EPA

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Office of Information
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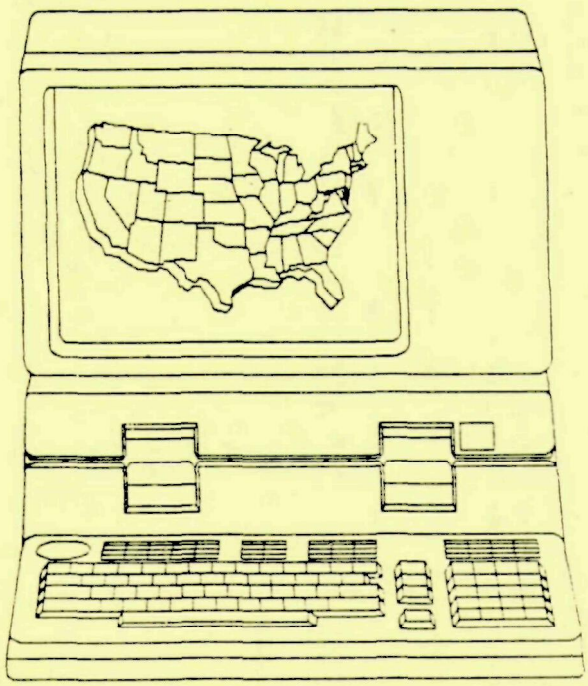
EPA/OIRM

GIS
MANAGEMENT STUDY

EVALUATION OF
CURRENTLY INSTALLED
GISs



GIS
MANAGEMENT STUDY

EVALUATION OF
CURRENTLY INSTALLED
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OVERVIEW

I. OVERVIEW

The material presented in this report represents a task, Evaluation of Currently Installed GISs, under the EPA GIS Management Study, conducted by American Management Systems, Inc., under contract 68-01-7281 for the Systems Integration Branch, Program System Division, Office of Information Resources Management (OIRM). The objectives of this study are to:

- Identify and characterize Agency requirements for GIS applications as they relate to program decision-making at EPA Headquarters, EPA Regions, and States (build on Surface Water Monitoring Study and Ground-Water Data Requirements Analysis)
- Summarize "lessons learned" in support and management of GIS systems/demonstration projects (such as EMSL-LV, Region IV)
- Identify GIS support requirements and alternative approaches
- Develop a plan for GIS program development
- Develop a procurement framework that realistically represents Agency GIS needs
- Obtain Agency management approval of "best" support alternative(s).

The task reported here encompassed the following activities:

- 3 Regions, 3 States, the Chesapeake Bay Program, and the Environmental Research Laboratory-Corvallis were visited:
  - Region I, Region III, Region IV
  - Rhode Island Department of Environmental Management (RIDEM) and the University of Rhode Island Environmental Data Center (EDC)
  - Georgia Environmental Protection Division (GAEPD) and the U.S. Geological Survey (USGS) Water Resource Division District Office
  - Florida Department of Environmental Regulation (DER).
- Interviews with over 40 key management and technical staff were conducted
- Each GIS effort was synthesized as a case study that included several major topics:
  - Project history
  - Environmental regulatory program applications
  - Future applications
  - Spatial environmental data
  - Overview of GIS hardware/software

-- Organizational structure/staffing
-- Costs
-- Benefits
-- Critical success factors
-- Constraints.

This evaluation was undertaken with the following objectives:

- Develop a Comprehensive Checklist of Relevant Issues
- Detail the Critical Success Factors and Constraints of GIS Implementation
- Identify a Framework for GIS Applications as a Data Integration Tool ("A guide for doing business").

In the next chapter we present our Findings and Conclusions.

FINDINGS AND CONCLUSIONS

II. FINDINGS AND CONCLUSIONS

In this section we present our findings and conclusions. In Figure 2.1 we present an overview of the Management and Technical Issues we feel are important. These issues are described in eleven categories below:

1. Data Sources Need to be Identified for Each Data Set (e.g., location of data, methods of collection, costs)

   - o Region I has invested significant resources in the Cape Code project to inventory appropriate environmental data.

2. Data Specifications (e.g., formats, scales) Are Not Uniform Between Data Sets--Data May Require Extensive Reformatting

   - o The Chesapeake Bay Program has been collecting data for more than 5 years and today its environmental data base contains approximately 100 million data elements and over 500 data files. Georeferencing has been developed for many of these data files.

3. Data Standards Are Not Easily Established and Require Extensive Resources to Implement "Post Facto"

   - o The Chesapeake Bay Program has established data standards and made a commitment to enforce strict data submission guidelines for all contractors and researchers.

   - o The USGS and Georgia have expended many contract hours reformatting data sets so that they could be incorporated into ARC/INFO.

4. Validation of Data is of Concern to All

   - o Every person engaged in GIS implementation communicated the need to establish data validation processes.

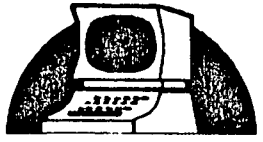
   - o Both Region IV/Georgia and Rhode Island have made compromises to provide products knowing that more data validation would have ensured better QA but weighed this against the need to have concrete GIS "products" at an early stage in the project development.

   - o Georgia and USGS spent 60% of their original contract support time to validate the various State and local data sets.

   - o The CBP invested 8-10 man-years of effort to validate data and provide lat/long coordinates for data that previously had no specific geographic reference.

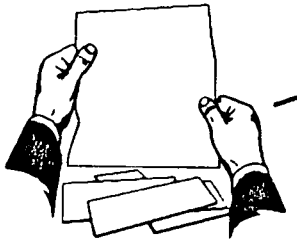
   - o The ERL-Corvallis has implemented data validation procedures to ensure data integrity.

AN OVERVIEW OF THE MANAGEMENT AND TECHNICAL ISSUES



Identify Data Sources

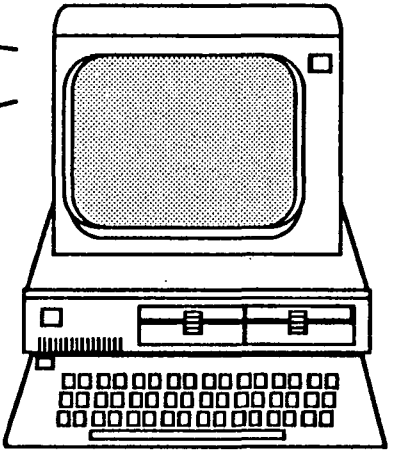
Data Reformatting

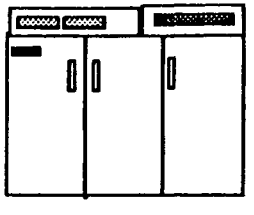


Data Validation

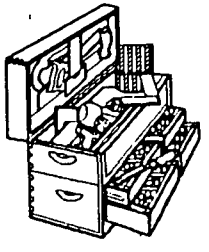
Staffing

GIS Implementation and Applications

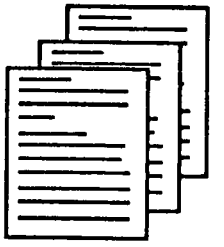




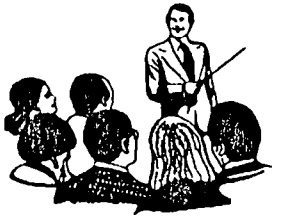
Hardware/Software



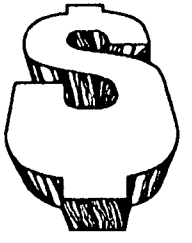
Part of a Toolbox



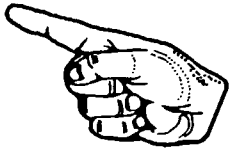
Data Standards

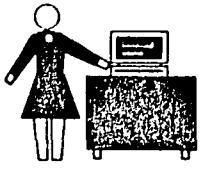


Communications



Digitizing





Data Sharing

5. Managers and Technical Staff Expressed Frustration Over the Lack of Open Communication and Information Exchange Among Agency and Related GIS Users

   - o Rhode Island feels particularly isolated and desires, in particular, to establish a more active estuary GIS network (e.g., with CBP).

   - o A description of products (e.g., aerial photos) and data sets (e.g., maps specific data bases) that already exist at on-going GIS programs would be useful so that duplicative efforts are avoided (e.g., share EMSL data with Region I).

   - o Several GIS programs have developed ARC/INFO "Macros" and the sharing of these routines would facilitate GIS use.

6. Most of the Needed Data Requires Digitization: An Expensive and Resource Intensive Process. This Process is Often a Bottleneck.

   - o The Georgia demo used the expertise of two GIS technicians to digitize and create the data bases.

   - o Rhode Island had to contract outside the University for digitizing services so that the data analysis could proceed quickly.

7. Data Sharing Between States and Regions is Not Easily Achieved in Most Cases: Guidelines and Procedures Need to be Established

   - o Region IV has States and Agencies issuing several different GIS systems (e.g., Intergraph at TVA and Florida; ARC/INFO at Georgia and the Region).

8. The Shortage of Trained GIS Staff Limits the Full Potential of System Use: Significant Resources and Management Commitment Are Required to Attract and Keep These Individuals

   - o At present, the full complement of Intergraph software routines is not used and GIS support to interested Florida programs is handicapped because of the shortage of trained staff.

   - o The slow process of developing in-house GIS expertise must be weighed against the advantages and disadvantages of contracting out for these services (e.g., comparison between Rhode Island and Florida).

9. The Selection of a Specific GIS Hardware/Software System Depends on Numerous Factors: There Are No Universal Solutions, Each Situation Must be Considered on its Own Merit

   - o Florida has been able to gain a multitude of benefits from using an Intergraph because of its close affiliation with Florida State University.

   - o Region I feels ARC/INFO is the logical system to acquire, since all its Environmental/Natural Resource State Agencies have or will shortly have this system.

10. Staff Support for GIS Implementation and Applications Requires a Combination of Technical/Program Skills: IRM/ADP Management Alone Will Not Make the Grade

    - Region IV has developed a central "core" of GIS and program experts to support Regional GIS activities.

    - Region III believes that each program will need to provide staff "on loan" to ensure that GIS benefits reach each program appropriately.

    - Each State visited, as well as others we are knowledgeable about, have or desire a full-time GIS Coordinator (e.g., Rhode Island, Florida).

11. GIS is Only a Tool to Provide Data Integration Capabilities: Regions and States Know This is One Tool in the "Tool Box"

    - Each Region and State expressed enthusiasm about GIS as a mechanism for spatial data integration.

    - The Region I IRM Branch has provided extensive cartographic and digitizing services to programs for some time.

    - The CBP has been conducting estuary geographic analysis for years -- even before CBP gained access to GIS software.

    - Region IV has created OIEA to facilitate integrated environmental analysis, with ARC/INFO as only one of its services.

During our investigations we also became aware of some very positive benefits associated with GISs. We feel it important to outline these observed benefits of operating a GIS for environmental regulatory and management applications. These benefits are presented under four general categories:

- Using a GIS Forces Development of Uniform, Centrally Accessible, Geographically Referenced Data.

  -- Data entry requires establishing decision rules for formatting non-uniform data.

  -- Data dispersed among Agencies, organizations, local governments and researchers are assimilated in a central facility.

  -- Data are centrally accessible through a DBMS once entered into the GIS.

  -- Geographic data analyses can be conducted for specific sites and Regions as a result of uniform spatial formats.

- An Integrated Spatial Environmental Data Base Improves the Ability to Identify Environmental Problems: Specific Programs Have Been Able to Do a Better Job.

  -- Numerous Agencies identified the utility of GIS in investigating potential ground-water contamination problems. This information

resulted in revising land-use policy and implementing corrective actions (e.g., Rhode Island, Region IV, Georgia, Florida).

-- The integration of point and non-point pollution impact data with living resource data provided realistic profiles of the status of several estuaries (e.g., Narragansett Bay, Chesapeake Bay) which in the past were difficult, if not impossible, to create.

-- Risk assessment, an Agency priority, can be conducted with a GIS. Region IV, Georgia, and EMSL are vigorously pursuing this application.

- o A GIS Assists Managers to Prioritize Resource Allocations for Program Activities: Choices Can be Made on How Best to Approach an Environmental Problem.

  -- Managers developed ground-water monitoring strategies and prioritized remedial actions for contaminated drinking water supplies (e.g., DER).

  -- In Georgia, siting sanitary landfills at the county level reduced the number of sites needing field investigation and remaining sites were defined according to selection criteria.

  -- Region IV Superfund staff identified and prioritized Superfund sites for ranking and adding to the NPL.

- o Perhaps Most Importantly, is the Use of GIS Products for Disseminating Information: Maps and Graphics Have High Impact.

  -- GIS products are used to communicate environmental issues to managers, government officials, and the public (e.g., the Region III Water Management Division Director used GIS produced maps of Chesapeake Bay pollution impacts to living resources at a multi-State legislative session. The result was a commitment to support Bay clean-up activities).

In addition, we provide the following insight in terms of constraints/limitations:

- o GIS Applications Have Been Limited in Scope to Relatively Small Geographic Areas and Program Applications.

- o Many Managers and Technical Experts Expound the Usefulness of GIS Without Having Practical Hands-on Experience -- A Degree of Uncertainty Remains in Terms of Environmental Regulatory and Management Applications.

- o Most GIS Applications Are for Program Planning and Evaluation of Environmental Conditions -- Few Permitting and Compliance Applications Have Been Noted.

- o GIS Applications for Environmental Regulatory and Management Applications Are in Their Infancy -- There is Still Much Work to Be Done.

Lastly, We present five major conclusions to date based on our visits and evaluation:

- o A commitment of substantial resources by the Agency to support GIS implementation and applications will be needed to assist Regions/States/Programs fully realize the benefits of GIS. No one GIS provides an optimal "organizational" solution.

- o Guidance for GIS data standards and data validation techniques is needed. EPA should support these activities to facilitate data sharing.

- o A multidisciplinary team to support data integration consisting of ADP specialists, scientists, and program experts is to be encouraged.

- o The Agency needs to spearhead a compaign that aids communication among GIS users and provides a mechanism for disseminating GIS related information to the user community.

- o The Agency should develop GIS training programs and GIS technology transfer procedures through "Centers of Excellence" such as EMSL-Las Vegas, ERL-Corvallis and Region IV.

CASE STUDIES

III. CASE STUDIES

This section contains our detailed case study reports for Region I, Rhode Island, Region III, the Chesapeake Bay Program, Region IV and the State of Georgia, and Florida. To facilitate synthesizing this information we provide an overview of sites visited, GIS hardware/software, program application and organizational structure in Table 3.1.

