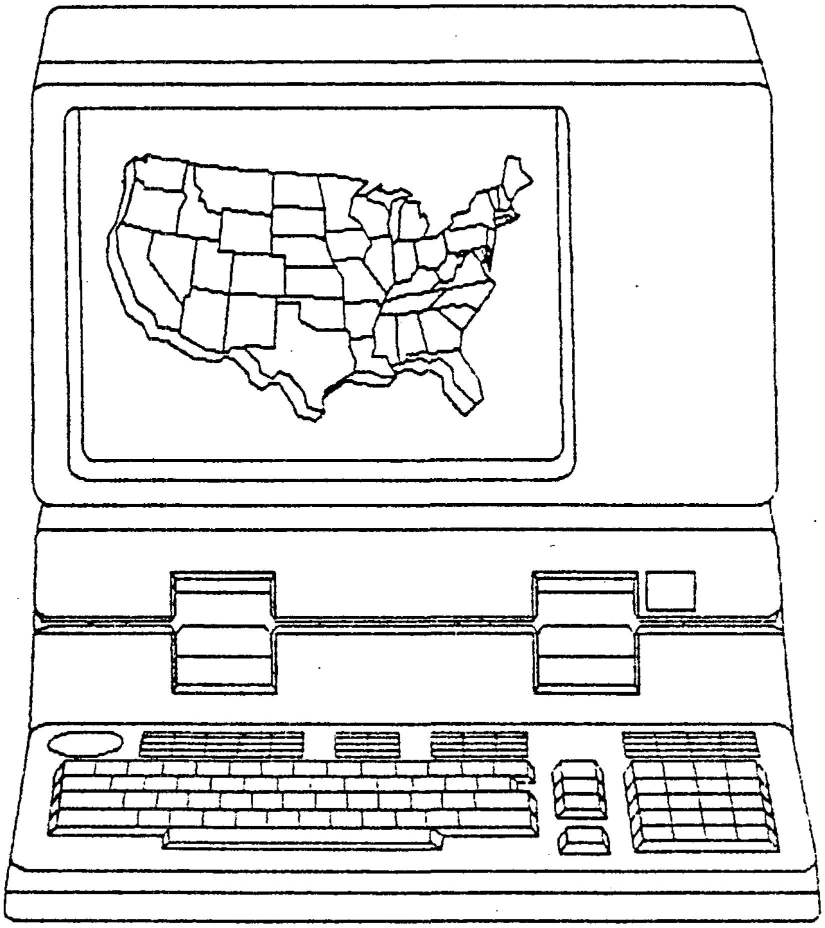
EPA United States Environmental Protection Agency
Office of Information Resources Management Washington DC 20460

EPA/OIRM

GEOGRAPHIC INFORMATION SYSTEMS (GIS) GUIDELINES DOCUMENT



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1.0 INTRODUCTION

The application of computer technology to environmental data management and analysis has greatly benefited the U.S. Environmental Protection Agency (EPA) in the past two decades. Modern environmental data management and analysis practices now rely on a wide variety of computer hardware, software, and telecommunications equipment. This document focuses on a specialized set of environmental data management and analysis tools, called Geographic Information Systems (GIS), which have the potential to enhance Agency program management and environmental decision-making. GISs are decision-support systems that can use spatial data to support interdisciplinary environmental studies and facilitate cross media analysis with unique data integration and display functions.

1.1 Purpose of This Document

The purpose of this document is to serve as a guideline both for EPA managers who want to determine whether a GIS may be appropriate for their program needs, and for managers who are "sold" on GIS technology and wish to develop a specific GIS application. This guidelines document provides an overview of GISs, discusses current and potential EPA and state GIS applications, and summarizes pertinent GIS management and technical issues.

The Agency is currently in the midst of determining its overall GIS needs and analyzing technical alternatives for an appropriate GIS hardware/software/data architecture. This document, which is a joint product of the Environmental Monitoring Systems Laboratory at Las Vegas (EMSL-LV), the Office of Information Resources Management (OIRM), and the Office of Policy, Planning, and Evaluation (OPPE), should be used as a starting point for further exploration.

1.2 Intended Audience

The intended audience for these preliminary guidelines consists of EPA program managers and staff who:

- o want to know enough about GISs to determine whether the technology can be of direct use to them, or

- o want to learn about the important issues in acquiring, using, and developing a GIS.

The document is intended to be useful for readers who have little background in GIS technology and terminology.

1.3 Format of Document

This document is organized into five main sections:

- o Chapter 1 Introduction
- o Chapter 2 Geographic Information System Overview
- o Chapter 3 EPA GIS Strategy
- o Chapter 4 Management and Technical Considerations for Planning a GIS Implementation
- o Chapter 5 Application of GISs to EPA Programs

Chapter 1, the current section, provides a general introduction to the document, while Chapter 2 functions as a GIS primer. It introduces the non-technical reader to GIS capabilities and terminology. Chapter 3 delineates some strategic GIS issues which have Agency-wide implications. Chapter 4 discusses management and technical issues which may be of concern to program offices and regions as they consider developing GIS applications. Finally, Chapter 5 reviews current and potential applications of GISs in selected states and at EPA.

2.0 GEOGRAPHIC INFORMATION SYSTEM OVERVIEW

Geographic Information Systems provide data input, storage, manipulation, analysis and display capabilities for geographic, cultural, political, environmental and statistical data in a common spatial framework. The data analyzed are a collection of spatial information (represented by points, lines and areas) and their associated attributes (characteristics of the features which the points, lines, and polygons represent). Examples of point data may include drinking water wells, dams, monitoring stations, and mountain peaks. Lines are commonly used to represent rivers, roads, or contours. Soil classes, crop types, political jurisdictions, and drainage basins are represented as area or polygon data. Some sources of data for GISs include maps, aerial photographs, censuses, crop records, field notes, satellite photos and meteorological records.

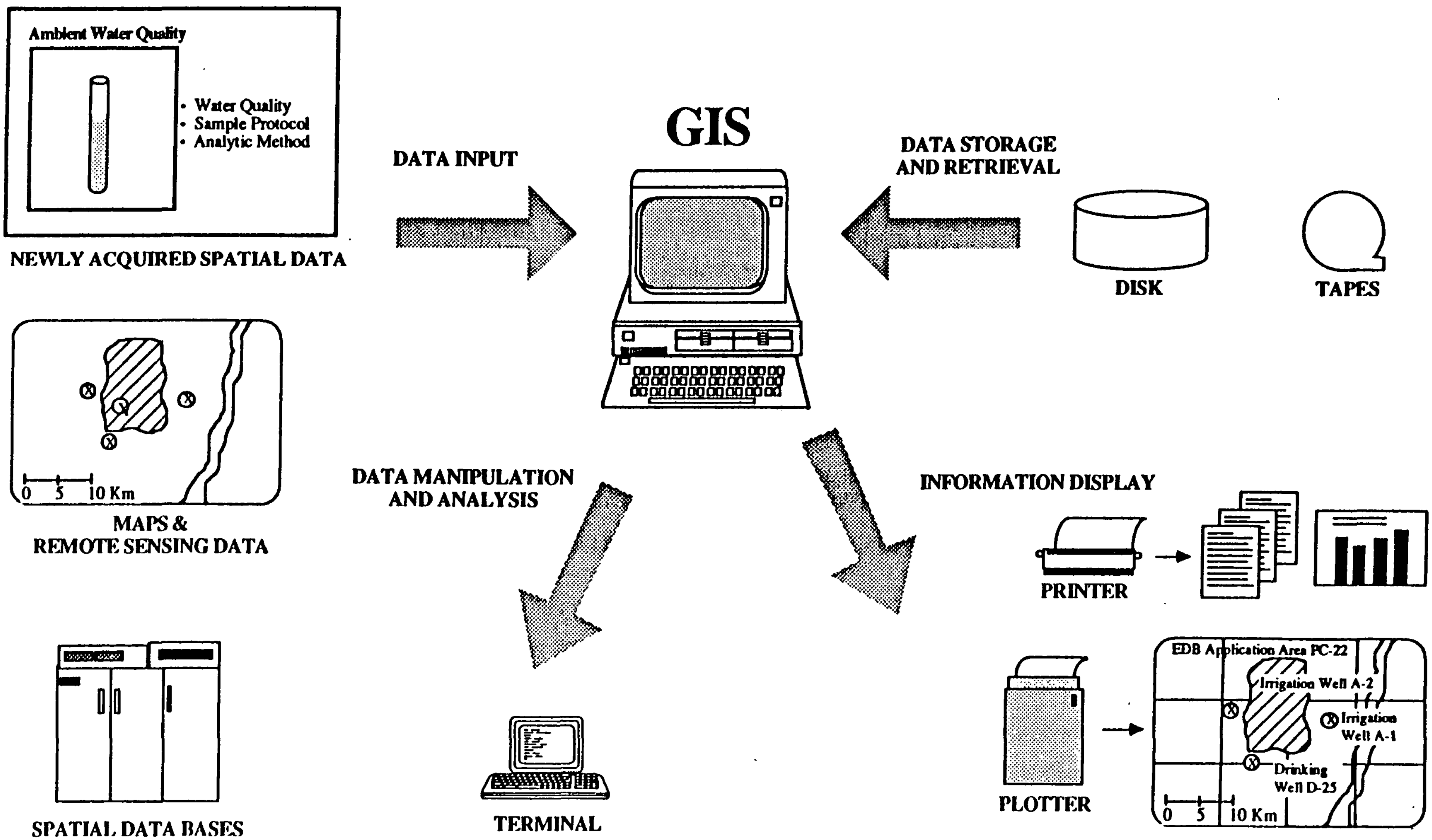
The advent of sophisticated computers with mass digital data storage devices has facilitated the integration of spatial data analysis, statistics, and computer graphics into comprehensive "turnkey" geographic information systems. GIS technology bridges the disciplines of computer science (e.g., image processing and pattern recognition), information management, cartography, and environmental management. The geographic information system is distinguished from other forms of information systems by its ability to perform spatial analysis.

There are many kinds of GIS turnkey systems. Some overlap exists in terms of their capabilities. Since technology and software are constantly changing, it is probable that vendors will be able to add extra capabilities without adding substantially to prices in the near future. One significant technology change during the last several years has been the availability of microcomputer-based GISs. These systems, although limited in terms of algorithm capabilities and computer processing speed, offer viable alternatives to the more expensive mini and mainframe systems. Selection of an appropriate system or collection of software tools must be linked to spatial data analysis needs.

A synthesis of the major GIS functions as discussed in this section is presented in exhibit 2.1.

Exhibit 2

An Overview of Major Geographic Information System Functions



2.1 Spatial Data Features

The geographic location of each data item (or "attribute") is a key identifier used to describe and organize data in a GIS. Maintaining the integrity of this spatial descriptor as part of the data base record permits normal data base management system operations and adds the capability to manipulate and analyze data geographically. The concept of data analysis in relation to geographic position is commonly encountered in map reading. Conventional maps are used in environmental analysis and natural resource management for numerous purposes.

One frequently used analytical approach is to assign colors or patterns to multiple map themes and overlay them with colored transparencies to reveal spatial relationships. This process of overlaying maps is a major function of a GIS. GISs also provide other analyses, including cross tabulations of data, attribute selections, Boolean combinations, modeling and customized displays. For example, a map of water well locations may be digitized using an x, y Cartesian coordinate system. Well attributes such as depth to water, depth to bedrock, water quality per 100-foot increments or well diameter may be attached to each well record in a relational data base. The GIS can then generate maps and associated tabular reports for unique subsets of the data (e.g., only wells located in areas where the aquifer surface is less than 200 feet deep, with a salt content greater than 1200 ppm, and within 500 feet of each other).

Geographic data can be represented using either of two formats -- raster/grid or vector/polygon ~~data structures~~. Raster/grid data refers to attribute values and spatial references tied to specific x, y intersections or grids in space (e.g., latitude/longitude). Fine grid spacing allows high resolution, and good definition of spatial characteristics. Scale is also important in grid spacing since large scale (small area) studies require higher levels of accuracy and finer grid spacing. In contrast, small scale (larger area) studies do not require rasters or grids in such fine detail. Vector/polygon data structures, on the other hand, describe unique lines or forms of geographic features. A lake, for example, can be described by the coordinates which comprise the circumference of the outer lake boundary and can be captured and stored in the GIS as a "tracing" of these features. The geographic attributes of the lake may remain constant even as the resolution of the lake boundary coordinates changes.

The advantages of raster/grid data structures over vector/polygon structures include low cost for computation, ease of comparison between data layers, and relative ease of data overlaying to generate integrated data sets. The benefits associated with vector/polygon data structures include enhanced spatial accuracy, more "correct" feature descriptions, and compatibility with traditional paper map descriptions of geographic features. The difficulties encountered with vector/polygon data structures include more complex computational requirements (with concurrent higher costs) due to increased geometric complexity. Consequently, some GISs have the capability to handle both data structures, while others are restricted to only raster/grid or vector/polygon.

2.2 Data Input

The data entered into a GIS often include spatial data from maps, remote sensors (aerial photography and satellite imagery), and environmental monitoring. GISs require entry of two distinct types of data: geographic references and attributes. Geographic reference data are the coordinates which describe the location of spatial information. This type of data entry usually occurs via a process known as digitization. A special peripheral device -- a digitizer -- is used to convert a drawing or map into a digital format. Most GIS projects require a large digitization data input process consuming many man-hours of effort. Attribute data entry (e.g., of water quality parametric values) often occurs via key-entry at a terminal, reading a magnetic tape, or downloading from a separate computer system (e.g., using a modem and telecommunication line to extract selected STORET parameter values from the EPA NCC IBM mainframe).

Since data which form the GIS data base often come from different sources, and since digitization may be done by staff with varying levels of skill, most GIS data base development efforts involve extensive levels of quality assurance and quality control (QA/QC). An initial and ongoing commitment to data quality is generally rewarded by confidence in the graphical and analytical results of the GIS.

2.3 Data Base Management and Data Storage

The characteristic which distinguishes a GIS from other data base management systems and manual map overlay procedures is the way a GIS stores the spatial data and makes it available for user access and analysis. Derived maps and data sets may become part of the GIS data base in a feedback process that permits future retrieval and display without rerunning the analysis procedure. These map and data layers can be superimposed during analysis to produce various map products with the GIS information display functions. This data generation process requires special spatial analysis and tabulation capabilities provided through the data base management system. Since the analysis and processing limits of each GIS vary from vendor to vendor, the anticipated analytical methods and data base management requirements should be well understood before selecting a particular system.

Efficient data storage organizes the spatial data in a format which permits rapid and accurate updates and corrections to the data base. Data storage refers to how the data formats and structures are supported during data operations. Frequently a data dictionary is used to organize a data base and record information about the geographic and attribute information in the system. Some of the information stored about data bases includes data structures, formats, and access methods. Data dictionaries can be very helpful and important tools, especially for managing active and growing geographic information systems.

2.4 Data Manipulation and Analysis

The GIS data base management system provides the ability to query, manipulate, and extract both geographic reference and attribute data. One of the major functions of a GIS is the analysis of multiple layers of data in a selected geographic area. With a GIS, standard statistical manipulations of attribute data are possible, as are boolean queries of attribute data files, generation of mean and standard deviation for numerical data ranges, and classification of data into mappable units. Other GIS data manipulation and analysis capabilities include querying unique spatial distributions of data and asking questions about data to display the unique spatial arrangements which meet a specific criterion.

2.5 Information Display

Information display includes the representation both of raw data and of the results of data manipulation and analysis. Outputs fall into several categories: maps, charts, graphs, surface models, listings, and hybrid representations. The form in which outputs are presented (medium of presentation) also varies, and includes: CRT images (monochrome or color), color slides (from virtual images or directly from graphic bit planes), film plots (print-ready masters), video disk images (requiring digital to analog image conversion), floppy disks of digital image data, microfilm (or "fiche") copies of graphic images, or printed hard copy graphics.

It is important to realize that outputs (as described above) are distinct from spatial analysis. Geographic/spatial analysis of data usually precedes data display, although initial display of "raw" data can serve as a useful hypothesis tester for attribute and/or spatial data analysis. A comprehensive geographic information system supports various computer mapping/graphics peripherals that provide most of the types of outputs described above.

3.0 EPA GIS STRATEGY

These guidelines represent a first step in developing an Agency-wide strategy for GIS acquisition and applications, technology development, technical support and training, data, and related resources. This strategy is intended to provide an overall organizational framework in which administrative offices, regions, program offices, research laboratories, and supporting contractors can address independent and cooperative needs for GIS. The rapidly evolving nature of GIS technology and its growing importance to environmental monitoring, analysis, management, and decision-making makes an Agency-wide GIS strategy and organizational framework increasingly important. A coordinated EPA strategy is also necessary to maximize the payoffs from Agency investments, since acquisition and implementation of this specialized information management technology will be expensive. The strategy discussed here is preliminary in nature and will be refined as further experience is gained in the technology.

