USING GEOGRAPHIC INFORMATION SYSTEMS FOR ENVIRONMENTAL DECISION MAKING

by

William H. McLemore and S. Jack Alhadeff

Department of Natural Resources
Environmental Protection Division
Georgia Geologic Survey

PROJECT REPORT NO. 13

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Department of Natural Resources
J. Leonard Ledbetter, Commissioner

Environmental Protection Division
Harold F. Reheis, Assistant Director

Georgia Geologic Survey
William H. McLemore, State Geologist

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1988

The Great Seal of Georgia
was created on a computer
using ARC/INFO software

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INTRODUCTION

GENERAL STATEMENT*

This document describes some of the results of the Georgia Environmental Protection Division's (EPD's) Phase II Comprehensive Data Management Project with the United States Environmental Protection Agency (EPA), Region IV. Basically, EPD was to evaluate the viability of using a computer-based Geographic Information System (generally referred to as a GIS) for environmental decision-making. That is, could an agency such as EPD develop information data bases, primarily maps, that would be useful in answering the following types of questions:

- Is a proposed new facility being sited in an environmentally acceptable area (e.g., a sanitary landfill away from and downgradient from public water supply wells)?
- If a spill were to occur, who would be affected?
- Which facilities have the greatest potential to cause significant pollution?
- Which facilities are permitted or are in compliance?
- To what portion of the State should new industries be directed (e.g., major water using industries are generally sited in the Coastal Plain where extensive ground-water resources occur)?
- Which facilities have or have not been inspected within a certain time period?
- Which facilities present the greatest actual or potential threat to human health or to the environment (e.g., where shall EPD direct its resources)?
- Which municipal water supply wells are vulnerable to pollution (e.g. Vulnerability Analysis as required by the Safe Drinking Water Act)?

The above examples represent only a few of the types of questions that environmental protection agencies are called upon each day to resolve. With the above in mind, the remainder of this report is directed at assessing the applicability of the GIS technology to the types of decisions that EPD must make. Lengthy discussions of the intricacies of programming or software applications are not provided; these are continually evolving and are best described by their vendors and/or developers.

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* The bulk of the data bases and GIS analyses were developed as part of a cooperative effort by EPD and the United States Geological Survey (USGS). The cooperation of the USGS was critical to the success of this project.

WHAT IS A GEOGRAPHIC INFORMATION SYSTEM?

A Geographic Information System (or a GIS) is not a new concept. Geologists, geographers and engineers have been applying the concept for over a hundred years. In simplest terms, a GIS represents the combining of information from two or more maps or data sources.

The GIS technology is laden with acronyms, and to some degree, a hodgepodge of Orwellian "new speak." Practitioners of GIS may speak in terms of "integrating data bases", "topological objects", "attribute data management", "raster versus vector data" and so forth. While the words are quite intimidating, the basic concepts of GIS, nevertheless, should be understandable to most technically trained persons and the products (typically maps or tables) should be understandable to virtually anyone. (Note: special terms are described in Table I).

The basic definition of a GIS as used by modern practitioners is:

> A Geographic Information System is an analytical mechanism for data capture, data management, data manipulation and analyses. Using the spatial nature of cartographic data, outputs are maps and/or tables, which can be referenced back to maps.

Figure 1 is an example of a GIS product from a recent Geologic Survey Bulletin (Griffin and Henry, 1984). This map shows the changes in shoreline for Wassaw Island between 1858 and 1982. To construct this map, the authors obtained copies of all coastal topographic survey maps or relatively recent aerial photography of Wassaw Island. The maps and photographs were converted to the same scale using a device called a Saltzman Projector*. Using latitude and longitude for reference, the high water line of Wassaw Island from each of the topographic maps or aerial photographs was traced onto a single sheet of paper. Thus, by comparing the high water lines, areas of accretion and erosion could be identified (Figure 2).

The difficulty with the above process is that such an effort, while relatively straightforward, is extremely labor intensive. The authors of the Wassaw Island maps had to spend many long hours over a hot and noisy machine. Consequently, because of the extensive time commitments necessary for a comprehensive analysis, GIS, in the past, has only had limited applications.

However, with the advent of relatively small, fast and versatile computers in the 1980's, algorithms were developed that could integrate cartographic data in a matter of seconds. This was the breakthrough for GIS; namely, an established but cumbersome technology was transformed by the computer into a technology that was both rapid and extremely flexible.

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* A Saltzman Projector is a machine consisting of mirrors and lenses that can project an image onto a drafting surface. Then by adjusting the lenses, the image can be projected at varying scales. Once the appropriate scale has been established, the image is traced onto a piece of paper.

TABLE I

SPECIAL TERMS

Digital Data:	A computer representation of map data stored in map units (i.e., degrees, minutes, seconds, etc.) or in arbitrary units (such as inches, or feet).
Digitizer:	An electronic peripheral to a computer where a map/map features can be processed into digital data. A digitizer has a fixed resolution (e.g., .001 in.) based on internal wiring and usually produces digital data in arbitrary units (such as inches or feet).
Grid or Raster Data:	A means of representing geographic data. This method represents a map as a grid of equally sized rectangles called grid cells. When polygon, line and point features are gridded they become aggregated as grid cells with identical attributes. Each grid cell is referenced in space by its row and column number within the grid. Grids allow for powerful math and analytical functions; but they are poor for graphical representation due to "stair-stepping" of grid cells.
Integration of Data Bases:	Integration of data bases involves combination of data coverages within the GIS. This means that several data bases, or selected portions of these data bases, are incorporated to create a larger data base.
Map Projection:	Since the earth is a sphere, some mechanism must be used to prepare a flat map from the spherical surface. A map projection is used to represent all or part of this spherical surface on a flat, 2-dimensional map.
Topology:	The spatial relationships or geometric configuration between connecting or adjacent features on a map, usually defined as any of the following: area definition, connectivity and contiguity.

TABLE I (Continued)

Vector Data:	A means of representing geographic data. Features on a map are represented by a series of vectors each having geographic coordinators. A point is a single vertex, linear features consist of multiple vertices, and polygons are linear features that are closed. Vectors are not particularly powerful for math and analytical processing, but they are excellent for graphical representation of data.

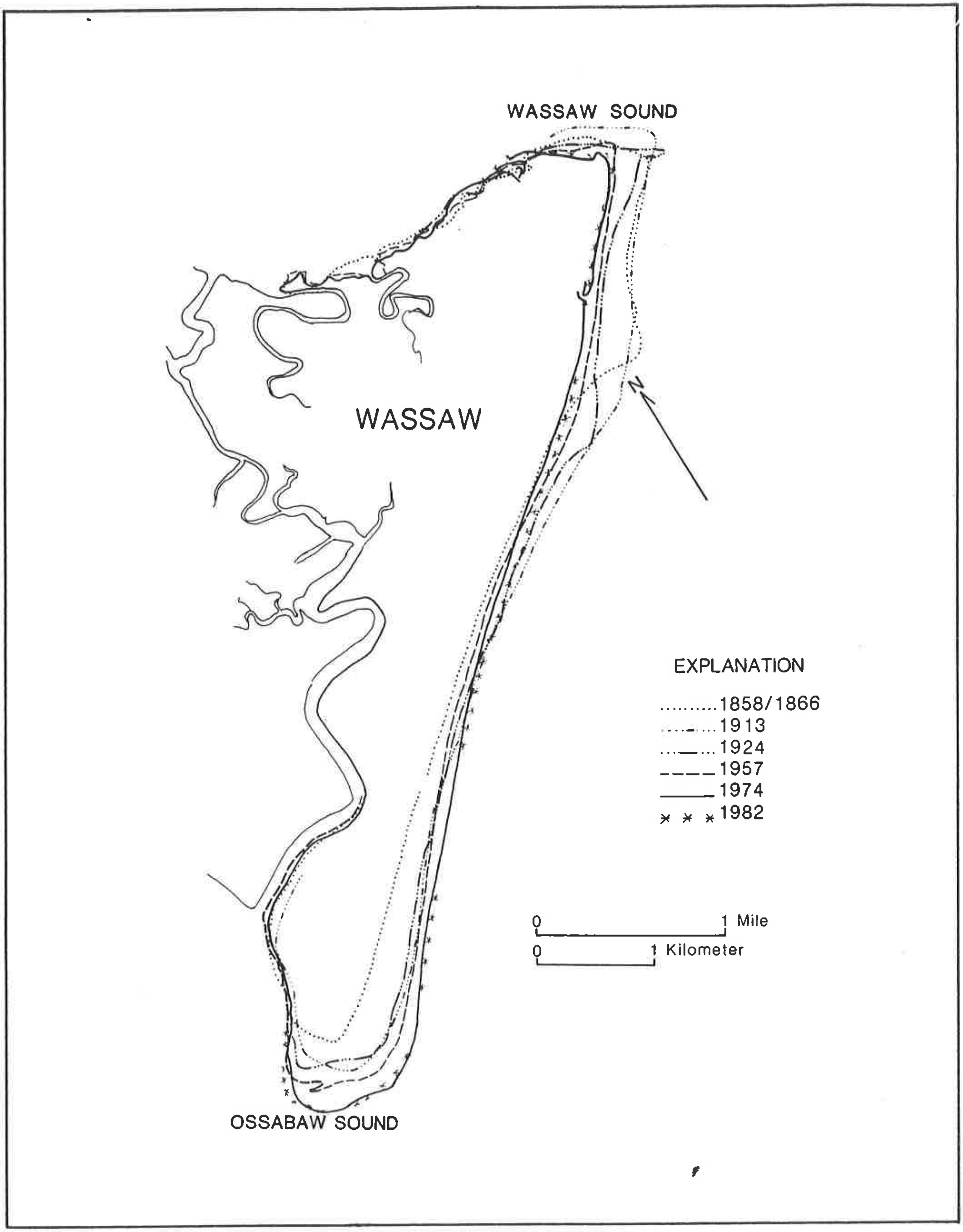

Figure 1. Wassaw Island MHW shoreline change, 1858-1982.

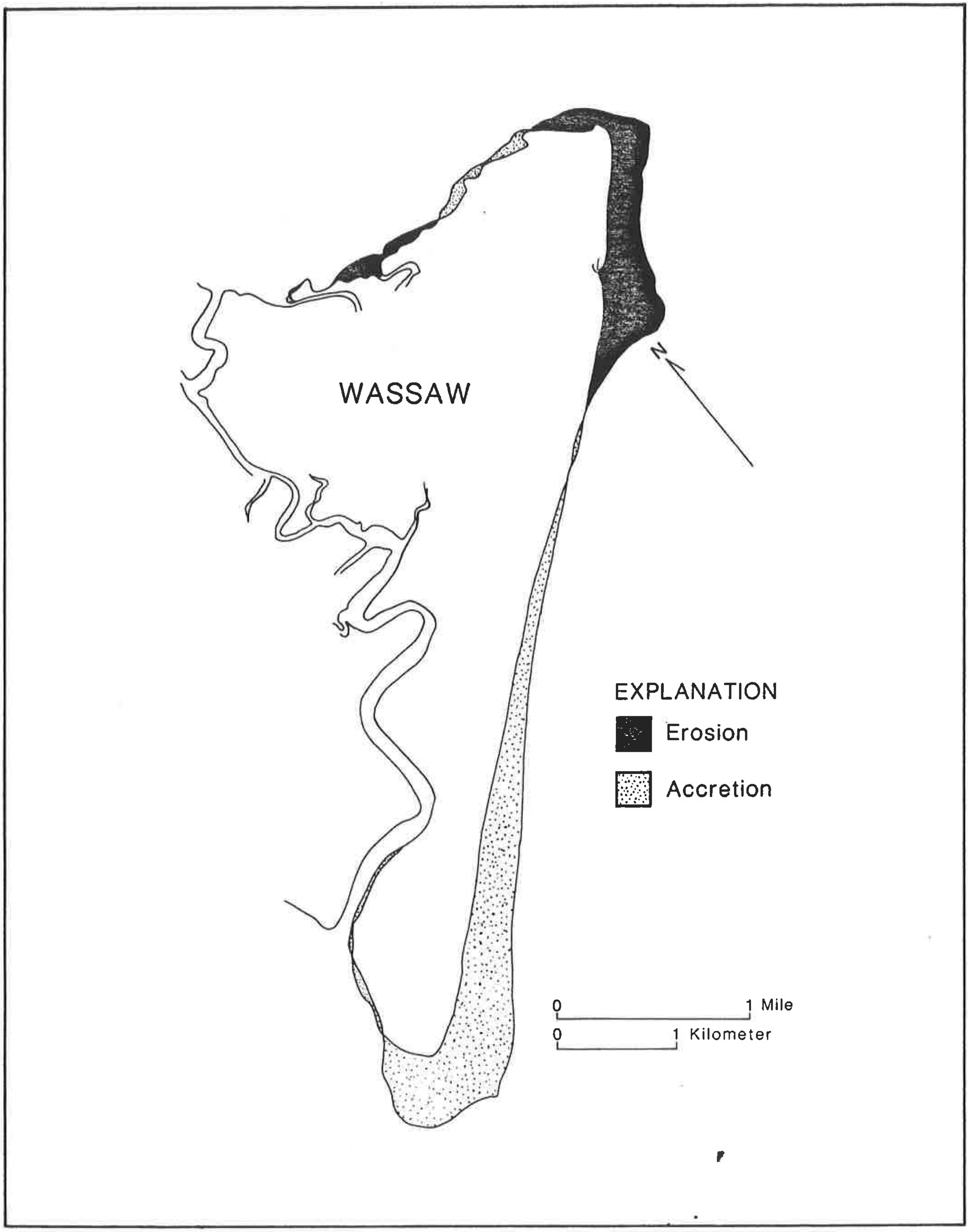

Figure 2. Wassaw Island net MHW shoreline change, 1858-1982.

ARC/INFO*

According to the 1987 edition of the User's Guide, ARC/INFO is a GIS used to automate, manipulate, analyze and display geographic (primarily map) data in digital format. It organizes geographic data using a relation and topological mode. This facilitates handling of two generic classes of spatial data: (1) location data describing the location and topology of point, line and area features; and (2) attribute data describing in narrative format the characteristics of these features. For example, locational data might be a map showing the location of a wastewater treatment facility in relation to roads and streams; attribute data, on the other hand, would be the facility name, address, telephone number, permit status, discharge volume, and so forth.

The ARC/INFO software system has been purchased by both the United States Geological Survey (USGS) District Office in Doraville, Georgia and the EPA Region IV. EPD, however, currently does not hold a license for ARC/INFO. This means that the software program does not reside on EPD's PRIME** 2550 minicomputer. Nevertheless, through the EPD-USGS joint funding agreement and the data management provisions of EPD-EPA grants, the computer facilities of both federal agencies may be used by EPD to access ARC/INFO. EPA, however, restricts access to only those persons trained by ESRI.

As mentioned earlier, ARC/INFO has two primary capabilities: namely handling of locational data and handling of attribute data. To the lay person, locational data may be thought of as a map showing points (e.g., any feature that can be expressed by latitude and longitude), lines (e.g., roads, streams, boundaries, etc.), and areas (e.g., rock outcrops, land-use patterns, soil classes, lakes, etc.). Attribute data, on the other hand, may be thought of as narrative or descriptive information.

The ARC/INFO system is unique in that different maps derived from different data sources can be integrated or "stacked, one on top of another." For example, Figure 3 is an ARC/INFO generated geologic map of Camden County and Figure 4 is an ARC/INFO generated map showing public water supply wells in Camden County. Figure 5, in turn, is an integrated map showing both geology and public water supply wells. This "stacked" map is especially useful in that the general geology in the immediate vicinity of each well is illustrated. Thus, environmental managers are in the position of being better able to evaluate whether or not the wells are in proximity to recharge areas, geologic formations that may be susceptible to pollution or contamination, geologic formations that may contain mineral resources, and so forth. Similarly, other maps can be stacked and incorporated into the analysis.

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* ARC/INFO is a registered trademark of the Environmental Systems Research Institute, Inc. (ESRI Systems Inc., 380 New York Street, Redlands, California 92373).