TABLE 3.1

AN OVERVIEW OF SITES VISITED, GIS HARDWARE/SOFTWARE, PROGRAM APPLICATIONS AND ORGANIZATIONAL STRUCTURE

Sites Visited	GIS Hardware/ Software	Program Applications	Organizational Structure
Region I	ARC/INFO	**Conduct Ground-Water Assessment** -- Locate and map threatened water supply sources	**IRM Branch Staffing Support** -- Graphic System Expert (10%) -- Ground-water Expert (50%) -- Cartographer (75%) -- Digitizing (50%)
Rhode Island	ARC/INFO	**Conduct Ground-Water Assessment** -- Locate and map threatened water supply sources **Conduct Water Quality Assessment** -- Determine conditions and trends -- Determine nature and extent of impact	**RIDEM** -- GIS Coordination -- Ground-Water Expert **University of Rhode Island EDC** -- Director (100%) -- Operations Manager (100%) -- Digitizing (2 people 50% each) -- Additional Work-study students
Region III	-----		**IRM Branch GIS Technical Core Group (PLANS)** -- ADP personnel -- Program experts (Detailed for 6-8 months)
Chesapeake Bay Program	ARC/INFO	**Evaluate Toxic Pollution to Bay** -- Locate and map existing and historic waster disposal sites	**General Data Center Support** -- Data Management Coordinator (100%) -- Contractor Staff (12 full-time)

TABLE 3.1 cont'd

AN OVERVIEW OF SITES VISITED, GIS HARDWARE/SOFTWARE, PROGRAM APPLICATIONS AND ORGANIZATIONAL STRUCTURE

--Continued--

Sites Visited	GIS Hardware/ Software	Program Applications	Organizational Structure
Region IV	ARC/INFO	**Conduct Air Quality Assessment** -- Display monitoring stations -- Determine violations to show problems **Evaluate Solid/Hazardous Waste Sites** -- Locate and prioritize sites based on HRS criteria -- Target water supply well monitoring -- Prioritize RCRA enforcement actions	**Office of Integrated Environmental Analysis (All Full-time)** -- Chief -- Air program scientist -- Remote sensing/environmental scientist -- Water pollution engineer -- GIS technical specialist
Georgia	ARC/INFO	**Determine Vulnerability of Drinking Water Sources** -- Identify and map drinking water supplies -- Prioritize monitoring **Evalutation of Sanitary Landfills** -- Locate and map aquifers and recharge areas	**USGS** -- 2 full-time GIS experts **GAEPD** -- GIS liasion (20%)
Florida	Intergraph Micro-based GIS	**Conduct Ground-Water Assessment** -- Target wells for cleanup and alternative water sources -- Integrate public and private well water quality data -- Prioritize monitoring **Indentify Contamination Sources** -- Identify extent of EDP well contamination -- Identify responsible parties and initiate corrective action **Conduct Water Quality Assessment** -- Report on conditions and trends (305b report) -- Establish priorities for water quality monitoring and controls	**DER Bureau of Information Systems** -- Systems manager (10%) **Bureau of Ground-Water Protection** -- GIS technical analyst (100%)

AN OVERVIEW OF SITES VISITED, GIS HARDWARE/SOFTWARE, PROGRAM APPLICATIONS AND ORGANIZATIONAL STRUCTURE

--Continued--

Sites Visited	GIS Hardware/ Software	Program Applications	Organizational Structure
ERL - Corvallis	ARC/INFO	**Evaluate Acid Deposition Impact to Surface Waters** -- Identify effected watersheds -- Understand ecological process **Determine Chemical Status of Lakes and Streams** -- Characterize chemical status of lakes and streams	**Contractor Support** -- Coordinator -- Systems Operator -- Digitizing and Map Archiving (4 people) -- Applications (scientists part-time)

-- GIS CASE STUDY --

REGION I AND THE CAPE COD AQUIFER MANAGEMENT PROJECT

Project History

EPA Region I has an active interest in geographic analysis and recently participated in a GIS application in Cape Cod. As part of the Planning and Management Division, the Information Management Branch (IRM) has been supporting Region I program data integration needs, including various types of geographic analysis, for many years. Four of the Region's six states are currently using ARC/INFO for environmental work. Massachusetts is currently developing a strategy to acquire ARC/INFO. Furthermore, there already exists a New England ARC/INFO users group that meets regularly to share experiences and exchange ideas and knowledge.

In addition, IRM staff have already trained in the use of ARC/INFO, both from the user and system management perspectives, through a cooperative ARC/INFO activity with the Rhode Island Department of Environmental Management. The resident IRM contract staff presently provide extensive in-house cartographic and digitizing services that has, for example, resulted in the location of over 5,000 FINDS sites. Region I IRM staff have also played a significant role in the Cape Cod Aquifer Management Project (CCAMP) which will be discussed in detail below.

The Cap Cod Aquifer Management Project

Cape Cod has long been recognized as having vulnerable water resources. In recognition of its importance as a regional water supply, Cape Cod's Aquifer was designated a Sole Source Aquifer in 1982, the first in New England and the 12th nationwide. Subsequently, EPA's Region I office and the Massachusetts Department of Environmental Quality Engineering (DEQE), in cooperation with the U.S. Geologic Survey and the Cape Cod Planning and Economic Development Commission, initiated a collaborative two-year effort in August, 1985 aimed at improving the coordination in ground-water management at the federal, state, regional and local levels of government.

Cape Cod's Aquifer, comprised largely of sand and gravel outwash deposits, forms a lucrative ground-water resource from which all Cape Cod residents obtain their drinking water. The porous nature of the subsurface environment, which contributes to the plentiful recharge of the ground water, also enhances the vulnerability of the aquifer to the passage of contaminants. To compound this, the number and variety of waste-producing activities on Cape Cod has been increasing as the County grows at the fastest rate in New England. This growth stresses existing potable water supplies as well as the local governmental agencies charged with their protection.

The Cape Cod Aquifer Management Project (CCAMP) involves the examination of existing ground-water protection programs at all levels of government and a consideration of environmental trade-offs, comparative cost considerations, current institutional structure, data management issues, and the pooling of technical expertise.

Land uses, having a direct bearing on the quality of both surface and ground-water, have already caused considerable damage to ground-water quality on Cape Cod. Historically, lack of information about the functional characteristics of the aquifer has been largely responsible for the preponderance of ill-suited land uses characteristic of the peninsula. It was not until the late 1960's and early 1970's with the advent of investigations by the U.S. Geological Survey and other geologists on Cape Cod , that questions regarding the protection of the water supply began to be addressed. At the same time Cape Cod was developing at an unprecedented pace.

Although the CCAMP project is expected to have broad application in terms of revising institutional approaches to resource management, it is focusing initially on two Cape Cod towns, Barnstable and Eastham. These towns represent the spectrum of characteristic problems facing Cape Cod communities. While Eastham and Barnstable are quite divergent in terms of urban/rural characteristics, they typify the variety of complex management challenges facing the Cape Cod region. Barnstable contains a major business and population center, a wastewater treatment facility, and extensive public water supply systems. In contrast, Eastham is a rural community, removed from population centers and completely dependent on private wells.

Initially, CCAMP participants selected a series of ground-water management issues to be examined and set up three specialized work groups to focus on these issues. The subgroups, discussed below, are concerned with development of scientific understanding of the aquifer, management of data pertaining to the aquifer, and analysis of institutional arrangements to govern use and abuse of the ground-water resource.

- o Aquifer Assessment Group. This group provides the scientific foundation for the project. Members, largely geologists and hydrogeologists, are charged with reviewing specific data, assumptions and analytical techniques upon which ground-water protection programs and regulations are based at all levels of government. The Aquifer Assessment group will also evaluate the threat of contamination from various sources, determine the relative acceptability of various land uses, and make recommendations on land use management approaches.

- o Data Management Group. The data management group serves a variety of functions associated with accumulating, collating and analyzing data. Members include data processing specialists and highly-trained computer technicians. The group's agenda includes identification of existing ground-water data bases and assessment of unmet data needs, integration of all available data bases to make them widely accessible to various governmental agencies, and development of Geographic Information Systems and computer graphic capabilities as long term management tools.

- o Institutions Group. The Institutions group is composed of government planners, managers and administrators. Their charge is to evaluate programs at each level of government which deal with an established list of priority contamination sources found in the study area and to formulate recommendations about improved program coordination and new approaches to ground-water management.

Presently, several functions of the Data Management Group are being supported through an Interagency Agreement between USEPA Region I and the U.S. Geological Survey's Water Resource Division's New England District Office's ARC/INFO.

Use of the GIS in the CCAMP

The Data Management activities associated with the CCAMP project include the identification of appropriate data sets, collection of new data, and extensive quality assurance/quality control of acquired data sets. This project is developing a digital data base for the: (1) zone of contribution (ZOC) to a selected group of wells for the town of Barnstable, and (2) a portion of the town of Eastham.

Computer-generated 'base' maps of the Barnstable ZOC and the town of Eastham will be generated from an assemblage of digital data: the boundary of the ZOC, primary transportation routes, town boundaries, well locations, aggregated land use (commercial, residential), water-table contours, and ground-water flow lines. The risk to the quality of ground-water near existing and planned public water-supply sites will be assessed by overlaying and aggregating waste-source data on the base map. Data from the following waste sources will be collected:

- Underground Storage Tanks (UST). Attribute data desirable for analysis include number, volume, age, material, content, and location by land parcel.

- Toxic and Hazardous-Material Sites. Regulated facilities, location by parcel, volume, character of material, and known contamination extent.

- Waste water. Municipal sewage-disposal sites, ground-water discharge sites, sewered/unsewered areas, feed lots, known septic systems.

- Road salt. Salt storage areas, volume, type of cover (shed, plastic, no cover). If data are available, road application rates.

A digital data base of Cape-wide information is being developed for general information and reference purposes. Depending on data availability and validation, Cape-wide data coverages may include landuse (USGS, 1:250,000, 1971), FINDS waste sites (USEPA), public water-supply and waste sites (DEQE Atlas), water-table contours (USGS), and the water-table lenses (CCAMP).

To date, EPA has played a major role in identifying and assimilating information on UST's local authorities. A second activity has been the synthesizing of other environmental data on local tax assessor parcel maps. A summary of those activities is presented below:

- UST information was collected and verified.
  - -- This information is maintained by the local fire marshal.
  - -- There is no standard reporting process or central repository of those data.

- -- The Town of Barnstable, for example, has 7 fire marshals.

- -- EPA and DEQE worked closely together to verify this data, and visited the UST sites to confirm reported locations.

- -- This data was incorporated into the USGS ARC/INFO data base.

- o A pilot study was undertaken in the town of Barnstable to determine the feasibility of collecting data at the site-specific parcel level.

  - -- DEQE and EPA staff reviewed available parcel maps to verify the location of properties and associated attribute information for 1500 parcels.

  - -- These maps contained useful information on potential sources of ground-water contamination (e.g., types of industrial facilities).

  - -- Generally determine what types of information are required to develop a prototype Well-Head Protection Program.

Future Applications

Region I has indicated its interest in applying GIS for several other program activities:

- o **The Bays Program.** The Bay Program is a cooperative effort undertaken by the EPA, Massachusetts Division of Water Pollution Control (DWPC), Office of Coastal Zone Management (CAM), and Division of Marine Fisheries (DMF), with the intent to manage the pollutants released to Buzzards and Massachucetts Bay and Boston Harbour and the necessary remedial actions to preserve the Bay's shellfish resources. Specific objectives, listed in the current Buzzards Bay workplan, to which a GIS would be of immediate benefit, include:

  - -- The development of a data management system to store and analyze baseline monitoring information, in order to assess long-term trends in water and sediment quality, fisheries resources, and land use. This information will also be used to help design a sound ambient monitoring program.

  - -- The identification of the relative importance of various inputs of coliforms to contaminated shellfish areas.

  - -- The determination of the extent and sources of toxic contamination in the sediments and biota of the Bay.

  - -- Prioritize key enforcement actions for the program in terms of Combined Sewer Overflows (CSO's), and industrial and municipal dischargers.

  - -- The education of the public in restoration and maintenance of resources by developing a series of workshops and public presentations.

Water quality data for the Bay is already stored using the Statistical Analysis System (SAS) and could easily be entered into ARC/INFO. EPA is also prepared to enter into a Cooperative Agreement with USGS to obtain the digitized 1:250,000 quadrangles for the entire Buzzards Bay area. This data will be provided in Digital Line Graph (DLG) format, which is compatible with the ARC/INFO system.

- **The Lead in Soils Initiative.** Concentrations of lead in soil in some areas of residential Boston are an order of magnitude higher than the levels that the Centers for Disease Control determined contribute to elevated levels of lead in blood, especially in young children. In addition, one out of every four children in some urban Boston neighborhoods was lead poisoned in the last five years. As part of the investigation into the problem, extensive information about the problem has been assembled (e.g., incidence of poisonings, levels of soil contamination, location of properties of greatest concern, property ownership, building type and condition and zoning designation). Some of this information has already been digitized by the Office of Environmental Criteria and Assessment (ORD) and some of it is resident on a DBASE application in Region I. The ARC/INFO system would improve the understanding of the geographic distribution of the lead poisoning problem in Boston.

- **Superfund Site Management Program.** The Information Management Branch believes there is potential for use of a GIS in the Superfund Site Management program for supporting efforts underway at active National Priority List (NLP) sites. At present there are approximately 57 such sites in New England. Superfund Site Managers currently use a variety of site maps prepared by contractors as part of the Remedial Investigation/Feasibility Study (RI/FS) process. These maps are manually prepared and contain baseline information from a USGS quadrangle and one additional layer.

  Presently, the Site Manager must combine two or more maps visually. Examples include zones of contribution combined with ground-water flow, contaminant levels combined with wetland or flood plain information, and others. Useful data include:

  -- Wetland boundaries
  -- Flood plain boundaries
  -- Ground-water contours
  -- Contaminant concentrations
  -- Drainage basin boundaries
  -- Bedrock contours
  -- Background information (from USGS quadrangles)

Spatial Environmental Data

The presently available, and soon to be acquired data are listed in Table 1.