This EPA GIS Strategy chapter discusses the four major steps which EPA should take to develop a coherent GIS strategy. The steps are: identify organizational roles and responsibilities, define Agency-wide GIS requirements, establish Agency-wide GIS standards, and provide management and technical guidance, support and assistance. Figure 3.1 shows a picture of some of the critical issues which will likely arise as EPA develops its GIS strategy.

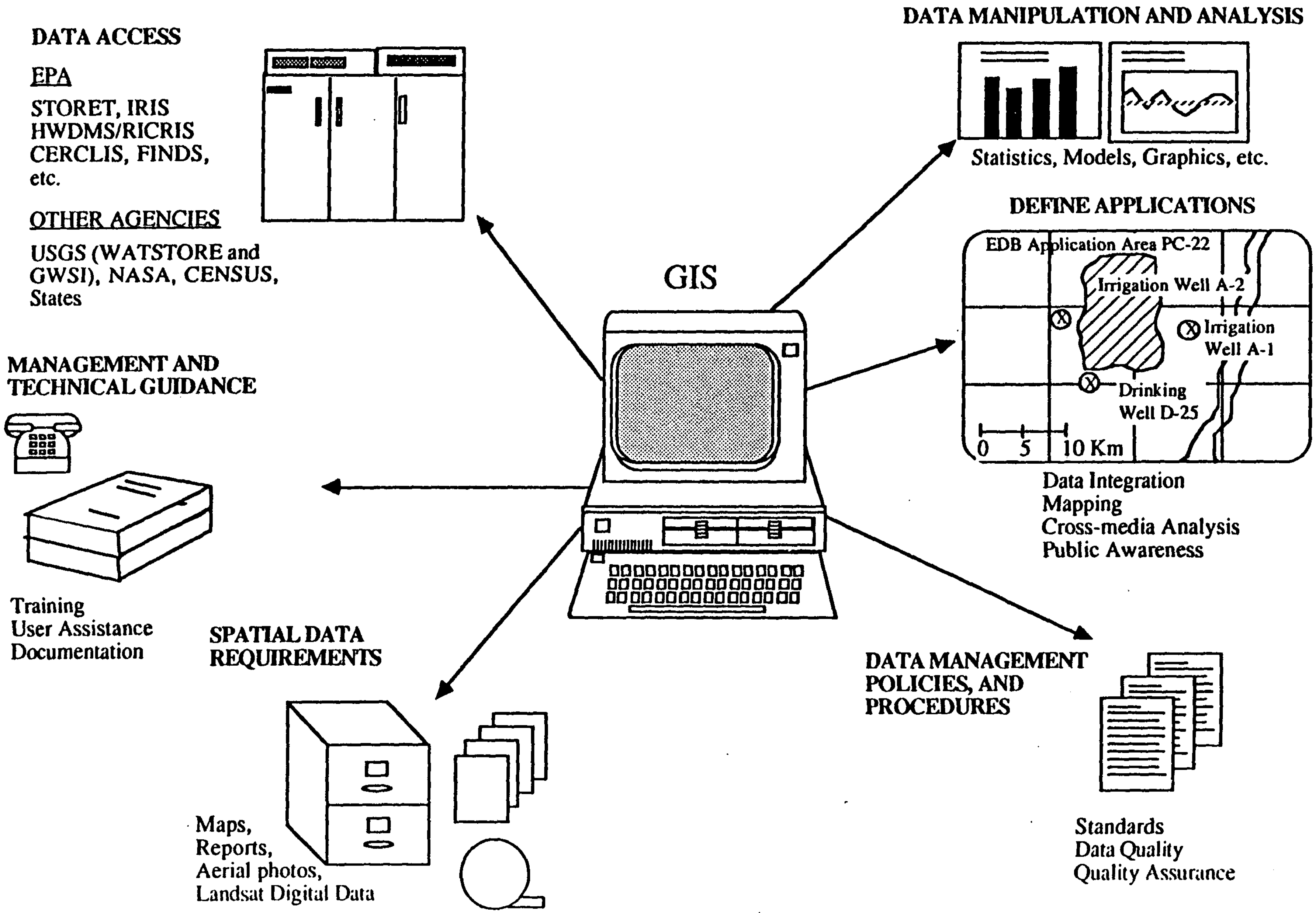
3.1 Identify Organizational Roles and Responsibilities

EPA program offices and regions have primary responsibility for analyzing and implementing appropriate GIS applications. OIRM, OPPE, and EMSL-LV will provide an overall management framework, technical support, and assistance to GIS users.

Numerous Agency offices have a significant role in developing an EPA GIS strategy. Key roles and responsibilities have tentatively been identified for EPA program offices, the Office of Information Resources Management (OIRM),

Exhibit 3.1

An Overview of EPA GIS Strategy Issues



the Environmental Monitoring Systems Laboratory at Las Vegas (EMSL-LV), and the Office of Policy, Planning and Evaluation (OPPE). Although specific, binding responsibilities would need to be formalized through communication between all involved parties, the following section outlines likely organizational roles.

Individual program offices and regions are responsible for identifying specific programmatic GIS requirements and implementing appropriate GIS technology, systems, and databases consistent with EPA GIS policies and guidelines. OIRM, EMSL-LV and OPPE have overall Agency-wide responsibilities for GIS in the areas of policy, training, technical support, technology development, research, standards development, and GIS information collection and dissemination.

Program offices and regions are responsible for:

- o Identifying specific programmatic requirements for GIS technology, systems, data, training, research and development, and related agency resources.

- o Developing GIS capabilities consistent with agency-wide policies and guidelines.

OIRM's responsibilities include:

- o Developing and issuing GIS policy in accordance with all applicable Federal laws, regulations, and executive orders.

- o Managing GIS information resources, functions and activities within EPA, in association with the appropriate lead offices and programs.

- o Developing and publishing GIS acquisition and implementation guidance for the Agency.

- o Coordinating with other Federal agencies, State offices, and/or private organizations for the purpose of sharing GIS applications and data bases.

OPPE is responsible for:

- o Assisting OIRM in coordinating GIS technology development and use throughout the Agency and within the various programs.

- o Working with appropriate EPA program offices (e.g., ORD, OSWER, etc.) to provide assistance to Agency programs for incorporating GIS technology into their decision-making process.

- o Evaluating the effectiveness of GIS technology in supporting program decision-making.

EMSL-LV is to fulfill responsibilities for:

- o Providing OIRM and OPPE with GIS technical assistance to support development of Agency GIS policy, guidelines and procedures.

- o Assisting the Agency by providing GIS technical expertise and support.

- o Conducting applications research in GIS technology.

- o Keeping pace with developments and innovations in GIS and related technology for environmental monitoring.

- o Developing and promulgating Quality Assurance/Quality Control (QA/QC) standards and guidelines for GIS data.

3.2 Define Agency-Wide GIS Requirements

EPA's overall GIS strategy and specific GIS applications must be based on mission-based requirements and lead to specific improvements in Agency effectiveness and efficiency.

A second step in developing an EPA GIS strategy is to define Agency-wide GIS requirements. It will be necessary to analyze the Agency's needs for spatial data, define the role of GIS technology and systems in environmental decision-making, and determine geoprocessing requirements.

Agency functional requirements may include specifications for: map digitizing, editing, and data structuring; data entry and management; map production, manipulation, and analysis; map and data library management; statistics; interfaces to modeling; graphics production; and user interfaces. Agency guidance and technical support issues include: training; system and software documentation; technical support; specialized algorithm development; system and data integration; hardware and software maintenance; and staffing.

Key Agency organizational and technical issues that need to be addressed include:

- Single media versus multimedia applications and program office mission responsibilities;
- Centralized database, software, and systems development/operation versus decentralized program office development and operation;
- Multipurpose GIS versus specialized geoprocessing;
- GIS and its interrelationship with EPA headquarters, EPA regions and state programs;
- Capability of existing Agency data to be used for geographic analyses, and required data base modifications;
- Data sharing, distributed processing, telecommunications, remote access by the public; and
- Appropriate levels of GIS technology, systems, and support commensurate with levels of environmental decision-making.

3.3 Establish Agency-Wide GIS Standards

All EPA GIS applications must be implemented in accordance with appropriate standards for hardware, software, data, and other GIS components to facilitate sharing, flexibility, and efficiency.

A third strategic step is the development of Agency-wide GIS standards. Whenever possible, previously established Agency standards should be followed, but the unique characteristics of GIS technology will require establishing additional standards. Since spatial data play a significant role in GIS applications, spatial data standards need to be established for:

- digital spatial data organization
- data georeference definitions
- data interchange formats
- data feature type definitions
- data quality

Other critical standards considerations include: software programming languages (e.g., Fortran or C); spatial data management systems and query languages; graphics support to facilitate the transfer of graphics software to different hardware environments or the output of graphics to a range of output devices from a single application (e.g., Graphics Kernel System (GKS) or Initial Graphics Exchange System (IGES)); GIS software packages (e.g., ARC/INFO, GRASS, AUTOGIS, or INFORMAP); GIS resident hardware systems (e.g., DEC, IBM, PRIME) for facilitating portability or conversion of GIS applications to different hardware environments; and telecommunications.

In some cases, it will not be appropriate for the Agency to promote standards but rather provide guidance. For software and systems documentation, the long term viability of GIS software in a dynamic technological environment can be facilitated through use of ANSI software standards. Another area requiring Agency-wide guidance may be GIS training. Centralized GIS training may prove to be a useful and cost-effective strategy for disseminating specialized GIS knowledge to program offices.

EPA should also use existing practical experience within the Agency, other Federal agencies (e.g., BLM, USGS, SCS), industry and academia to develop standards which promote the effective use of GIS technology and facilitate access to GIS capabilities by program offices. Program and research offices in the Agency should be consulted throughout the development of GIS standards.

3.4 Provide Management and Technical Guidance

EPA program offices and regions should be supported by "centers of excellence" in GIS planning, acquisition, implementation, and operations.

The final EPA GIS strategy issue revolves around the provision of management and technical guidance to program managers considering the application of GIS for environmental monitoring, management, and decision-making. EMSL-LV has developed expertise in GIS applications through a number of studies, and will function as the Agency's first "center of excellence" to provide detailed GIS assistance to program staff. This assistance will cover the full lifecycle of GIS applications, from initial planning to final operations.

EMSL-LV will provide other parts of the Agency with the benefits of its experiences with:

- o spatial data and development of GIS data bases;
- o GIS technologies, techniques, and systems; and
- o GIS support structures and organizational impacts.

The guidance offered by the Agency's center of excellence will facilitate development of GIS implementations throughout the Agency. The particular types of support that EMSL-LV may offer include:

- o providing technical support in the use of GIS software;
- o developing user-friendly software tools (macros) to perform repetitive GIS tasks;
- o assisting program staff in evaluating and selecting appropriate GIS software and peripheral equipment (e.g., digitizers, plotters, graphics display devices);

- o developing methods to extract geo-referenced data from EPA systems and reformat them into GIS formats;
- o serving as a "clearinghouse" to guide Agency offices to sources and already-purchased copies of spatial data;
- o conducting training sessions, tutorials, and workshops;
- o developing and documenting interfaces between important models and GIS software;
- o keeping pace with developments and innovations in GIS and related technologies for environmental monitoring; and
- o developing and promulgating quality assurance/quality control (QA/AC) standards and guidelines for GIS data.

4.0 MANAGEMENT AND TECHNICAL CONSIDERATIONS FOR PLANNING A GIS IMPLEMENTATION

This chapter presents some considerations on which EPA regions and program offices should focus while planning their development of a GIS application. Management considerations are addressed first, then technical considerations are presented. Finally, the chapter concludes with key questions which can help focus attention on the critical managerial and technical issues in GIS implementation.

The considerations presented in this chapter do not constitute a final "cookbook" detailing how to implement a GIS. The considerations do, however, present a good starting point for further refinement as the Agency makes progress in developing an overall GIS strategy and framework.

4.1 Management Considerations

The Agency recognizes that numerous program offices and regions may want to benefit from GIS applications. This section discusses key considerations that must be addressed by program management desiring GIS support. This section may help program managers judiciously plan for GIS implementation. The broad categories of considerations discussed include:

- o Mission-based planning objectives
- o Scope of the GIS application
- o Identification of existing data sources
- o Staffing requirements
- o Quality assurance
- o Life cycle/staffing costs.

4.1.1 Mission-based Planning Objectives

Initially, the program offices, regions, and research laboratories must thoroughly evaluate their GIS needs before attempting to acquire a system. Identification of how program activities and decision-making (e.g., issuance of RCRA permits for a TSD facility) will be improved with GIS tools is mandatory. A thorough analysis of needs requires answers to the following questions:

- o What Agency activities will be supported by the proposed GIS activity?
- o How will these program activities be supported?
- o What are the anticipated benefits of these GIS activities (timeliness, workload, and enhanced management)?
- o How can these GIS applications also provide cross-program assistance?

4.1.2 Scope of the GIS Application

In beginning to plan a GIS implementation, a program office or region should define the scope of its GIS needs. This means that managers should determine or take active roles in decisions relating to the:

- o number of anticipated users
- o number and types of decisions to be supported by the GIS
- o geographic and programmatic areas to be covered by the GIS.
- o types of data required by the GIS.

These are among the crucial decisions which set the scope of the GIS application and determine the utility and versatility of the final product.

4.1.3 Identification of Existing Data Sources

The geographic boundaries and scale of data required in the proposed GIS program need to be detailed. They must be considered in conjunction with the types of data that will be used in the system and the status of these data. Some of the data will probably already exist in computerized formats, while other data will be manual files in a variety of conditions (e.g., hand-drawn maps and technical reports). The manual files will have to be computerized using the GIS software/hardware (e.g.,digitizer), while the computerized files will have to be converted to the GIS format. In addition, datasets must be reviewed to determine which files/fields need to be computerized and which ones, if any, can be eliminated. During this dataset inventory phase, identification of requirements for entirely new data should also occur. It is expected that the program will be able, in a parallel fashion, to describe these datasets in detail and provide a synopsis of their expected use.

4.1.4 Staffing Requirements

The organizational environment in which the GIS will function depends on the existing ADP support services and potential for incorporating the GIS into an existing ADP support structure. For example, the choice between the use of a stand alone dedicated system versus one that is "added on" to an existing computer system will change the staffing level and expertise required. Personnel required to operate the GIS may include computer system managers, computer operators, data analysts, programmers, supervisors, environmental scientists, cartographers, and specific program experts. Typically, full-time computer system managers and/or operators will be needed for mainframes and large minicomputers. The number of technicians required will depend on the amount of processing to be done, budget constraints, and time allocated for completion of the initial database.

It is extremely important to also have on hand computer-literate program management staff who are experienced with Agency regulatory and scientific requirements. GIS projects are multidisciplinary in nature, and are most successful when developed by multidisciplinary teams.

4.1.5 Quality Assurance

The issue of quality assurance must be addressed in the early phase of GIS data base planning. Program managers must determine if incorporation of existing QA measures for already existing data is sufficient. Furthermore, QA standards will also have to be established for newly acquired data. Data acquired from other data bases should always be thoroughly examined to reveal QA problems. These tasks should become the responsibility of appropriate QA and GIS staff and follow previously established Agency data quality objectives.

The quality assurance procedures for each GIS application must reflect a conscious decision, on the part of management, as to the level of data quality necessary to support decision-making. Required levels of data quality can vary, depending on the decisions which the GIS will support (e.g., data quality may have to be higher to support permitting decisions than to support region-wide planning and assessment). Quality indicators in the GIS data base or fields which identify data sources should be considered as means of improving quality assurance.

4.1.6 Life Cycle/Staffing Costs

The implementation of a GIS system includes numerous costs associated with equipment purchase, installation, database development, etc. In estimating costs, the program must pay particular attention to software and hardware prices and the additional costs of:

- Upgrade of CPU or purchase of new CPU to support GIS applications
- Shipping of hardware
- Modifications to existing hardware or purchase of new hardware
- Site preparation and installation
- Training
- Quality assurance
- Data gathering and updating
- Supplemental utility programs
- Regular maintenance to both hardware and software
- System upgrades.

Also included in this cost estimate are required resources for the manpower staffing. These staffing requirements must be converted to hourly costs. For example, a 40 man-year effort to create the working database can be accomplished over a four year period with 10 programmers/analysts or over 10 years with 4 programmers/ analysts. The total staffing costs will vary significantly between the two scenarios.

4.2 Technical Considerations

A number of technical issues must be addressed while planning for GIS implementation. This section highlights the following key technical considerations:

- Data acquisition
- Data input
- Data access, manipulation and analysis
- Quality assurance
- Data updates and maintenance
- Storage requirements
- User access and security
- Technical environment

4.2.1 Data Acquisition

Data loaded into the GIS may come from a multitude of sources. These data may have been newly collected from environmental observations or acquired from existing data bases. In either case, decisions will have to be made concerning quality assurance of the data before incorporation into the GIS.