** Prime Computer, Inc., Prime Park, Natick, Massachusetts 01700.

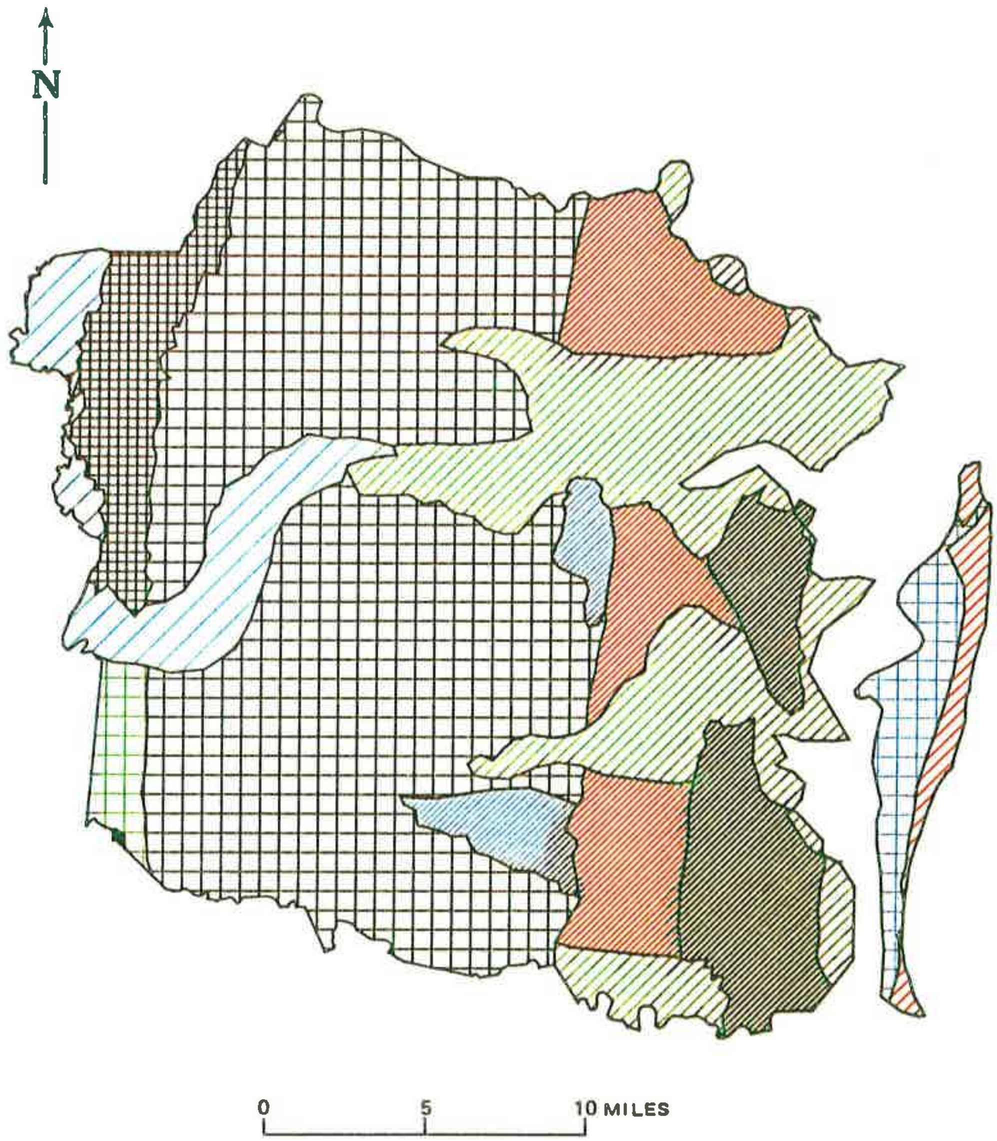

Figure 3A. Geologic map of Camden County.

PCD	CHARLTON FORMATION AND DUPLIN MARL
QAL	STREAM ALLUVIUM and undifferentiated deposits
QHI	HOLOCENE SHORELINE COMPLEX (island facies)
QHM	HOLOCENE SHORELINE COMPLEX (marsh facies)
QPAI	PRINCESS ANNE SHORELINE COMPLEX (island facies)
QPAM	PRINCESS ANNE SHORELINE COMPLEX (marsh facies)
QPMI	PAMLICO SHORELINE COMPLEX (island facies)
QPMM	PAMLICO SHORELINE COMPLEX (marsh facies)
QPNM	PENHOLOWAY SHORELINE COMPLEX (marsh facies)
QSBI	SILVER BLUFF SHORELINE COMPLEX (island facies)
QTI	TALBOT SHORELINE COMPLEX

Figure 3B. Legend to geologic map of Camden County. Geologic units listed in alphabetical order of symbol.

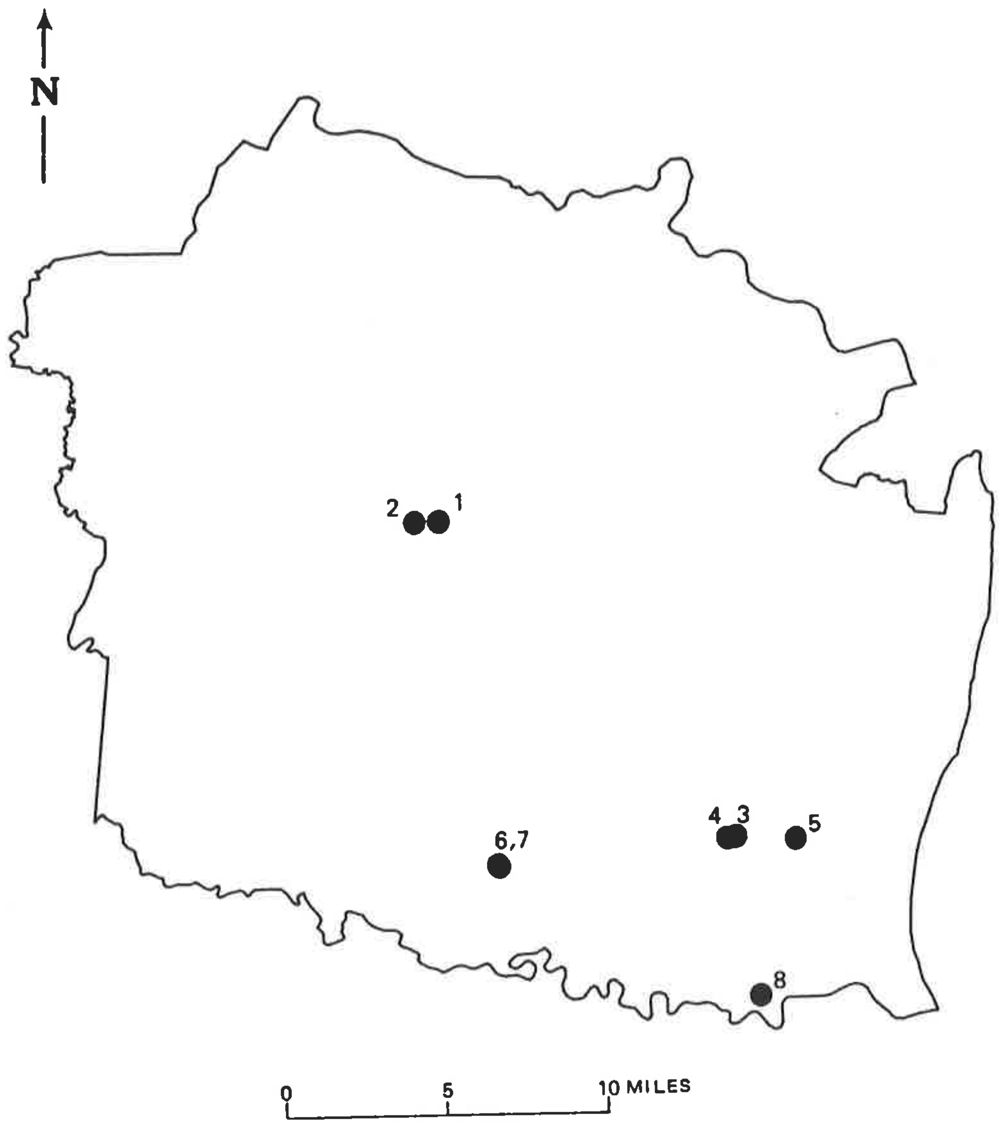

Figure 4. Map of Camden County showing location of public water supply wells (with ID numbers).

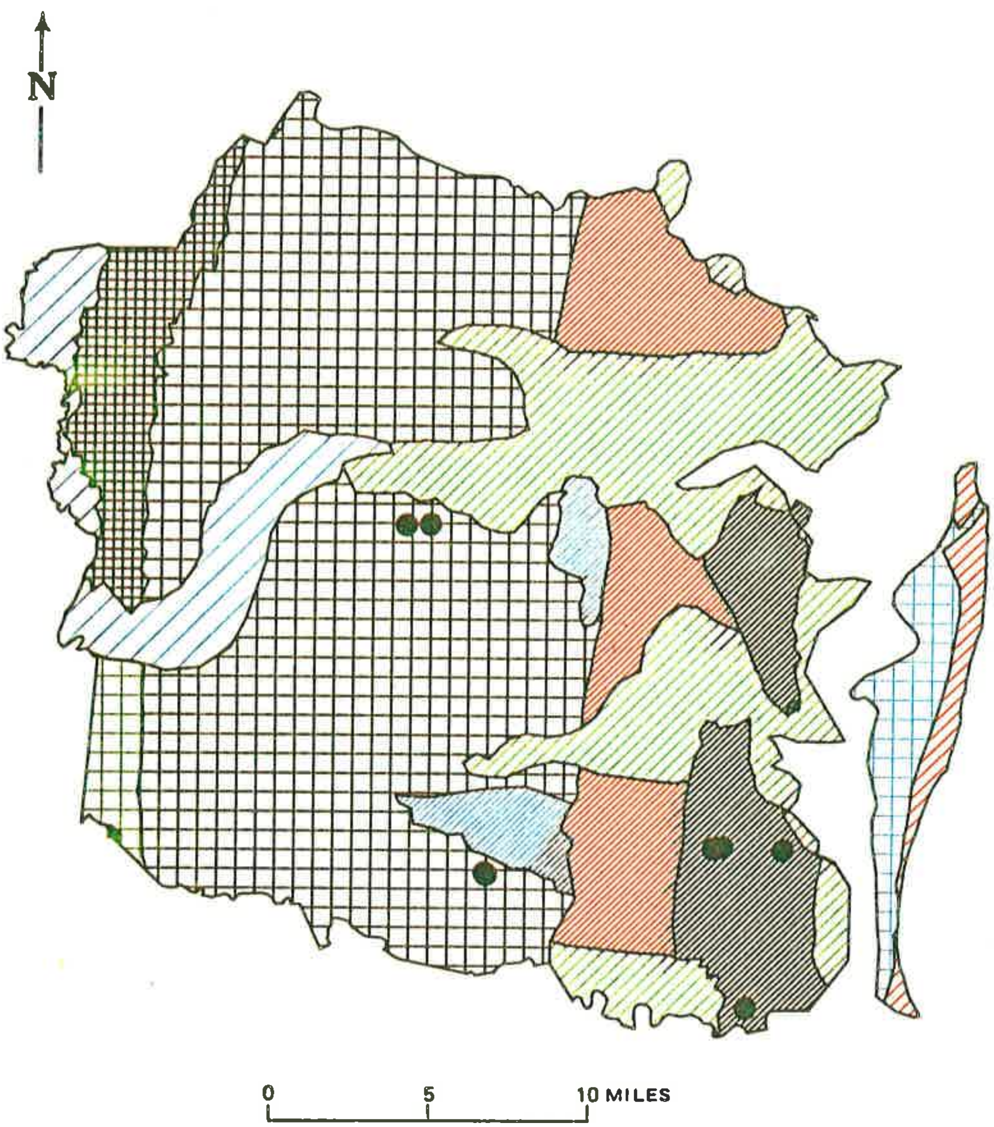

Figure 5. Integrated map of Camden County showing geology and public water supply wells (refer to Figure 3 for legend to geologic map and Figure 4 for identification numbers for public water supply wells).

Attribute or narrative data provide descriptive information for the various map elements. Figure 6 is the attribute data for the eight public water supply wells for Camden County shown on Figure 4.

Another valuable aspect of the ARC/INFO is the ability to create buffers (Figure 7 is a map of Camden County showing a two-mile buffer surrounding each public water supply well) or selectively edit maps (Figure 8 is an edited version of the Camden County geologic map showing only the marsh of Princess Anne Shoreline Complex).

Some examples of other ARC/INFO manipulations could involve:

(1) Developing a map and listing all of the water supply wells within a certain distance of a sanitary landfill.

(2) Developing a map and listing of all environmental facilities out of compliance.

(3) Developing a map and listing of facilities having permits scheduled to be renewed in the current fiscal year.

(4) Developing a map of a facility showing location of leaks along underground pipelines.

(5) Developing a map and listing of all facilities handling a particular pollutant.

(6) Developing a map and listing of water use by city, county, congressional district, etc.

(7) Developing a map showing the distribution of low permeability soils within a county.

As part of the FY 1987 EPD-USGS joint funding agreement, the Triangulated Irregular Network (TIN) software program was purchased to store, manage and analyze three-dimensional surfaces for ARC/INFO. Basically the TIN program permits surfaces such as topography, depth, thickness and slope to be integrated with one another. A depth to aquifer from land surface map represents the type of product that TIN is capable of generating. Moreover, TIN display capabilities include viewing of profiles or three dimensional surface displays at specified viewing angles, orientations and resolutions. Figure 9 is a TIN generated 3-dimensional elevation map of Walton County.

<u>THE PHASE I DATA MANAGEMENT PROJECT</u> (modified from Chelsea International Corp., 1986).

In 1984, EPD was faced with a serious data management problem; namely, how to deal with the conversion of its ADP support systems as the central State computer center was converted from UNIVAC to IBM. The major cost

```
                       1
AREA                 =         0.000
PERIMETER            =         0.000
PS#                  =    1
PS-ID                =   90
PUBLIC.SUPPLY-ID=  110
LONGITUDE            =81.7077
LATITUDE             =30.9602
NUMBER               =020M0302
SOURCE_NAME          =CITY OF WOODBINE
SOURCE-TYPE          =1
SOURCE-CODE          =G
HUC                  =03070201
COUNTY               = 39
SOURCE               = 2
POP                  =        910
GW-WITH              =    0.08
SW-WITH              =    0.00
SYMBOL               =     2
```

```
                       2
AREA                 =         0.000
PERIMETER            =         0.000
PS#                  =    2
MORE?
PS-ID                =   89
PUBLIC.SUPPLY-ID=  109
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LATITUDE             =30.9605
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SOURCE-TYPE          =1
SOURCE-CODE          =G
HUC                  =03070201
COUNTY               = 39
SOURCE               = 2
POP                  =        910
GW-WITH              =    0.08
SW-WITH              =    0.00
SYMBOL               =     2
```

```
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PERIMETER            =         0.000
PS#                  =    3
PS-ID                =   91

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LATITUDE             =30.8019
MORE?
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SOURCE-CODE          =G
HUC                  =
COUNTY               = 39
SOURCE               = 2
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SW-WITH              =    0.00
SYMBOL               =     2
```

```
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PERIMETER            =         0.000
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PS-ID                =   93
PUBLIC.SUPPLY-ID=  114
LONGITUDE            =81.5594
LATITUDE             =30.8013
NUMBER               =020M4B02
SOURCE_NAME          =KINGS BAY NAVAL SUBMARINE
SOURCE-TYPE          =1
SOURCE-CODE          =G
MORE?
HUC                  =
COUNTY               = 39
SOURCE               = 2
POP                  =          0
GW-WITH              =    0.00
SW-WITH              =    0.00
SYMBOL               =     2
```

Figure 6A. Attribute data for public water supply wells in Camden County.

```
                    5
AREA                =         0.000
PERIMETER           =         0.000
PS#                 =    5
PS-ID               =    92
PUBLIC.SUPPLY-ID=   112
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LATITUDE            =30.7991
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SOURCE_NAME         =KINGS BAY NAVAL SUBMARINE
SOURCE-TYPE         =1
SOURCE-CODE         =G
HUC                 =
COUNTY              = 39
SOURCE              = 2
POP                 =         0
MORE?
GW-WITH             =    0.01
SW-WITH             =    0.00
SYMBOL              =     2
```

```
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PERIMETER           =         0.000
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LATITUDE            =30.7944
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SOURCE_NAME         =CITY OF KINGSLAND
SOURCE-TYPE         =1
SOURCE-CODE         =G
HUC                 =03070204
COUNTY              = 39
SOURCE              = 2
POP                 =     2,008
GW-WITH             =    0.53
SW-WITH             =    0.00
SYMBOL              =     2
```

```
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LONGITUDE           =81.6847
LATITUDE            =30.7936
NUMBER              =020M0102
SOURCE_NAME         =CITY OF KINGSLAND
SOURCE-TYPE         =1
SOURCE-CODE         =G
HUC                 =03070204
COUNTY              = 39
SOURCE              = 2
POP                 =     2,008
GW-WITH             =    0.53
SW-WITH             =    0.00
SYMBOL              =     2
```

```
                    8
AREA                =         0.000
PERIMETER           =         0.000
PS#                 =    8
PS-ID               =    88
MORE?
PUBLIC.SUPPLY-ID=   107
LONGITUDE           =81.5455
LATITUDE            =30.7250
NUMBER              =020M0201
SOURCE_NAME         =CITY OF ST. MARYS
SOURCE-TYPE         =1
SOURCE-CODE         =G
HUC                 =03070204
COUNTY              = 39
SOURCE              = 2
POP                 =     3,596
GW-WITH             =    0.33
SW-WITH             =    0.00
SYMBOL              =     2
```

Figure 6B. Attribute data for public water supply wells in Camden County.