Table 1. - Data Types

Data[1]	Source	Digital Data Available	Extent
Point Coverages (est. number of points)			
- Underground storage tanks (200)	EPA	yes	B/E[2]
- Regulated facilities (15-35)	EPA, DEQE	yes	B/E
- Public water-supply wells (10-15)	USGS	yes	Capewide
- Hazardous waste disposal sites (2-15) (landfills, junkyards, transfer stations)	DEQE		Capewide
- Municipal sewage disposal discharge (1)	USGS		Capewide
- Road salt piles (2-5)	DEQE		B/E
- Public water-supply test sites	CCPEDC		B/E
- Spills and Leaks (SPOT)	DEQE		Capewide
- Geographic names	USGS	yes	Capewide
Line Coverages			
- Primary transportation routes	USGS		Capewide
- Water-table contours	USGS		Capewide
- Ground-water flow paths	USGS		Capewide
- Town boundaries	USGS		Capewide
- Hydrography (ponds, wetlands)	USGS		Capewide
- 'DRASTIC' contours	EPA		B/E
Polygon (area) Coverages			
- Barnstable ZOC	CCPEDC		B
- Landuse, aggregated parcel level or better	CCPEDC		B
- Zoning CCPEDC			B/E
- Public water-supply service areas (5)	CCPEDC		B
- Planned growth zones (proposed changes)	CCPEDC		B/E
- Planned water-supply ZOC's	CCPEDC		
- Known contamination plumes in aquifer	USGS, EPA, DEQE		Capewide
- Sewered service areas	CCPEDC		B
- Seasonal-use areas	CCPEDC		E

1/ Within Barnstable ZOC, unless otherwise noted
2/ B (Barnstable), E (Eastham)

Overview of GIS Hardware/Software

The ARC/INFO system is located at the USGS District Office, and Region I staff conducts GIS activities at the USGS site. The ARC/INFO software is maintained on PRIME 9952 mainframe. Peripheral hardware include several color graphic display devices (Tektronix 4000 series), an Altek 4860 digitizer and several plotters (Tektronix 4696 ink jet plotter; Zeta 3653; HP7475 desktop). In addition to the basic INFO DBMS from Henco and ARC, the ESRI software developed for storing cartographic data, other ARC/INFO software subsystems include:

- NETWORK - applications module for modeling network files (e.g., minimum path, routing optimization, address matching); and
- Triangulated Irregular Network (TIN) - applications module for structuring and modeling digital terrain data (e.g., contour maps, viewshed creation, slope mapping).

Organizational Structure/Staffing

The Information Management Branch provides staff support to the CCAMP program. Two EPA staff members work on the project; a cartographer works seventy-five percent (75%) and a ground-water/computer application specialist spends one-third to one-half time. Another EPA employee, a graphics system expert, spends 10% of his time on the project and digitizing activities are the equivalent of 50% of a man-year. The GIS applications supported by USGS use the services of highly-trained ARC/INFO experts for data input, analysis, and generation of maps.

Costs

Numerous people are involved with data gathering and analysis. The staffing of the project amounts to approximately $63,000. Additional costs for data support services are difficult to estimate.

Benefits

Since the CCAMP project is still in progress and GIS applications have only recently begun, potential benefits will be briefly discussed.

- Foremost is the assimilation of dispersed and non-standardized environmental data from numerous agencies into a uniform, accessible data base.
- Region I, and the other cooperating organizations are developing a data base with extensive QA/QC.
- The pilot project will demonstrate the utility of using a GIS for Well-Head Protection data needs and understanding relevant issues.
- The Region I IRM staff believe that the development of the GIS will assist future modeling efforts, ground-water risk assessments, and support State environmental management programs.

Constraints

Region I believes the acquisition of an ARC/INFO would improve its capability to integrate environmental data. The IRM Branch Chief is convinced that EPA Region I will be able to cooperate more readily with States in the area of data integration and analysis with an ARC/INFO.

-- GIS CASE STUDY --

THE RHODE ISLAND DEPARTMENT OF ENVIRONMENTAL MANAGEMENT

Project History

In 1984 the Rhode Island Department of Environmental Management (RIDEM) conducted a feasibility study for establishing a statewide GIS data management system. The final report recommended that DEM acquire a GIS and that ARC/INFO software would best serve DEM needs. In the summer of 1985, the Department of Natural Resources Science at the University of Rhode Island (URI) was awarded a grant from DEM to create a center of GIS data input/output and begin developing the GIS database. In January 1986, ESRI installed ARC/INFO on an existing Prime 9955 computer at the URI Computer Center. The necessary peripheral hardware was purchased and placed at the Environmental Data Center (EDC) at URI and was fully operational in February 1986.

In Rhode Island, as in many other states, protection of ground water resources has become a priority environmental concern. Ground water contamination not only results in potential risks to public health but also degrades, often permanently, a valuable resource that represents a critical reserve of water for drinking and other uses. Over the past 10-15 years, nine public wells and upward of 450 private drinking water wells in the State have been found to be contaminated as a result of sources such as leaking underground storage tanks, hazardous waste sites, surface impoundments, landfills, road salt storage and application, failing septic systems and cesspools, pesticide use, and improper disposal of household hazardous substances. Vigilant regulation of known pollution sources and careful planning is required to ensure adequate and clean ground-water supplies for future needs at both the state and local levels.

The Rhode Island Department of Environmental Management obtained authority to regulate pollution to ground-water in 1983, and in 1984 was designated by the Governor as the lead agency in developing a comprehensive program to protect the State's ground-water resources. In 1985, a Ground-water Protection Act (GWPA) was passed which authorized the RIDEM to carry out a number of tasks to gather the necessary information and establish a framework for ground-water protection. These tasks include conducting a study of the State's ground-water resources and current and projected use, classifying ground-water, establishing standards for ground-water protection, and making recommendations regarding land use controls for ensuring the most beneficial use of ground-water at the local and regional levels. All of this is to be accomplished by 1989.

The second major RIDEM GIS application has been associated with the Narragansett Bay Project. In this program, numerous environmental data sets have been entered into the GIS and mapped. Previously, these data had not been available for analysis in one computing environment nor available for integrated data analysis.

Environmental Regulatory Program Applications Using the GIS

The GIS applications in RIDEM have been undertaken as pilot programs to provide technical staff and management with: an understanding of how GIS applications can help meet long and short term program objectives; define the advantages and limitations of these applications and the GIS operating system; and to document the various trial applications for specific geographic analysis. A summary of these activities is presented below.

Using the GIS in the RIDEM Ground-water Protection Program

To carry out the mandates of the Ground-Water Protection Act and uphold the State's overall commitment to developing a comprehensive ground-water protection program, effective means to inventory, manage, and analyze many types of environmental data are required for successful GIS application. To accomplish these objectives, RIDEM has embarked on a well-defined process that includes the following components:

- o Identify available information by compiling a comprehensive catalogue of available information pertaining to the resource in question. Since such a catalogue of information was not available for Rhode Island's ground-water resources, one of the first tasks was to define the existing base of information on the most relevant topics.
  - -- Through a joint project with the USGS, the RIDEM has inventoried all published information gathered by the USGS or in State-USGS cooperative projects pertaining to the State's hydrogeology. The inventory includes a description of the information in terms of the topic, source(s), scale(s), and date(s) of publication.
  - -- To supplement this effort, the RIDEM staff inventoried other sources of information pertaining to ground-water within the agency and at other appropriate State agencies. Additional published and non-published information not included in the USGS inventory were identified in this manner.

- o Determine the priority for automating data. The priority for automating specific information depends upon the required information to meet program objectives and characteristics of the existing data base. Criteria need to be established to decide what existing information is most suitable for automation.

- o Determine information requirements for each of five program elements (ground-water classification; technical assistance for local ground-water protection planning; regulation of pollution sources; enforcement and emergency response; and monitoring and investigation), of the Rhode Island Ground-Water Protection Program in which application of ARC/INFO would be most beneficial. The approach is to identify the principal objectives within each of these program areas and the desired outputs associated with each objective, and to define the specific data and characteristics needed to produce each output.

- Although this assessment is still in progress, the RIDEM has thus far identified significant gaps in the existing information base -- i.e., information that either does not exist or which is not of acceptable quality. Many instances where the available information, although acceptable, is not of optimal quality have also been found.

- Evaluate the suitability of information for automation based on the following criteria:

  -- is the information acceptable in terms of resolution, level of detail, accuracy, currentness, etc.? If not, can new or revised information be obtained within an acceptable time frame that can be used, and therefore automated, instead?
  -- will automating the information increase the effectiveness with which it is utilized to an extent that justifies the costs associated with the automation process?
  -- is the information compatible, or can it readily be made compatible, with other data with which it will be integrated?

- Identify the appropriate geographic coverage for automation. The geographic study area for automation refers to the areal unit that is considered as the focus for digitizing geographic information.

  -- The USGS topographic quadrangle (scale = 1:24,000) is the basic areal unit in the RIGIS library. Automation for most topics will therefore proceed one quadrangle at a time according to the priority established for each of the 37 quadrangles which cover the State.

Using the ARC/INFO for Ground-water Programs

Based on the above criteria, the Kingstown Quadrangle in southern Rhode Island was selected as the first quadrangle for GIS input.

- Data entry consisted of digitizing the following information from existing maps.

  -- political boundaries
  -- roads and railroads
  -- power transmission lines
  -- surface hydrography
  -- glacial geology
  -- public water supply wells
  -- pollution sites (e.g., salt storage sites, injection wells, landfills, surface impoundments, underground tanks)

- Data analysis focused on a northern portion of the outwash in this region defined by the boundaries of surface water drainage basins to the Chipuxet River and the Chickasheen Brook.

  -- Potential water supply services were identified by developing a transmissibility map from saturated thickness and hydraulic conductivity, as defined by USGS reference reports.

- -- These data were used to generate a "principal aquifer" delineation and recharge areas to the principal aquifers.
- -- An existing land use map for the region acquired from the Town of South Kingstown was also digitized with 5 out of 7 land use categories considered potential threats to ground-water quality.
- -- Potential sources of ground-water pollution were mapped and included underground storage tanks, salt storage sites, sewage disposal sites, and landfills.
- -- These data layers were integrated in a common spatial scale to show "threatened" water supply sources.
- -- A final analytical product was the digitization of the Town's zoning map and integration with the above data layers to show zoned areas that are incompatible with maintaining good ground-water quality.

o Hard copy products of all of these analyses were produced to illustrate the spatial relationships and identify "areas of concern".

Using the GIS for Estuary Programs

The second GIS application involved the Narragansett Bay Program. Highlights of this activity are summarized below:

o This GIS application is under the direction of a Bay Data Management Coordinator who assists the EDC access appropriate data sets.

o The GIS serves as a Bay Program data archive, and provides data analysis capabilities for numerous applications including:

- -- mapping of shellfish closure areas
- -- showing the impact of municipal wastewater treatment facility discharges into the Bay by mapping the results of field dye studies and inputs from a low and high water plume model.
- -- digitizing aerial photos from different time periods to evaluate brown tide impacts.
- -- evaluating the impact of the manufacturing of tin on estuary ecosystems by inputting water quality monitoring data into the ARC/INFO data base and transferring the frequency data sets to the SAS environment for subsequent data analysis.

Future Applications

RIDEM has indicated its interest in expanding the use of ARC/INFO to generate State-wide Ground-water classification maps, provide maps and data to towns and for the Well-Head Protection Program.

Spatial Environmental Data

The data sets used for the above discussed applications are listed in tables 1 and 2.

TABLE 1

Coverages Used in the Kingston Quad Pilot Project

Coverage	Source	Scale
Drainage Basin Boundaries	RIDEM	1:24,000
Hydrography	USGS Kingston Quad	1:24,000
Transportation	USGS Kingston Quad	1:24,000
Till and Outwash Deposits	USGS Geologic Bulletin No. 9	1:31,680
Saturated Thickness	USGS Water Supply Paper 1821	1:24,000
Hydraulic Conductivity	USGS Water Supply Paper 1821	1:24,000
Land Use	Town of South Kingstown	1:24,000
Zoning	Town of South Kingstown	1:24,000
Pollution Sites	RIDEM	1:24,000
Water Supply Wells	RIDEM	1:24,000
Power Transmission Lines	USGS Kingston Quad	1:24,000
Protected Areas	USGS Kingston Quad	1:24,000

TABLE 2

NARRAGANSETT BAY PROJECT - ARC/INFO AND RIGIS TASKS

DATA SET	DESCRIPTION	TYPE OF DATA	SCALE
CSO DATA SET	BLACKST,WOONASQ,MOSHASS, PAWTUXET	POINT	1:24,000
NB BASE MAP BOUNDARIES	UP RIVERS TO SAMPLING STATIONS	POLYGON	1:24,000
CSO RIVERS	DIGITIZE CSO RIVERS	LINE	1:24,000
SUBSURFACE TOPOGRAPHY (NOAA)	NOS DATA FOR NARR BAY	POINT	TIN
LAND USE IN NB DRAINAGE	USGS GIRAS DATA	POLYGON	1:250,000
WATER QUALITY MAP OF NB	NOAA	POLYGON	1:40,000
WATER QUAL & MGMT CLOSURES	SHELLFISH & FINFISH/NAUTICAL CHARTS	POLYGON	1:40,000
QUAHAUG STATIONS	PROV R. & MT. HOPE BAY	POINT	
QUAHAUG DISTRIBUTION	PROV R. & MT. HOPE BAY	POINT	
CO-OP SAMPLING STATIONS	MAP FOR REPORTS	POINT	
RIPDES DATA	POLLUTANT DISCHARGES ON RI RIVERS IN NB DRAIN.	POINT	
MODELLING SEGMENTS	KREMER & NIXON,CHINMAN & NIXON	POLYGON	1:40,000
SUB-BASIN BOUNDARIES	NARR BAY DRAINAGE BASIN	POLYGON	1:24,000
SEDIMENT DISTRIBUTION IN NB	MCMASTER DATA	POLYGON	1:40,000
PROV. R. OXYGEN	CROSS-SECTIONAL PROFILE	POINT	CANTOR MAPS
SHIPPING CHANNELS	NARR BAY CHART # 13221	POLYGON	1:40,000
MODEL SEGMENTS	SWANSON'S CIRCULATION MODEL	POLYGON	1:40,000
METALS IN QUAHAUGS, SEDIMENT	THIBAULT AND KERN DATA		
CRMC WATER QUAL CLASS	FROM CRC MAPS	POLYGON	1:24,200
PLANKTON TRANSECT MAP	SMAYDA DATA		
BROWN TIDE DISTRIBUTION	1985 AERIAL PHOTOS	POLYGON	VARIOUS
SHELLFISH DENSITY	PRATT DATA		
DISTRIB. OF MICROBIAL INDIC.	CABELLI DATA		
GREENWICH COVE BATHYMETRY	EPA-ERLN: SURFACE AREA, VOLUMES AT MLW, MHW DIGIT., ANALY., MAP		

Overview of GIS Hardware/Software

The configuration of the GIS and associated hardware systems is presented in Figure 3.2. ARC/INFO was installed on a Prime 9955 computer with 12 MB of main memory and a 315 MB disk dedicated to GIS datasets. For the first year of the project the EDC was equipped with a Calcomp 9100 digitizer, Tektronix 4107 and 4109 terminals, a Visual System 550 terminal, a Tektronix 4692 ink jet printer, a Calcomp 1044 GT plotter, an IBM PC-XT, and a 300 cps dot matrix printer connected to the PC. All devices were connected to the Prime with an 8-port multiplexor and modem operating at 9600 baud. In addition, a Tektronix 4107 was installed at the DEM offices in Providence and was connected to the Prime with a 4-port multiplexor and modem. Recently, a second Calcomp 9100 digitizer was installed at the EDC and a Tektronix 4692 ink jet printer was installed at DEM.

