to obtain data by submitting a request to the A/P Study Program through CGIA. In general, this form of access will prohibit transferring large amounts of data on a frequent basis and data transmission to remote sites could take several days.

5.4.5 Tape Transfer

Users with computers that have tape drives will be able to receive data from the A/P host computer on nine-track magnetic tapes or cartridge tapes. With this form of access, users need not be linked interactively to the A/P System, but will be able to obtain data by submitting a request to the A/P Study Program through CGIA. In general, this form of access will enable users to obtain large data files on a frequent basis, but data transmission to remote sites could take several days.

SECTION 6

SYSTEM IMPLEMENTATION PLAN

The purpose of Section 6 is to describe a plan of implementation for the A/P System. Although system implementation is not directly linked to construction of the A/P Database, many system features require the availability of a preliminary version of the database for testing of software functions. System functions, priorities, and a timetable for implementation are provided below.

The A/P System consists of three major categories of functions. These include: system management, application-general, and application-specific functions. They have been described earlier in Section 4.2 and are listed below for review:

System Management Functions

- Database Interface
- Cartographic Data Management
- Attribute Data Management
- Data Archive and Restore

Application-General Functions

- Data Extraction and Management
- Data Creation and Editing
- Data Manipulation and Summarization
- Data Analysis and Display
- Core Routines

Application-Specific Functions

(to be determined based on specialized user needs)

Many of the functions already exist in some form in the ARC/INFO GIS software or as procedures that have been developed at CGIA over the years in performing projects for state government agencies and other clients. They key to implementing the A/P System is to group the GIS and other tools needed by A/P System users in a user friendly interface based on pull-down menus. Implementation will begin with creating cartographic and attribute data management capabilities. Basic data extraction, analysis, and display capabilities will be built next to provide users with a foundation for using the A/P System. CGIA plans to offer this limited A/P System to users when it is completed. Then, the remaining functions of the A/P System will be implemented to provide more breadth to the functionality of the system. The proposed order of

implementation of the functions is as follows with a target date listed for completion of each function:

Function	Date of Completion
Cartographic Data Management	December 1990
Attribute Data Management	December 1990
Data Extraction and Management	February 1991
Data Analysis and Display	February 1991
Data Creation and Editing	April 1991
Data Manipulation and Summarization	April 1991
Data Archive and Restore	April 1991
Database Interface	June 1991

Core routines will be implemented as a part of the development process for each of these other functions. Some of the core routines developed early in the implementation cycle will be reused in implementing the latter functions in the cycle. Software will be written in a modular fashion to maximize reuse of these core routines.

APPENDIX A

TERMS AND ABBREVIATIONS

Albemarle/Pamlico Estuarine Study (A/P Study) - a project aimed at providing scientific knowledge and improving public awareness about the estuarine environment to foster better resource management in the area.

A/P Data Management and Analysis System (A/P System) - the hardware, software, data, procedures, and personnel necessary to enter, manage, manipulate, analyze, and report on data related to the A/P Study.

A/P Database - a term used to collectively refer to the data layers (including cartographic and attribute data) in the A/P System; also referred to in this document as the centralized database.

Applications Software - the programs that will be written as part of the A/P System to provide a user friendly interface to the operating system and support software on the A/P host computer.

ARC Macro Language - a high-level command language through which the user communicates in the ARC environment; AML provides complete programming capabilities and a set of tools to tailor the user interface to streamline ARC/INFO processing.

Attribute Data - a collection of codes, numbers, and text that provides descriptive information and are stored as a table of columns and rows; examples of these tables are the polygon or point attribute table (PAT), arc attribute table (AAT), relate table, extension table, or look up table; these data are linked to cartographic data by a feature identification number; one of two primary components of a data layer.

Cartographic Data - a collection of points, lines, and/or polygons stored as x,y-coordinates that are used to represent map features such as roads, streams, or county boundaries; one of two primary components of a data layer.

Commercial Software - the software on the A/P host computer that provides the geoprocessing, database management, image processing, and communications capabilities.

Coverage - a computerized file residing in a user's workspace that generally contains a subset of a data layer.

Data Layer - a set of computerized files residing in the centralized database that contains cartographic data for one type of map feature (e.g., roads, streams, or county

boundaries) and the attribute data associated with each feature (e.g., route number of a road, classification code for a stream); also referred to in this document as a data layer.

External Database - any large collection of data that resides outside the A/P Database and that is usually maintained by a federal or state government agency; these databases are too voluminous to store within the A/P Database but may be useful to A/P System users; database interfaces will be developed to obtain these data for users.

External Data Files - a collection of data that was not developed under ARC/INFO or on the A/P host computer but needs to be combined with data from the A/P Database to assist users in their analysis.

Geographic Information System (GIS) - a specially designed computer system for data capture, storage, management, analysis, and display of spatial data.

Item - a single column of data in an attribute table that describes a characteristic common to all records in that table; for data layers, an item contains descriptive information (e.g., road class) for all the features in a data layer.

Map - a display of cartographic data from one or more data layers, related attribute data, and supporting information such as a title, scale bar, north arrow, and a legend; maps can either be displayed on the screen or produced in hardcopy format.

Map Feature - a single, discrete object on a map such as a lake or well, or the portion of a road between two intersections.

Operating System - the software on the A/P host computer that translates commands provided by commercial software, applications software, and users into commands understood by the computer.

Record - a single row of data in a data set or that consists of one or more items which provide descriptive information; for data layers, a record contains all the descriptive data for a single feature in a data layer.

Report - a display of data from one or more sets of attribute data; reports can either be displayed on the screen or produced in hardcopy format on a printer.

State Center for Geographic Information and Analysis (CGIA) - the state government agency that operates the state's GIS and is responsible for the hardware, software, data, procedures, and personnel needed to support the A/P Data Management and Analysis System.

Statistical Graph - a document that displays attribute data in a graphic format such as a bar chart, line graph, or scatter diagram; statistical graphs can either be displayed on the screen or produced in hardcopy format.

Workspace - a location on the A/P host computer that contains information such as software programs, reports, coverages, and external data.