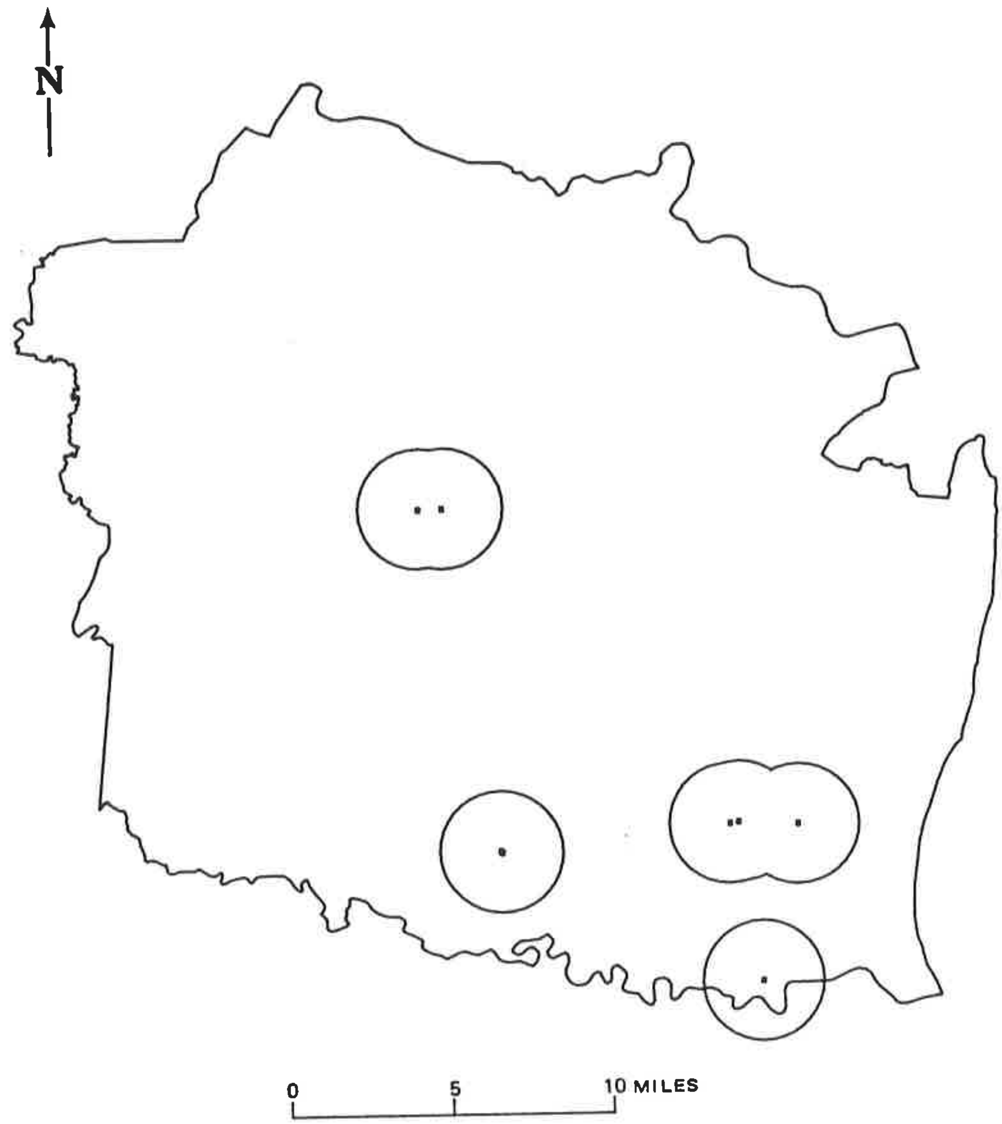

Figure 7. Map of Camden County showing two-mile buffer around each water supply well.

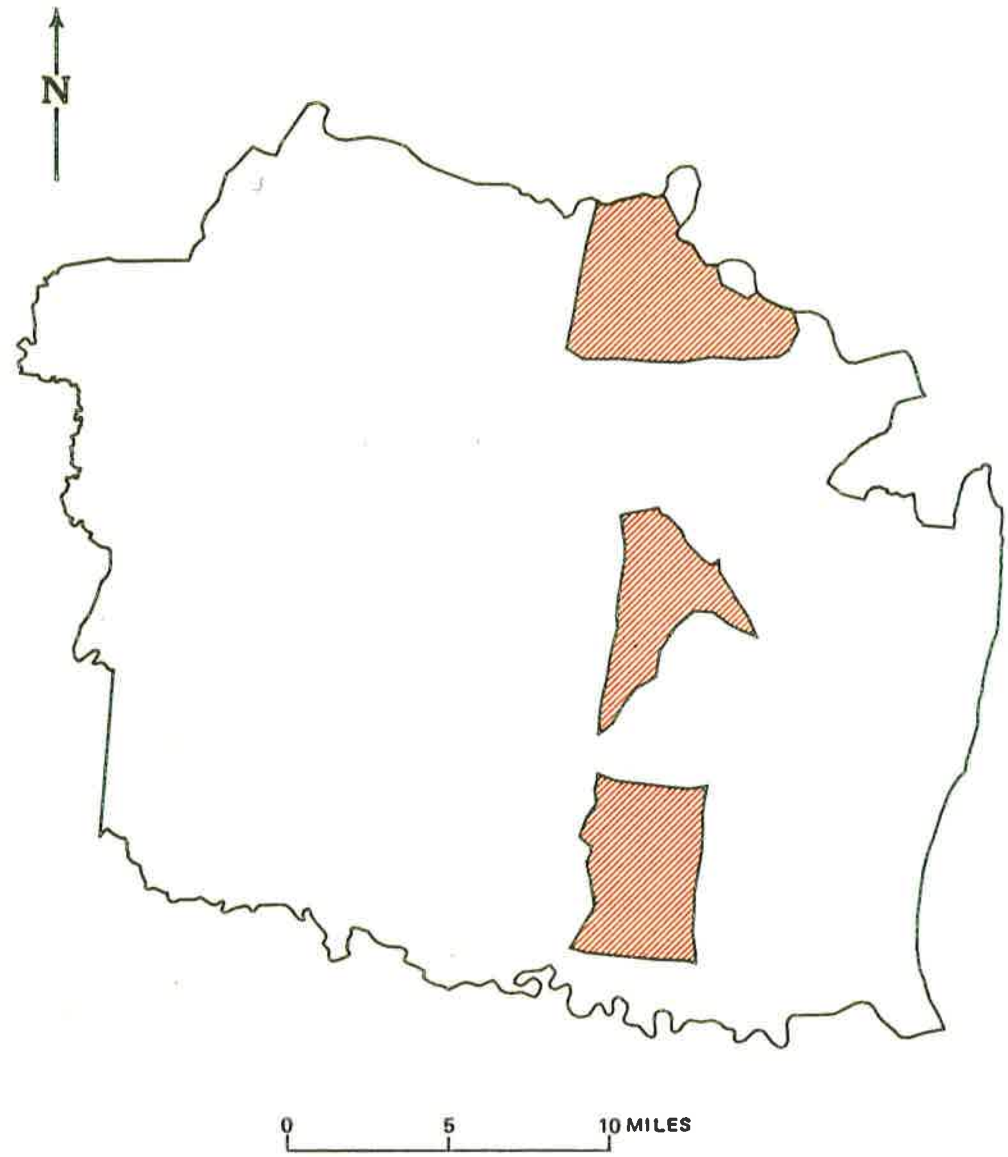

Figure 8. Map of Camden County showing marsh of the Princess Anne Shoreline Complex.

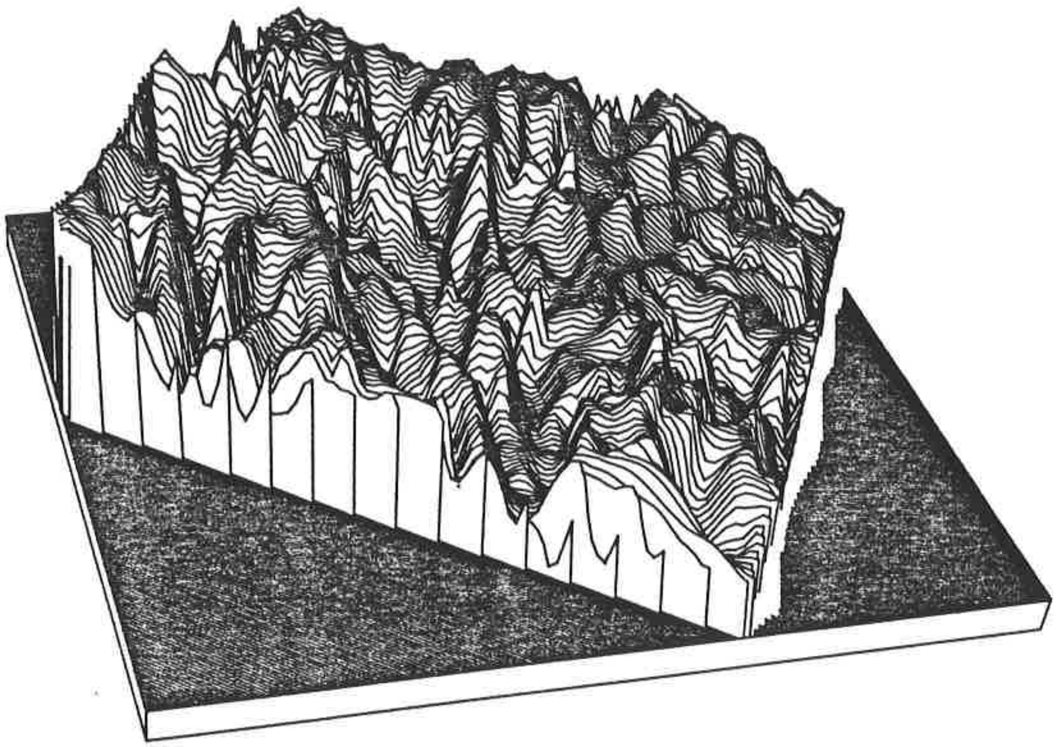

Figure 9. TIN generated three-dimensional elevation map of Walton County (lower block is oriented north-south and east-west).

of converting existing software, the short timeframe to accomplish the conversion, and the limited access to persons skilled in data management pointed to a need for a comprehensive assessment of EPD's overall data management needs. Inasmuch as EPA Region IV had just begun such an analysis of its own information management needs, the Region and EPD entered into an agreement whereby the data management needs of EPD would be evaluated by Region IV's project consultant, Chelsea International Corporation.

Chelsea recommended that EPD implement an information management strategy that included direct use of EPA's existing program management systems. A large mini-computer was recommended to manage the automated high-speed telecommunications links to EPA's national IBM data processing network as well as to serve the EPD's in-house data processing needs.

Following analysis of Chelsea's recommendation, EPD decided to fully implement the program and requested that Region IV use Georgia program management grant funds to purchase a PRIME 2550 minicomputer through an existing EPA contract. This request was reviewed and approved by EPA.

Because of the potential for changing the way EPA would deal with automated and manual exchange of information with other states, the agency decided to make the Georgia effort a National Pilot Project with the results to be presented at a national conference. The joint EPD-EPA project included the installation of the computer, operating software, telecommunications equipment and software, as well as EPD staff training.

As the Pilot or Phase I Project progressed, it became apparent that voluminous amounts of data and numbers were being generated; and, to some degree, they only could be interpreted by those persons who were intimately familiar with the programs from which the data originally were compiled. In other words, much of the data could not be utilized in an effective manner; and, for practical purposes, ran the risk of being ignored in the decision-making process.

Because of the concern that data would become no more than "stacks of paper," Chelsea recommended that the Pilot Project be expanded with some of the data being incorporated into a GIS. To achieve this, EPA entered into an interagency agreement with the Georgia District of the USGS, who held an ARC/INFO license, to develop several GIS data bases for a three county area in southwest Georgia. The three counties (Dougherty, Lee and Terrell) were selected by EPD as having both urban and rural characteristics as well as being in the recharge area of several major drinking water aquifers. EPD personnel, in turn, working with USGS personnel developed three hypothetical ground-water management scenarios; namely, siting a sanitary landfill, general susceptibility of ground water in recharge areas to non-point source pollution, and identifying those hazardous waste facilities upgradient from public water supply wells.

The three scenarios were quickly developed and presented at a July 1986 national conference in Atlanta, sponsored by the Association of State and Interstate Water Pollution Control Administrators (ASIWPCA). Because of EPA's commitment to spread the results of the Phase I project, the agency provided grant funds so all states could send representatives to the conference. As part of the conference, a work station with a color monitor was set-up; then, during scheduled intermissions, the logic behind the development of the three scenarios was explained to interested persons.

THE PHASE II DATA MANAGEMENT PROJECT

As a result of the favorable comments that EPA Administrator Lee Thomas and Region IV Administrator Jack Ravan received at the ASIWPCA Conference, a decision was made to proceed beyond the Pilot Project and initiate a joint EPD-EPA Comprehensive Data Managment Project (e.g. the Phase II project). Unlike the Phase I project, which dealt with the mechanics of getting on-line and using implementation procedures for data base management systems, the Phase II project was designed to demonstrate the use of integrated information approaches to specifically support environmental decision-making in managing for environmental results. In order to demonstrate how data management systems could more effectively support environmental decision-making, three related but distinct areas of activity were included:

(1) Implementation of a GIS.

(2) Implementation of data integration to support decision-making.

(3) Identification and use of data base systems to support toxics and risk assessment programs.

Activities (2) and (3) above are described in separate reports to be submitted by EPD to Region IV. This report, therefore, only addresses the implementation of a state-wide GIS for Georgia.

The GIS technology offers a unique opportunity to more effectively utilize the increasingly vast amount of environmental, geologic, hydrologic and anthropogenic data so that EPD can concentrate funding and personnel on the most pressing environmental problems. EPD believes that utilization of GIS also should help insure the proper management of Georgia's environmental resources so that correcting one environmental problem would not worsen another environmental problem.

As part of its long-term planning process, EPD previously had determined ground-water management (e.g., implementation of Georgia's protection strategy) as a critical management issue that needed to be addressed and effectively implemented over calendar years 1987-1990. To augment and accelerate completion of Georgia's ground-water protection strategy, EPD identified several key areas, where GIS was particularly attractive. In particular, EPD needed effective management for the following:

(1) Locating sanitary landfills for ground-water protection.

(2) Identifying hazardous waste facilities that should receive priority attention.

(3) Identifying recharge areas susceptible to non-point source pollution from septic effluent and from agricultural chemicals.

For Phase II, EPD proposed to develop and use a series of GIS data bases (e.g., maps) upon which some of the initial decisions regarding these three matters could be made. Obviously, each of these is a multiyear evaluation and could not be completely resolved during the time frame of the Phase II project. In addition to the aforementioned application of GIS to ground-water protection, the technology could be used immediately for other applications. One of these would be to help identify favorable areas in north Georgia for regional water supply reservoirs.

The above four scenarios constitute the Phase II GIS program. Basically by utilizing the GIS technology so that decisions could be made in these four areas, EPD would have demonstrated that the technology is a viable tool for managers to make a wide variety of environmental decisions. In other words, the Phase II project would remove the technology from a computer "concept" to "real-world" management applications.

As the Phase II project progressed, additional applications of the GIS technology become apparent. One of these involved radon. In December 1987, EPD was requested by the Georgia General Assembly to provide an assessment of radon danger potential in the State. As part of this assessment, GIS generated maps were prepared illustrating those zip codes having high radon levels superimposed on a geologic map showing rock formations having relatively high natural concentrations of radioactive minerals.

Also from EPD's FY 1988 grant from EPA as part of the Safe Drinking Water Act, EPD is being required to initiate Vulnerability Analyses of public water supply wells. Vulnerability Analyses, which involve identifying potential sources of pollution in the vicinity of public water supply wells, are particularly amenable to being performed using the GIS technology.

WALTON COUNTY TEST CASE

The data bases that were developed as part of EPD's Phase I and Phase II projects involve thousands of facilities as well as a number of detailed and complex maps. Because of the extremely large amount of data, statewide maps tend to be cluttered and difficult to read on an 8½" x 11" sheet of paper. Therefore, for the purposes of illustrations for this report, most of the data bases and maps and all of the decision scenarios are presented for a single county, Walton County.