Organizational Structure/Staffing

A DEM employee was assigned to be the DEM GIS Coordinator. This person was responsible for organizing and prioritizing which datasets the EDC was to enter and what GIS analyses were to be conducted. The DEM GIS Coordinator attended the ESRI training session and was familiar with all aspects of GIS processing. Originally the GIS Coordinator was a half-time position, which developed into a full-time responsibility six months after the project began. At present, however, this position is vacant. EDC staffing consisted of a full-time Director, a full-time Operations Manager, two half-time graduate students, and varying numbers of undergraduate work-study students. The Director of the EDC acted as the liaison between the GIS lab and DEM. The Operations Manager coordinated the activities of the graduate and undergraduate student staff.

Costs

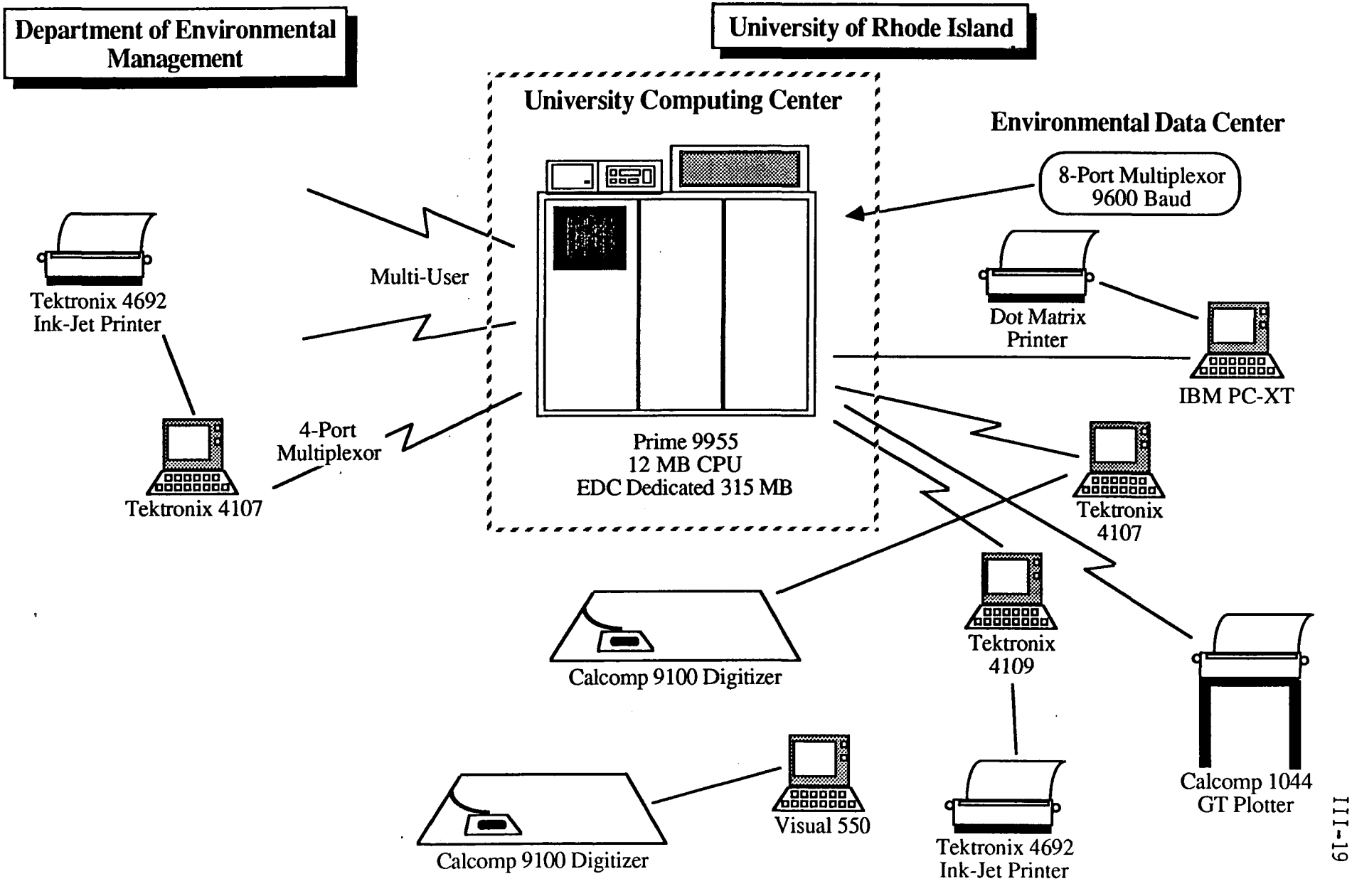
The majority of equipment and salaries for EDC staff are being provided by the RIDEM. The total cost of equipment, software and operation of the GIS for the two year operational period is $160,000 per year, with an annual operations cost thereafter estimated to by $120,000 per year. The majority of the funding for the first two years of operation is being provided through the Ground-Water Protection Program and the Narragansett Bay Project. The University is providing as a project sharing contribution the computer center support services, which is estimated to be worth $40,000 for the two year period. These figures do not include the costs of staff involvement by DEM staff.

Benefits

Based on RIDEM reports and interviews, the benefits of implementing the ARC/INFO system fall into the broad category of improved program management as a function of more effective use of environmental information. This benefit is highlighted below.

FIGURE 3.2

Overview of Rhode Island Department of Environmental Management's GIS



- Data integration. The ARC/INFO system acts as a central repository for numerous spatial environmental data sets. These data are entered in a standard format, permitting an integrated analytical view.

- The incorporation of divergent data sets from numerous sources that have not been previously integrated is a function of the desire to provide a broad range of multiple applications. A GIS is not the only way that these data can be made available, but it serves as an important catalyst to accomplish this task.

- ARC/INFO maps, with color coded symbols, enhance data analysis by providing graphics that are more easily understood than extensive tabular results.

Critical Success Factors

The successful use of GIS at RIDEM can be attributed to the factors summarized below:

- **Technical support** for the ARC/INFO program has been provided through the University of Rhode Island's Environmental Data Center. This center of excellence has been responsible for all hardware/software support. Qualified support staff are trained at the EDC and act as a service bureau for RIDEM.

- **Management support** through the creation of a GIS coordinator for RIDEM has enabled senior-level program management direct input to the GIS activities. Furthermore, this position has been essential for enlisting specific program support and maintaining day-to-day contact with the EDC. The existence of a full-time EDC (director, who is responsible for technical operations and liaison to the RIDEM GIS coordinators) has been instrumental in contributing to the successful operation of ARC/INFO.

- Recognition of the need for **strategic planning** can be traced back to the initial requirements analysis in 1984. GIS implementation at RIDEM was accomplished in a well-designed implementation program.

- Additionally, providing short-term results, although considered preliminary and at times suboptimal products, demonstrated "real applications" to maintain political inertia with minimal hindrance to long-term goals. Providing GIS products to local government officials has also demonstrated the utility of this technology at a grass-roots level.

Constraints

The RIDEM ARC/INFO implementation program has made great strides during its short operational tenure. Several factors have been identified that have slowed or inhibited the program. These are:

- The shortage of program staff available to work with the ARC/INFO system has slowed the implementation process. Although RIDEM has had

a GIS Coordinator , this position is at present vacant which has inhibited the GIS activities.

- Since the ARC/INFO is running on a university mini-computer, peak demands do cause GIS processing to be bogged down on occasion. Although frustrating, this phenomena is predictable and EDC staff can work around this constraint.

- RIDEM and EDC staff expressed concern over the lack of communication between similar EPA programs (e.g., Chesapeake Bay/USGS ARC/INFO pilot) and the exchange of ideas and experience. Although not a constraint, it was felt that the GIS program could benefit from this knowledge.

-- GIS CASE STUDY --

PLANNING FOR GIS IMPLEMENTATION IN REGION III

Background

Region III is engaged in a initiative by which the Region may explore, gain familiarity with, and develop a capability in managing data using a GIS. Program managers have been faced with the complicated task of processing and integrating a wide variety of environmental and spatial data. The Office of Policy and Management, Information Resources Management (IRM) Branch, is the lead Regional office to undertake this Merit Proposal over a one and one-half year period at an estimated cost of $75,000. The IRM Branch Chief has indicated that his office has provided extensive support to the Regional program office for data processing and integration and that GIS is another tool to be provided.

Process

An initial activity will be a regionally-offered two week GIS course at the University of Pennsylvania's School of Landscape Architecture and Regional Planning. Interested persons will be invited to participate in this program to gain a familiarity with spatial data manipulation and analysis using an Intergraph GIS.

A second initiative will be the implementation of a pilot study, in conjunction with the Environmental Services Division. The proposed pilot study is the Cedar Island, Virginia, Advanced Identified Project. This pilot study will use a GIS to assist in the advanced identification of wetlands by automating the present traditional methods of accessing, storing, and analyzing appropriate natural resource data. This is a logical extension of the Water Management Division's extensive regional wetlands mapping program that has been conducted during the past two years.

Another potential application is in the area of human health. The production of maps showing epidemiological information will benefit program activities dealing with public health oversight. For example, geographic regions faced with contaminated ground-water reserves due to leaking underground storage tanks can be analyzed by integrating data on the population at risk, drinking water consumption, water quality and hydrologic parameters. These data layers can be evaluated separately or in various combinations. Additionally, Region III plans to use the GIS to graphically depict trends, provide statistical summaries and provide modeling capabilities.

Organization/Structure

Region III is planning to develop a technical core group, consisting of ADP staff that will work through IRM with program personnel detailed for a 6-8 month period to work on GIS. The program offices have expressed support for

this approach because they will not loose staff and will gain valuable GIS expertise for future program directions. The IRM Branch Chief has also idicated that Region III GIS activity will be conducted, whenever possible, in close partnership with those State organizations already using GISs (e.g., New Jersey Department of Environmental Protection).

-- GIS CASE STUDY --

THE CHESAPEAKE BAY PROGRAM

Project History

The Chesapeake Bay Program (CBP) was commissioned by Congress in 1975. The Environmental Protection Agency (EPA), in cooperation with other federal, state and private institutions began a concerted effort in 1976 to study the primary sources of Bay pollution. In 1981 the research phase ended, and for the next two years, the agencies involved analyzed and integrated their findings.

Reports from this scientific research phase verified what many people already knew, but more importantly, it initiated a cooperative political management structure to address the problem. In December 1983, chief executives from Maryland, Pennsylvania, Virginia, Washington, D.C., and EPA signed the Chesapeake Bay Agreement. The parties to the Agreement called for preparation and implementation of coordinated plans to improve and protect the water quality and living resources in the Bay.

In addition, cooperative agreements have been signed between EPA and other federal agencies that share the environmental responsibility for the Bay. These agencies include the National Oceanic and Atmospheric Administration (NOAA), The Army Corps of Engineers (COE), the Fish and Wildlife Service (FWS), the Geological Survey (USGS), and Soil Conservation Service (SCS). These Memoranda of Understanding (MOU)s were intended to create joint ventures of scientists and managers to make more efficient use of public funds and other institutional resources involving Chesapeake Bay.

The CBP has been interested in GIS since early 1984. During the spring of 1985, the US Fish and Wildlife Service was permitted to use the CBP Computer Center to develop a GIS project to show its applicability to Program goals. About the same time, the CBP performed a study of GIS software products and projects being used in the Bay area. That study concluded that existing CBP software could not fully support the critical Program data management tasks, and recommended using GIS to enhance data integration and management.

Environmental Program Applications Using GIS

CBP has used GIS for three pilot projects: toxics, living resources/water quality, and non-point sources.

Toxics - the Elizabeth River area study of toxic pollution

This three year pilot study between EPA and the U.S. Geological Survey (USGS) began in the summer of 1985. Its purpose was to investigate the feasibility of using GIS to pinpoint existing and historic hazardous waste disposal sites. Historical aerial photographs were obtained and interpreted by staff at EPA's Environmental Photographic Interpretation Center (EPIC) to determine land use. The data were then digitized by UGS using ARC/Info on a PRIME computer at their National Mapping Division in Reston, VA. Various other data, i.e., hydrology, transportation, population, public water/well

sites, were obtained from local and national data bases. On top of these data, the USGS Water Resources Division staff in Richmond, VA overlayed EPA's National Priority List hazardous waste sites.

Preliminary results of the Elizabeth River study have clearly shown the feasibility of using GIS to investigate proximity of hazardous waste sites to public and private water supplies. This information could be used to target sites for cleanup and/or monitoring. The project has also shown how historical land use data can be used to discover potential hazardous waste sites that might otherwise go undetected, i.e., current data showing poor water quality could be traced to a historical land use practice, or vice versa.

Living Resources - Linking Water Quality to Living Resources Criteria

The CBP is using the public domain MOSS family of GIS software to show how living resources, i.e. finfish and shellfish, critical habitats are matching up with water quality in the Chesapeake Bay and its tributaries. Striped bass spawning and oyster spat distribution data are being overlayed with seasonal water quality monitoring data to see how these areas overlap. Water quality model simulations are also being overlayed on the distribution areas to recommend alternative pollution load control strategies to the states.

Non-Point Sources - Targeting Non-Point Source Pollution Control

Two CBP GIS pilot projects are ongoing in the non-point source pollution program. FWS is using detailed, subwatershed stream reach maps of the Choptank River, together with water quality monitoring station data and a regression model to pinpoint areas of non-point source pollution. They are using the enhanced version of MOSS, called AutoGIS, on the CBP CC VAX 11/780 computer.

The other GIS pilot for non-point sources is vested with the Virginia Department of Soil and Water Conservation. They are using the MAPS grid, and Henco's INFO data base management system on a Virginia Tech PRIME computer. The application is using soils data, the Universal Soil Loss Equation, and slope data to target county conservation districts for implementation of Best Management Practices (BMPs).

Future Applications

Future CBP GIS applications will expand the current pilot projects in the toxics, living resources/water quality, and non-point source areas. The CBP has indicated its interest to expand the Elizabeth River Project area to other toxic "hotspots" in the Bay basin. Also there is interest to integrate pollution loading and subsequent surface and groundwater quality modeling with GIS. CBP would like to try combining GIS with expert systems or other knowledge-based software to further the potential of the technology.

Spatial Environmental Data

CBP has been acquiring Chesapeake Bay data since its inception. This has resulted in an environmental data base that contains over 100 million data

points stored in Statistical Analysis (SAS) format. Data cover the entire 64,000 square mile Chesapeake Bay basin, and date back as far as the early 1900s.