The spatial data used in the GIS will contain attributes such as raw data values, test scores, or indices that must meet GIS data input formats. In addition, the spatial data itself may be in the form of published maps, printed tables, digital map attributes or digital tabular files. Incorporation of data attributes such as source, scale, projection, geographic location, year of acquisition, and reliability must be defined and standardized prior to data loading.

4.2.2 Data Input

Most GIS projects require significant data input efforts which consume many man-hours. The method of data input can include downloading, digitizing, scanning and keyboard entry. The selection of a data input process should be ilored to the volume of data requiring input, the peripherals supported by the GIS, and manpower and time constraints. Digitizing requires many man-hours of tedious work and establishment of input protocols and quality assurance measures to maintain acceptable data quality standards. Loading data into the GIS from other data bases (e.g., STORET) is often complicated by a need to reformat the data to comply with the host computer or GIS data record format. Graphic data is commonly the most difficult data to reformat. Anticipation of format conversion needs is required for realistic GIS data input planning since format conversion represents substantial levels of effort by programming and technical staff. When data are acquired from manual files of historic or newly collected spatial data, and then automated in-house, the data input process is generally less complicated because data formats are well understood.

4.2.3 Data Access, Manipulation and Analysis

Data access and manipulation functions permit retrieval of specific data by any attribute or combination of attributes. Well-designed DBMS software generally provides these capabilities by using existing structured queries. However, custom queries are often needed and require DBMS software modification.

A map library should provide rapid indexing to all digital maps within the data base. This library can be maintained as an on-line index and provide the user the capability to query by project identification, geographic area, or place name. The need for a map library increases as the size and complexity of a GIS data base grows.

Use of a data dictionary will assist in maintaining an inventory of map and other spatial data sources used in the GIS. Additionally, QA standards, integrity and data explanation are well served by the use of a data dictionary. A description of data attributes for each map, photo, or image used in the GIS data base can be catalogued and described in text form. Additionally, quality assurance standards can be included in the data dictionary. Experience shows that insufficient documentation may handicap GIS operation. An on-line data dictionary can be part of the GIS data base and provide the user with any of the preceding information upon request.

Data manipulation can also include tabular and graphic display of the GIS data. Tables and listings may be displayed and printed on CRTs, printers or plotters. Data display is an important step for data base verification and subsequent data analysis.

GIS data analysis requires extensive computer processing for calculating areas, distances, buffers, volumes, overlays, frequency occurrences and Boolean combinations. The power and flexibility of the GIS become readily apparent during these analysis processes. Proper data base design will fulfill user expectations and avoid disillusionment.

Modeling of spatial data is often an important program analytical need. The GIS may contain modeling algorithms, or modeling may be conducted in an independent external computer environment. When using a separate system for modeling, results can be incorporated into the GIS through the input methods discussed above and retained as part of the GIS data base for other analysis objectives.

4.2.4 Quality Assurance

Quality assurance (QA) ensures that acquired data meet acceptable data quality standards and maintains data integrity throughout GIS data processing. The spatial data incorporated into the GIS must be verified to ensure proper formatting. Using reformatted data increases the risk of data conversion errors. Program management and GIS staff must determine what level of QA is needed for acceptable data quality. This determination dictates what data validation processes are required in the GIS. Data quality standards must be maintained throughout data retrieval, display, analysis and modeling functions. During data retrieval and display, mechanisms for detecting errors in base data can ensure improved data quality. Additionally, QA algorithms n be used to check erroneous data ranges and values. It is also necessary that data maintenance activities employ QA standards (e.g., scheduled backups).

4.2.5 Data Updates and Maintenance

A GIS is a dynamic decision-support system that requires data updating and revision. Updates should not be confused with data validation corrections that are associated with QA actions. Updates are provided to maintain the currency and utility of the data base. Changes to the GIS data records should only be permitted by authorized staff. Scheduled updates should occur during specified periods to reduce the possibility of inadvertent alteration of the data base. Proper data maintenance requires the periodic system backup procedures common to all ADP installations.

Attention should be paid to reciprocities in data exchange. When data are obtained from other systems and are found to be in error, every attempt should be made to correct the error in the source data base as well as in the GIS data base. By emphasizing communication back to the managers of the source systems from which data are extracted, GISs can contribute significantly to the minimization of data quality problems at the Agency and elsewhere.

4.2.6 Storage Requirements

Realistic understanding of data storage requirements is important to the long term success of the GIS effort. Disk storage provides the most accessible but most expensive form of data storage. Often in a multiple hardware/software environment, competition for disk storage becomes keen as disk storage space becomes limited by growth in users and data bases. Tape storage is often a viable alternative but problems may be encountered with physical storage demands and tape reading delays. Tapes quickly fill limited shelf space and may become a major handling and storage task. There are certain risks associated with the transfer of information from disk to tape -- losing or misreading records is possible.

Alternative mass storage devices such as laser disks may relieve some of the on-line data storage bottlenecks. However, this is a relatively new technology, and is not an available add-on option with all GISs. These storage requirement issues should be addressed during both the management life cycle planning and the technical requirement phases of GIS implementation planning.

4.2.7 User Access and Security

Potential users include GIS staff, program managers, scientists and the public. Data base access should be carefully evaluated to determine the level of data base access each user needs. The ability to update, copy and delete data is not needed by all users. Restricting certain users to "read only" privileges is sometimes appropriate. Those users who manage the GIS and are involved with data base development should have a high level of access.

4.2.8 Technical Environment

Numerous hardware and software requirements must be specifically identified according to the program activities to be supported, such as:

- Amount of computer memory and storage required;
- Number and kinds of peripherals needed;
- Size and number of data sets to be incorporated into the GIS;
- Ability to use existing operating systems, and add-on software/ hardware; and
- Predicted software/hardware demand by task and program (days per week, hours per day).

Furthermore, if the GIS is to be created by adding software and peripherals to an existing computer, additional requirements for data communications and device compatibility may include:

- Multi-user support and the ability to expand the number of ports as user demands grow, and
- Ability to access data in a timely fashion (either batch or

interactively), perhaps via remote workstations.

- o Ability to support multiple graphics output devices of different types and makes (e.g., plotters, graphics terminals, printers).

4.3 Guidance for Focusing on the Critical Managerial and Technical Issues for GIS Implementation

A well planned management approach for implementing GIS technology is necessary for ensuring development of successful GIS program applications. This series of questions and corresponding discussion is provided to help program managers focus on the critical managerial and technical issues associated with GIS implementation.

1. What types of data should be entered into the GIS, and what additional data should be collected? Just because certain types of data have been collected does not justify their entry into a database. Furthermore, the gathering of new types of data should not occur merely because a new tool is available to process that data.

2. Should database development be performed in-house or contracted? Contracting has several advantages: the database may be completed sooner, funds for contracting may be more readily available than manpower, and contracting the digitizing may alleviate the need for data entry hardware and/or software. However, when digitizing is performed by a contractor, any errors on the maps given to the contractor will find their way into the digital database. If users familiar with the data do the digitizing, such errors may be caught prior to digitizing. Also, in-house digitizing produces trained operators, making the tasks of updating and editing less difficult.

3. What type of data validation needs to be incorporated into the creation of the data base? Data validation is a matter often confronted in the justification and implementation of a GIS. The process of computerizing information will often reveal data errors that may have been present, but unnoticed, for some time. For example, when maps of adjacent land parcels are overlaid by a computer for the first time, discrepancies in common boundaries may be noticed. The initial response to the discovery of such errors may be a

costly attempt to improve the accuracy of the data. Some questions that should be asked first are:

- -- Are the data accurate enough?
- -- In the absence of a GIS, would the data be accurate enough?
- -- What costs might be incurred because of inaccurate data?
- -- Are inaccurate data better than none?
- -- What is the marginal cost of improving accuracy/precision?

In the above example, boundary line errors could be corrected by conducting a new land survey or redrafting the maps to a common base, solutions that are both costly.

4. How important is accuracy compared to consistency and appearance? In order to accurately reference a map of a tract of land to known ground coordinates, the shape, orientation, or total area of the tract as mapped may change. A user may be forced to choose between keeping the appearance and acreage of a tract map consistent with legal records, or adjusting the map to gain locational accuracy.

5. Should more time be taken to build a database that can be accessed efficiently, or should the database be completed more quickly at the expense of subsequent data analysis? Because of technical considerations regarding file formats and database structures, shortcuts taken during database development can lead to difficulty in the later access of that data. Conversely, digitization procedures that may seem tedious and time-consuming can enhance the efficiency of later processing steps.

6. What is the desired spatial resolution of the database? For example, in a map of water bodies, one may have many small map units representing small streams, or fewer large map units representing larger rivers. The choice of map unit size will influence the size of the resultant computerized database as well as its variability, accuracy, and precision. The size of the minimum mapping unit should reflect the eventual use of the

data. Generally, higher level managers are satisfied with information in a broader, more general form; lower level managers may require more detailed fine-resolution data.

7. Is the data base anticipated to be static, or are additions and deletions anticipated? The answer to this question will have a significant impact on the development of file-naming conventions and coding schemes used to represent attributes associated with maps. It is important to devise a coding system that provides enough flexibility to accommodate changes while meeting the constraints of a particular GIS. For example, assigning code numbers or names to map features when digitizing will have a significant impact on the ease with which items may be later retrieved from the database. Questions regarding coding systems will arise during pilot projects and are best resolved through consultation with vendors and other organizations experienced with the same GIS.

8. How should the digitizing effort be prioritized? Three general approaches should be considered. The first is the application-oriented approach, which involves digitizing data as specific analysis needs arise. In this way, a database is built in pieces in response to certain projects or problems. A second approach is to build a comprehensive database for the entire area to be managed, proceeding by geographic or administrative areas. This is especially useful when an organization has an administrative hierarchy that reflects geographic regions. This approach provides a useful set of data for each region in turn, allowing regional users to begin to use the GIS one at a time. The third approach is to build the comprehensive database by categories. For example, Superfund site inventory data could be digitized for an entire region, then soils information, political boundaries, hydrology, etc., added in sequence. Using this approach, numerous users get access to a portion of the database at the same time.

5.0 APPLICATION OF GEOGRAPHIC INFORMATION SYSTEMS TO EPA PROGRAMS

This chapter describes the value of GISs in improving program management and decision-making. First, the role of a GIS in program decision-making is discussed. Next, this chapter presents an overview of selected EPA and State environmental agency GIS applications and their associated information needs and programmatic benefits. Lastly, some potential GIS applications are presented for selected Agency programs.

Four case studies, one discussing ground-water and pesticides in Florida, another dealing with Region IV's use of GIS for integrated environmental analyses, and two describing EMSL-Las Vegas applications in the San Gabriel Basin and Chattanooga, are presented as Appendices to show specific examples of how GISs are used in program activities and decision-making.

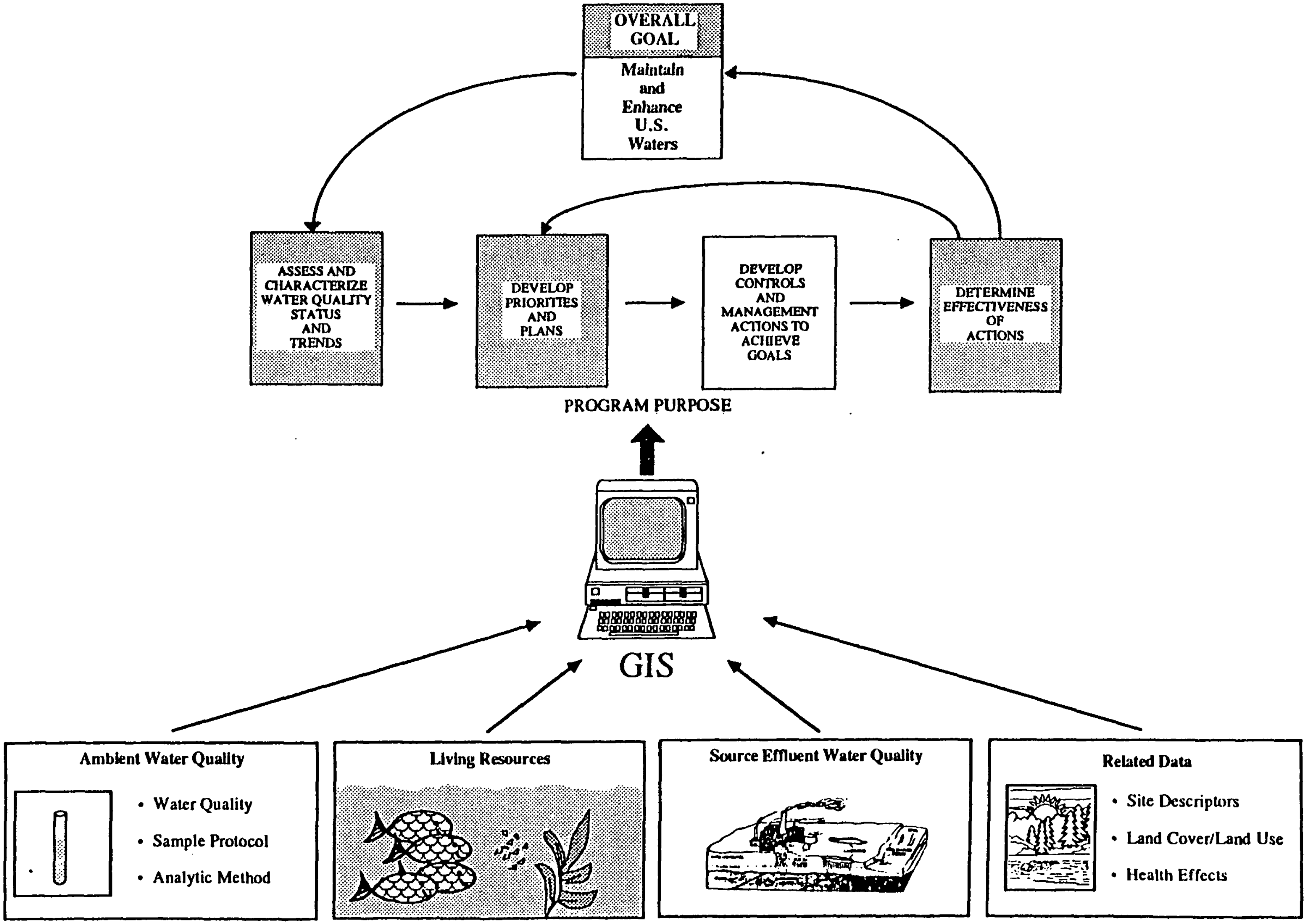
5.1 GIS and Decision-Making

To properly understand the role of GIS applications within EPA, it is necessary to first understand how data and information are used in program activities. Agency programs use numerous types of environmental and related data obtained from a variety of sources. This information may include an assortment of historic scientific reports available in manual files, data extracted from current EPA systems (e.g., STORET, PCS) or other state and Federal data bases (e.g., Soil Conservation Service soil maps), or the results of other monitoring activities (e.g., sediment or biological samples).

An examination of the role of surface water monitoring data in water program activities illustrates how data is used for decision-making. Exhibit 5.1 summarizes how surface water monitoring data are used for program activities and where a GIS can be used. Monitoring of surface water is conducted to collect and analyze numerous types od data. Both ambient data (information about water quality conditions and trends) and source monitoring data (information about the kinds and quantities of pollutants entering the aquatic ecosystem from specific point dischargers) are extensively collected throughout the Agency.

Exhibit 5.1

Relationship Between Surface Water Monitoring Data and Program Purposes and Role of a GIS



The overall goal of the surface water monitoring program is to identify and characterize the nature, extent and likely causes of water quality problems. The Office of Water uses this information to make decisions, set priorities and develop plans to address these problems. The monitoring program also collects data to determine if pollution controls have been effective or if they need to be revised. Monitoring data are also used to report on the effectiveness of Agency programs to EPA policy makers, Congress, and the public.

For effective environmental decision-making, program priorities and associated implementation plans should be based on water quality monitoring information. GISs can provide these linkages by integrating and mapping data which show water uses, water quality targets, in-stream pollutant concentrations, pollutant discharges and compliance records over time for specific water bodies. Decision-makers can then set priorities and develop pollution control strategies based on this spatial information.

For example, integrating these data to provide pollutant profiles enables "what-if" and sensitivity analyses. Such integrated spatial analyses, as provided through GIS applications, can be used to determine emission and risk implications of alternative control options when comparing various pollutants and facilities within a watershed or larger area. Similarly, these analyses can assist in choosing the highest payoff control option within a regulatory or standard setting context. The types of decisions will vary according to management level, organizational level and geographic area of responsibility, but all levels will benefit from improved understanding of the spatial distribution of pollution sources and effects.

In summary, the benefits realized from use of a GIS in Agency programs are linked to spatial data integration (e.g., surface water quality data combined with land use and NPDES data) and the capability to display and analyze these data on maps at a common scale. Further details about these functions are provided in the following sections.