Walton County (Figure 10) is in the Piedmont Physiographic Province of Georgia and is approximately midway between Atlanta and Athens. Until the 1970's, Walton County was mainly rural in character with some light industry. However, because of its proximity to both Atlanta and Athens, the county, during the 1980's, began to experience significant population growth. Estimated population and water use in 1985 for Walton County are 33,000 persons and 4.67 mgd, respectively. As a result of the increasing population, there has been an increase in the volume of wastes generated

Figure 10. Map of Georgia showing the location of Walton County.

as well as there are more people dependent on both surface and ground-water. At one time, the rural population could use their wells with little worry of possible pollution; however, as more and more houses are built, effluent moving from one house's septic system to another house's well should not be dismissed. In a similar light, the cities of Monroe and Social Circle, sooner or later, will need to increase their water supply to provide new residents and new industry with drinking water. These new water supplies, regardless of whether they are from surface or ground-water sources, need to be protected. Thus, there is a critical need to know the location of potential sources of pollutants.

One additional point needs to be made. While Walton County represents a test case, similar maps and analyses can be made for other Georgia counties. The geology, hydrology and demography will vary from place to place; but the general GIS methodology is applicable throughout the State.

DATA BASES

INTRODUCTION

Thirty six state-wide Georgia data bases have been entered into the GIS using ARC/INFO. Of these, four were developed as part of the EPD-USGS joint-funding agreement prior to Phase I; eight were developed for Phase I; and twenty four were developed for Phase II. Each of the above is identified on Table II including name, scale, sources and status (e.g., completed, partially processed, etc.). A short general discussion of each data base follows. Where appropriate, an ARC/INFO generated map for Walton County or, in some cases, a State-wide map illustrates the data base.

POINT DATA

Geographic Names: The geographic names data base was developed prior to the Phase I project by the USGS and identifies common geographic names such as populated places, schools, cemeteries, etc. Figure 11 is a map of Walton County showing county boundaries and the names of populated places proximal to the centroids of the locale.

Ground-Water Site Inventory (GWSI): As part of the EPD-USGS joint funding agreement, the USGS continually identifies wells from which useful geologic and hydrologic data can be obtained. These wells, typically field-verified by USGS personnel, are located by latitude and longitude. Attribute data are available for the majority of these wells. The GWSI, however, does not always contain data on all public or industrial water supply wells in a county; rather the GWSI only identifies those wells where such attribute parameters

TABLE II

GIS DATA BASES

NAME OF DATA BASE	SCALE	SOURCE	STATUS/COMMENTS
POINT DATA:			
Geographic Names	--	USGS	Processed
Ground Water Site Inventory	--	USGS	Processed
Water Use Sites - Withdrawals	--	USGS	Processed/Updating
Water Use Sites - Discharges	--	USGS	Processed/Updating
Minor Facilities Data	--	EPD	In House/Not Processed
Sanitary Landfill Facilities	--	EPD	Processed (IIMS available)
Solid Waste Facilities	--	EPD	Processed (IIMS available)
High Hazard Dams	--	EPD	Processed (IIMS available)
CERCLA Sites	--	EPA	Processed (IIMS available)
Hazardous Waste Sites	--	EPD	Processed
Stream Gauging Stations	--	USGS	Processed
Surface Water Quality Stations	--	USGS	Processed
Georgia Ground-Water Monitoring Network	--	EPD	Processed
Surface Water Impoundments	--	EPD	Processed
High Recharge Impoundments	--	EPD	Processed
Pesticide Loading Data Base	--	USGS	Processed
Census Bureau Population Centroids	--	Census Bureau	Processed
LINE DATA:			
DLG Data for GA: Hydrography	1:100,000	USGS	Processed
Roads and Trails	1:100,000	USGS	Processed
Railroads	1:100,000	USGS	Processed
Pipelines	1:100,000	USGS	Processed
Major Roads	1:100,000	USGS	Processed
Clayton, Claiborne and Floridan Depth to Aquifer	1:500,000	EPD and USGS	Processed
Floridan Aquifer Potentiometric Surface/Flow Direction	1:500,000	EPD and USGS	Processed
River Reach File	1:500,000	EPA	Processed
Five (5) cfs 1986 Drought Stream Flow Data	1:500,000	USGS	Processed

TABLE II (Continued)

NAME OF DATA BASE	SCALE	SOURCE	STATUS/COMMENTS
POLYGON or AREA DATA:			
DEM Data for GA: Elevation Data	1:250,000	USGS	In House/Partially Processed
Slope	1:250,000	USGS	In House/Partially Processed
DEM Data for GA: Elevation Data	1:250,000	NOAA, et al	Processed
Land Use/Land Cover - Level II	1:250,000	USGS	Processed
Land Use/Land Cover - Level I	1:250,000	USGS	Processed
County Boundaries	1:250,000	USGS	Processed
Hydrologic Unit Boundaries	1:250,000	USGS	Processed
Census Tract Boundaries	1:250,000	USGS	Processed
Most Significant Recharge Areas	1:500,000	EPD	Processed
Geology	1:2,500,000	USGS	Processed
Geology	1:500,000	EPD	Processed
Zip Code Boundary File	---	USGS - Proprietary source	Processed
Public Lands: National Forests	1:24,000	USDA	Processed
National Parks	1:24,000	DOI	Acquiring Maps
Lakes Reservoirs	several	COE and TVA	Acquiring
Military Reserves	1:2,000,000	USGS	Processed
State Parks	1:24,000	DNR	Processed
Soils - Statewide	1:750,000	SCS	Processed
Soils - County	1:250,000	EPD, GA DNR	In House/Partially Processed

IIMS is EPD's Integrated Information Management System. The Facility ID Module of this system contains accurate and up-to-date information.

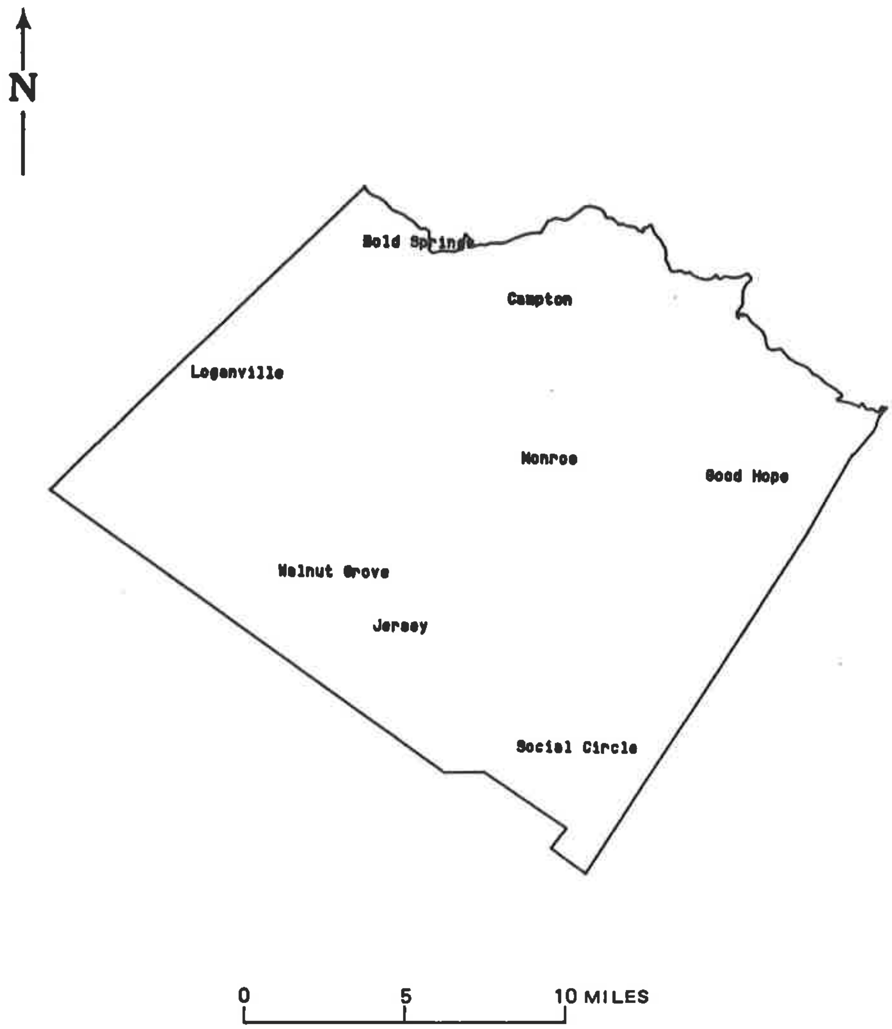

Figure 11. Map of Walton County showing names of populated places.

as depth, aquifer, yield, construction characteristics, etc. are known. Figure 12 is a map of Walton County showing those wells in the GWSI.

Water Use Sites - Withdrawals: EPD and the USGS, for the past eight years, have identified and located the majority of all public water supply systems for surface and ground water throughout the State. Considerable attribute information is available for most of the sites. Except for a few very small (and low volume) users, such as trailer parks, the data base is complete. Sources of data are identified in Table III. Figure 13 is a map of Walton County showing two groundwater well sites and two surface water withdrawal sites.

Water Use Sites - Discharges: Coincident with gathering withdrawal information (see above), the files of the municipal and industrial wastewater programs of the Water Protection Branch of EPD were reviewed. From these files, the location and general characteristics (e.g., the attribute data) of wastewater discharge sites have been entered into the GIS. These also include spray irrigation facilities. The data base is complete except for a few minor facilities. NPDES discharge sites in Walton County are shown on Figure 14.

Minor Facilities Data: As part of the Phase II work effort, personnel from EPD's Regional Offices visited all permitted facilities, for which they are responsible, during November and December of 1987. Using a LORAN-C device, they measured latitude and longitude. While latitude and longitude were known for the majority of the permitted major facilities, the LORAN-C readings will be used to establish the locations of the minor facilities. In addition, the LORAN-C readings for the major facilities will be cross-checked with existing data bases for quality control purposes. The LORAN-C readings are scheduled to be entered into the GIS during the spring and summer of 1988.

Sanitary Landfill Facilities: Approximately 211 sanitary landfill sites with some limited attribute information have been entered into the GIS. These data were provided by the Land Protection Branch of EPD. Two sanitary landfill sites are located in Walton County (Figure 15).

Solid Waste Facilities: Currently there are 79 solid waste landfills in Georgia. These landfills, which do not handle putrescible or hazardous wastes, are used to dispose of construction debris, old appliances, and other non-leachate generating wastes. Their locations and some limited attribute data, which were provided by the Land Protection Branch, have been entered into the GIS. None of these occur in Walton County.

High Hazard Dams: The Water Resources Management Branch of EPD administers the Safe Dams Programs. Currently 257 dams are considered as "high-hazard" or Class I dams. One of these occurs in Walton County (Figure 16). No attribute data, as yet, have been entered into the GIS on these dams.

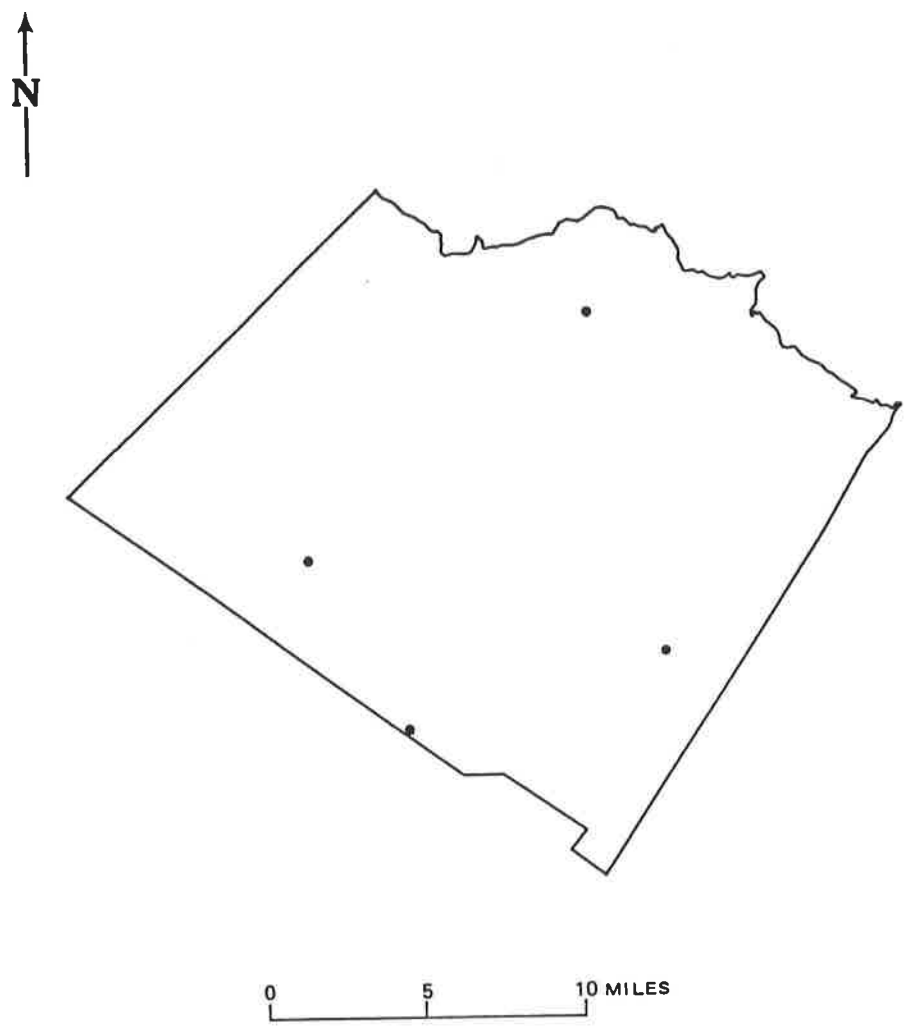

Figure 12. Map of Walton County showing locations of wells in GWSI.

TABLE III

DATA SOURCES FOR WATER USE SITES

WATER USE CATEGORY	DATA SOURCE	TYPE OF DATA PROVIDED
Public Supply	Permit files, Water Resources Management Branch (WRMB), Environmental Protection Division (EPD)	Withdrawals by permitted users
	Operators of large municipal systems (mail survey)	Population served, interconnection of systems
	Ground Water Program, WRMB, EPD	Population served by small public supplies (subdivisions and mobile home parks)
Domestic	U.S. Bureau of Census	County and city populations
Commercial	Permit files, WRMB, EPD	Withdrawals by permitted users
	1980 inventory of small users (<100,000 gal/d) by Ground Water and Surface Water Programs, EPD	Estimated water use
Industrial	Permit files, WRMB, EPD	Withdrawals by permitted users
Livestock	Georgia Crop Reporting Service Georgia Dept. of Agriculture Cooperative Extension Service U.S. Bureau of Census	Animal populations by county
Irrigation	Cooperative Extension Service 1984 Irrigation Survey	Crop areage and inches applied by county
Thermoelectric Power Generation	Permit files, WRMB, EPD	Withdrawals by power plants
Hydroelectric Power Generation	Plant owners	In-stream use by hydroelectric facilities

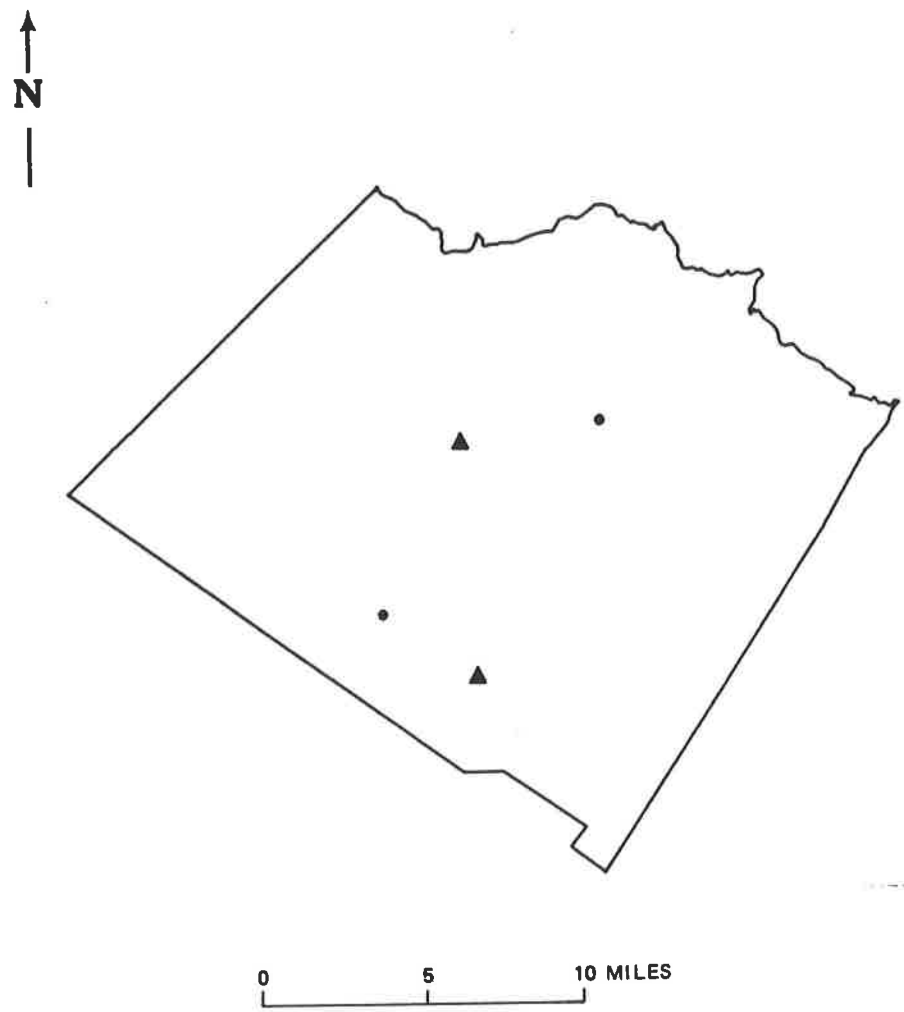

Figure 13. Map of Walton County showing water withdrawal sites (dots represent wells, triangles represent surface water intake structures).