Much of the data base is geo-referenced with associated latitude and longitude, hydrologic unit, or some other spatial parameter. It can therefore be used as the basis for developing a more specific and integrated GIS data base. The current CBP data base contains the following types of data:

- Coliform
- Cultural (land use and population)
- Discharge (point and non-point source loadings)
- Flow (fresh water inflow from tributaries)
- Nutrients (water quality data organized by study and Bay segment)
- Physical (tides, climate, and current)
- Resources (fisheries, SAV, and other biological)
- Toxics (in sediment and water)

As a result of the ongoing and planned GIS applications, a spatial data base is being developed at CBP. The current GIS data base includes the following types of data:

- Land use/land cover
- Hydrology by watershed
- Agricultural practice
- Pesticide application
- Timber survey
- Shellfish, finfish
- Waterfowl
- Bathymetry
- Political boundaries
- Shoreline
- Topography
- RCRA/CERCLA
- Transportation

Numerous data sets are still required by CBP to perform its intended applications. To identify existing Chesapeake Bay GIS data bases, the CBP Data Management Coordinator convened a regional GIS conference. The May 1987 event was attended by close to 100 participants, representing roughly 50 public and private institutions. From that initial meeting, a Chesapeake Bay Basin GIS Workgroup was formed to coordinate the development of a regional GIS data base, and to address other GIS issues, like data mapping standards, data sharing mechanisms, and data base documentation requirements.

CBP CC Hardware/Software Configuration

The current CBP CC hardware and software are supporting GIS applications, but with minimal results. Numerous problems with both the MOSS public domain and the AutoGIS software require mixing and matching data, software, and input and output devices. All GIS functions: storage, analysis, and presentation are affected. CBP has thus recently procured ARC/Info as an EPA pilot GIS site. Installation of ARC/Info is scheduled for the fall of 1987.

Current CBP CC hardware includes:

- VAX 11/780 CPU
- 12 megabytes of memory
- 64 I/O ports
- 6 disk drives
- 2 tape drives
- 3 line printers
- 1 eight pen plotter
- 1 four pen plotter
- 2 medium resolution graphics terminals
- 1 color ink jet printer
- 2 digitizers

With the arrival of ARC/Info, and increased use of mathematical models, CBP is planning a major hardware upgrade. Planned procurements in FY88 are:

- VAX 8600 CPU
- 1 high speed tape drive
- 9 disk drives
- 1 high resolution, color graphics terminal
- 1 digitizer
- 1 color ink jet printer

Organizational Structure and Staffing

CBP management created by the Bay agreement is headed by an Executive Council comprised of the agreement signers. The Chair of the Executive Council rotates between EPA and one of the agreement partners each year. Under the Executive Council are three committees, the Implementation, Scientific and Technical, and Citizens committees. The Implementation Committee has five technical subcommittees to advise it. They are the Planning, Modeling and Research, Non-point Source, Monitoring, and Data Management subcommittees. Each committee and subcommittee have representatives from the participating agencies. Chairship of committees and subcommittees is spread among the groups involved.

The Data Management Subcommittee has responsibility for all data related policies and procedures of the CBP. Through its multi-agency representatives, common data management plans have been developed. These include monitoring methods, data formats, quality assurance requirements, analytical methods, documentation standards, and graphic techniques. The CBP agencies have likewise provided the Data Management Subcommittee with common software and hardware tools to store, analyze, and present Chesapeake Bay data. The Program's tool box is the Chesapeake Bay Program Computer Center (CBP CC).

CBP CC provides a full range of services through an EPA staffed Data Management Coordinator at EPA's Chesapeake Bay Liaison Office (CBLO) in Annapolis, Maryland. The Center is operated and maintained by a contract with Computer Sciences Corporation (CSC). Computer services include systems management, data quality assurance and analysis, planning and procuring ADP equipment, preparing the data management budget, controlling use of the computer system, and responding to requests for data and presentations. The

Center is accessible by the EPA CBLO staff, and from remote sites by the Program participants and by other public and private institutions involved in the Bay cleanup effort.

Costs

GIS costs for CBP have been minimal until recently. The pilot projects described earlier have been performed using other agency hardware and software, except for the FWS Choptank study, and the CBLO Living Resources/Water Quality Study. The two in-house projects required digitizing efforts by clerks trained in the procedures, and used primarily donated hardware and software. About 1.2 man-years has been spent in FY87 on GIS development in the CBLO, which includes CSC contractor staff. The amount of VAX 11/780 CPU time accountable to the MOSS software since it has been installed is negligible. The only significant cost to CBP so far has been in the reformatting of data. This effort was made primarily to improve the general documentation and organization of the data base, not primarily for GIS use. GIS efforts will benefit, though, from the 6-8 man-year task. ARC/Info and graphics peripherals purchased with CBP FY88 funds will total approximately $75K.

In FY88 GIS costs could rise significantly. The procurement of the VAX 8600, though not exclusively for GIS, will increase access to ARC/Info, and thus increase CPU use. The hardware upgrade will cost just over $500K. Staff resources for data base building and GIS applications is expected to increase from 1.2 to 2.0, which includes a full-time federal GIS technical coordinator, and part-time, contracted, digitizing technicians.

Benefits

Benefits of GIS have been acknowledged throughout the CBP management structure. In the pilot projects in the Chesapeake Bay basin, and from outside public and private demonstrations, CBP is confident that the technology can assist the Program goals in three primary ways:

1) Appropriate Technology for Type of Data Collected and Stored

CBP is in a developmental stage called Implementation Phase II. This stage requires the collection and storage of spatial data, or parameters that contain multiple, connected points represented by geographic coordinates. For example, defining distribution of a particular species of vegetation or location of the spawning area of a certain finfish in the Bay requires a unique data management tool. A GIS is the most appropriate software tool to collect and store this type of data.

2) Appropriate Technology for Current Data Analysis Needs

The spatial data being collected during Phase II Implementation are required for very specific types of analyses. CBP managers are asking questions that require comparing various types of geographically dependent data. This means being able to search a data base for striped bass spawning areas that are in waters within a range of dissolved oxygen or other survival determining habitat

parameters. A GIS is the best software tool to provide this type of analysis of different types of data, from various sources, at different scales. Other more common analytical packages cannot provide this type of geographic-based comparison.

3) Appropriate Technology for Data Display and Presentation

CBP Implementation Phase II also requires the ability to display and present the spatial data analysis results in a meaningful way to management, Congress, and the public. Graphic representation using multi-color, shaded maps is far more attractive and informative to a non-technical audience that tabular or x,y coordinate line graphs. A GIS is, again, the software that allows multiple types of data to be displayed on easily recognized base maps.

Critical Success Factors

Critical success factors have been revealed by CBP's limited experience with GIS applications. They include aspects of both a management and technical nature.

1) Management Success Factors - Much of CBP's experience with GIS has relied on established interagency agreements. As a cooperative venture with limited individual agency funding, CBP has used these agreements to gather resources to accomplish goals. This is evidenced by the joint pilot projects involving USGS, USFWS, Virginia, and EPA. Numerous other agencies have supplied data, including NOAA, Maryland, the Corps of Engineers, and others. Private donations of hardware and software were also instrumental in the management of this initial phase. Given the multi-disciplinary, resource intensive nature of GIS technology application, cooperation among the CBP agencies has been critically important.

2) Technical Success Factors - the CBP organizational structure also creates technical advantages in implementing a GIS program. There is a pool of technical staff and state-of-the-art technology available among the Program agencies. The Chesapeake Bay GIS Workgroup is a unique group of GIS managers and technicians, working toward the same goals. Together, there is technical expertise to provide an efficient, effective mechanism for implementing GIS on a basinwide scale.

Constraints

GIS constraints have become obvious, as well, in the CBP experiences. These constraints can by grouped into three categories:

1) Budgetary Constraints - CBP has been searching for funding for GIS since 1984. There has been a need for additional hardware each year just to keep up with growth of CBP CC users and other software use. Until recently, CBP agencies other than EPA were in the hardware/software procurement business. Now, only EPA is buying the much needed equipment and software to keep the computer center ahead of demand. The CBLO has had to reduce demand at certain times to allow completion of priority model runs.

GIS will add another significant demand on the existing VAX 11/780. The planned, major CPU upgrade to the VAX 8600 is necessary if CBP does not want to reduce its ability to meet demand in other areas, or establish rigid scheduling/prioritizing of computer work.

2) Data Constraints - As with any data integration application, GIS requires consistent, quality controlled data bases. Numerous problems have been encountered by CBP during the pilot projects with poor quality data, missing data, or data in the wrong format. In some cases, there is a complete lack of data to perform certain tasks, or a conflict between collecting agencies on parameter definitions.

3) Software Constraints - Like data compatibility problems, CBP found numerous constraints in the ability to use various software products together. Multiple agencies, using different software are unable to communicate the each other. There is a general lack of software to translate or convert from one GIS to another. Given that some software packages have certain advantages over others for specific applications, this lack of software flexibility is a major problem.

-- GIS CASE STUDY --

REGION IV AND THE STATE OF GEORGIA

Project History

The Regional Administrator (RA) and senior management consider multimedia analysis a keystone to their approach for environmental decision making. This approach has been endorsed by the EPA Administrator as evidenced by the guidance for preparation of the FY-87 Operating Plan calling for an increased emphasis on multimedia, environmental results-oriented decision making.

EPA efforts to enhance communication networks and computer hardware at RTP, Washington, and the Region, although improvements for the conducting of EPA business, does not, in the opinion of Region IV, provide mechanisms for improving the use of environmental data in decision making. Similarly, Region IV feels that projects developed and managed at Headquarters by the Office of Water and the Regulatory Integration Division (formerly IEMD) of the Office of Policy Planning and Evaluation are too far removed from the day to day environmental decision making needs of the Regions and States.

Subsequently, Region IV and the Environmental Protection Division of the Georgia Department of Natural Resources (GAEPD) have implemented two overlapping, yet distinct, GIS activities. At the time of this report, June 1987, GAEPD's GIS applications were being supported by the U.S. Geological Survey's (USGS) Water Resources Division (WRD), Doraville District Office. Region IV's GIS applications were also initially conducted at the same facility, but Region IV recently acquired its own ARC/INFO GIS. The State of Georgia Pilot will be discussed first, followed by the Region IV experience.

The State of Georgia Pilot

In early 1986, EPA Region IV and the State of Georgia agreed to undertake a collaborative effort to show how GIS could assist Water Management programs. The USGS WRD Office was selected as the GIS work site since they already were operating an ARC/INFO GIS that contained several useful Georgia data sets. A memorandum of understanding was developed between Region IV and USGS that outlined a GIS demonstration project for developing several state-wide spatial data bases (e.g., geology, land use). Region IV funded this initial project to demonstrate the benefits of using a GIS to integrate USGS/State and EPA data and analyze the data base to support ground-water decisions.

Environmental Regulatory Program Applications Using GIS for the GAEPD Pilot

The GIS applications supported by the Georgia Pilot were undertaken by the USGS Doraville office in two phases. The first phase focused on a 3-county (Terrell, Lee and Dougherty) area in the southwest section of the state; and a second broader application covering the entire state. A summary of the important GIS data management and analysis processes associated with the phase I activities are presented below:

- Several digital data sets (e.g., elevation, digital line graphs, outcrop features, surface hydrography) were purchased by USGS for use in both phases of the project.

- The USGS GIS technical staff reformatted several of the data sets.
  - -- The 1978 State MIADS Soil Base had to be converted from 4-acre grids to polygons by creating a new data base through digitizing the grid-based maps into polygon files.
  - -- The location of hazardous waste sites was determined using the HWDMS EPA National data base by downloading to INFO and then transferring electronically to ARC/INFO at USGS.
- Maps that did not exist in a digital format had to be digitized by the USGS GIS staff to create new data files and other non-graphic data sets had to be entered into the GIS with new geographic identifiers (e.g., RCRA land disposal sites).
- The GIS technical staff used the ARC/PLOT routines to overlay the following files: RCRA land disposal sites (with 500 and 1000 meter buffers), municipal withdrawals, and potentiometric maps. This process consisted of displaying these files on a color video display screen, and evaluating several display scenarios (e.g., color assignments, scales and symbol selection). An acceptable display scenario was then produced as a map on the plotter.

The GIS data base was used in the Phase I pilot to assist in the evaluation of potential sanitary landfill sites and to map the location of hazardous waste sites to assist in planning drinking water monitoring activities.

- The evaluation process of sanitary landfill siting used the GIS data base to locate and map aquifers and recharge areas vulnerable to subsurface ground-water contamination. These sites were eliminated from further consideration and decision-makers dedicated resources to investigating other potential sites.
- In addition, RCRA land disposal sites with 5000 and 10000 meter buffer zones were mapped in conjunction with the location of municipal surface water and ground-water withdrawals that are the sources of drinking water supplies. This analysis provided a mechanism to assist decision-makers prioritize monitoring of drinking water sources to those most vulnerable to ground-water contamination.

The Phase II GIS applications are similar to Phase I but have an expanded geographic coverage to the other 156 counties in the state. The Phase II applications will be continued for the next several years.

The Region IV Approach

Region IV initiated the pilot with the support of GAEPD and evaluated the GIS as part of an overall Regional data integration initiative. This initiative was based on a data and reporting requirements analysis that concluded that EPA managers and staff in Region IV needed better ways to:

- Analyze and report trends in environmental results;

- o Assess ambient data for intermedia impacts;
- o Identify emerging problems; and
- o Set priorities for program actions based on actual problems.

Furthermore, this study emphasized the need to access various EPA and other Federal data systems to assess relevant permit, enforcement, and grant actions for effective environmental results management. A high priority requirement was the integration of ambient (e.g., STORET, SARODS) and other program data (e.g., PCS, GICS). Consequently, Region IV endorsed the use of GIS technology to access and analyze these important EPA data bases.

Additionally, the study recommended that Region IV establish an Office of Integrated Environmental Analysis (OIEA) to develop the advanced technology and information management tools required to support effective Regional and State environmental decision making. The RA implemented many of the report's recommendations, including the creation of OIEA with the following mandate:

- o Develop integrated environmental analysis techniques using the latest technology (including but not limited to GIS);
- o Provide leadership and act as a catalyst for development of analytical tools to support multimedia decision making;
- o Maintain liaison with Headquarters integrated information management developments;
- o Develop analysis and report techniques for assessing environmental results;
- o Assemble a high quality staff with programmatic and ADP technology capabilities;
- o Provide leadership and serve as a catalyst for joint data integration projects with other federal agencies;
- o Coordinate data collection activities by the Region; and
- o Liaison with Regional States.

To date, the OIEA has developed several geographic data integration products including GIS applications through the use of a recently installed ARC/INFO system. OIEA is also developing an Automated Results Analysis and Management System (RAMS) that will:

- o identify and prioritize problems and risks;
- o relate these problems and risks to regulatory programs; and
- o track environmental trends.

Environmental Regulatory Program Applications Using GIS in Region IV

Region IV has used its GIS capabilities to support several EPA programs. Progress to date is highlighted below.