5.2 Selected Current GIS projects

Presently a large number of Federal agencies use GISs for resource management (e.g., U.S. Geological Survey, Soil Conservation Service, National Park Service, Fish and Wildlife Service, Forest Service, National Aeronautical and Space Administration (NASA), National Oceanic and Atmospheric Administration (NOAA), Bureau of Land Management, and the Tennessee Valley Authority). GIS uses in these organizations are highly varied in terms of geographic scope and type of application. Applications include:

- **Land Use Planning**
  - -- assisting state and local governments in planning and zoning
  - -- mitigating development impacts on protected natural areas

- **Resource Management**
  - -- forest and crop inventories
  - -- wetlands mapping
  - -- wildlife habitat inventories and mapping
  - -- soil mapping

- **Environmental Assessment**
  - -- mapping aquatic vegetation and water quality
  - -- determining forest pest impacts
  - -- determining fire damage to forest lands
  - -- monitoring land use changes and impacts.

Several EPA programs and numerous state environmental agencies are also presently involved in GIS applications. Three case studies, one discussing ground-water and pesticides in Florida and two describing EMSL-Las Vegas applications in the San Gabriel Valley and Chattanooga, provide examples of how GISs can assist program management. Exhibit 5.2 gives an overview of some agency applications. One major benefit common to all these applications is that the GIS provides a centralized and integrated archive of information.

Overall, the information contained in Exhibit 5.2 shows that a GIS can improve program management in six broad categories:

- Improved access to Agency, state and contractor spatial data
- Better integration of environmental information for cross-media and cross-program data analysis
- Improved ability to determine status and trends of environmental problems in specific geographic areas
- Improved risk assessment capabilities
- Improved ability to set priorities and target regulatory actions with environmental data
- Better communication of environmental data in the form of maps and spatial data overlays.

Exhibit 5.2

An Overview of Selected EPA and State Environmental Agency GIS Applications

Organization	Program	Headquarters	Region	State	System	Data Types/Sources	Purpose
Minnesota State Planning Agency	Water			●	ARC/INFO	Census Sewer Pipe Discharges	**Develop Water Quality Controls** -- Identify new sewer service needs and sewer maintenance priorities
Minnesota Pollution Control Agency						STORET Point Source Discharges Non-point Source Discharge; -- soil -- rainfall -- slope -- land cover -- hydrology	**Conduct Water Quality Assessment** -- Determine conditions and trends -- Determine nature and extent of impact -- Identify violations -- Identify waters needing controls -- Report on conditions and trends (305b report) **Develop Water Quality Controls** -- Implement non-point source controls in priority watersheds
Florida Department of Environmental Regulation	Water			●	Intergraph	STORET Water Quality Data Reach File Supplemented With Hydrographic Data	**Conduct Water Quality Assessment** -- Report on conditions and trends (305b report) -- Establish priorities for water quality monitoring and controls
ERL - Corvallis	Water	●	●	●	ARC/INFO	Water Quality (National Lakes Survey) Land Cover/Land Use Soils Depth to Bedrock Geology	**Conduct Assessment of Acid Rain Impact on Water Bodies** -- Determine conditions and trends -- Determine nature and extent of impact -- Report on conditions -- Establish priorities for control measures

An Overview of Selected EPA and State Environmental Agency GIS Applications (Cont'd.)

Organization	Program	Headquarters	Region	State	System	Data Types	Purpose
EPA Region III ESD	Wetlands		●		Manual Map Overlay	Land Use/Land Cover National Wetland Inventory Habitat and Natural Resource Data (USFWS)	**Conduct Wetlands Assessment** -- Identify and map valuable/threatened wetlands -- Establish priorities for future program actions
Illinois Department of Conservation	Wetlands			●	ARC/INFO	Geology Surface Hydrology Infrastructure (roads, highways) Land Use/Land Cover Soil Type Point-Source Parameters	**Conduct Wetlands Assessment** -- Predict/model potential impacts -- Report on wetland conditions and trends
Minnesota State Planning Agency	DOE Nuclear Waste Siting			●	ARC/INFO	Infrastructure Air Photos Soil Type Hydrogeology Land Use/Land Cover	**Evaluate Potential Facility Sites** -- Determine areas inappropriate for nuclear waste sites
Massachusetts Hazardous Waste Facility Site Safety Council	RCRA			●	ARC/INFO	Hydrogeology Geography Infrastructure Wetlands (from USFWS) Facility Data (from FINDS) Public Water Supplies Landfills	**Identify Potential Facility Sites** -- Predict potential impacts from hazardous waste releases -- Recommend locations for hazardous waste facility
Region IV Policy and Management Division	RCRA/ Superfund		●		ARC/INFO	Land Use/Land Cover Depth to Aquifer Soil Porosity RCRA/Superfund Site Locations Wells Hydrogeology Demographic Data	**Evaluate Solid/Hazardous Waste Sites** -- Locate and prioritize sites based on HRS criteria -- Target water supply well monitoring -- Prioritize RCRA enforcement actions

An Overview of Selected EPA and State Environmental Agency GIS Applications (Cont'd.)

Organization	Program	Headquarters	Region	State	System	Data Types	Purpose
Minnesota State Planning Agency	Superfund			●	ARC/INFO	Soils Hydrogeology Drinking Water Wells Ground-water Quality	**Conduct Remedial Investigations/ Feasibility Studies** -- Identify contamination sources and impacts -- Prioritize monitoring
EMSL - Las Vegas	Superfund San Gabriel			●	ARC/INFO	Ground-water Quality Demographic Land Use/Land Cover Water Purveyor Districts Aquifer Characteristics	**Characterize San Gabriel Superfund Site** -- Predict extent of contamination -- Identify priorities from RI/FS
New Jersey Department of Environmental Protection	Superfund			●	In-House GIS	Point Source (FINDS) Soil Type Geology Hydrology Epidemiological	**Characterize RCRA/Superfund Sites** -- Predict impacts -- Target permitting and enforcement actions
New Jersey Department of Environmental Protection	Air			●	In-house GIS	Radon Measurements Census Soil Geology Topography	**Conduct Radon Problem Assessment** -- Map nature and extent of known naturally occuring radon -- Map potential radon hazard areas

An Overview of Selected EPA and State Environmental Agency GIS Applications (Cont'd.)

Organization	Program	Headquarters	Region	State	System	Data Types	Purpose
Florida Department of Environmental Regulation	Ground-water/ Pesticides			●	Intergraph	Well Water Quality Land Use Vulnerability (DRASTIC)	**Conduct Ground-Water Assessment** -- Target wells for cleanup and alternative water sources -- Integrate public and private well water quality data -- Prioritize monitoring
						Well Samples Water Bodies Pesticide Application Sites	**Identify Contamination Sources** -- Identify extent of EDB well contamination -- Identify responsible parties and initiate corrective action
Minnesota State Planning Agency Minnesota Pollution Control Agency	Ground-water			●	ARC/INFO	Well Logs/Drinking Water MCL's Ground-water Quality	**Conduct Ground-Water Assessment** -- Determine conditions and trends of ground-water supplies -- Identify areas needing monitoring
Connecticut Department of Environmental Protection	Ground-water			●	ARC/INFO	Hydrogeology Soil Types Depth to Bedrock Land Cover/Land Use Waste Facilities Ground-water Quality Public Well Supplies Conservation Areas	**Conduct Ground-Water Assessment** -- Determine conditions and trends of ground-water supplies -- Identify contamination sources

An Overview of Selected EPA and State Environmental Agency GIS Applications (Cont'd.)

Organization	Program	Headquarters	Region	State	System	Data Types	Purpose
Region IV Policy and Management Division	Pesticides/ Ground-water		●		ARC/INFO	Depth to Aquifer Soil Porosity Land Use (prime farmland) Hydrogeology Well Locations Demographic Data	**Target Pesticide Monitoring** -- Identify wells most likely to be contaminated
Wisconsin Bureau of Natural Resources	Ground-water			●	ARC/INFO and ODYSSEY	Depth to Bedrock Depth to Watertable Type of Bedrock Soil Characteristics Surficial Deposits	**Conduct Ground-Water Assessment** -- Locate and map highly susceptible areas in state
	Water					Water Quality Runoff Soils	**Conduct Water Quality Assessment** -- Determine nature and extent of non-point source impacts -- Identify areas needing control -- Evaluate BMPs
Rhode Island Department of Environmental Management	Ground-water			●	ARC/INFO	Saturated Thickness Hydraulic Conductivity Drainage Basin Boundaries Hydrography Land Use Zoning Pollution Sites Till and Outwash Deposits	**Conduct Ground-Water Assessment** -- Locate and map threatened water supply sources
	Estuary			●		Shellfish Closure Areas Point Sources Pollution Land Use Water Quality Brown Tide Distribution	**Conduct Water Quality Assessment** -- Determine conditions and trends -- Determine nature and extent of impact

An Overview of Selected EPA and State Environmental Agency GIS Applications (Cont'd.)

Organization	Program	Headquarters	Region	State	System	Data Types	Purpose
Minnesota State Planning Agency	UST			●	ARC/INFO	Underground Tanks	**Determine Status of Underground Tanks** -- Identify whether tank is empty or active -- Target tanks requiring further testing
EMSL -- Las Vegas (Chattanooga Environmental Methods Testing Site)	Multimedia	●	●	●	ARC/INFO	Soils Land Use/Land Cover Hydrology Meteorology Demography Health Related Biological Resources Point Sources Pollutants -- air -- water	**Assemble Data for Pollution and Health Risk Studies** -- Determine conditions and trends across media -- Establish priorities for control actions

An Overview of Selected EPA and State Environmental Agency GIS Applications (Cont'd.)

Organization	Program	Headquarters	Region	State	System	Data Types	Purpose
EPA Integrated Environmental Management Projects	Multimedia	●	●	●	PIPQUIC	Integrate various EPA data bases <u>Air</u> NEDS HATREMS NAPAP SAROAD <u>Water</u> IFD PCS STORET <u>Hazardous Waste</u> HWDMS GICS Other Appropriate State and Local Data	**Conduct Multimedia Risk Assessments** -- Determine priority problems in specific locations -- Identify risk management options and recommend actions
ERL - Corvallis	Multimedia	●	●	●	ARC/INFO	Land Use/Land Cover Soils Water Quality	**Identify Ecoregions for Water Quality Standard-Setting** -- Map and characterize ecoregions -- Recommend water quality standards for ecoregions -- Predict water quality impacts associated with changes in land use and pollution control

5.3 Potential Applications

In addition to the numerous current EPA and state environmental GIS applications described above, there are many other opportunities for incorporating GIS technology into Agency programs. This discussion presents only a selection of potential GIS uses by EPA. Virtually any Agency decision that could be assisted with information about the location of environmental conditions, contamination sources and exposures represents a potential GIS application. If reliable data are available, the GIS can be a useful tool for storing, analyzing, and displaying this information. Exhibit 5.3 details some potential applications for the Superfund, RCRA, Pesticide, and UST programs. Other potential applications are discussed below to provide further ideas for how GISs could benefit Agency programs (it should be noted that some of these "potential" applications are in fact already being conducted by several states, EPA Region IV, and other EPA programs):

Drinking Water/Groundwater

- **Identify potential sources of contamination to public water systems that rely on surface waters.** A GIS can integrate and map drinking water intake locations in association with NPDES effluent discharge data. Data types used in this application include location of NPDES facility, NPDES I.D. number, NPDES SIC code, permit limits, and parametric discharges. Such information would identify the number and location of upstream dischargers that have the potential to release pollutants into the drinking water source. The identification of chemicals used or produced by each discharger could enhance emergency planning by the public water system for health threatening accidental releases. With this information, the public water system could improve monitoring and notification procedures, establish threshold action levels (concentrations in the water source, and discharge quantities from the discharger that will produce those concentrations) for chemicals that might be released, and develop appropriate mitigation plans for each chemical.

Exhibit 5.3

SUPERFUND | **Examples of How GIS Technology Can Benefit Program Management**

<table>
<tr><th>Program Activity</th><th>Information Requirements for Program Management</th><th>Potential GIS Uses</th></tr>
<tr><td>Preliminary Assessment/Site Investigation
• Determine ground-water conditions
• Determine nature and extent of ground-water contamination
• Conduct preliminary risk assessment
• Develop a hazardous ranking score</td><td>• Ground-water sample data
• Drinking water sample data
• Identification of site hazardous substances
• Hydrogeologic descriptors
• Demographic data
• Land use/land cover
• Health effects data</td><td rowspan="3">• Model and map plume direction and dispersion
• Map sources of contaminants
• Integrate plume and drinking water sources to provide maps of "hot spots"
• Model and map results of alternatives for remedial action
• Prioritize sites by integrating and mapping critical parameter data (e.g., waste type, contaminant risk, population exposed, drinking water supplies)
• Integrate RCRA and Superfund site data to map combined program "hot spots"
• Integrated picture of numerous environmental impacts in geographic areas of interest</td></tr>
<tr><td>Remedial Investigation/Feasibility Study and Remedial Action
• Conduct rigorous assessment of site contamination and risks
• Conduct a feasibility study to evaluate clean-up alternatives
• Select a remedial response</td><td>• Soil permeability
• Depth to saturated zone
• Proximity to drinking water aquifers
• Hydrogeologic data
• Chemical fate and transport
• Health effects
• Demographic data
• Ground-water transport model
• Clean-up alternatives
• Cost-benefit analysis</td></tr>
<tr><td>Site Monitoring
• Monitor long-term site conditions
• Prioritize monitoring</td><td>• Ground-water quality samples
• Drinking water supply samples</td></tr>
</table>

Exhibit 5.3

RCRA	Examples of How GIS Technology Can Benefit Program Management

<table>
<tr><th>Program Activity</th><th>Information Requirements for Program Management</th><th>Potential GIS Uses</th></tr>
<tr><td>Facility Permitting
• Evaluate current and potential facility sites
• Develop permit conditions</td><td>• Air emission data
• Ground-water sample data
• Hydrologic data
• Land use
• Soil characteristics
• Plume modeling maps
• Location of monitoring wells
• Site descriptors (wastes on site)
• Health effects data
• Demographic data</td><td rowspan="3">• Model and map plume direction and dispersion
• Map sources of contaminants
• Integrate plume and drinking water sources to provide maps of "hot spots"
• Model and map projected results of alternative remedial actions
• Prioritize sites by integrating and mapping critical parameter data (e.g., waste type, contaminant risk, population exposed, drinking water supplies)
• Integrate RCRA and Superfund site data to map combined program "hot spots"
• Integrate soils, hydrogeology, land use and other data to map and designate suitable areas for solid/ hazardous waste disposal sites</td></tr>
<tr><td>Compliance Monitoring and Enforcement Action
• Evaluate solid/hazardous waste sites
• Target water supply well monitoring
• Predict potential impacts from hazardous waste releases
• Prioritize enforcement actions</td><td>• Hydrogeologic data
• Ground-water sample data
• Inspection and analysis data
• Plume modeling maps
• Contingency action plan
• De-contamination procedures</td></tr>
<tr><td>Post-closure Monitoring
• Monitor long-term site conditions
• Prioritize monitoring</td><td>• Ground-water sample data
• Hydrogeologic data
• Soil characteristics</td></tr>
</table>

Exhibit 5,3

PESTICIDES | **Examples of How GIS Technology Can Benefit Program Management**

Program Activity	Information Requirements for Program Management	Potential GIS Uses
Pesticide Registration/Reregistration **Pesticide Suspension, Cancellation or Restriction** • Prepare exposure profile • Develop labelling restrictions • Reassess permissible residue levels • Prioritize chemicals for special review • Develop exposure and risk assessment for chemicals undergoing special review	• Ground-water quality data • Hydrogeologic data • Pesticide use in area • Location of drinking water wells • Soil data • Economic benefit • Health effects • Wildlife and plant threats • Weather data • Environmental fate • Demographic data	• Map pesticide ground-water quality contamination and vulnerability • Integrate ground-water quality data with pesticide application area and human exposure information • Identify wells located in or adjacent to contamination sites • Model environmental fate of pesticide and map "high risk" areas • Prioritize pesticide candidates for review based on environmental and/or human health risk with map overlays • Prioritize sampling of drinking water from wells and surface water intakes

Exhibit 5.3

UST	Examples of How GIS Technology Can Benefit Program Management

Program Activity	Information Requirements for Program Management	Potential GIS Uses
Site Investigation/Corrective Action • Develop a monitoring strategy • Determine nature and extent of ground-water contamination • Develop exposure and risk assessments • Develop a plan for corrective action **Site Monitoring** • Monitor site to ensure ground-water is no longer contaminated	• Soil samples • Ground-water sample data • Drinking water sample data • Hydrogeologic descriptors • Exposure assessment data • Demographic data • DRASTIC data	• Identify and map tank locations and status (e.g., leaking, not leaking) • Integrate ground-water data, demographic data, and DRASTIC maps and files to pinpoint areas of concern • Evaluate environmental and human health risks

- **Establish Wellhead Protection (WHP) Areas and develop ground-water plans.** Some of the most promising uses of GISs are for ground-water protection, which depends heavily on geographic information. During the next few years, local governments and states, with EPA assistance, will be preparing plans for protecting underground drinking water supplies and other valuable ground-water. WHP management plans will draw on mapped information such as well locations, hydrogeologic data (extent of WHP areas, and vulnerability analysis), populations served, existing and potential contamination sources, alternative water supplies, and land use controls or other measures to protect ground water. GISs will be useful for preparing these maps at common scales and for overlaying these data types for WHP planning. Other GIS uses might include regional or national ground-water vulnerability mapping based on various hydrogeologic paramaters (DRASTIC model), and mapping of nonpoint contamination sources. For example, the incorporation into the GIS of land use/land cover maps derived from remote sensing imagery would assist in identification of agricultural lands. Subsequent mapping of crop patterns, and associated fertilizer and pesticide usage data for these agricultrual areas would allow identification of significant nonpoint contamination sources.