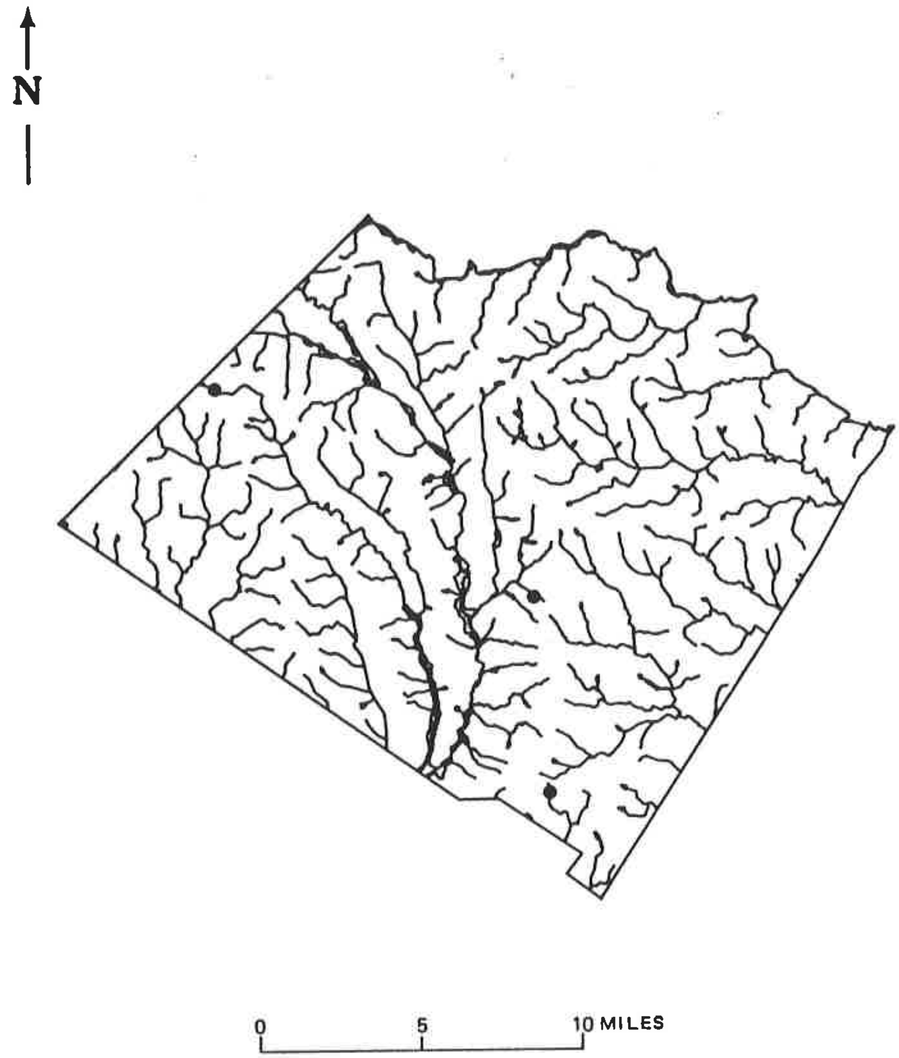

Figure 14. Map of Walton County showing location of NPDES discharge sites (dots) and hydrography.

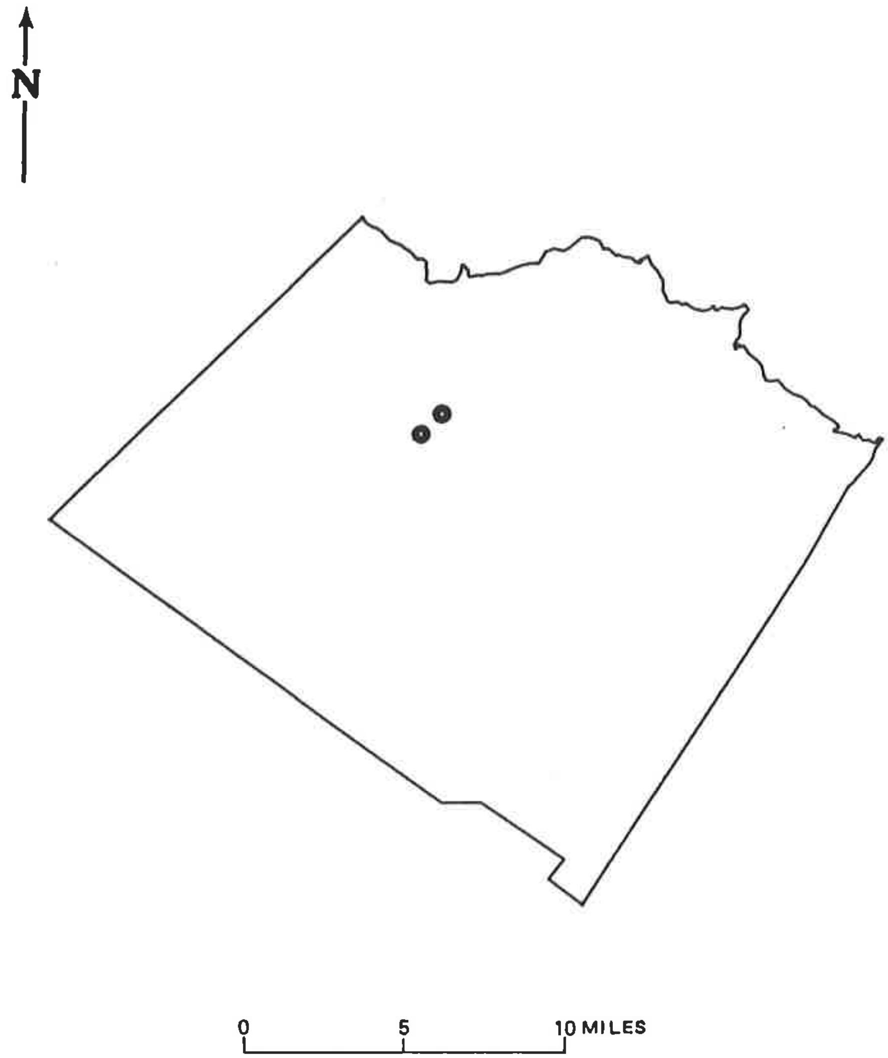

Figure 15. Map of Walton County showing location of sanitary landfills.

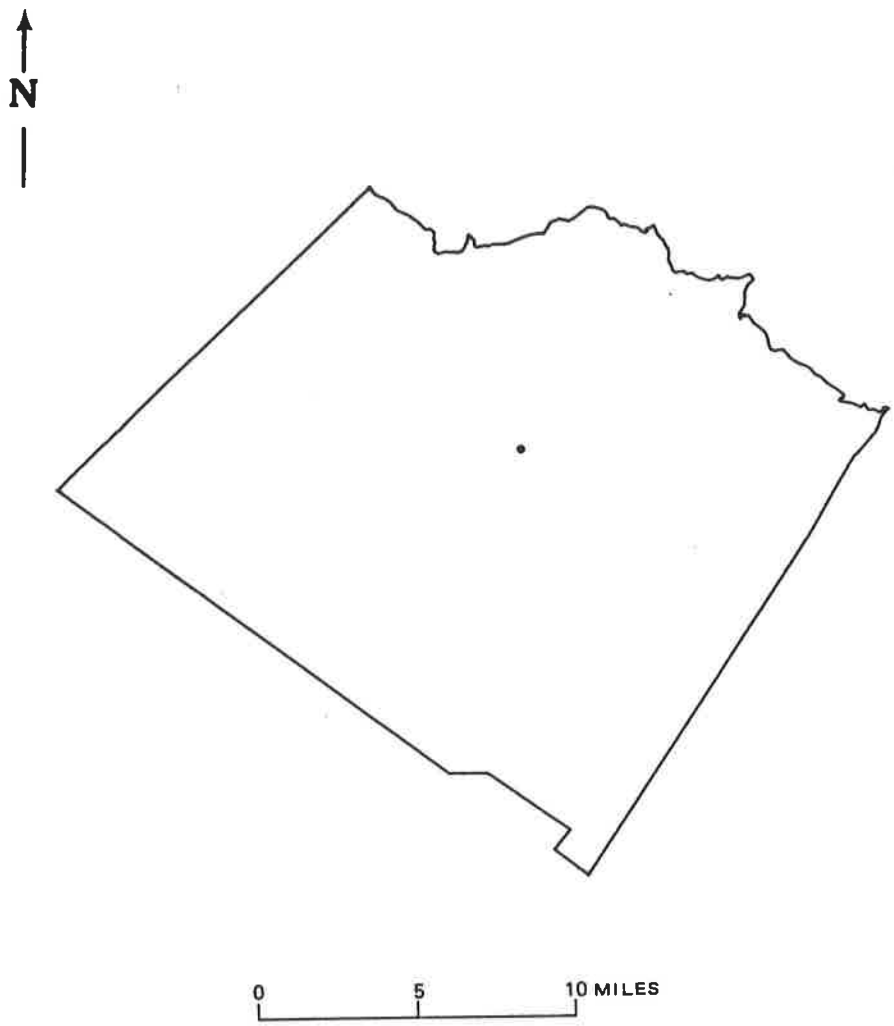

Figure 16. Map of Walton County showing location of the single high-hazard dam.

CERCLA Sites: The location, names, and attribute data of hazardous waste sites covered by the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) were obtained from EPA and entered into the GIS. Four of these (Figure 17) currently are on the National Priorities List for remedial action under Superfund.

Hazardous Waste Sites: Those persons who generate and transport or treat, store or dispose (TSD facilities) of hazardous wastes are regulated under the Georgia Hazardous Waste Management Act (HWMA). Figure 18 shows 84 of the 86 TSD hazardous waste facilities in Georgia regulated under the authority of HWMA. A subset of the TSD facilities' list includes 33 of the 34 land disposal facilities (Figure 19); land disposal facilities are considered to have a more significant potential for contaminating ground water than other types of hazardous waste facilities.

Stream Gauging Stations: There are 108 active stream gauging stations on Georgia rivers and streams with continuous recorders; all are maintained by the USGS under several joint funding agreements with State and local governments. The USGS publishes an annual summary of flow characteristics. The stream gauging station localities in Georgia are shown on Figure 20.

Surface Water Quality Stations: There are 141 stations on Georgia rivers and streams where periodic and miscellaneous water-quality measurements are made. This is a USGS data base and is part of the National Water Information System (NWIS). Figure 21 shows the surface water quality stations in Walton County.

Georgia Ground-Water Monitoring Network: The Georgia Ground-Water Monitoring Network consists of 127 wells and springs that are sampled one or more times each year by the Geologic Survey Branch of EPD for a wide variety of potential pollutants. This network of wells, most of which are located in recharge areas, provides data on the ambient quality of ground water for ten separate aquifer systems. EPD, each year, summarizes the testing results in a Georgia Geologic Survey Circular. Figure 22 shows the location of the Network monitoring sites.

Surface Water Impoundments: This data base contains information on 785 impoundments across the State from a 1983 study to identify potential hazard from waste impoundments. The data include names, addresses, contacts, permits, soils, county, health hazard and geocodes. Of the 785 sites, 674 had latitude and longitude, which allowed for their integration into ARC/INFO.

High Recharge Impoundments: Follow-up data from the aforementioned 1983 Impoundment Study was developed in 1986 by EPD. The follow-up data address the pollution potential of the 255 sites which are located in recharge areas.

Figure 17. Map of Georgia showing the location of the four Superfund sites on the NPL list as of March 1988.

Figure 18. Map of Georgia showing hazardous waste treatment, storage or disposal facilities regulated under HWMA.

Figure 19. Map of Georgia showing land disposal facilities.

Figure 20. Active stream gauging stations with continous stage recorders.

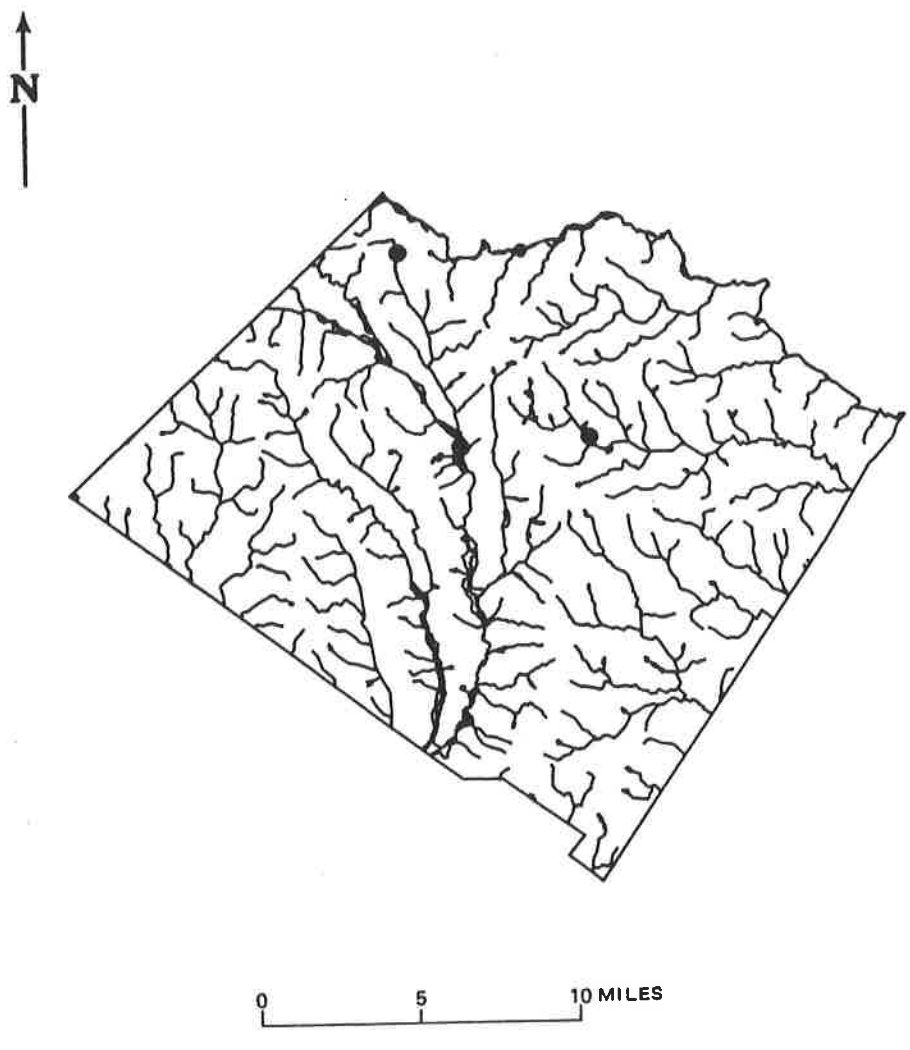

Figure 21. Map of Walton County showing surface water quality monitoring stations (dots) and stream hydrography.