- The OIEA has developed a geographic analytical technique that displays all water monitoring stations and identifies all water quality violations on a computerized map. Incorporation of NPDES permit information allows the mapping of point sources of discharge. Computer maps showing violations for different time periods are also generated to track water control progress and prioritize water body problems. These automated analytical techniques are provided to the States to assist in development of 305 (b) reports. At present, these applications are not conducted with ARC/INFO, but with other computer tools. OIEA plans to incorporate these functions into the GIS in the near future.

- Computer analysis techniques have been developed to display ambient air quality monitoring stations and associated violations of air quality standards. Violations are depicted on the maps to show where air quality problems exist. Trends analyses are also possible when data from different time frames are analyzed and displayed.

- The OIEA staff has developed an analytical mapping capability for the ground-water program that identifies sources of ground-water pollution from facilities (such as RCRA and Superfund sites) in association with drinking water wells, population served, and ground-water vulnerability. These three factors are used to prioritize ground-water problems.

Future Applications

The GAEPD plans to expand its pilot GIS activities, with the ARC/INFO system at the USGS/WRD, to the entire State for several other program activities:

- **Siting sanitary landfills.** The State Geologist would like to expand their pilot study conducted in Dougherty county. The integration of the environmental data enables the local government to make better informed decisions.

- **Hazardous waste management.** GAEPD has a need to identify the location of both RCRA and Superfund sites throughout the state. This will assist, for example, in ranking Superfund sites to determine priorities for conducting preliminary assessments and subsequent site investigations.

- **Locating sites for regional reservoirs.** In the past, county level decision-makers have designated potential reservoir sites in areas unsuitable for such use. The GIS can integrate geologic, topographic and hydrologic data to enable analysts to better predict water quality degradation (e.g. as a result of heavy siltation) at potential sites.

- Continue to develop RAMS.

Region IV's interest in GIS application parallels that of the State of Georgia. In addition, the Region is interested in using GIS to assist State's develop their Community Water Systems (CWS) vulnerability analysis, prioritization of RCRA enforcement activities, and screening of Superfund sites.

Spatial Environmental Data

GAEDP and Region IV have used some of the same environmental data. These common and other appropriate data sets and sources are summarized below:

- o USGS 1:2,000,000-scale Digital Line Graph Data (derived from USGS National Atlas separates)
  - Political Boundaries
    -- state and county
  - Water Bodies
    -- perennial lakes or ponds
    -- intermittent lakes or ponds
    -- marshes/swamps
    -- reservoirs
    -- islands, etc.
  - Rivers and Streams
    -- shorelines
    -- river/stream centerlines (coded by length)
    -- canals
    -- ditches
    -- intercoastal waterway
- o USGS Hydrologic Unit Boundaries
- o EPA River Reach File (EPA only)
- o U.S. Bureau of the Census Block Group Centroids
  - Thiesson polygons generated from centroids (EPA only)
- o U.S. Bureau of the Census DIME Files
- o U.S. Bureau of the Census Summary Tape File (STP #3)
  - demographic and socio-economic date tied to census geography
- o USGS 1:250,000-scale Land Use/Land Cover Data
  - Land Use/Land Cover
  - Census Tracts
  - Political Boundaries
  - Hydrologic Units
  - Federal Land Ownership
- o U.S. Defense Mapping Agency (sold by USGS) 1:2,500,000 Digital Elevation Models (GAEPD only)
- o USGS Public Water Supply Data

- o U.S. EPA (derived from STORET, PCS, WHDMS, GICS)
- o Soil Conservation Service MIADS Soils Data
- o USGS Geographic Names File
- o District Data Bases 1:500,000-scale (GAEPD only)
  - Rivers
  - Lakes
  - Cities
  - Physiographic Provinces
  - Runoff Contours
  - Precipitation Contours
  - Population Density
  - Depth to Top of Aquifer
  - Recharge/Outcrop Areas
  - Faults
  - Surficial Geology
  - Soils Data
  - Slope Data
- o EPA Pesticide Data
- o USGS 1:100,000 Digital Line Graphs (June-July 1987)

Overview of GIS Hardware/Software

The discussion below provides details about the ARC/INFO systems.

USGS ARC/INFO

The ARC/INFO software is maintained at the USGS/WRD Doraville office on a PRIME 9952. Peripheral hardware includes two Tektronix color graphics terminals (4111 and 4107), a Calcomp 9100 digitizer, and a HP 7586 plotter. The GAEPD has access to the USGS Prime via a 2400 baud port. The ARC/INFO software includes the basic INFO DBMS from Henco and ARC, the ESRI software developed for storing cartographic data. Other functionally linked ARC/INFO software subsystems include:

- o NETWORK- applications module for modeling network files (e.g.,minimum path, routing optimization, address matching);
- o Triangulated Irregular Network (TIN)- applications module for structuring and modeling digital terrain data (e.g., contour maps, viewshed creation, slope mapping);
- o ARC/COGO- applications module for processing legal land descriptions and related survey data; and
- o GRID/TOPO- applications module similar to TIN except for handling regularly spaced (as opposed to triangulated) three-dimensional terrain data.

Region IV

Region IV installed its ARC/INFO in November of 1986. The software runs on a PRIME 2655 with a standard 3200 BPI tape drive. Two Textronix 4125 are used for interactive data processing and analysis. Data entry is accomplished using a Tektronix 4857 digitizer. At the present time OIEA does not have a high quality, large format plotter but plans to acquire one in the near future. Optional ARC/INFO software acquired by the Region includes NETWORK, TIN, and ARC COGO.

Organizational Structure/Staffing

The State of Georgia

The initial GIS applications supported by USGS used the services of two highly-trained GIS experts for developing the Phase I and Phase II products for GAEPD. GAEPD has not allocated any technical or program manpower support to this activity, with the exception of the State Geologist's liaison role and occasional other staff involvement with GIS output evaluation.

Region IV

The Regional IV use of the ARC/INFO, as previously mentioned, is supported by the OIEA. At present, OIEA staffing consists of:

- A chief;
- A Ph.D. air program scientist with extensive computer programming experience;
- A M.S. remote sensing/environmental scientist;
- A M.S. water pollution engineer familiar with permit, grant, and technical support activities; and
- An ADP/GIS technical expert familiar with EPA data systems and ARC/INFO.

Plans are to add two other staff positions; one ground-water and one Superfund specialist. The assignment of these "program" positions is accomplished by each program allocating an FTE to OIEA.

Costs

The State of Georgia did not buy any software/hardware for conducting the pilot but entered into an interagency agreement in which $10,000 was committed by EPA to USGS to support the GAEDP GIS applications. Participation by GAEPD staff was not calculated as a separate cost. USGS indicated that the actual project costs exceeded the funding provided, but USGS gained an understanding of new applications through this project.

The costs associated with the Region IV ARC/INFO acquisition include:

PRIME Upgrade	$90,000
2 Graphic Terminals	$15,000

ARC Info Software	$17,500
Digitizer	$12,000

It is important to note that there are additional costs associated with data purchase and OIEA staffing. Unfortunately, it is not possible to provide dollar values for these costs.

Benefits

The benefits to GAEDP and Region IV as a result of GIS implementation include **data integration, identification of environmental problems, prioritization of resource allocations based on potential risk, and information dissemination.**

- The use of the GIS for siting sanitary landfills at the county level saves innumerable resources by reducing the number of sites needing field investigation. The ability to assemble numerous data sets in one central computer system with common geographic dimensions provides a useful analytical capability for State and Regional environmental regulatory programs.

- Region IV OIEA staff feel that the use of GIS will accelerate the Superfund site ranking process. At present, only two sites per year in each state are being added to the NPL. Integration and analysis of the various environmental data layers has enabled Superfund staff to identify and prioritize sites. Without using the GIS, these sites would have to be evaluated by contractors in the field. Consequently, the Agency is able to reduce expenditures in this program activity.

- Program managers and senior management can analyze and track environmental trends more efficiently. This is possible because of the creation of a state-wide GIS environmental data base containing pollution impact information (e.g., emission and discharge data) and ambient data across media for numerous time periods. This data base also provides a capability to geographically analyze the effectiveness of controls and conduct risk assessments.

Critical Success Factors

The successful use of GIS at GAEDP and Region IV can be attributed to the factors summarized below:

- **Technical support** for the GAEPD pilot was provided by highly trained GIS professionals. This minimized the "learning curve" time lag associated with such projects. The "technical center" role of the Region IV OIEA serves a similar role to provide GIS support to various programs without requiring program staff to become GIS experts.

- **Management/infrastructure support** has been instrumental in backing the original GAEPD effort and Region IV GIS acquisition and implementation. The EPA Region IV RA and the Commissioner of the Georgia Department of National Resources have been strong advocates of this technology. Such high level backing has resulted in EPA Regional IV program support for the OIEA multidisciplinary team concept.

- **Communication/information exchange** has been encouraged between technical GIS staff at USGS and the appropriate senior GAEPD and EPA Regional IV management. This process has resulted in important synthesis of ideas. The dialogue and interaction existing between Regional, State, and local management levels has been also extremely important.

- GIS implementation has been a deliberately slow paced process that avoided a large expenditure at the early stages. Region IV has also stressed that GIS applications are only one "tool" in the "tool box."

Constraints

Several factors need to be addressed that are limiting the full potential of the GIS:

- Developing a GIS data base requires extensive data entry processing before any analysis can be done. The resources required for this process, the need for "results", and the concern for data validation compete with each other in trying to get an application up and running.

- Both GAEPD and Regional IV are concerned with establishing a mechanism for indicating some kind of confidence limit for each data set. At present, this is absent in the ARC/INFO environment.

- There is a great need to establish data standards for use in all phases of state and local data base development to enable data to be used effectively in the GIS arena.

- ARC/INFO contains hundreds of software routines. The non-expert will need some type of user-friendly tools (e.g., macros) to be able to use this technology without ADP support.

- Region IV has states and agencies using several different GIS systems (e.g., Intergraph at TVA and the Florida Department of Environmental Regulation). The OIEA is presently determining how these important data bases can be easily linked and incorporated into ARC/INFO.

- Data storage needs are expected to increase rapidly and exceed present storage capacity. Consequently, Region IV will have to develop sufficient data storage to maintain efficient data access.

-- GIS CASE STUDY --

THE FLORIDA DEPARTMENT OF ENVIRONMENTAL REGULATION

Project History

Florida's Department of Environmental Regulation (DER) began using a geographic information system (GIS) in 1984 to help the Bureau of Ground-Water Protection map the location of pesticide application areas and contaminated drinking-water supplies. The products derived from the GIS were was used to provide a comprehensive overview of the activities of numerous State agencies involved in collecting samples of drinking-water from wells, performing laboratory analyses of these samples, taking various remedial actions, and subsequent follow-up monitoring.

Recently, the State of Florida has mandated DER to conduct an ambient ground-water monitoring program to determine the present condition and future trends of this critical resource. (In Florida, 86% of the publicly supplied drinking water comes from ground water.) As part of this effort, DER has implemented a state-wide geographical "vulnerability" screening tool using a microcomputer-based GIS. An overview of these GISs and associated activities is discussed below.

Intergraph System

The Florida Department of Environmental Regulation began making extensive use of geographic environmental data in the early 1980s in conjunction with its pesticide monitoring and ground-water protection programs. Initial concern over the potential threat to Florida's ground-water supply from a particular pesticide, ethylene dibromide (EDB), required an analysis of drinking water samples from wells in close proximity to EDB-treated citrus groves to determine if a problem existed.

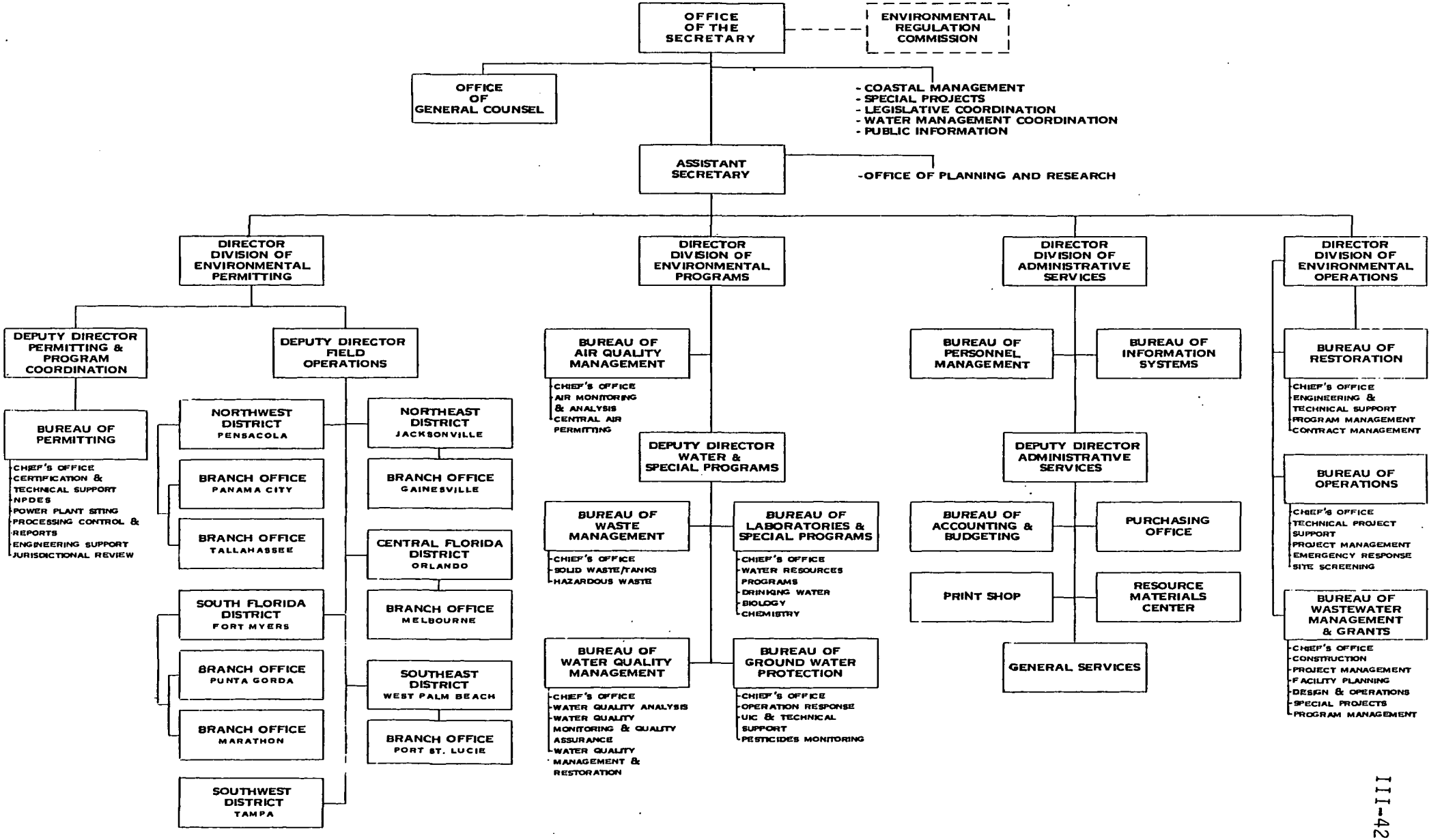
In early 1984, the Bureau of Groundwater Protection (see the DER organization chart in Figure 3.3) developed an EDB pesticides data base on the Agency's Sperry mainframe. This data base started as a simple file structure of name and address of sampled well and corresponding EDB laboratory test results. DER then awarded a contract to the Florida Resource and Environmental Activities Center (FREAC) at Florida State University to add a location field for all the records. A simple mapping capability was possible using the Sperry's Mapper package, a fourth generation software language. Over time, however, it became more cumbersome to map these data with the existing Sperry hardware and software, and DER decided in the spring of 1984 to use the Intergraph software maintained on the FREAC VAX minicomputer. Later in 1984, DER purchased a dedicated Intergraph workstation and plotter and linked them to FREAC via a high speed communication line. DER acquired a second Intergraph workstation in 1986.