<u>Water Programs - Permit Writing/Estuaries</u>

- **Establish priorities for permit writing and related analyses such as TMDLs/WLAs, and for developing other management actions.** The Water Program collects ambient water quality data, point source discharge data, and conducts other special studies (e.g., bioaccumulation survey, dioxin study) to determine the nature, extent and significance of water quality problems. Currently, the ability to aggregate and display this data for geographical areas such as coastal watersheds or hydrologic units is limited. Watershed analysis would require integrating STORET water quality data, corresponding NPDES data extracted from PCS or directly from DMRs, information on living resources, and watershed land use/land cover, soil type, and demographic data. The integration and analysis of these data with a GIS would provide Water program managers with a clearer and more easily understandable visual analysis of water quality problems. This capability would result in better environmental management decisions by using all relevant data on water quality conditions and isolating probable pollution causes. A scenario for undertaking this type of analysis first requires identifying degraded water quality to establish geographic areas of concern. This analytical step would match the designated use of each water body with its corresponding water quality criteria and standards and indicate what parameters exceed acceptable levels. Then, for the same water bodies, all point and suspected nonpoint sources with effluent or runoff data for the same parameters would be listed and mapped. Next, the reported discharge values for these parameters would be listed to help focus on the cause of water quality degradation. Mapping these data and providing graphic products showing high, medium, and low pollution impact areas would assist managers responsible for designing surface water monitoring plans and water quality controls. Managers could use this information to establish priorities for writing permits, to implement Best Management Practices (BMPs), or to initiate other corrective actions.

<u>OSWER - RCRA</u>

o **Integrate hazardous waste site evaluation data for more efficient ranking and understanding of hazardous waste facilities.** Using a GIS for the central collection of voluminous site data will improve hazardous waste facility permitting and site management. For example, many of the

RCRA ground-water program requirements include the need to analyze spatial information over time. The use of a GIS could assist the RCRA permit writer and reviewers in various ways. Evaluation of the status of a facility could be improved with map overlays showing disposal areas, surface drainage, areas where chemical seepage or leachate might affect water resources, discharges to surface waters, and vegetation damage. This stored spatial data could also be mapped for use in siting studies to help determine land suitability for proposed hazardous waste facilities. For example, maps could show the relationship between a proposed facility site and areas that should be protected such as wetlands, marine sanctuaries, endangered habitats, drinking water sources or recreational areas. In addition, a GIS could assist compliance monitoring of permitted RCRA facilities by comparing maps showing original permit conditions with update maps showing whether the permits are being complied with. For RCRA facilities no longer in operation, the GIS database could provide a cost-effective method for review of post-closure monitoring data. This method might involve combining remote sensing information (in the GIS) with other newly acquired leachate, vegetation stress, or erosion data for the facilities. This data could also be used for spill or release planning, and to identify the population at risk for design and placement of ground-water monitoring wells.

<u>Air Programs</u>

- **Analysis of vegetation damage and water pollution as an environmental indicator of air quality.** Incorporating air pollutant data with results of vegetation and lake or stream monitoring data along projected pollutant corridors can serve as an environmental indicator of ozone, acid rain and other air pollution. Maps of damaged rangelands, crops, trees, and water bodies might be useful air pollution "warning signs." The maps could be used to locate monitoring activities to determine what agents are contributing to the vegetation damage (e.g., air pollutants, ground-water contamination, natural chemical stress), or water pollution. Confirmation of air pollutant impacts would then warrant analysis of air emission data (e.g., from NEDS) in association with transport models to identify specific air emission sources contributing pollutants to the area of concern. Incorporation of these air emissions data (e.g., location of stationary source, types and amounts of air contaminants discharged per source) and transport models into the GIS would enable mapping and identification of facilities discharging problem air contaminants. Air program managers could use this approach to establish priorities for inspection and compliance activities.

Underground Storage Tanks

o **Improve the identification of areas highly susceptible to contamination from underground storage tanks (UST).** The regulated UST community is very large and responsible State agencies cannot realistically analyze each tank in detail. A viable approach to this problem would be to use a GIS to identify geographic areas of highest concern. To accomplish this task, a GIS would archive DRASTIC maps and files (or other measures of ground-water vulnerability), ground-water quality data, and demographic data. The GIS would be used to map those hydrogeologic zones with a high DRASTIC index (indicating high vulnerability to ground-water contamination). The next step would be to overlay population and water supply data to identify areas having both high populations dependent on wells and vulnerable ground-water supplies. This approach would pinpoint geographic areas of concern and help program managers target compliance inspections and enforcement action.

Glossary

GLOSSARY

Algorithm: a series of specific steps for solving a problem, usually used in the context of a set of instructions a computer follows as it processes data.

Alphanumeric: consisting of both letters and numbers, and possibly including other symbols such as punctuation marks.

Analog: an altered version of the same thing. A printed map is an analog of the digital version of the same map. In electronics, representation of numbers by physical quantities as electrical voltages or intensity of light.

Attribute: a variable reserved to describe a characteristic of a data element.

Boolean: decision logic which uses the operators and, or, not. Used to combine attributes of classes of sites into a new class of sites.

Cartesian: a common two-dimensional description of point locations using x and y distances.

Coordinates: linear and (or) angular quantities that designate the position of a point in relation to a given reference frame. In a two-dimensional plane, x and y are commonly used to designate coordinates of a point.

CPU: an acronym for central processing unit, the part of the computer that controls the flow of data and performs the computations.

CRT: a cathode-ray tube, similar to a television picture tube, on which an image is displayed by a pattern of glowing spots produced by directing a beam of electrons at a phosphorescent screen.

Data: a collection of unorganized facts that have not yet been processed into information.

Data Base: the collection of integrated data that can be used for a variety of applications.

Data Element: a unit of information used to describe data, data characteristics and attributes.

Data Standards: refers to the standards generally, but not exclusively, used for automated systems to ensure that one type of data is defined the same way in all systems.

Data Validation: the process of providing some confidence limit to data indicating the degree of accuracy, precision, and general acceptance of the data value.

Digital Data: refers to those particular data elements which have some coordinate reference attribute established through conversion from an image or map to numerical format in an automated system.

Digitizer Tablet: a device used to determine and communicate to a computer the coordinates of points designated with a cursor or stylus. Locations are sensed electronically by the tablet bed on which a graphic image or instruction menu is placed.

Digitizer: a device for converting point locations on a graphic image to plane (x, y) coordinates for digital processing.

Directory: a look-up table indicating the storage locations in a file of various data records and used for gaining access to these records.

GLOSSARY (Continued)

Disk Storage: a rotating plate having magnetized surfaces on which data may be stored. (Alternate spelling: Disc).

Floppy Disk: a circular, flexible, relatively inexpensive piece of magnetic material for the storage of digital data.

Geographic Information System (GIS): a computer-based system that combines geographic and/or cartographic analysis capabilities with a computer data base management system that can support data entry, data management, data manipulation and data display capabilities.

Hard Copy: a permanent image of a map or diagram, for example, a paper map produced on a line printer or pen plotter.

Hardware: refers to physical equipment such as the computer and its related peripheral devices, tape drives, disk drives, printers, etc.

Imagery: the visual representation of energy recorded by remote sensing instruments. Representation or reproduction of objects and/or phenomena as sensed or detected by cameras, scanners, radar, etc. Recording may be on photographic emulsion or on magnetic tape for subsequent conversion and display on a cathode ray tube.

Information: any communication or reception of knowledge such as facts, data, opinions, including numerical graphic or narrative forms, whether oral or maintained in any medium, including computerized data bases, paper, microform, or magnetic tape.

Interface: an electronic translator of the signals of two devices, such as a computer and a plotter, so that otherwise incompatible information can be transferred between them.

Land Cover: cultural objects and natural and cultivated vegetation occupying the landscape that can be grouped or classified and subsequently mapped.

Land Use: utilization of land. A land use map employs categories such as pasture, wasteland and unimproved land, all of which might conceivably fit into a grassland category of a land cover map.

Life Cycle: the complete time span of a system from the origin of the idea that leads to the creation of the system to the end of its useful life.

Map Projections: techniques for depicting the earth's surface (round body) on a flat sheet (map).

Peripheral: a device that may be added to a computer to provide additional data storage or to receive or display data.

Polygon: a closed plane figure which may be defined by straight lines, arcs or combinations of both. Digitally the perimeter of the polygon is usually represented by a list of point coordinates.

Program: a set of declarations and logically organized instructions coded in a computer language in order to direct the operation of the computer.

Programming Language: a formal set of verbal or symbolic instructions and declarations that can be used to code an algorithm for later translation into machine instructions.

Raster: the pattern of parallel scan lines consisting of cells digitally designated by a numerical value. These values are displayed on a CRT either as shades of gray or color-coded according to red-green-blue intensities.

Record: a group of items in a file treated as a unit. For example, all data items for a census tract can be grouped as a record and assigned to a single segment of a magnetic tape file for convenient storage and retrieval.

Registration: the mathematical or visual alignment of multiple maps or images.

Remote Sensing: the non-tactile imaging of an object by virtue of its electro-magnetic properties.

Software: refers to the computer programs, procedures, rules and associated documentation pertaining to the operation of a computer system.

Spatial: refers to the location of, proximity to, or orientation of objects with respect to one another.

Spatial Data: Discrete symbols (numbers, letters, or special characters) used to describe some entity, organized according to the location of that entity in the three-dimensional world.

Turnkey: an adjective used to describe a computer system consisting of compatible hardware and software.

Vector: a directed line segment, which can be represented by the coordinates for the pair of end points. Vector data refers to data in the form of a list or lists of point coordinates.

APPENDIX A

Overview of How A State Uses A GIS In Ground-Water Program Management

FLORIDA AND PESTICIDES

Overview of How A State Uses a GIS in Program Management: The State of Florida and Pesticide Contamination of Ground-Water

Ground-Water Contamination Concern

Florida's ground-water is especially susceptible to contamination because of the state's thin soils, high ground-water table, and porous limestone formations. Over 90% of the state's population relies on ground-water as a source of drinking water. Four major aquifers supply this drinking water to the populace. The Floridian aquifer is highly susceptible to pesticide contamination due to the large concentration of citrus groves in the central portion of the state.

Initial concern over the potential threat to Florida's ground-water supply from a specific pesticide, ethylene dibromide (EDB) occurred in July of 1983 when the Commissioner of Agriculture was convinced by his staff that contamination of ground-water supplies by EDB in California, Hawaii, and Georgia warranted his attention. It was well known that EDB had been used for years in the citrus growing regions of Florida . Futhermore, previous discovery of aldicarb ground-water contamination in Florida had sensitized the Department, legislature, environmental action groups and citizens to the potential for drinking water contamination by pesticides.

Role of Data in the Decision to Ban EDB Soil Fumigant Use

Numerous state agencies cooperated in providing the following critical pieces of information:

- the location, dates and amounts of state EDB application in citrus groves determined from detailed maps
- the location of wells in close proximity to known pesticide application areas
- monitoring data from sampling irrigation and drinking water wells in several central Florida counties
- laboratory analysis of the water samples using standard water quality analytical techniques.

Integration of the above information culminated in the temporary suspension of use of EDB as a soil fumigant in Florida through issuance of an emergency order on September 16th, 1983. This was shortly followed by the permanent ban prohibiting sale, distribution and use of EDB as a soil fumigant.

The Use of a GIS for Ground-water Protection Programs

Following the suspension of EDB use as a soil fumigant by the State of Florida in late 1983, the Department of Environmental Regulation (DER) began the creation of a spatial data base containing both well site and EDB application information:

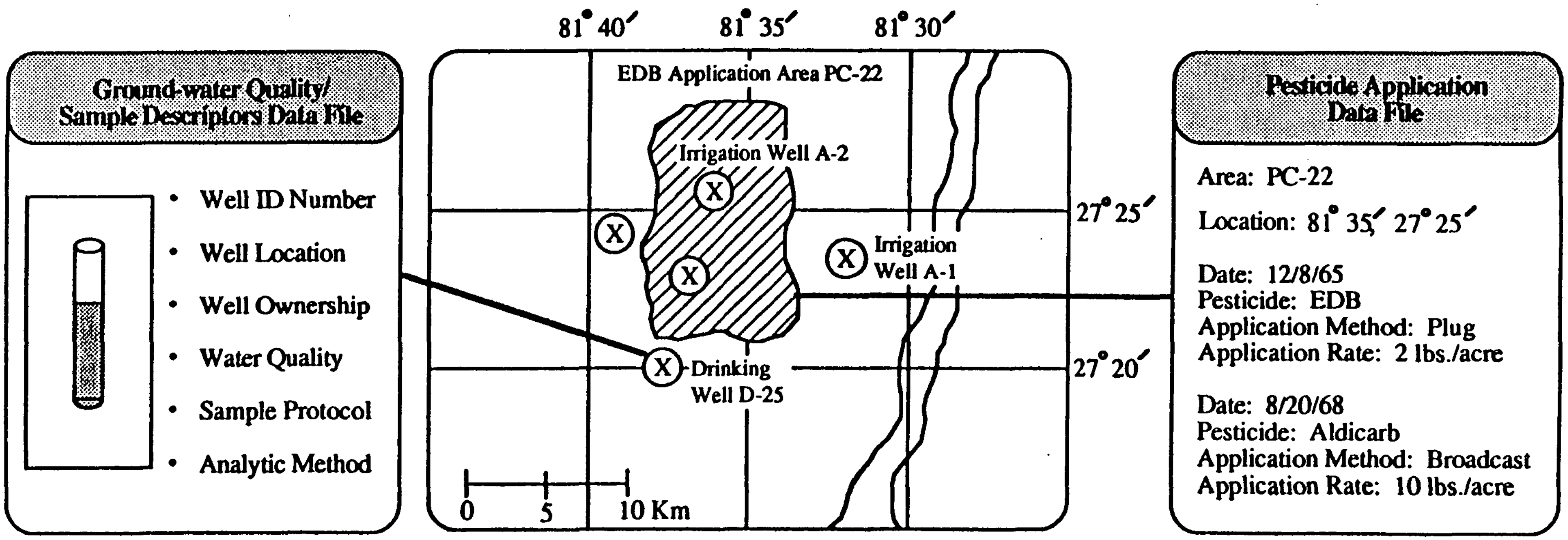
- Initially a computerized data base was created on a Sperry computer using "Mapper" to retain both well name and address and EDB sampling results.
- Eventually this data base was transfered to an Intergraph mapping and data base management system at Florida State University.
- A dedicated Intergraph workstation and plotter was made available at DER for analyzing monitoring data for EDB and other pesticides within the ground-water protection program.

This GIS has been used to produce maps showing the sites where EDB and other pesticides were applied. The GIS was then used to target sampling of all wells within 300 feet of EDB application sites. Priority was given to sampling public drinking-water wells located within 1,000 feet of EDB applications (see exhibit 1 for an illustration of how the GIS integrates tabular file data with map data). To date, more than 11,000 drinking wells have been sampled to determine ground-water quality. This information enables program managers to determine if susceptible wells have been sampled, prioritize sampling activities, and identify contaminated wells requiring remedial action. Corrective Action for those wells identified as being contaminated by EDB included use of charcoal filters, drilling of new wells, or hook ups to city water supplies. These actions have resulted in classifying as uncontaminated 90% of the previously identified EDB contaminated drinking water wells.

The EDB monitoring program conducted over the last four years in Florida has provided a relatively good picture of the extent and severity of ground-water contamination with EDB. In conclusion, this review demonstrates how a GIS is used to identify a ground-water problem, assess the extent and severity of the problem and provide pertinent information to undertake corrective action.

Exhibit 1

Integrating Florida EDB Application Data With Ground-water Sample Data



APPENDIX B

Overview of How a Region Uses GIS in Integrated Environmental Analysis

REGION IV

OVERVIEW OF HOW A REGION USES A GIS IN INTEGRATED ENVIRONMENTAL ANALYSIS

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, the Association of State and Interstate Water Pollution Control Administrators (ASWIPCA) and EPA agreed to undertake a collaborative effort to show how GIS can 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).