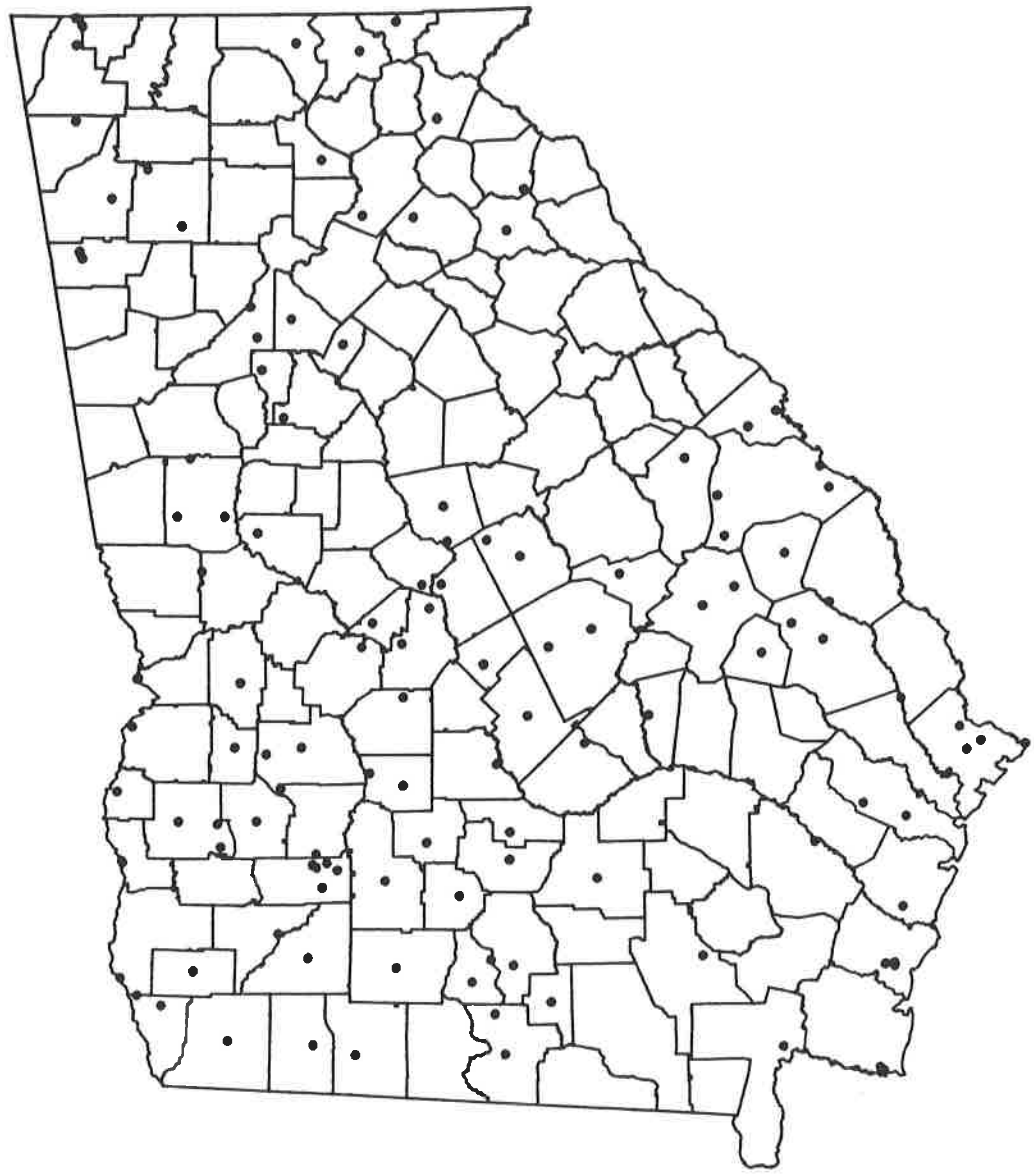

Figure 22. Map of Georgia showing locations of Georgia ground-water monitoring network wells and springs.

Pesticide Loading Data Base: Through a contract with the USGS, Resources for the Future (the contractor) developed a data base for each Georgia county of crop types, units, pesticides (based on crop types) and consumption/use. These were entered into the INFO data base.

Census Bureau Population Centroids: Population centroids of Census Bureau enumeration districts (6651 sites) in Georgia were compiled by the USGS for the 1970 census and the 1980 census as well as for the 1982 and 1984 census estimates.

LINE DATA

DLG Data: Digital line graphs (DLG's) are the digital representations of planimetric information (line map data) usually portrayed on a map. DLG data for the forty-three 1:100,000 quadrangles in Georgia were purchased from the USGS for Phase II (see Figure 23). These data include: hydrography, roads and trails, railroads, pipelines and transmission lines and major roads. As an example, Figure 24 is a DLG map showing pipelines in Walton County.

Depth to Aquifer: Depth to aquifer maps were developed for the Clayton, Claiborne and Floridan aquifers of the Georgia Coastal Plain for the Phase I project by EPD and the USGS.

Potentiometric Maps: A potentiometric map of the Floridan aquifer, along with ground-water flow directions, has been digitized. This is shown on Figure 25 for the southeastern Coastal Plain in the vicinity of Savannah-Jesup. This map was developed for the Phase I project by EPD and the USGS.

River Reach File: The EPA River Reach File is a digital data base of streams, lakes, reservoirs, and estuaries divided into segments called "reaches." Each reach is uniquely identified by a reach number. Data available from the file includes stream names, open water names, stream and shoreline traces and mileage information. Reaches are referenced to each other in a special manner making it possible to perform water quality modeling upstream and downstream from a facility. Figure 26 shows those river reaches in Walton County for which water quality modeling has been performed.

Five (5) cfs 1986 Drought Stream Flow Data: A major drought occurred in Georgia during calendar year 1986; and many streams experienced record low flows. For the Phase II project, those portions of Piedmont and Blue Ridge streams where the flow always exceeded 5 cfs during 1986 were estimated by the USGS and then digitized. Figure 27 shows those Walton County streams having continual flows of 5 cfs or more in 1986.

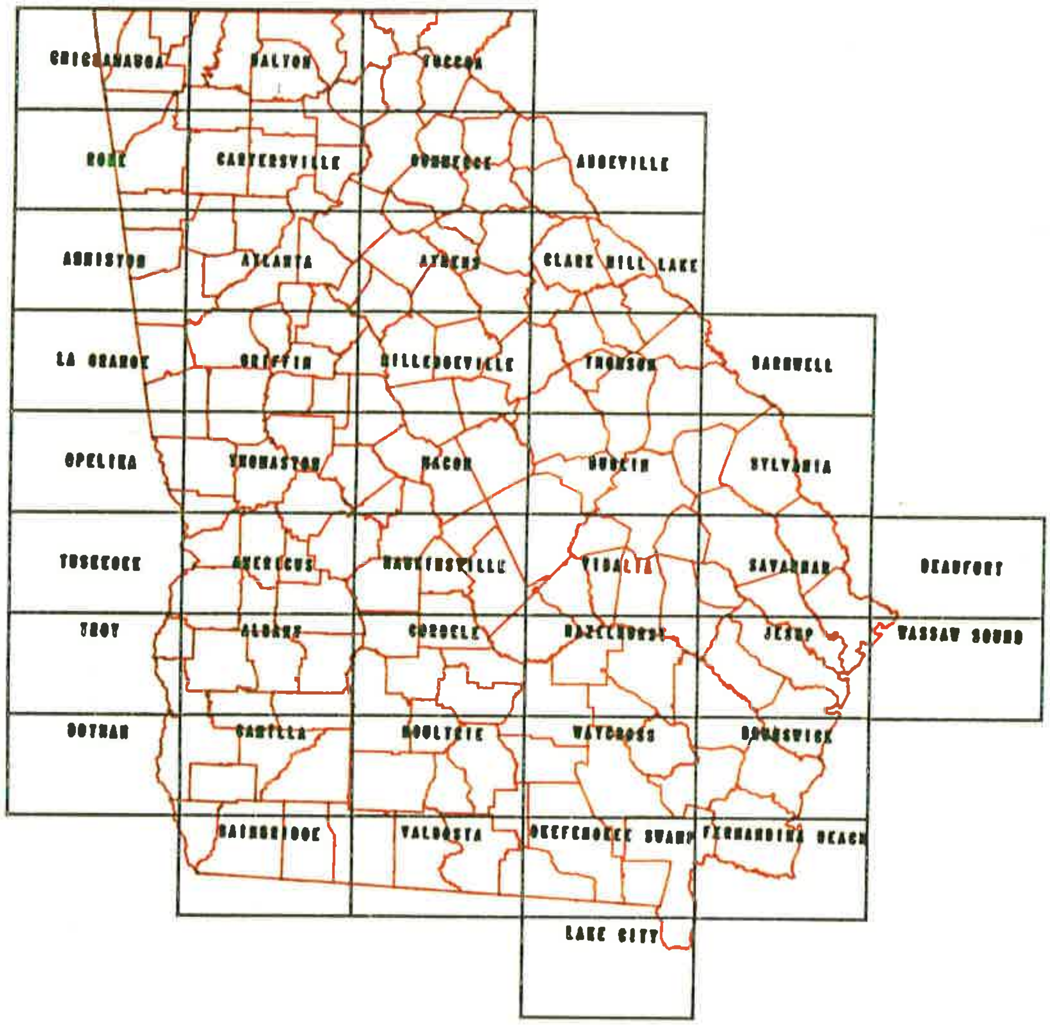

Figure 23. Map of Georgia showing location of forty-three 1:100,000 quadrangles for which DLG data are available.

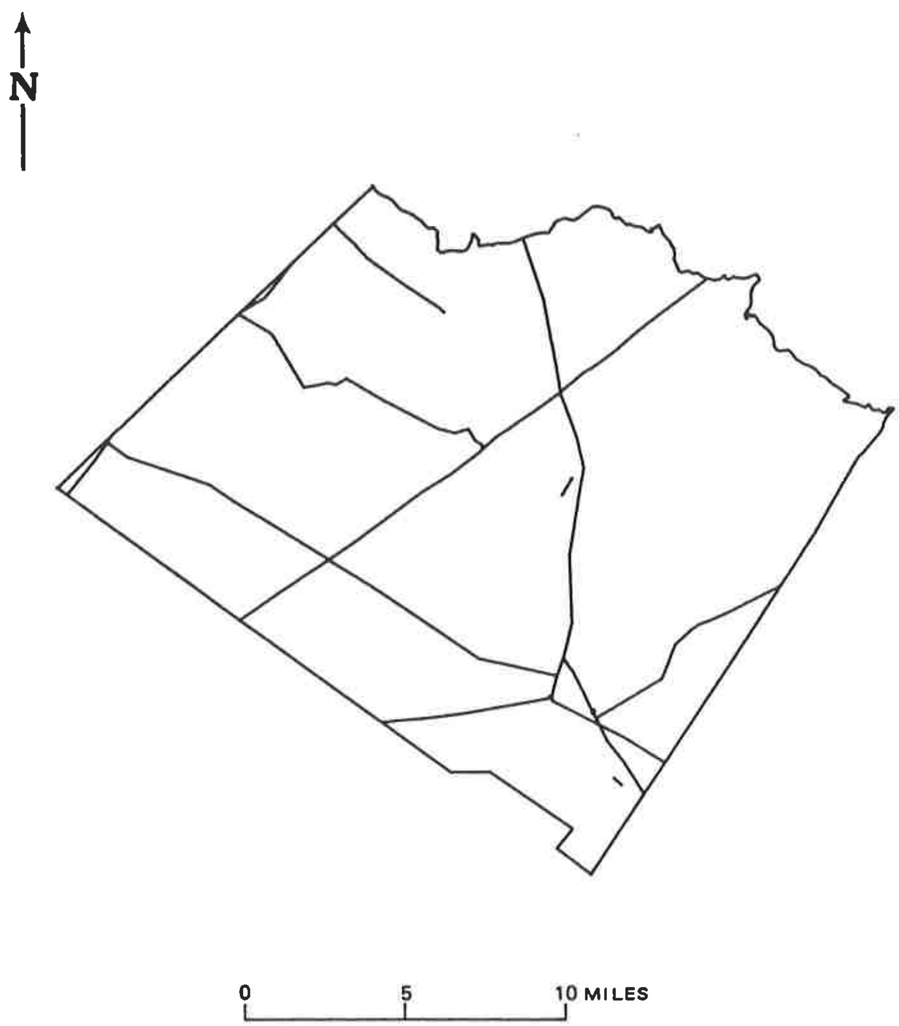

Figure 24. Map of Walton County showing locations of pipelines.

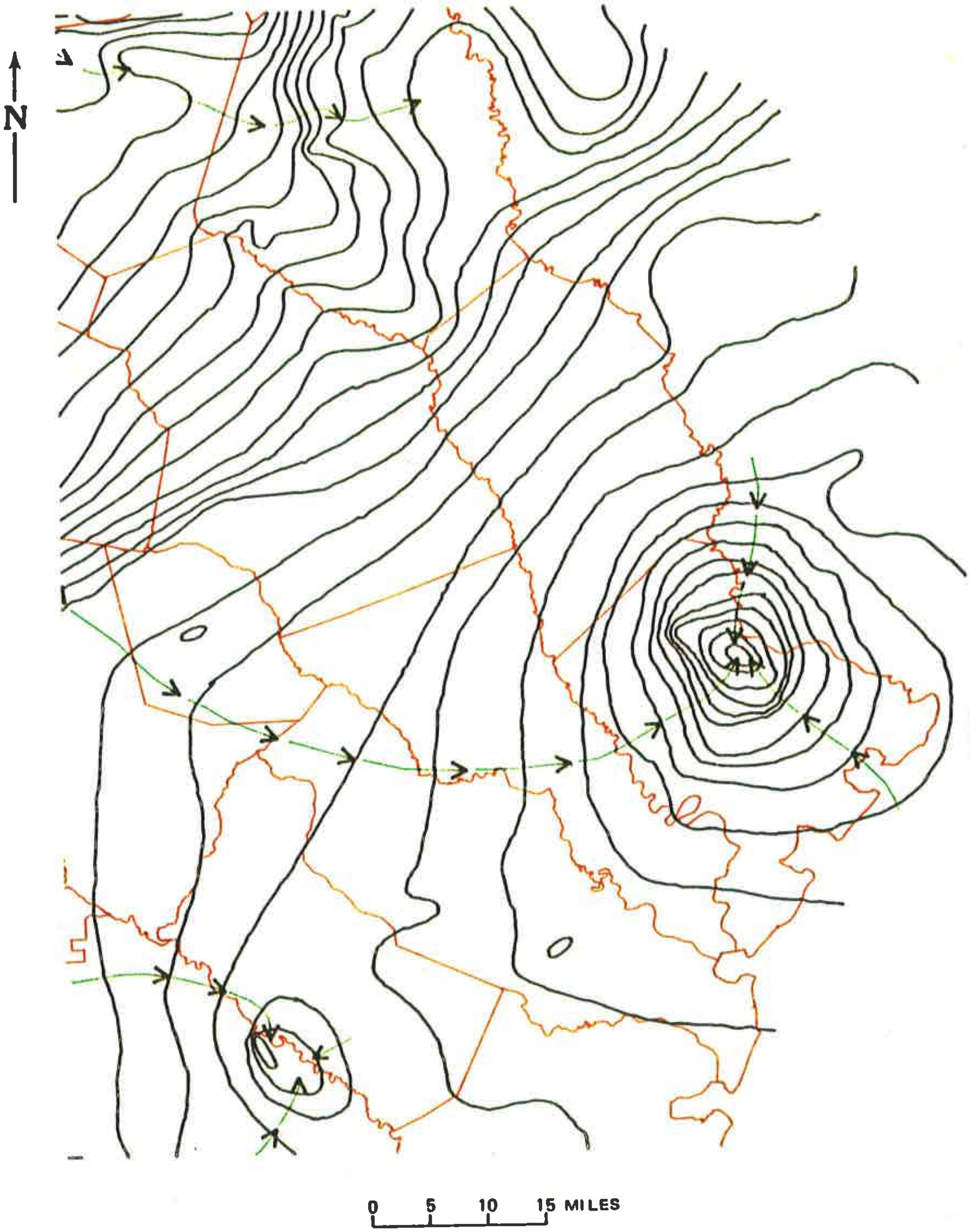

Figure 25. Potentiometric map of the Floridan Aquifer in southeastern Georgia showing ground-water flow directions (county boundaries are red). Note large cone depression at Savannah.