Microcomputer-based GIS

Recently, DER contracted with the University of Florida to develop an IBM PC-based GIS with a relational data base and mapping capability. This system

FIGURE 3.3

Department of Environmental Regulation



called the Florida Waste Source Locator Information System is being tested and used for identifying "background" wells sampled between 1983 and 1986 as part of the recently enacted State ambient ground-water monitoring program. The GIS is a raster-based system using 1 square mile grids based on county tax assessor records to generate land use categories and associated pollution indices.

Environmental Regulatory Program Applications Using the GIS

The GIS applications in DER have been primarily dedicated to determining the extent and severity of EDB ground-water contamination in the State using the Intergraph system. A smaller level of effort has been used to produce parts of the 1986 305b report. Recently, a microcomputer-based GIS has been developed and tested in the ground-water protection program. A summary of these activities is presented below:

Using the Intergraph System to Determine Pesticide Contamination in Ground-Water

- **Data entry** required tape loading and digitization.
  - -- Well owner and location (via UTM coordinates) information of wells sampled for pesticide contamination are resident data files on the State of Florida's Sperry mainframe.
  - -- The results of all laboratory analyses of drinking-water well samples collected by the Florida Department of Health and Rehabilitative Services are stored in a data base in the Sperry mainframe.
  - -- These data sets are reformatted as a routine procedure, dumped to tape, and subsequently delivered to the FREAC data center for loading into the VAX.
  - -- Florida Department of Agriculture maps containing the location, dates, type of EDB treatment, and amounts of pesticide application were digitized using the Intergraph workstation.
- **Data analysis** consisted of overlaying the different data files to produce maps.
  - -- Software routines that merge pesticide application data with well data were used to produce maps displaying location and method of pesticide application and status of sampled wells (contaminated or non-contaminated).
  - -- Wells located within 300 feet of EDB application were identified.
  - -- Public drinking-water wells located within 1,000 feet of EDB applications were identified.
  - -- Ground-water sampling was prioritized based on the above process.
- **Ground-water monitoring and corrective action** were undertaken based on this data integration and mapping capability.
  - -- The success of corrective action programs (installation of charcoal filters, drilling of new wells, or hook-ups to city water supplies) for positively identified EDB contaminated wells

has been monitored with this spatial data base.
-- Regular reporting of progress to the public and State legislature is provided in both statistical and map formats.

Using the Intergraph System to Produce the State 305b Report

A component of the 1986 Florida 305b (a biannual report describing the status of the State's surface water quality) report was developed by conducting data analysis with STORET (a data storage and retrieval software system residing on the EPA National Computer Center's IBM mainframe):

- Water quality summaries were calculated for each river reach using STORET River Reach files.
  - -- Water quality for each river reach was determined by using a water quality index for specific parametric monitoring data in STORET.
  - -- A STORET map of each river reach was subsequently produced.
- A base map of river reaches for the entire State was created in the Intergraph data base.
  - -- The STORET maps were digitized.
  - -- The water quality (good, fair, poor, unknown) for the entire State and four geographic regions was mapped by color code for each river basin.
  - -- These maps were incorporated into the State 305b report.

Using a Micro-based GIS for the Ambient Ground-water Monitoring Program

The Bureau of Ground-water Protection is using the micro-based GIS as part of its ambient ground-water monitoring program:

- Pollution indices are generated to assist in determining the vulnerability of specific regions and sites.
  - -- A matrix of land use types and tax assessment categories is used in conjunction with SIC classifications to establish a hazardous ranking for each square mile grid.
  - -- These rankings are then overlaid with DRASTIC (a numerical rating scheme that evaluates the potential for ground-water pollution at a specific site given its hydrogeological setting) maps that are developed by each Water District to locate "vulnerable" areas.
  - -- Those areas considered highly vulnerable are then targeted as very intensive study areas (VISAs) and prioritized for future intensive sampling to determine ground-water trends.
- Future plans are to develop a linkage to the Intergraph system.
  - -- Downloading existing Intergraph data onto the micro GIS and uploading data from the micro to the Intergraph is under development.
  - -- These data bases will be linked in the next one to two years.

Future Applications

DER has indicated its interest in utilizing the Intergraph system for several other program activities:

- **Ambient Ground-water Monitoring** program. The 1983 Ground-water Act requires DER to determine the status and trends of Florida's ground-water resources via a long-term monitoring effort. This process, presently utilizing the micro-based GIS, can benefit from using the Intergraph for evaluating water quality by aquifer segment.

- **Underground Storage Tank** program. The Bureau of Restoration is presently identifying leaking underground storage tanks to conduct a restoration program. DER can determine the location of tanks through the Early Detection Incentive program in which owners can voluntarily turn themselves in or through a second process that integrates various sources of information (e.g., county Health Department reports) to rank the potential environmental hazard of each tank. The Intergraph would be a useful management tool for identifying the location of leaking tanks. It is also estimated that the State will be collecting 15,000 well samples a year under this program and this data could be mapped together with tank registration data.

Spatial Environmental Data

DER uses a Sperry Univac mainframe to archive most of its program data. The appropriate spatial environmental data from this data base as well as other data sets and sources are summarized in Table 1.

Overview of GIS Hardware/Software

The configuration of the GISs and associated hardware systems is presented in Figure 3.4. The discussion below provides details about the appropriate systems.

Intergraph

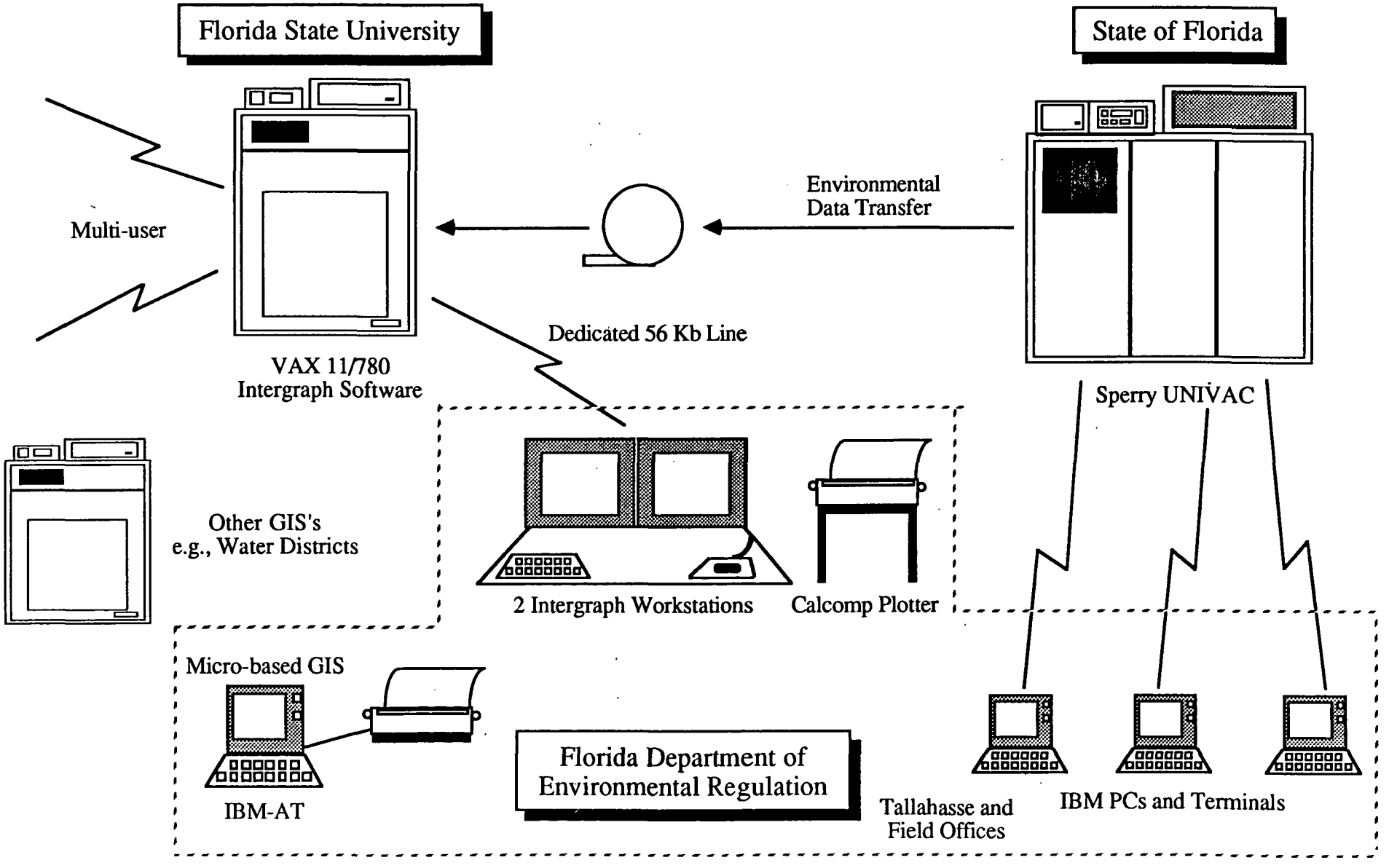
The Intergraph software is maintained by FREAC on a VAX 11/780. Several State agencies have access to this GIS with DER ensured of sufficient storage and access through a telecommunications link and separately purchased and installed storage disk at the FREAC computer center. DER owns 2 Intergraph workstations. Each workstation has a black and white monitor, color monitor, digitizer, and stand alone disk storage. DER also has a Calcomp plotter for producing 24 inch by 36 inch color maps. All DER program data resides in a Sperry mainframe. This mainframe has no direct link to the Intergraph VAX and consequently selected data must be reformatted in the Sperry environment and downloaded onto tape for transfer and incorporation into Intergraph at the FREAC computer center. In addition, the 6 DER field offices have no access to the Intergraph but do have direct access to the Sperry.

Micro-based GIS

The custom developed micro-based GIS is designed around an IBM AT workstation operating with DOS 3.1. This system also has a high resolution

FIGURE 3.4

Overview of Florida Department of Environmental Regulation GIS and Related Computer Systems



color monitor display and a color printer. The system at present has a 20 Mb hard disk storage capacity that will be increased with the addition of a Bernoulli Box in the near future. Data is maintained on floppy diskettes, with each county on a separate diskette. The data base is developed in a raster format with 1 square mile grids. The GIS software does not have the flexibility to modify scale easily nor provide rubber sheeting of data layers. There is at this time no capability for digitizing any new data at the DER workstation since there are no data entry software routines. Whether this GIS will become available as public domain software through DER is unresolved.

Other Office Systems

In addition to these DER-maintained GIS systems, Water Districts have their own GISs (Computervision, ARC/INFO) for independent data analysis and mapping. Often these programs collect independent data. It is also important to note that many program offices within DER have acquired PCs for individual program applications.

Organizational Structure/Staffing

The Bureau of Information Systems in the Division of Administrative Services is responsible for operation of the Intergraph. One systems manager has responsibility for the Intergraph software, which is only a small part of his overall responsibilities. Technical staff to operate the system have been made available within DER program offices. Presently there is only one full-time GIS technical analyst in the Bureau of Ground-water Protection. In the past, DER had more GIS technical staff, but staff reductions have seriously inhibited the efficient use of this system by other program offices. Senior managers have attended Intergraph classes while other staff have acquired Intergraph working knowledge through in-house training and user assistance at FREAC. The Information Systems manager indicated that the ideal situation would be to have two full-time scientifically trained staff knowledgeable in both regulatory programs and ADP systems to provide GIS and microcomputer support.

The micro-based GIS is managed independently of the Bureau of Information Systems within the ground-water program office. At present, the DER ADP staff do not provide any technical support for the IBM AT operations.

Costs

DER did not purchase the Integraph software but pays an annual service fee of approximately $30,000 to FREAC for system access and data base maintenance. The cost of purchasing the first Intergraph workstation in 1984 was $55,000 while the second workstation purchased in 1986 cost $45,000. In addition DER bought a Calcomp plotter for $20,000 in 1984 to produce high quality color maps. A dedicated 56Kb communication line to FREAC costs $122 per month.

Development costs paid by DER to the University of Florida for the micro-based GIS will be $287,000. This cost includes providing all hardware and software to DER but does not include annual updates of the Florida tax information which is projected to cost between $ 40,000 and $50,000.

Benefits

The benefits to DER as a result of GIS implementation include **data integration, identification of environmental problems, strategic planning,** and **information dissemination** to the public and State legislature.

- Integration of several different sources of data (e.g. EDB application maps, laboratory analysis of drinking water samples) provided a unique analytical capability for the pesticide monitoring program through computer mapping. This integration is also unique for the ambient ground-water monitoring program. It is reasonable to conclude that these programs would not have been able to conduct their business as quickly and efficiently in the absence of these GISs.

- The integration of different pieces of information (e.g. tax information, DRASTIC maps, drinking-water supplies) has resulted in a better understanding of environmental threats to Florida's ground-water resources. Geographic integration and mapping allow for specific identification of problems. Using the GIS to integrate these data sets has resulted in establishing a "baseline" of specific environmental conditions. Data analysis procedures have been developed to identify specific "problems". Updating this baseline data base with new environmental spatial data will also enable managers to track program progress.

- DER has been required to tackle several monumental environmental problems in the State of Florida during the past several years. The GIS has assisted management in developing monitoring strategies (e.g. pesticide contamination to drinking-water) and prioritizing remedial actions (e.g. type of corrective action for contaminated wells and allocating financial resources).

- GIS products have been used regularly by DER to brief the legislature as well as educate the public concerning program progress. Maps showing where problems exist and the locations for corrective action have proved invaluable to program managers.