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:

- o 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.

- o 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.

- o 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).

- o 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.

- o 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.

- o 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. Examples of the ARC/INFO map products are provided in figures 1-6.

<u>The Region IV Approach</u>

Region IV participated in the GAEPD pilot 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:

- o 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.

<u>Environmental Regulatory Program Applications Using GIS in Region IV</u>

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

- o 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. 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.

- o 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.

- o The OIEA staff has developed a 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 and population served. Other environmental information such as geology, soil permeability, and depth to the aquifer can also be displayed for analytical purposes.

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:

- o **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.

- o **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.

- o **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.

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.

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
- o U.S. Bureau of the Census Block Group Centroids
  - Thiesson polygons generated from centroids
- 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 (GAEPD only)
  - 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 (GAEPD only)
- o U.S. EPA (derived from STORET, PCS, WHDMS, GICS)
- o Soil Conservation Service MIADS Soils Data (GAEPD only)
- o USGS Geographic Names File (GAEPD only)

- 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 Douraville 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 PR1ME 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.

- o 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.

- o 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.

- o 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:

- o **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 "information 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.

- o **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.

- o **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.

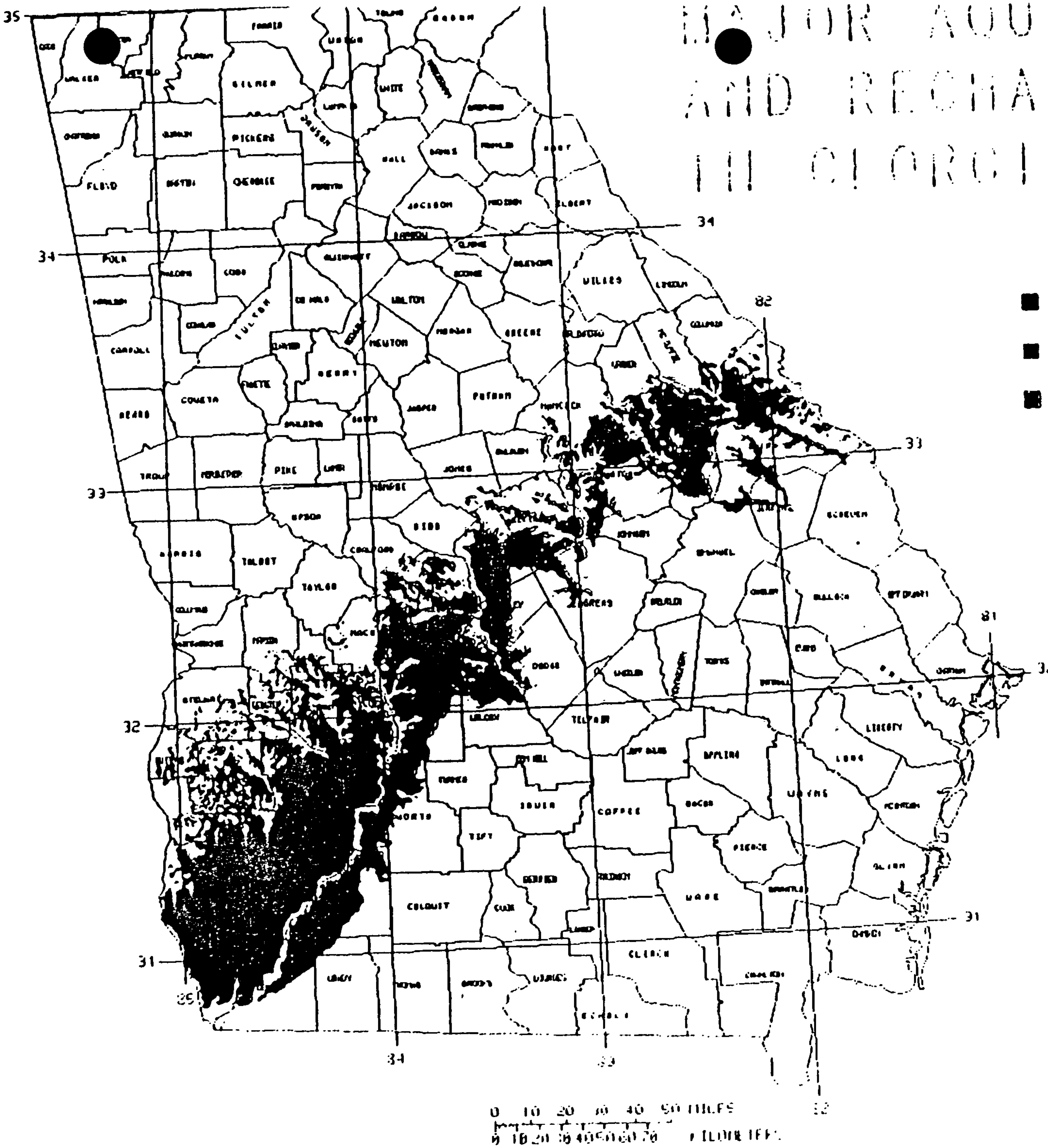
- ARC/INFO contains hundreds of software routines. The non-expert will need some type of user-friendly tools (e.g., macros) to be able to use this technology without ADP support.

- 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.

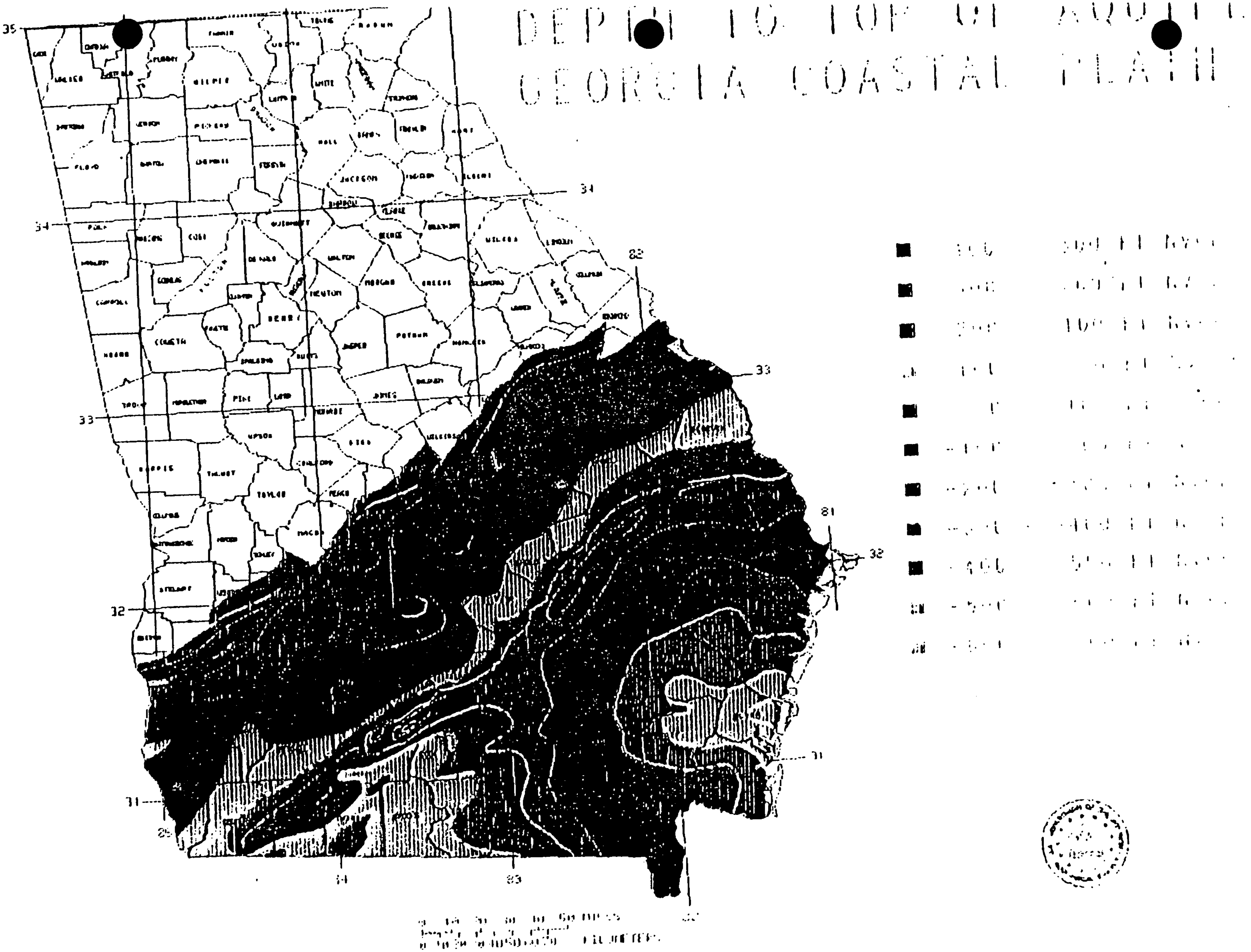
Examples of ARC/INFO Products

Figures 1-6

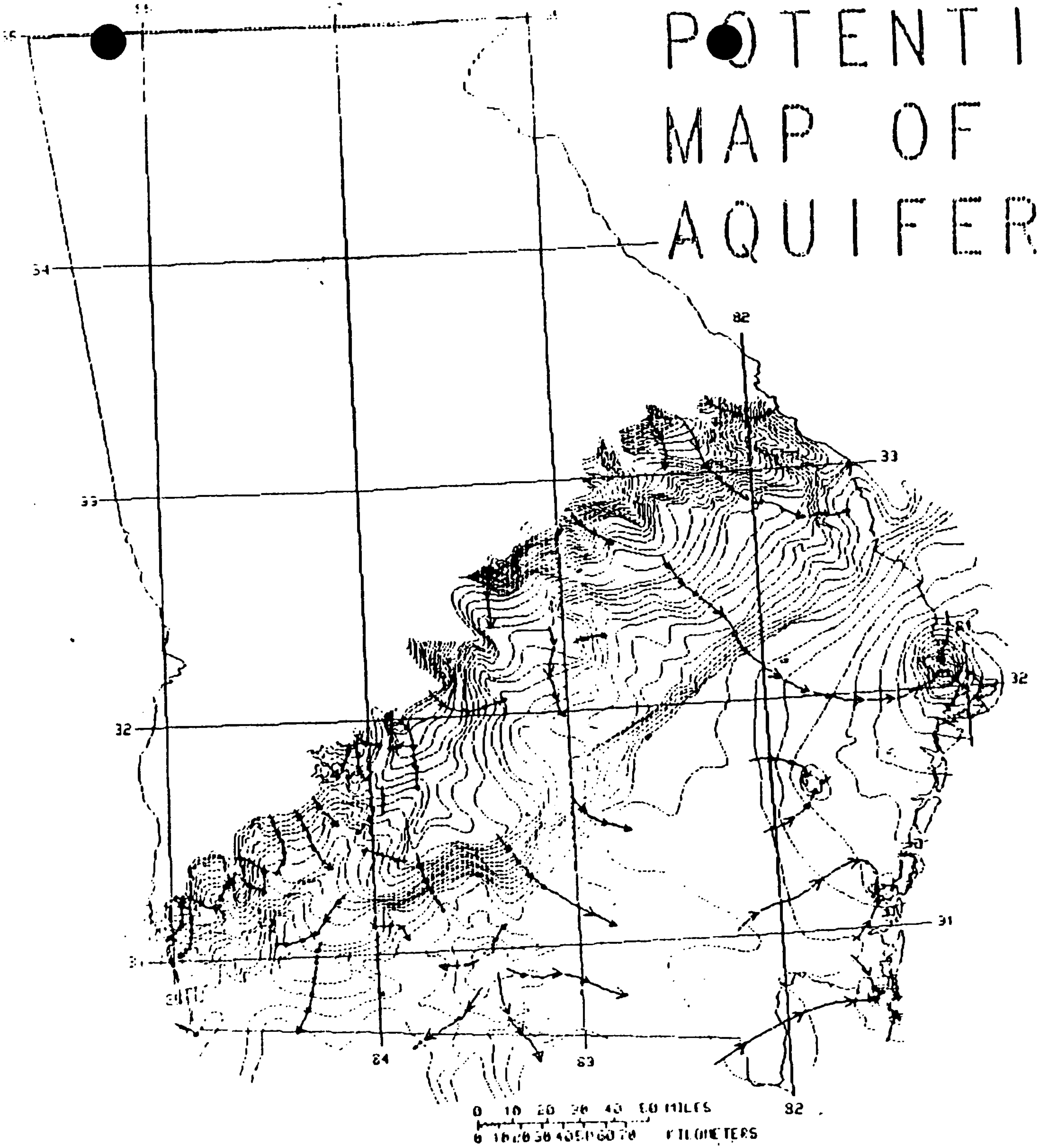
MAJOR AQUIFER OUTCROP AND RECHARGE AREAS IN GEORGIA



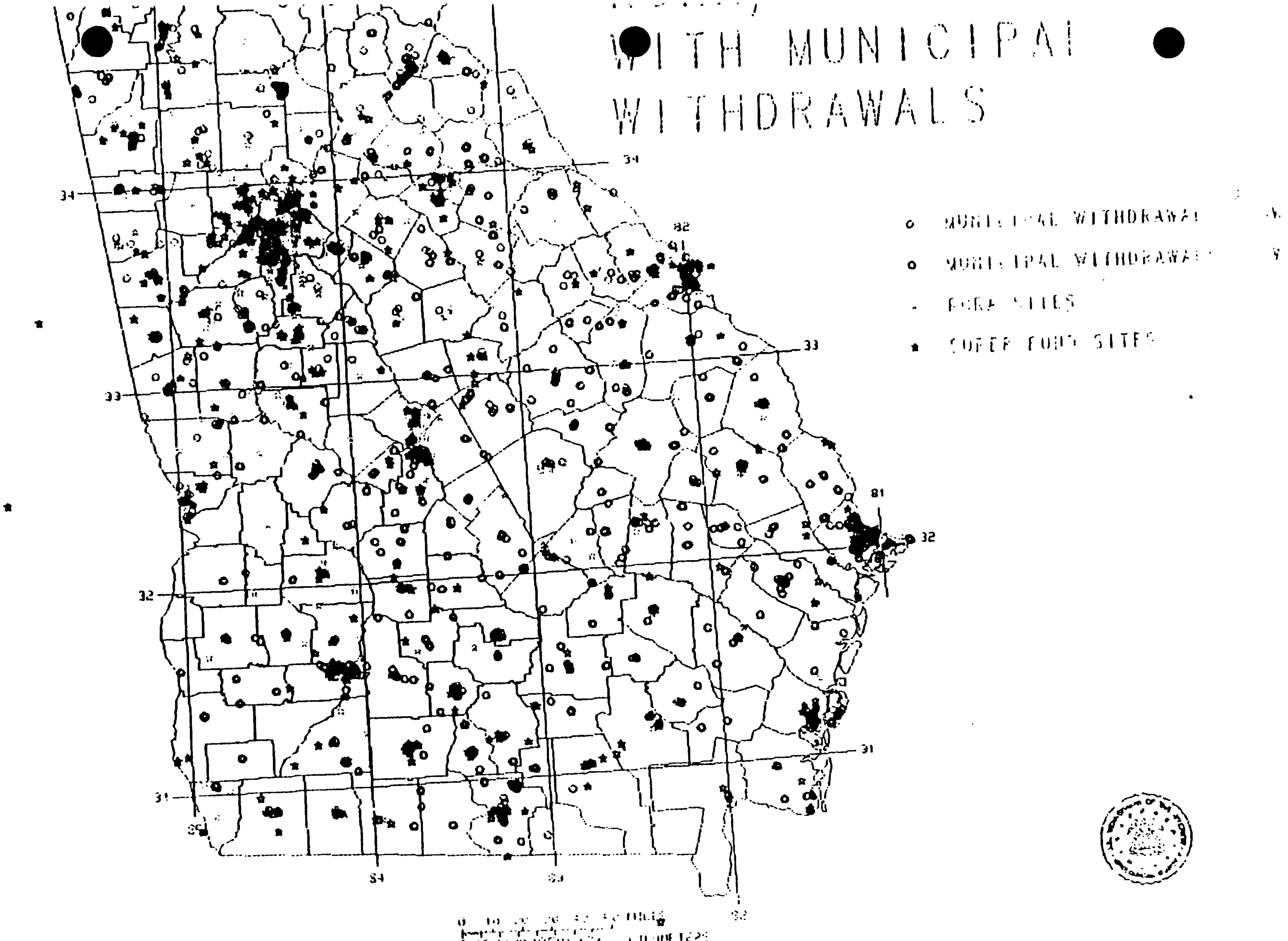
DEPTH TO TOP OF AQUIFER
GEORGIA COASTAL PLAIN