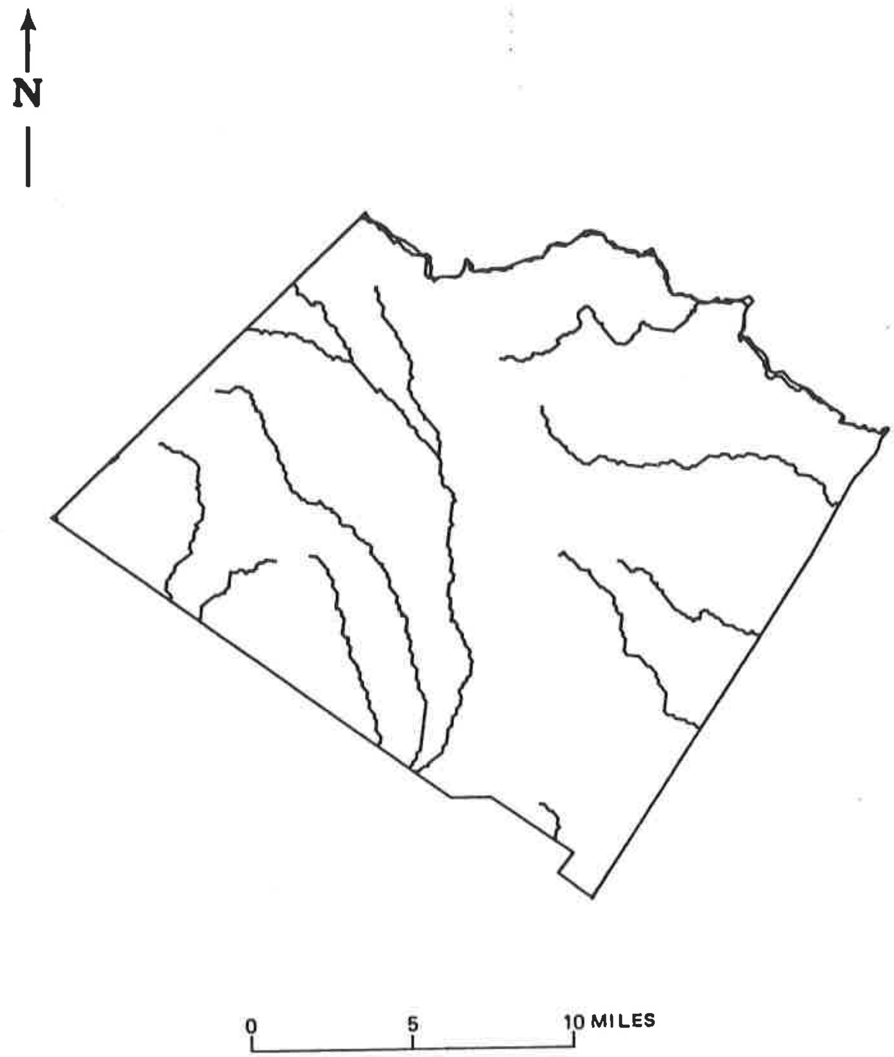

Figure 26. Map of Walton County showing river-reaches for which EPD has performed water quality modeling.

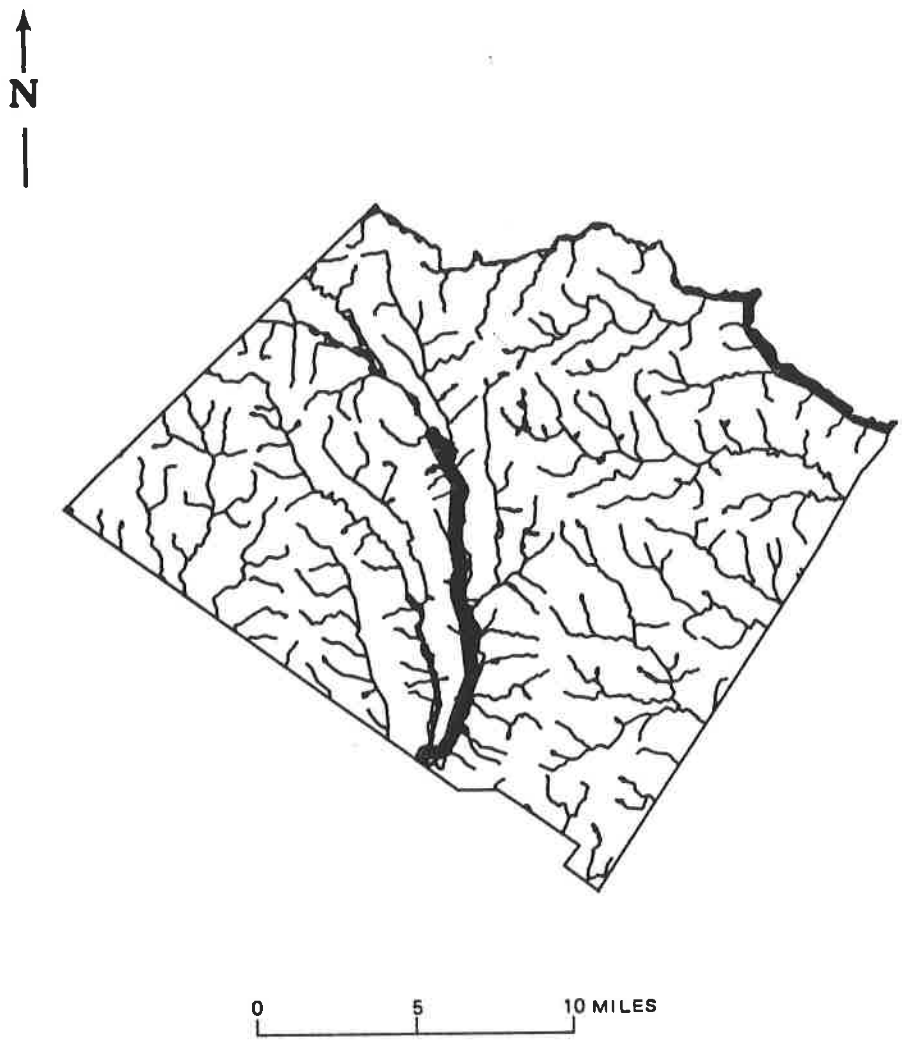

Figure 27. Map of Walton County showing hydrography. Those stream reaches having a continual flow of 5 cfs or more in 1986 are shown by a thicker line.

POLYGON OR AREA DATA

DEM Elevation Data for Georgia: Digital Elevation Modeling (DEM) data from the USGS was processed using ELAS, Earth Resources Laboratory Applications Software (NASA, NSTL, ERL). This allowed for examination of elevations, on a grid basis, every 60 meters on the ground. Elevation contours of 20 meters were chosen and the resulting data were processed into ARC/INFO. Figure 28 is an example of a DEM map of Walton County showing areas having an elevation between 280 and 300 meters and greater than 300 meters.

Slope Data: DEM data from the USGS also were processed, using ELAS software, to calculate slopes. The slope classes were 0-1, 1-2, 2-3, 3-5, 5-8, 8-10, 10-12, 12-15, 15-25 and greater than 25 percent. The resulting data were processed into ARC/INFO. Figure 29 is a map of Walton County showing areas having a slope in excess of fifteen percent.

Land Use/Land Cover: Digitized land use and land cover data, circa 1973, were purchased from the USGS as part of the Phase II project. Land use refers to man's actitivies that are directly related to the land (e.g., commercial, residential, etc.). Land cover, on the other hand, describes the vegetation, water, natural surface and artificial constructions at the land surface. The land use/land cover maps have been compiled using a classification system of nine general Level I categories, which are further subdivided into 37 Level II categories (see Table IV). Figure 30 is a Level I land use/land cover map of Walton County showing urban and built-up land.

County Boundaries; Hydrologic Unit Boundaries, and Census Tract Boundaries: For the Phase I project, digitized county boundaries, hydrologic unit boundaries, and census tract boundary data were obtained from the USGS. Figure 31 shows the census tract boundaries within Walton County.

Most Significant Recharge Areas: As part of a ground-water protection grant from EPA, EPD developed a map of the Most Significant Recharge Areas in Georgia at a scale of 1:500,000. The Most Significant Recharge Areas Map, which was digitized as part of the Phase II effort, is scheduled to be published by the Geologic Survey as a separate publication. Table V describes how the Most Significant Recharge Areas Map was prepared. Attribute data identify the aquifer system. Figure 32 shows the most significant recharge areas in Walton County.

Geologic Maps: Two statewide geologic maps have been digitized; namely:

(a) The Georgia portion of the USGS's 1:2,500,000 Geologic Map of North America.

Figure 28. Map of Walton County showing areas having an elevation between 280 and 300 meters (diagonal line pattern) and greater than 300 meters (black).

Figure 29. Map of Walton County showing areas having a slope in excess of fifteen percent.

TABLE IV

LEVEL I AND LEVEL II LAND USE CATEGORIES

1 Urban or Built-up Land
- 11 Residential
- 12 Commercial
- 13 Industrial
- 14 Transportation, Communications, and Utilities
- 15 Industrial and Commercial Complexes
- 16 Mixed Urban or Built-up Land
- 17 Other Urban or Built-up Land

2 Agricultural Land
- 21 Cropland and Pasture
- 22 Orchards, Groves, Vineyards, Nurseries, and Ornamental Horticultural Areas
- 23 Confined Feeding Operations
- 24 Other Agricultural Land

3 Rangeland
- 31 Herbaceous Rangeland
- 32 Shrub and Brush Rangeland
- 33 Mixed Rangeland

4 Forest Land
- 41 Deciduous Forest Land
- 42 Evergreen Forest Land
- 43 Mixed Forest Land

5 Water
- 51 Streams and Canals
- 52 Lakes
- 53 Reservoirs
- 54 Bays and Estuaries

6 Wetland
- 61 Forested Wetland
- 62 Nonforested Wetland

7 Barren Land
- 71 Dry Salt Flats
- 72 Beaches
- 73 Sandy Areas Other Than Beaches
- 74 Bare Exposed Rock
- 75 Strip Mines, Quarries, and Gravel Pits
- 76 Transitional Areas
- 77 Mixed Barren Land

TABLE IV (Continued)

8 Tundra
- 81 Shrub and Brush Tundra
- 82 Herbaceous Tundra
- 83 Bare Ground Tundra
- 84 Wet Tundra
- 85 Mixed Tundra

9 Perennial Snow or Ice
- 91 Perennial Snowfields
- 92 Glaciers

Note: Level I Categories 8 and 9 do not occur in Georgia. Categories 3 and 7 are not common.

Figure 30. Map of Walton County showing urban and built-up land.

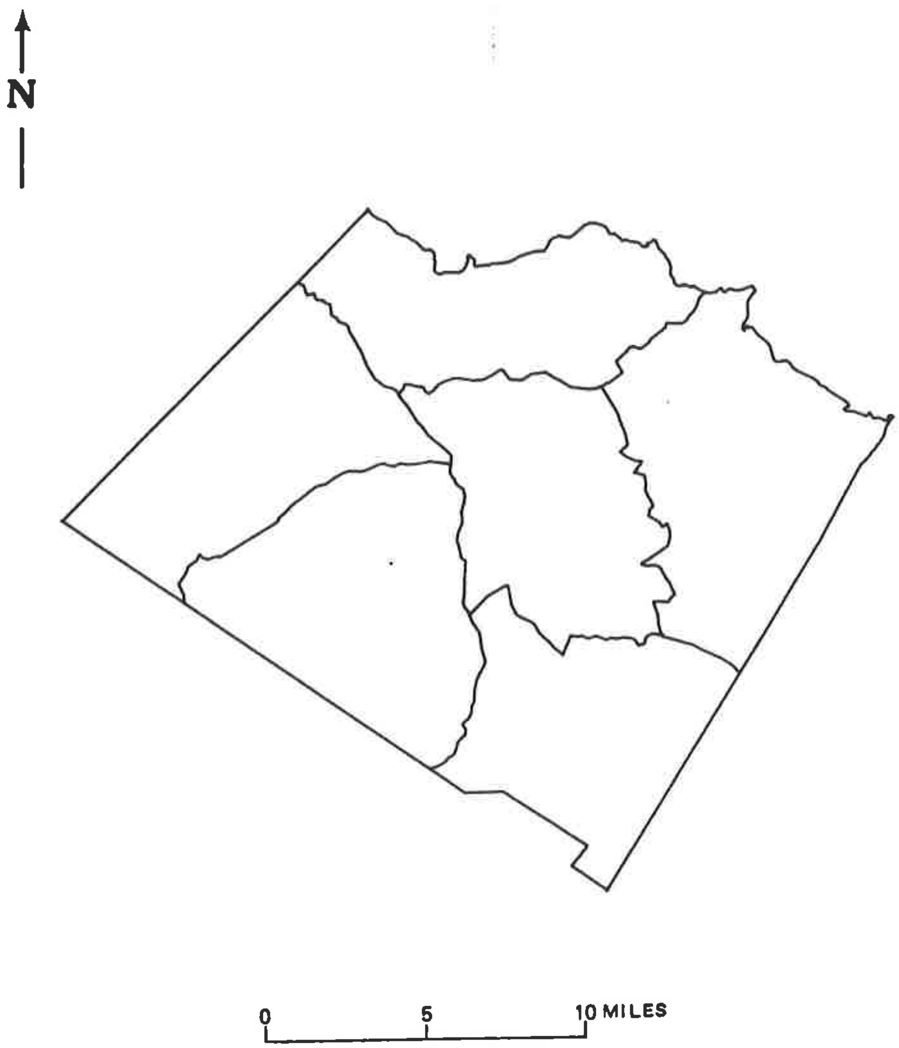

Figure 31. Map of Walton County showing census track boundaries.

TABLE V

DEVELOPMENT OF THE MOST SIGNIFICANT GROUND-WATER RECHARGE AREAS MAP

Ground-water recharge occurs, to some degree, throughout practically all of Georgia's land area. Because the natural recharge process is a critical control of ground-water quality and availability, a study was initiated by EPD to define important recharge areas. A map entitled Most Significant Ground-Water Recharge Areas, which identifies the thirty percent of the State that is most likely to include important settings of recharge, has been developed. This map will be used to target areas for more detailed pollution-susceptibility mapping.

Two types of recharge settings were identified: (1) areas that have the greatest vulnerability to pollution because of natural factors and (2) areas around public water supply wells susceptible to the consequences of induced recharge. Because ground-water systems and the factors controlling recharge vary with geology, the different geologic terranes of the State establish the need for several approaches for identifying significant recharge areas.

Extensive portions of the Coastal Plain Province are underlain by four major artesian aquifer systems. Significant recharge areas of the major artesian aquifer systems are largely defined by the outcrop area of these aquifers' permeable formations. Over one-half of the Coastal Plain, however, is underlain by Miocene age and younger sediments of limited permeability. The widespread use of these shallow and unconfined water-bearing units for domestic supplies establishes their importance. Significant recharge areas for these smaller aquifer systems are defined by the location of permeable surficial soils which allow infiltration and storage of rainfall.

Crystalline rocks with little intergrannular permeability underlie most of the north Georgia Piedmont and Blue Ridge Provinces. Ground-water is generally obtained from fractures in the bedrock. Overlying soils serve as the reservoirs for these fracture systems. Areas of significant recharge are characterized by low slope, multiple geologic contacts and brittle geologic structures; these factors contribute to the development of thicker soils.

Folded and faulted sedimentary formations of the Ridge and Valley Province underlie portions of ten counties in northwest Georgia. Ground-water supplies, adequate for domestic uses, can be obtained almost everywhere. However, larger ground-water withdrawals are most readily obtained from the broad valleys, which are typically underlain by Cambro-Ordovician age limestones and dolostones. Significant recharge areas of northwest Georgia are defined as the outcrop area of carbonate rocks combined with low slopes.

TABLE V (Continued)

Ground-water withdrawals from unconfined aquifer systems tend to increase the rate of recharge in the vicinity of a well. Relatively fast rates of ground-water flow are induced, increasing the chance of pollutants reaching the well before natural filtering and degradation processes are effective. Where public water supply wells are completed in unconfined aquifers, EPD arbitrarily established a 3½-mile radius encircling the well as an induced recharge area. Such areas are termed as Induced Recharge Areas.

Figure 32. Map of Walton County showing most significant recharge areas. Unconfined aquifers are shown in black and induced recharge areas surrounding public water supply wells are shown in diagonal pattern.

(b) The 1:500,000 Geologic Map of Georgia (Georgia Geologic Survey, 1976).

The 1:2,500,000 map was digitized as part of the Phase I effort whereas the 1:500,000 map was digitized as part of the Phase II effort. Attribute data are formational names. Figure 33 is a geologic map of Walton County derived from the 1:500,000 map.

Zip Code Boundary File: Zip code boundaries and zip code centroids have been integrated into the GIS. All of the 743 Georgia zip codes reside in the data base. The zip code data base, however, is proprietary and is available only from the USGS as part of the EPD-USGS joint funding agreement. Figure 34 illustrates the zip code boundaries for Walton County.

Public Lands: Five separate state and federal agencies own and manage extensive tracts of land in Georgia. These are the United States Forest Service, the National Park Service, the Tennessee Valley Authority, the Department of Defense, and the Georgia Department of Natural Resources. As an example, Figure 35 shows that portion of Hard Labor Creek State Park occurring in Walton County. Attribute data identify land ownership.

Soils: Two different soils maps were digitized for the Phase II project; these are:

(a) The 1:750,000 Soil Conservation Service Map (SCS) of Georgia (1977). This map, based on soil associations, characterizes land-use Suitability Classes. Attribute data identify soil associations with suitability codes (unsuited, poor, fair, good or low, medium, high) for row crops, wetlands, top soil, reservoirs, light industry, sanitary landfills, etc. Water capacity, permeability and slope data also are related to the various soil associations.