Critical Success Factors

The successful use of GIS at DER can be attributed to the factors summarized below:

- **Technical support** for the GIS program has been closely associated with FREAC which serves as a center of excellence in Intergraph applications and system support. Futhermore, DER does not have to invest significant resources in maintaining the Intergraph GIS software. Efficient data exchange protocols exist between the Sperry and the Intergraph. Trained GIS system operators and analysts have been available in the past to support program applications. Presently, DER requires more experienced staff to work with the GIS.

- **Financial support** for purchase and operation of the Intergraph has been available through specially legislated State environmental

programs. Funds for staffing, however, have not been part of this budget allocation.

- **Management support** has been instrumental in implementing GIS program applications. This infrastructure support includes State legislature, DER senior management, and program management support. The successful GIS program applications with pesticides and ground-water have interested other programs in using this tool.

Constraints

Several factors need to be addressed that are limiting the full potential of the GIS:

- A **GIS Coordinator** with full responsibility to direct and manage the DER GIS activities is needed. Having a person in this role will assist other DER programs in gaining access to the Intergraph.

- Management and funding support to hire, train, and maintain GIS **technical staff** to use the Intergraph hardware. At present the full complement of software routines have not been used because of the shortage of staff and lack of familiarity with the entire range of Intergraph capabilities.

- There is a need to establish more efficient **data integration.** The use of the Intergraph could be expanded within DER if other environmental data residing on the State Univac could be incorporated into the VAX on a selected basis. Similarily, a wealth of data exists on other State GISs that selectively could prove useful for various DER programs.

-- GIS CASE STUDY --

THE ENVIRONMENTAL RESEARCH LABORATORY -- CORVALLIS

Project History

The Environmental Research Laboratory - Corvallis (ERL-Corvallis) is the U.S. Environmental Protection Agency's national center for atmospheric, terrestial and aquatic ecological research. A major thrust of the Laboratory's research is understanding the ecological effects of pollutants as they move through the air, soil, and water.

The Laboratory research programs are organized into several broad areas, including: the ecological effects of airborne pollutants such as ozone and acid rain; the effects of toxic chemicals on plants, animals, and ecosystems; the assessment and restoration of contaminated or degraded environments; the characterization and assessment of the vulnerability of ecological systems (e.g., wetlands) to human impacts; and the ecological risks from bioengineered organisms and other biological control agents.

The Laboratory's research approach to the analysis of environmental processes is generally holistic, with individual research projects contributing to an understanding of specific processes occurring within an ecosystem. Research consists of laboratory, aquarium, greenhouse, aviary, and field studies on the acute and chronic effects of environmental pollution. Mathematical modeling, experimental design, and statistical analysis are applied to help understand and predict changes in natural and stressed environments. These research activities support the information needs of the EPA air, water, pesticides, hazardous waste, Superfund, and toxics programs.

The ERL-Corvallis has undertaken several multimedia ecological assessments during the past decade emphasizing integrated spatial analysis. The acquisition and implementation of ARC/INFO in April 1985 was a direct outgrowth of these activities and interests.

Environmental Program Applications Using GIS

GIS applications at ERL-Corvallis include several major efforts which are described below.

National Lakes and Streams Survey

The relationship between acidic deposition and the acidification of surface waters has become an important environmental issue in the United States. Alkalinity and ANC have been used as indices of surface water sensitivity to acidic deposition. The actual sensitivity of a lake or stream to acidification, however, depends on the Acid Neutralizing Capacity (ANC) generated both within the lake and its watershed. Hence, because many physical, chemical and biological factors, (both aquatic and terrestrial) collectively determine the biotic composition and chemical environment within lakes, the response of an aquatic ecosystem to acidic deposition is a composite of many factors.

The U.S. Environmental Protection Agency initiated the National Surface Water Survey (NSWS) in 1983, which includes both lakes and streams, to: quantify the present chemical status of surface waters in the U.S.; assess the temporal and spatial variability in aqautic chemistry; define the key biological resources associated with surface waters; and identify temporal trends in surface water chemistry and biology. Each subsequent phase builds on the results of the previous one, ultimately identifying those lake or stream populations upon which to base a regionally characteristic, statistically sound long-term monitoring project designed to study long-term trends in chemistry and biological resources.

The ARC/INFO GIS is being used to provide the information needed to assess the chemical status of lakes and streams in areas of the U.S. containing the majority of low alkalinity systems. The GIS is providing data base management mapping capabilities to investigate correlations among chemical variables on a regional basis and to estimate the chemical status of lakes within a specific region.

Direct/Delayed Response Project

The Environmental Protection Agency's Direct/Delayed Response Project (DDRP) is examining the question "What is the possible long-term chemical response of surface waters to continued acidic deposition?". The DDRP requires detailed watershed maps of those characteristics associated with the effects of acidic deposition. To provide this information, the USEPA contracted with the USDA Soil Conservation Service to map soils, vegetation, geology, and depth-to-bedrock on 145 watersheds in the Northeast and 35 watersheds in the Southern Blue Ridge Province. Land use maps are provided by the EPA Environmental Monitoring and Systems Laboratory in Las Vegas, Nevada.

The DDRP is integrating data from the intensively studied DDRP watersheds with data from other sources, including lake chemistry data from the EPA's National Surface Water Survey (NSWS), U.S. Geological Survey runoff maps, dry and/or wet deposition estimates, precipitation and evapotranspiration estimates, existing regional physiographic and land use maps, and 1:250,000 Digital Elevation Models. These data are being used in three levels of DDRP analysis: system description, single factor response time estimates, and dynamic systems models.

The influence of key watershed variables on surface water chemistry can be examined by characterizing or displaying the spatial distribution of individual and/or aggregated variables (e.g., soils, soils/vegetation intersection). These spatial characterizations can ultimately be related to surface water chemistry via statistical, graphical, or cartographic techniques. Watershed characterization involves describing individual variables, identifying map units in close proximity to the study lake or stream reach, and aggregating map units within and between layers.

Characterizing spatial relationships among the watershed variables allows researchers to develop and test various hypotheses concerning the effects of individual variables on surface water chemistry. The watershed variables, particularly soils, that occur closest to the water body might exert the greatest effect on its chemistry. The influence of these proximal land units

can be investigated by determining the land area components within certain distances (either longitudinal or elevational) of the lake or stream reach. Although a single variable (e.g., soil mapping units) might not adequately explain the chemistry of surface waters, particular aggregations or combinations or variables might yield significant results.

A variety of GIS-based cartographic techniques are used to display and/or interpret regional or sub-regional variations in selected parameters. These spatial displays are used to explain or predict water chemistry across the regions of concern. Both analytical (e.g., interpolation of modeled distributions to points) and descriptive (e.g., depiction of the distribution of sulfate concentrations in sampled water bodies) processes are used in the analyses. Outputs include point location maps, circle maps, contour and/or interpolated maps or datasets, and Thiessen polygon maps.

Future Applications

ERL-Corvallis is in the preliminary stages of determining the role of ARC/INFO in the new Global Climate program. The objective of this initiative is to assess the ecological effects resulting from climatic change. The GIS is expected to provide essential parametric overlay mapping capabilities and ecosystem level atmospheric modeling results.

The Corvallis Lab has been developing ecoregion mapping products for the last several years to portray the interrelationships among natural and anthropogenic factors affecting ecosystem quality. These products are in great demand by numerous state agencies. ERL-Corvallis is exploring mechanisms for producing regional and ecoregion map products for this user community.

Spatial Environmental Data

The data sets and sources used by the ERL-Corvallis in the GIS program are summarized below:

- USGS 1:2,000,000-scale Digital Line Graph Data (derived from USGS National Atlas separates) containing Political Boundaries (state and county);
- US EPA National Lake Survey Data Base
- US EPA National Stream Survey Data Base
- Adirondacks Lake Survey Corporation Data Base
- Watershed Maps (1:24,000) for 145 Northeast and 35 Southeast watersheds

  -- soils
  -- geology
  -- depth to bed rock
  -- vegetation
  -- land use

- o US EPA East Coast Emissions Data for 1984 (SO4 & NOx)
- o Wet and Dry East Coast Deposition Data for Water Year 1984
- o USGS Runoff Data for the East (1951-1980 and Water Year 1984)
- o USGS Gaging Station Data (1951-1980 and Water Year 1984)

Overview of GIS Hardware/Software

The ARC/INFO software resides on a dedicated VAX 750. ERL-Corvallis is presently upgrading its computer system with the installation of a VAX 785/8600 cluster that will also be linked to the VAX 750 for additional computing capabilities. Peripheral hardware includes eight Tektronix color graphics terminals (4107 and 4207), two Calcomp 9100 digitizers, a Calcomp 1075 4-pin plotter and a Calcomp 5800 electrostatic plotter. The ARC/INFO software includes the basic INFO DBMS from HENCO and ARC, the ESRI software developed for storing cartographic data. In addition, the Triangulated Irregular Network (TIN) application module for structuring and modeling digital terrain data (e.g., contour maps, viewshed creation, store mapping) is incorporated into the GIS.

Organizational Structure/Staffing

The ARC/INFO GIS activities at ERL-Corvallis are supported by numerous contractor staff. A GIS Coordinator is responsible for overall administrative organization, prioritizing work loads among different projects, overseeing GIS staff, liaison with the lab professional staff and hardware maintenance. This person dedicates slightly more than half of his time for this GIS role. Three to four full time employees divide responsibilities for digitizing, map archiving, and data validation. There also is a full time system operator responsible for plotter operation and maintenance, and system backup. In addition each project has the equivalent of one man year devoted to GIS operations, analysis, program planning and project implementation.

Costs

The costs associated with the ERL-Corvallis ARC/INFO implementation and operation include:

	Acquisition	Maintenance
ARC/INFO package with TIN	$ 50,000	$ 15,000
8 Graphic Terminals	$ 32,000	$ 6,000
2 Calcomp Digitizers	$ 14,000	$ 600
Calcomp 4-Pin Plotter	$ 18,000	$ 3,000
Calcomp Electrostatic Plotter	$ 80,000	$ 10,000
General Supplies (plotter paper,tapes)		$ 25,000
VAX 750 (dedicated for GIS with System Industry Disk Drive and Clock Accelerator)	$200,000	$ 50,000

Two systems operators cost approximately $100,000 and the estimated cost to the Laboratory for other GIS contractor support is $400,000 annually.

Benefits

Benefits of the GIS have been acknowledged throughout the lab management structure and fall into the broad category of improved understanding of complex ecological processes through efficient **data integration, analysis** and **mapping.**

- o Data integration is accomplished with having the ARC/INFO system serve as a central repository for extensive ecological field measurements. These data are entered in a standard format and subsequently validated.

- o Project teams of multidisciplinary scientists are very enthusiastic about the types of analyses provided through ARC/INFO. Interactive color graphic displays enable the scientists to evaluate numerous ecological relationships.

- o ARC/INFO maps, with color coded symbols, provide unique display products enhancing the project teams' analysis capabilities.

Critical Success Factors

The successful use of GIS at ERL-Corvallis is attributed to the following factors:

- o **Management support** by the Laboratory Director, Administrative Officer, and Branch Chiefs. These senior managers support the GIS activities through project funds and central administrative support.

- o **Technical support** for the ARC/INFO is provided through contract services with Northrop Services, Inc. This support is both technically competent and scientifically knowledgeable.

- o A unique collection of extremely capable **multidisciplinary scientists** receptive to learning how to use a "new tool".

Constraints

The ERL-Corvallis ARC/INFO GIS application program is a well-functioning operation. The only major problem encountered during the two years of operation has been insufficient CPU and inefficient processing capabilities as user demands increased. These problems were minimized with providing Systems Industry Disk Drives and a Clock Accelerator. The soon to be installed VAX 785/8600 cluster will improve GIS services dramatically.

INTERVIEWEES

IV. LIST OF INTERVIEWEES

REGION I

Office of Information Management

Michael MacDougall	Chief
Ed Woo	Chief, Information Resource Section, GIS Technican
Ethan Mascoop	
Robin Fletcher	

Narrangansett Bay Project

Katrina Kipp	Coordinator
Stephen Hale	Data Management Coordinator

RHODE ISLAND DEPARTMENT OF ENVIRONMENTAL MANAGEMENT

Marion Gold	Former GIS Coordinatort
Ernie Panciera	Groundwater Section

UNIVERSITY OF RHODE ISLAND ENVIRONMENTAL DATA CENTER

Bill Wright	Chairman, Department of Natural Resources
Pete August	Director
Tom Faella	Operations Manager

REGION III

Information Resource Management Branch

Joe Hamilton	Chief

Environmental Systems Division

Rich Fetzer
John Ruggero
Brigitte Farren

Water Management Division

Al Morris	Director

CHESAPEAKE BAY PROGRAM

Chuck Spooner	Director
Dennis Fuze	Data Management Coordinator
Joe Macknis	
Lacy Nasteff	Contractor CSC
Lowell Bahner	Contractor CSC
Jeff Booth	U.S. Fish and Wildlife Service

REGION IV

Joe Franzmathes — Deputy Regional Administrator

Office of Integrated Environmental Analysis

George Collins	Chief
Henry Strickland	GIS Coordinator

Office of Drinking Water

Al Korgi
Helen Lunsford
Tom Grubbs

U.S. GEOLOGICAL SURVEY - DORAVILLE

Jeff Armbruster	Chief, Water Resources Division
Bob Pierce	GIS Specialist
Jack Alhadeff	GIS Specialist

GEORGIA ENVIRONMENTAL PROTECTION DIVISION

William McLemore — State Geologist

FLORIDA DEPARTMENT OF ENVIRONMENTAL REGULATION

Division of Administrative Services

Jon Winter	Chief, Bureau of Information Systems
Rick Mitchell	Systems Project Administrator, Bureau of Information Systems

Division of Environmental Operations

John Buickerood	Scientific Engineer, Bureau of Restoration

Division of Environmental Programs

Marilyn Glasscock	Groundwater Protection
David Vogal	Groundwater Protection
Rodney Dettan	Groundwater Protection
Gary Maddox	Groundwater Protection
Rick Copeland	Groundwater Protection
Joe Hand	Water Quality Management

ENVIRONMENTAL RESEARCH LABORATORY -- CORVALLIS

Tom Murphy	Director
Charles Frank	Administrative Officer

Terrestral Branch

Bob Lackey	Branch Chief

Aquatics Branch

Spence Peterson	Branch Chief
Dixon Landers	Aquatic Team
Dan McKenzie	Watershed Team
James Omernik	Geographer

Contract Support

Andy Herstrom	GIS Coordinator
Trish Southern	GIS Technician
William Campbell	Direct Delayed Reponse Program (DDRP)
Gary Bishop	Direct Delayed Reponse Program (DDRP)
Dorothy Martenson	Direct Delayed Reponse Program (DDRP)
Sue Pierson	Direct Delayed Reponse Program (DDRP)
Barry Rochelle	Streams
Doug Brown	Streams
Colleen Johnson	Small Lakes
Barb Rosenbaum	Small Lakes

Visiting Scientist

Ron Nielson	Global Climate