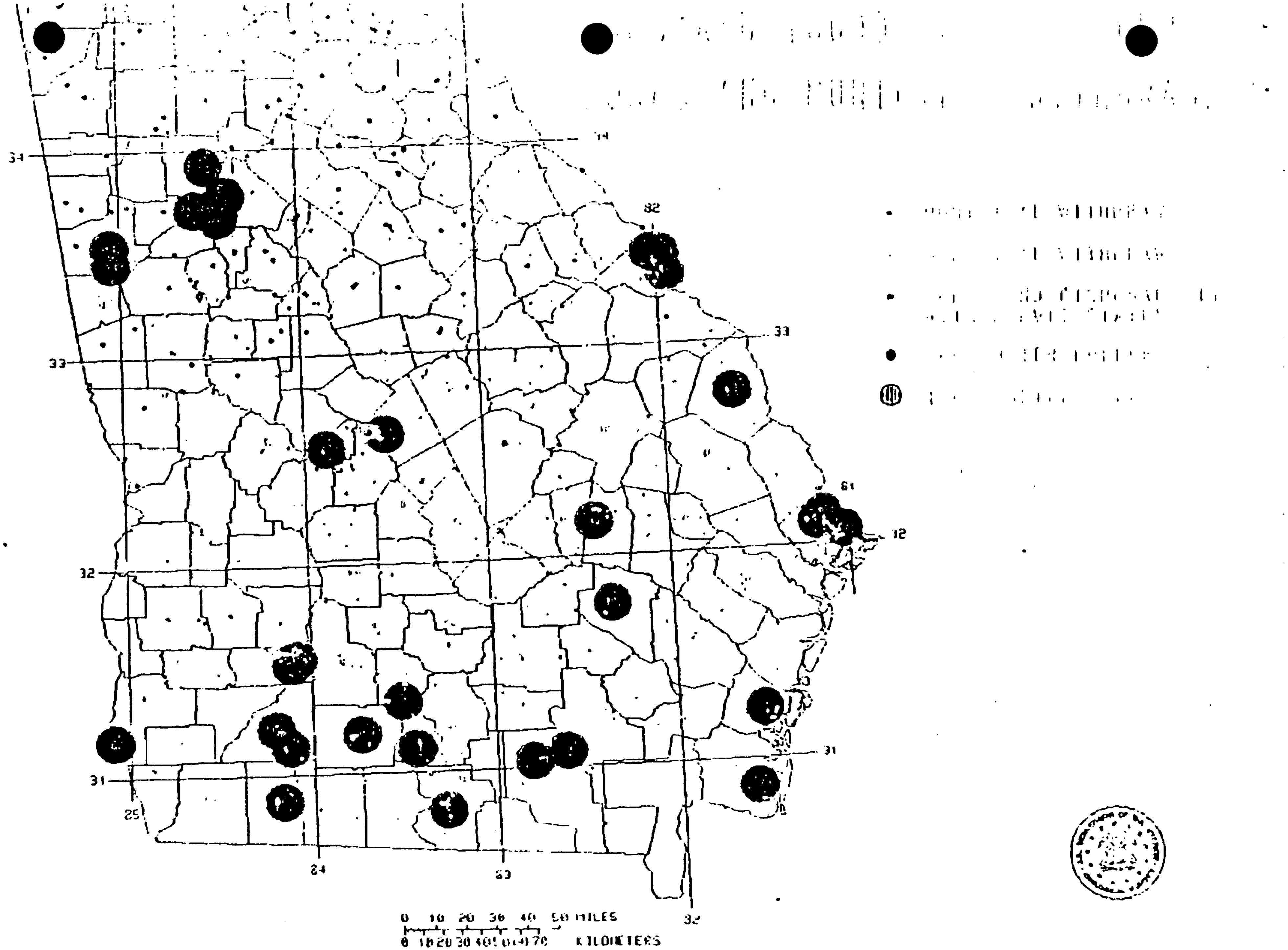


POTENTIOMETRIC MAP OF FLORIDAN AQUIFER -- 1985

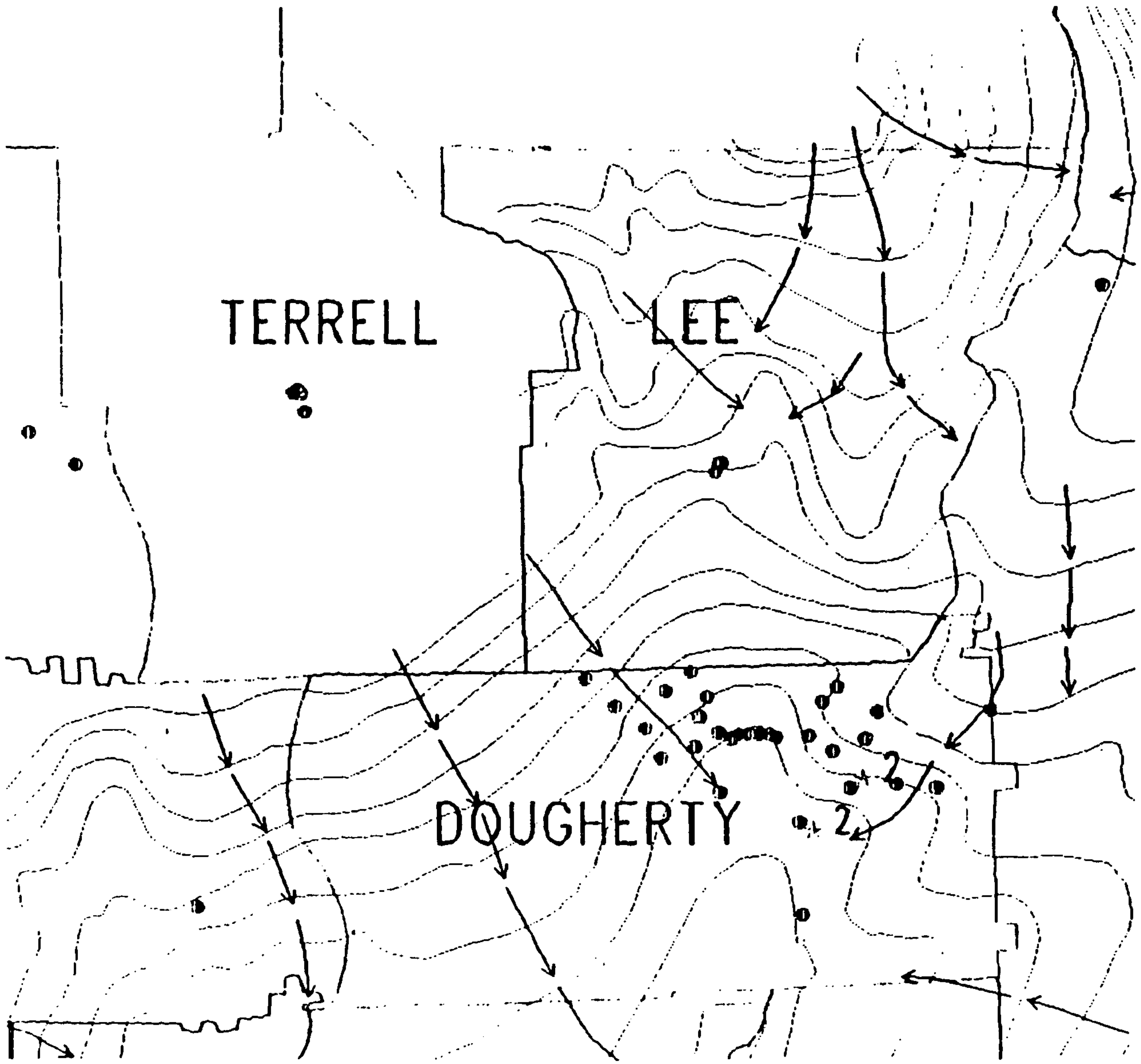


WITH MUNICIPAL WITHDRAWALS




34
33
32
31
82
81
84
83
85
0 10 20 30 40 50 MILES
KILOMETERS

POTENTIOMETRIC SURFACE MAP



THREE-COUNTY STUDY AREA

- MUNICIPAL WITHDRAWALS – GW
- RCRA LAND DISPOSAL SITES

APPENDIX C

Geographic Information System
Briefing for the Administrator
and Deputy Administrator

SAN GABRIEL BASIN GIS DEMONSTRATION

ENVIRONMENTAL METHODS TESTING SITE*

* Including only a selection of the plates listed in the Table of Contents

United States Environmental Protection Agency

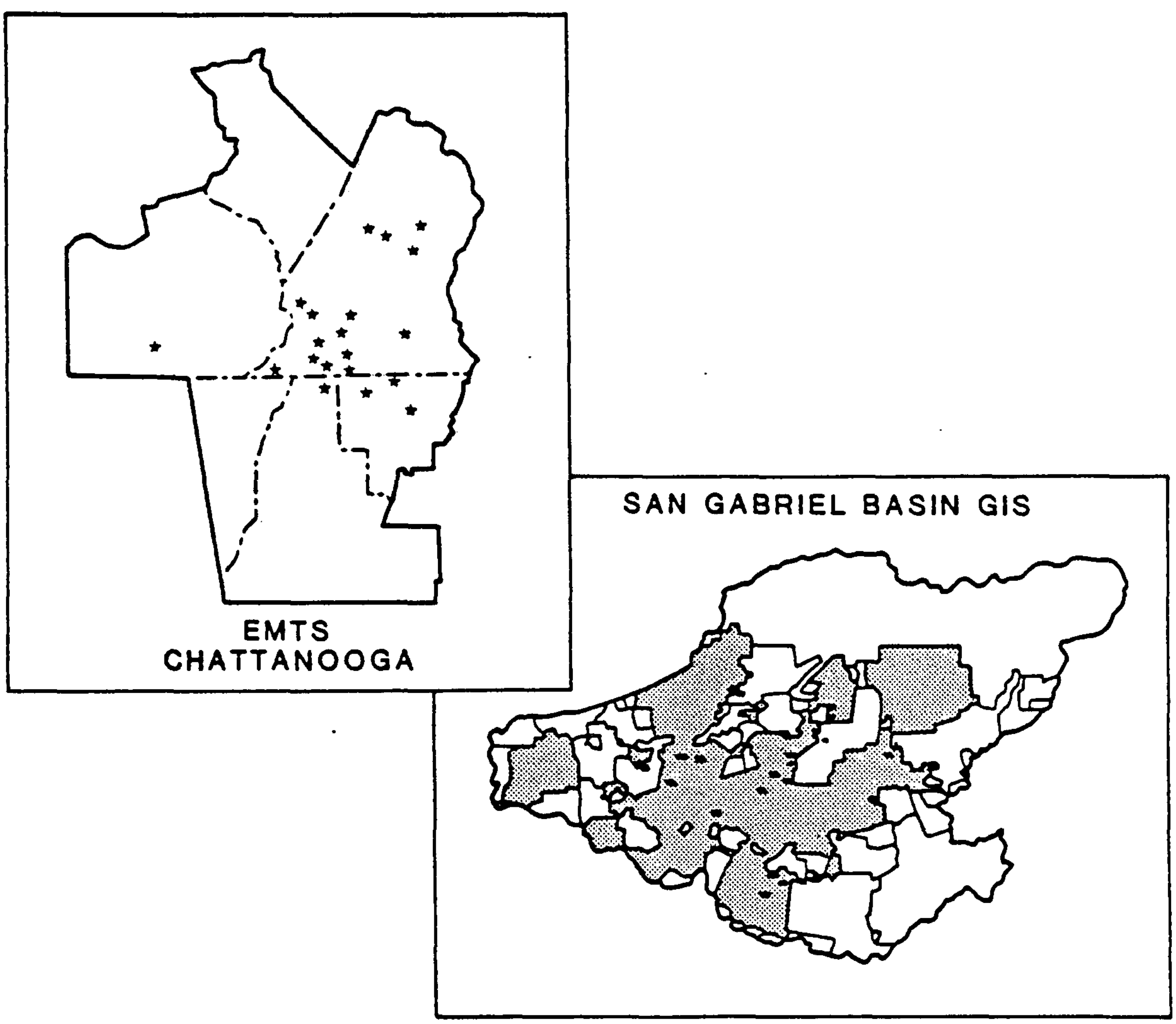
Environmental Monitoring Systems Laboratory
P.O. Box 15027
Las Vegas, Nevada 89114

TS-AMD-87650
January 1987

Research and Development

EPA

GEOGRAPHIC INFORMATION SYSTEM BRIEFING FOR THE ADMINISTRATOR AND DEPUTY ADMINISTRATOR



TS-AMD-87650
January 1987

GEOGRAPHIC INFORMATION SYSTEM BRIEFING FOR THE ADMINISTRATOR AND DEPUTY ADMINISTRATOR

by

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PLATES

TABLE OF CONTENTS (Cont.)

PLATES (Cont.)

INTRODUCTION

This briefing document summarizes two geographic information system (GIS) projects undertaken by the Environmental Protection Agency's Environmental Monitoring Systems Laboratory in Las Vegas, Nevada (EMSL-LV). The material presented demonstrates a few of the applications the EMSL-LV is able to provide with its GIS system.

Part 1 of this book is extracted from the "San Gabriel Basin Geographic Information System Demonstration" final report (TS-AMD-85742-0, October, 1986). The San Gabriel Basin GIS project was undertaken as EMSL-LV's first GIS project. As such, the primary purpose of the project was to demonstrate the utility of GIS as a tool in CERCLA/RCRA investigations.

Part 2 is extracted from the "Environmental Methods Testing Site Data Status" book (TS-AMD-86534, September, 1986). The Environmental Methods Testing Site (EMTS) encompasses the Chattanooga, Tennessee standard metropolitan statistical area (SMSA), an area of 2100 square miles. The primary purpose of this project is to build a comprehensive data base to be utilized in the testing of exposure methods.

United States
Environmental
Protection
Agency

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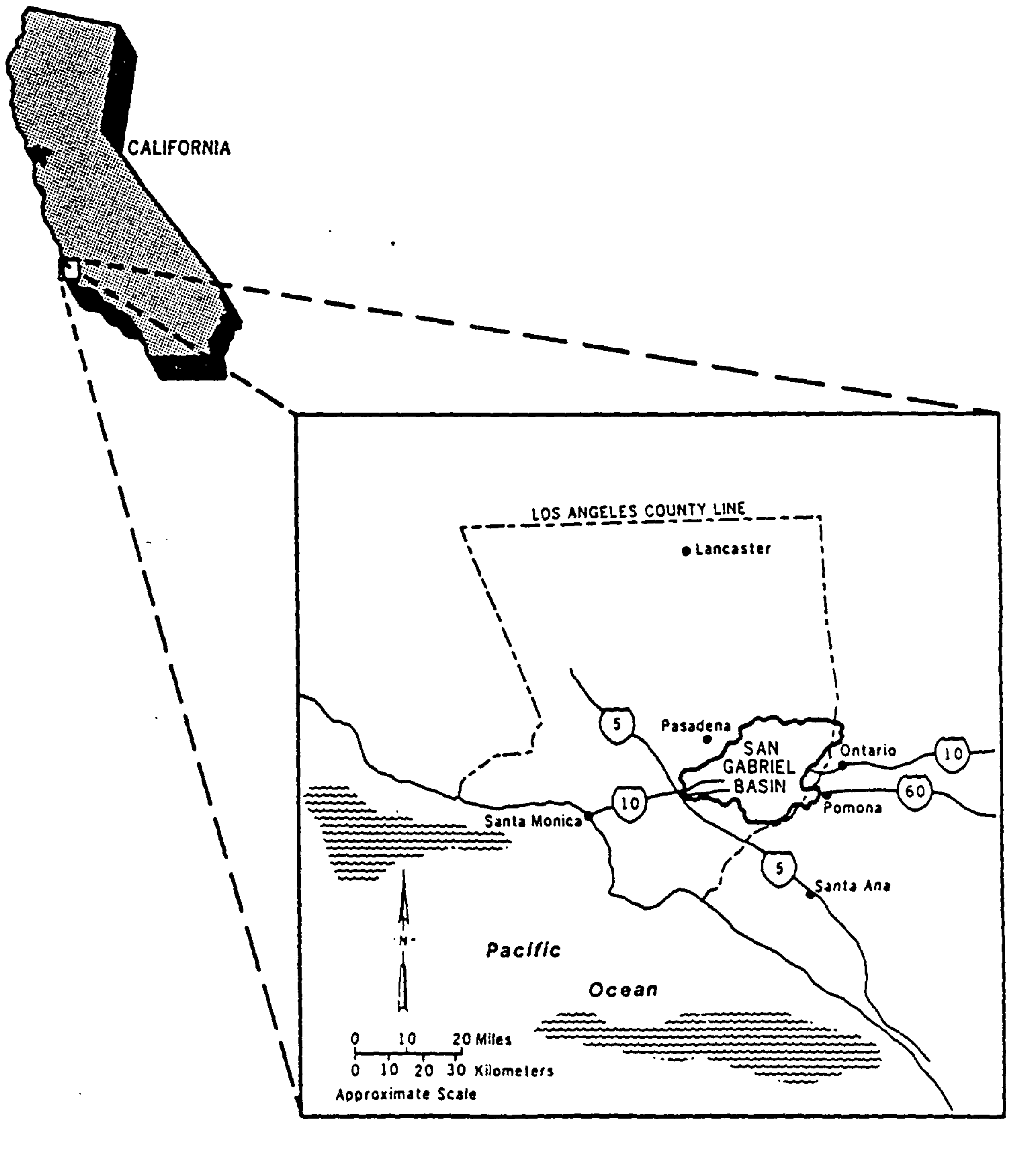
TS-AMD-85742-0
October 1986

Research and Development

EPA

SAN GABRIEL BASIN GEOGRAPHIC INFORMATION SYSTEM DEMONSTRATION

Los Angeles County, California



ABSTRACT

The San Gabriel Basin Geographic Information System (GIS) Demonstration project was undertaken by the U.S. Environmental Protection Agency's Environmental Monitoring Systems Laboratory in Las Vegas, Nevada at the request of EPA's Office of Emergency and Remedial Response and EPA Region IX. The purpose of the study was to examine the utility of GIS technology in support of regulations for environmental monitoring and recovery. The objectives were to develop a GIS data base, examine some of the spatial environmental relationships, and interface with a ground-water flow model. Existing data were acquired from EPA Region IX and its contractors, and automated into a GIS data base. The data automated either described cultural features or features detailing the geohydrology of the area. The data base can be separated into two general types of computer files, coverages and attribute tables. Coverages contain the points, lines, and polygons which describe a feature, and the topology or relationship of one feature to another. Attribute tables contain the information which provide definition of those points, lines, and polygons. Combined, the two sets of files make it possible to analyze attribute information in an accurate spatial context. The analyses performed in this study examined certain feature attributes, and relationships among selected features and their attributes to characterize the ground-water contamination and its impact in the San Gabriel Basin. Other GIS techniques were performed to prepare a set of aquifer data for direct input to a ground-water flow model. The modeling utilized potentiometric surface data from different years to estimate flow pathlines from contaminant sink to potential source. A series of historical aerial photographs were acquired and analyzed for potential point sources of contamination. The area surrounding the endpoints of the flow pathlines were selected for the historical aerial photographic analysis. Of the eight study areas chosen for photographic analysis, five yielded potential hazardous substance sources. These results clearly indicate that GIS technology is a valuable tool for environmental assessment and monitoring.

SECTION 1

Section 1 contains plots displaying arcs (lines) of several coverages within the San Gabriel GIS Data Base. The plots which are described below were generated by overlaying several coverages (data layers). The individual coverages are displayed in different colors to provide feature separation. Plot 1 displays the boundaries for the 7.5 minute U.S. Geological Survey quadrangles, aquifer, and watershed (hydrologic boundary). Plot 2 maps the boundaries of the municipalities within the San Gabriel Valley. Plot 3 maps the census tract boundaries. Plot 4 consists of arcs defining land use polygons. Anderson Level III land use classification was used to define the boundaries of the polygons. Plot 5 is an aggregation of plot 4 into 13 general land use categories. In this plot the polygons were color encoded and shaded to pictorally display the 13 land use categories. Plot 6 is a zoom of the bottom right corner of the previous land use classification plot.

SECTION 2

Section 2 is a sequence of plots describing the relationship between contaminated wells and the population serviced by those wells. The first plot maps the location of wells by contaminant type and quantity. The contaminants are trichloroethylene (TCE), perchloroethylene (PCE) and carbon tetrachloride (CTC). The second plot displays boundaries of water purveyor districts within the San Gabriel Valley. The third plot utilized the information from the previous two plots to distinguish between water purveyor districts which either do or do not have contaminated wells. The final plot of the series maps the population densities within the contaminant-impacted water purveyor districts. This application of the GIS could be used to examine potential risks to the populace and prioritize areas for clean-up.

SECTION 3

Section 3 depicts interim steps and results of the reverse flow ground-water modeling which was performed for the San Gabriel Basin GIS Demonstration. The first plot in this series maps the potentiometric surfaces for the three dates that were used in the model.
The second plot displays the grid that was developed for the basin (aquifer). The ground-water flow model that was used required that the data be input into the model in a regular gridded format. Once the grid was developed, hydraulic conductivity, effective porosity, and the potentiometric surface arc data were interpolated to the grid. The next plot depicts hydraulic conductivity after interpolation to the grid.

Since the model required a rectangular grid, the largest rectangular area containing a majority of the contaminated wells was chosen. The rectangle chosen was in the center of the basin and contained 21 contaminated wells. The UTM coordinates of these wells were input to the model as starting points for the pathlines generated by the model. As the goal of the modeling procedure was to locate potential source areas of contamination, it was necessary to start the reverse trajectory pathlines at known points of present contamination. The historic potentiometric surface data was then used to by the model to estimate the reverse flow of water from sink to source. The first step was to generate 10 pathlines within a radius of 200 meters of each starting point (i.e., known contaminated wells) and calculate the ground-water flow path from 1980 to 1975, five years. The endpoints of the resulting pathlines were then used in the next iteration of the model. In this iteration the average of the 1980 and 1965 potentiometric surface data was used to continue the pathlines back in time 7.5 years to 1967. The endpoints of the pathline continuations were then used for the next model iteration. In this iteration 1965 potentiometric surface data were used to take the pathlines back in time another 7.5 years to 1960. This same process was used for two more iterations of the model, each continuing the estimation of flow paths back in time 7.5 years using the 1965 and 1950 averaged potentiometric surface data, and the 1950 potentiometric surface data sequentially.

The end result was a series of ten pathlines for each contaminated well (a total of 210 pathlines) estimating the flow path of contaminated water from sink to potential source for the period of 1980 to 1945. Based upon the existing information for the basin, EPA Region IX staff believed contamination occurred during the 1950's. To examine whether or not the model accurately estimated the flow paths from sink to source, eight sub-areas were chosen for historical aerial photographic analysis. Of the eight sub-areas selected, five sub-areas showed evidence of potential contaminant sources. The results of the modeling effort, the eight sub-areas, and an example from the historical aerial photographic analysis are displayed in the remaining three plates.

SUB-AREAS 4 & 5 - 1948

Analysis of the 1948 photographs reveal a potential pollution source in the northwest corner of Sub-area 4. There is a small industrial facility which has a rail access and a loading rack for the transfer of liquids. At least three railroad tank cars are present as are two tank trucks. Just west of the rail line is an area of heavy stains indicating numerous spills in the past. There are no storage tanks present so it is possible that this transfer point is at the end of an underground pipeline. A larger industrial facility to the southeast has one small lined pond which appears to contain liquid. Also there are two areas of mounded material which appears to be construction rubble. The only other significant developments within these two areas are the sand and gravel operations. There was no indication of any type of disposal within these pits.

INTERPRETATION CODE

BOUNDARIES AND LIMITS

- FENCED SITE BOUNDARY
- UNFENCED SITE BOUNDARY
- x x x x x x FENCE
- STUDY AREA

DRAINAGE

- DRAINAGE
- FLOW DIRECTION
- INDETERMINATE DRAINAGE

TRANSPORTATION / UTILITY

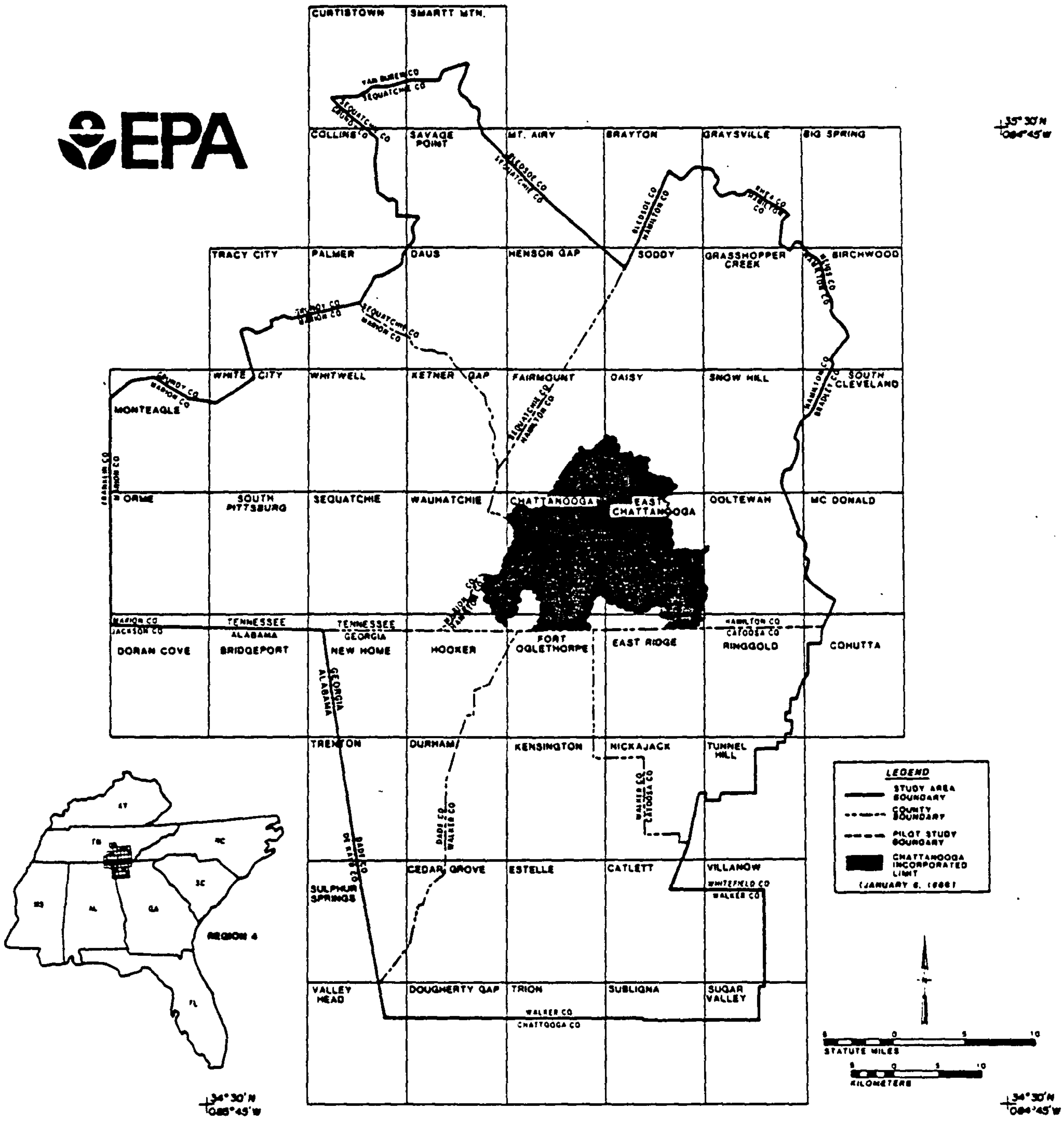
- = = = = = VEHICLE ACCESS
- RAILWAY

SITE FEATURES

	DIKE
	STANDING LIQUID
SL	STANDING LIQUID
	EXCAVATION, PIT (EXTENSIVE)
	MOUNDED MATERIAL (EXTENSIVE)
MM	MOUNDED MATERIAL (SMALL)
CR	CRATES/BOXES
DR	DRUMS
HT	HORIZONTAL TANK
PT	PRESSURE TANK
VT	VERTICAL TANK
CA	CLEARED AREA
DG	DISTURBED GROUND
FL	FILL
IM	IMPOUNDMENT
LG	LAGOON
OF	OUTFALL
SD	SLUDGE
ST	STAIN
SW	SOLID WASTE
TR	TRENCH
VS	VEGETATION STRESS
WD	WASTE DISPOSAL AREA
WL	WETLAND

Sub-areas 4 & 5, July 10, 1948.
Approximate scale 1 inch = 870 feet.

ENVIRONMENTAL METHODS TESTING SITE
CHATTANOOGA SMSA



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ENVIRONMENTAL METHODS TESTING SITE
CHATTANOOGA, TENNESSEE

Data Status, September 1986

by

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NOTE

This document contains data inventory information collected by Lockheed Engineering and Management Services Company, Inc., for Phase 1 of the EMTS project. More information will become available as new data sources are identified. (September 1986)

PROJECT SUMMARY

Project History

The Environmental Methods Testing Site (EMTS) was initiated by EPA's Office of Research and Development to provide a well characterized site for evaluation of various monitoring methods and models. This will enable better assessment of human exposure to toxic substances and support regulations in The Toxic Substances Act of 1976.

The EPA's Environmental Monitoring Systems Laboratory in Las Vegas, Nevada, (EMSL-LV) has the responsibility of site management, while the EPA EMSL at Research Triangle Park, North Carolina (EMSL-RTP) is responsible for data management. The tasks being performed by EMSL-LV and its contractors fall under three general headings: project management, Environmental Research Center, University of Nevada, Las Vegas (ERC-UNLV); quality assurance ERC-UNLV; and collection of data and implementation into a Geographic Information System (GIS) data base, Lockheed Engineering and Management Services Company, Inc (LEMSCO).

The first planning decisions were made during the week of August 12-15, 1985 when representatives of the Office of Toxic Substances (OTS), the Office of Research and Development (ORD), EMSL-RTP and EMSL-LV met. It was decided at that time that EMSL-RTP would manage non-spatial tabular data and EMSL-LV would manage spatial data. Integration of non-spatial data with spatial data would occur at EMSL-LV after pre-processing at EMSL-RTP.

The group also developed a list of data sets considered to be important to the development of a complete GIS data base. Listed below are the data sets selected.

1. Base Map
   - -political boundaries
   - -transportation
   - -drainage/water bodies
   - -topography
   - -land use/land cover
   - -soil/geology
   - -census geography

2. Sewerage System
3. Public Water Supply Pipe/Source Network
4. Public Buildings
5. Zip-code Boundaries
6. Industries: location, type, chemicals used, potential for air and/or water pollution
7. Geohydrology: well locations, groundwater characteristics
8. Demography: population, age, sex, economics, residence, and work place
9. Agricultural Practices
10. Monitoring Sites: locations, media, and sample data
11. Climatology: averages, and daily for specific sites
12. Other data sets: to be defined by individual projects and their objectives

Of these data layers, it was decided that the items listed under #1, Base Map, would be acquired first and incorportated into a GIS data base.

The first steps taken toward acquiring data for the GIS were to contact Federal, State, Regional, and local agencies, and inventory their existing data. This information was compiled into a data matrix book, and later inserted into the dBASE III Inventory File developed by ERC-UNLV. From the inventory information gathered, the base map data layers were purchased or acquired from the best source for that data. Table 1 lists the data sets acquired by LEMSCO and ERC-UNLV along with quantity, scale/resolution, and cost.

Table 1: A list of data sets purchased during FY86 associated with purchaser, scale/resolution, quantity, and cost. Combined, these data sets provide all of the information required for the base map except geology, plus some of the other desired data sets.

DATA NAME	ERC/LEMSCO PURCHASE	SCALE/ RESOLUTION	QUANTITY	COST
DLG	LEMSCO	1:24,000	16 (quads)	$1920.
DLG	LEMSCO	1:100,000	2 (quads)	$325.
DEM	LEMSCO	1:24,000	43 (quads)	$4325.
SPOT MSS	LEMSCO	20 meter	2 (SMSA)	$4020.
AERIAL PHOTO	LEMSCO ERC	1:24,000 "	3 copies 1 original	$8640. $10000.
ETAK	ERC	STREET/ CENSUS TRACT	1 (metro)	$5100.
DONNELLY MARKETING FILE	ERC	BLOCK	1 (SMSA)	$1800.
MONITORING STATIONS	ERC	POINT	1 (SMSA)	0.
SOIL SURVEYS	LEMSCO	SOIL TYPE	2 (counties)	0.
REACH FILE	ERC	POINT/STREAM	1 (SMSA)	0.
PUBLIC WATER SUPPLY NETWORK	ERC	PIPE	1 (metro) (200 maps)	0.
UTPP Urban Transportation Planning Package	ERC	UNKNOWN	1 (SMSA)	$4300.

SECTION 1

This section contains plots displaying data acquisition status of key data layers for the EMTS GIS data base. The plots are color encoded to show the availability of data based upon acquisition unit. Data for the EMTS is commonly available by quadrangle, county, or SMSA. The availability of data has been broken down into four categories.

* Obtained - the data has been acquired.
* Current availability - the data is currently available but has not been acquired for the EMTS at this time.
* Future availability - the data is not available, but will be available at some future date.
* Unavailable - the data is not available and is not presently scheduled for future availability.

SECTION 2

Section 2 contains plots of the data (coverages) presently incorporated into the EMTS data base. Selected features have been color encoded in most of the plots to demonstrate the ability of the GIS to attach attributes to map data. Attributes define point, line, and polygon features. For example, on page 2-4 red lines represent primary hard surface routes and hatched red lines are foot trails. The plots also display the extent of the data for the EMTS.