(b) The 1:250,000 Department of Natural Resources (DNR) County Soils Maps. In 1974, the Office of Planning and Research of DNR, gathered all of the available soils data from Georgia; and then using twenty-four separate soil associations, 1:100,000 soil maps were developed for each county. The soils associations provide information on engineering characteristics (e.g., Unified Soil Classification, depth to bedrock, permeability, etc.) as well as Suitability Classes.

The 1:250,000 DNR maps currently are being digitized and are scheduled to be completed by December 31, 1988. Figure 36 is a map of Walton County, derived from the 1:250,000 DNR maps, showing alluvial and terrace soils along floodplains.

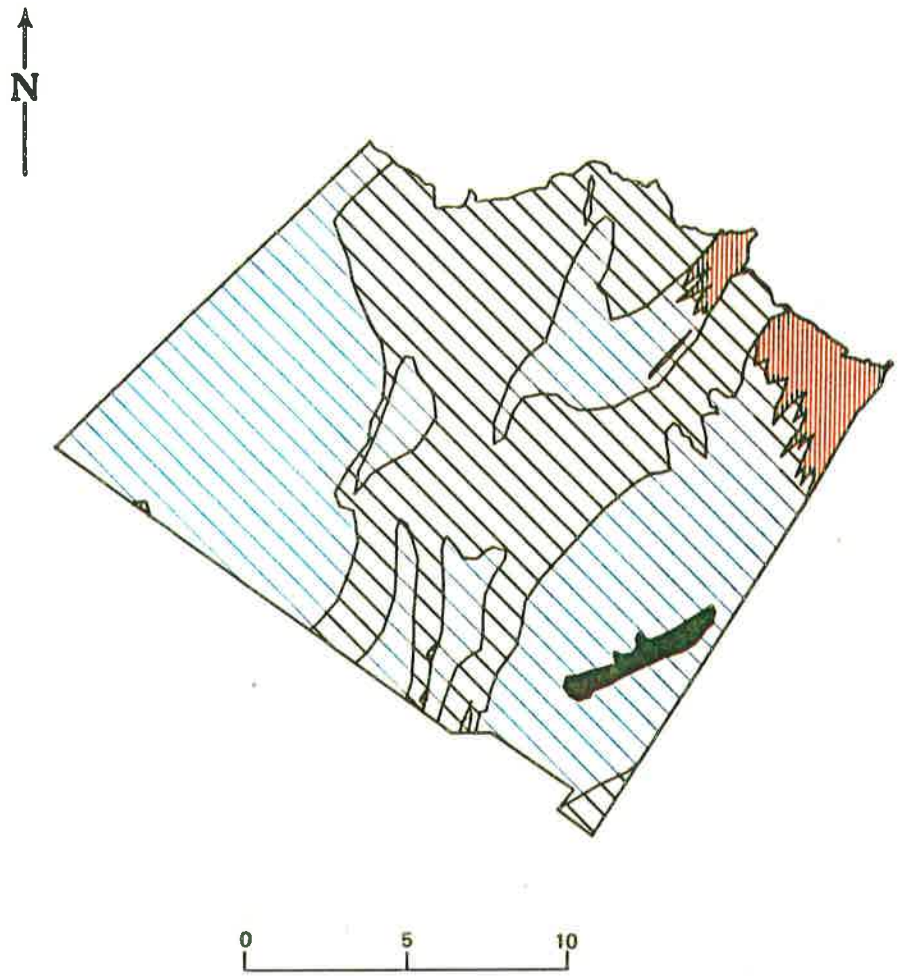

Figure 33A. Geologic map of Walton County.

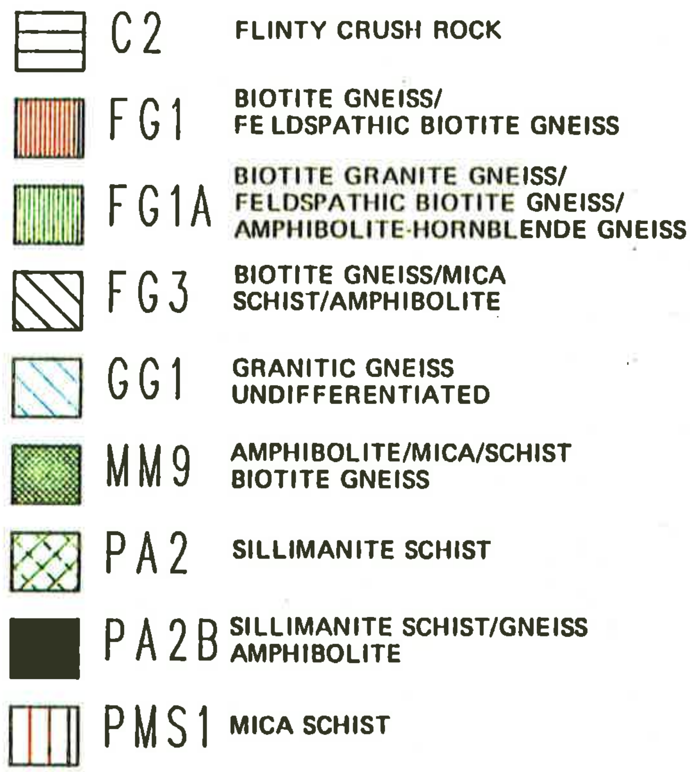

Figure 33B. Legend to geologic map of Walton County. Geologic units listed in alphabetical order of symbols.

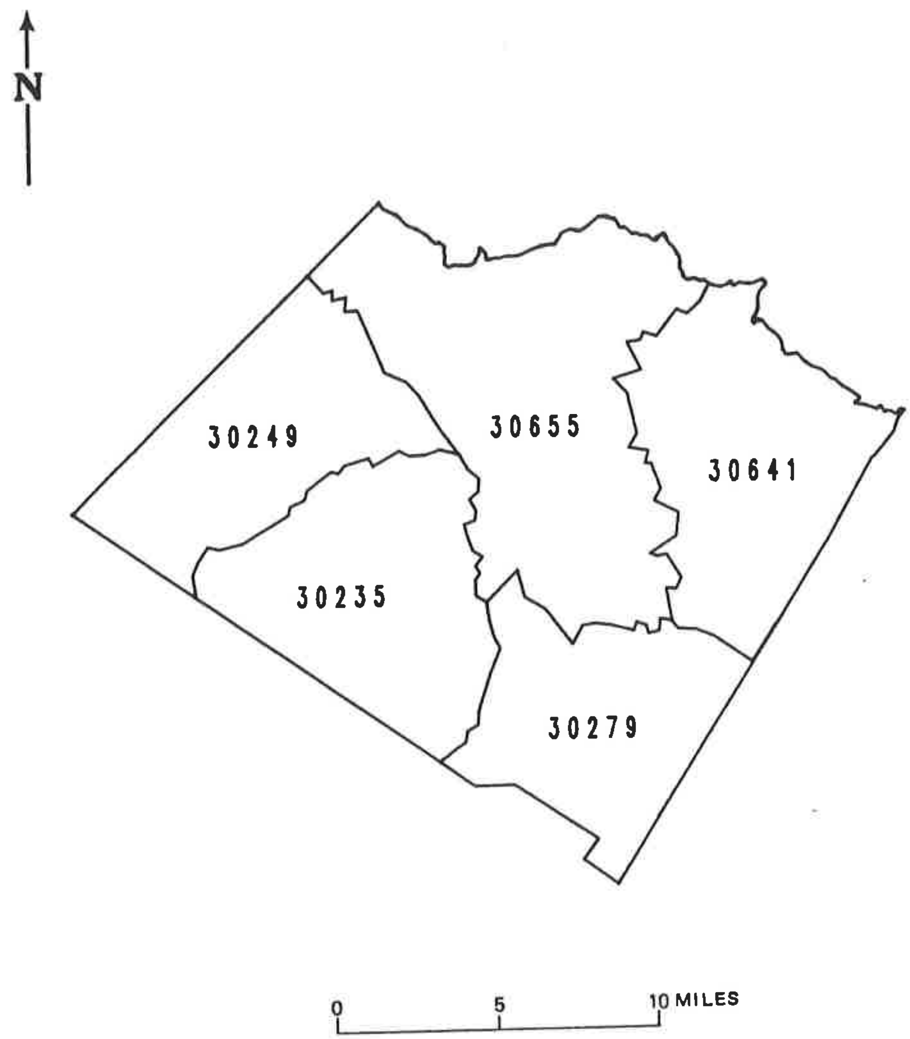

Figure 34. Map of Walton County showing zip codes.

Figure 35. Map of Walton County showing location of state owned land (that portion of Hard Labor Creek Park in Walton County).

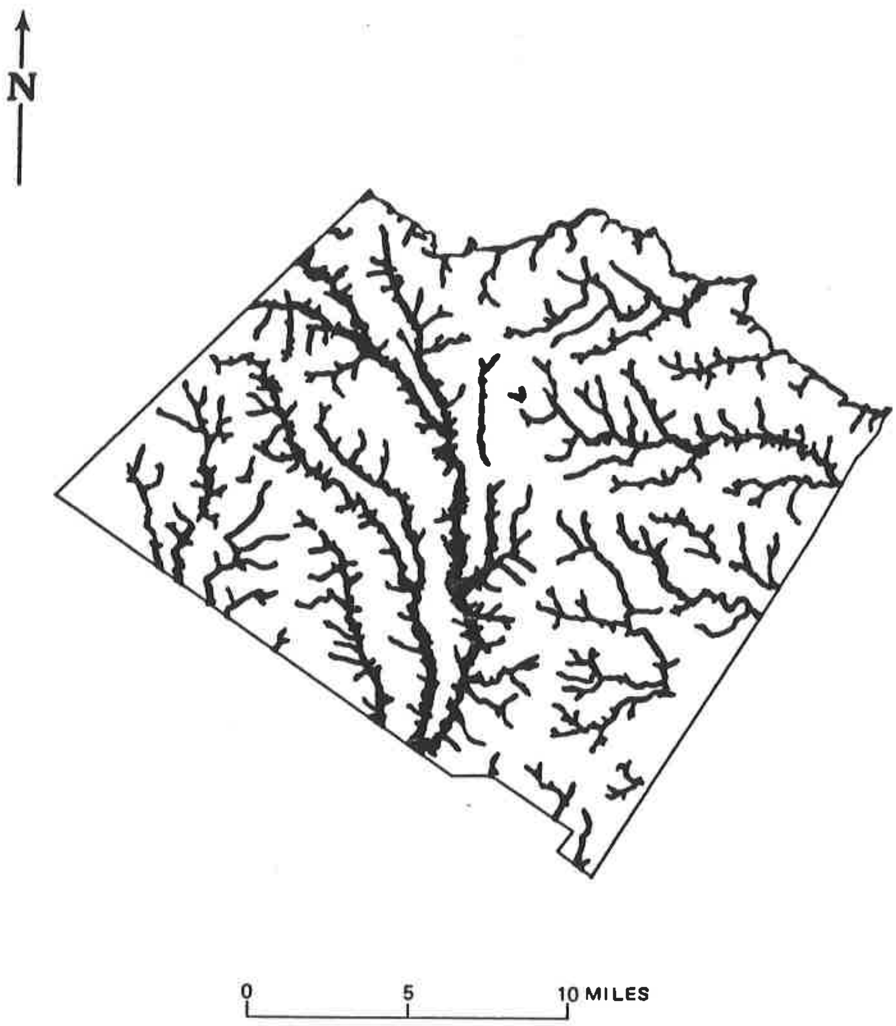

Figure 36. Map of Walton County showing alluvial and terrace soils along floodplains.

QUALITY ASSURANCE

Perhaps the greatest handicap to full implementation of a GIS as a tool for environmental decision-making is the lack of quality control in data bases. Two examples can be used to illustrate this point:

(1) The locations of a number of environmental facilities were obtained from the application forms submitted by the applicant. In general, the persons filling out the application forms were not engineers nor geologists; and, for the most part, they were unfamiliar with the concept of latitude and longitude. During the course of the Phase II project, it became apparent that locational data, particularly for minor facilities, often were inaccurate. To rectify this type of discrepancy, a trained person would have to go through all of the original data (the application forms) and make a determination about each facility as to whether data submitted were correct. And if incorrect, this person would have to make the necessary corrections. (Note: As part of the Phase II project, EPD has loaded accurate locational data into the PRIME, Facility ID Module).

(2) A comparison of the digitized 1:750,000 Soil Conservation Service (SCS) Soils Map of Georgia with the digitized version of the 1:500,000 Geologic Map of Georgia indicates a number of areas, where soils do not reasonably correlate with the underlying geology. For example, one can compare the soils and geologic maps (Figure 37 and Figure 38; for side-by-side comparison) of Walton County. Since soils in Georgia typically are residual (non-transported), there should be a high degree of correlation between the two maps. Visual inspection of the two figures indicates only a relatively low level of correlation between the soils and geologic maps; thus the larger-scale Soils Map should be considered of lower accuracy.

The above examples are not unique to Georgia; rather, they are representative of quality control problems that are endemic to any GIS.

As part of the Phase II effort, considerable effort had to be directed at quality assurance. In general, for every hour spent inputting or digitizing data another hour had to be spent on quality assurance. At the present time, EPD is developing a formal written addendum to its Quality Assurance Plan to cover data entry to all future GIS work effort. Moreover, EPD is performing quality assurance reviews of all previously developed data bases, including those from the Phase I and Phase II projects. The general elements of EPD's quality assurance plan for the GIS are presented in Table VI.

Obviously, data bases of lower accuracy (Category III) can be upgraded to the highest accuracy (Category I). For the Phase II project, all of the Walton County data bases have been upgraded to Category I.

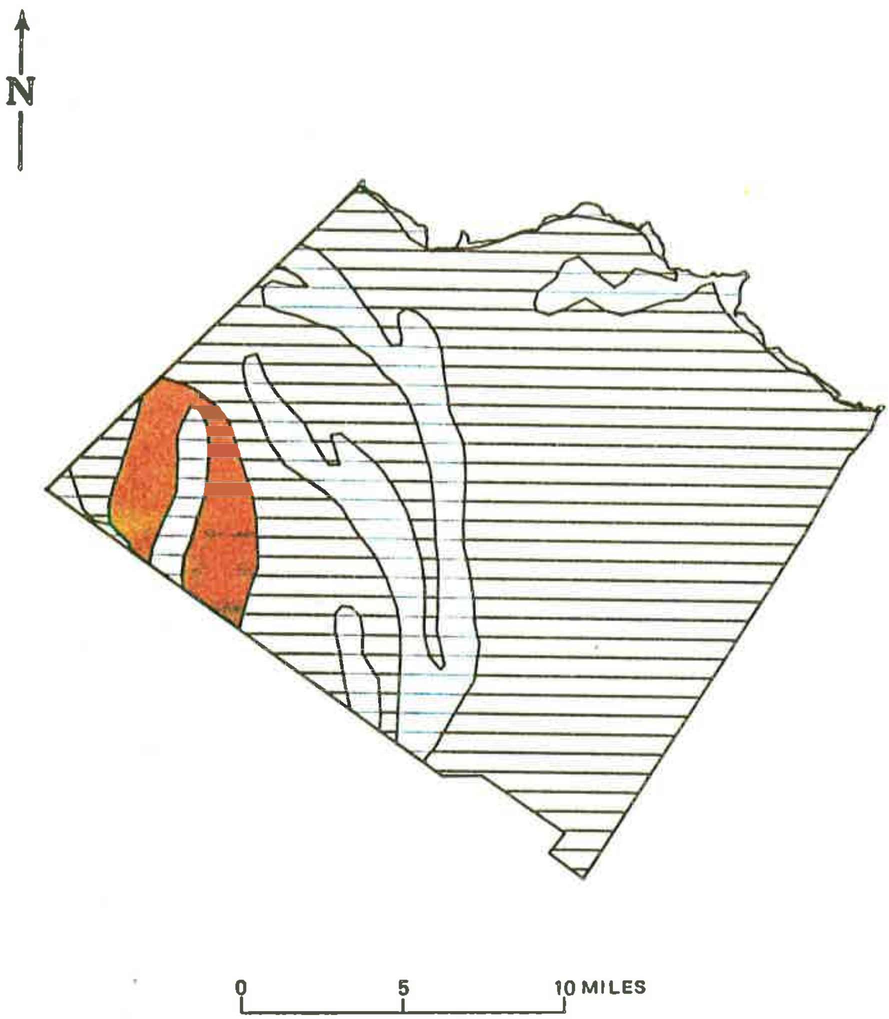

Figure 37. Map of Walton County showing soil associations as digitized from 1:750,000 SCS map of Georgia (note: area in blue line pattern corresponds to the alluvial and terrace soils shown on Figure 36). The black line pattern corresponds to residual soils but does not reflect the widely varying rock types shown on Figure 38.

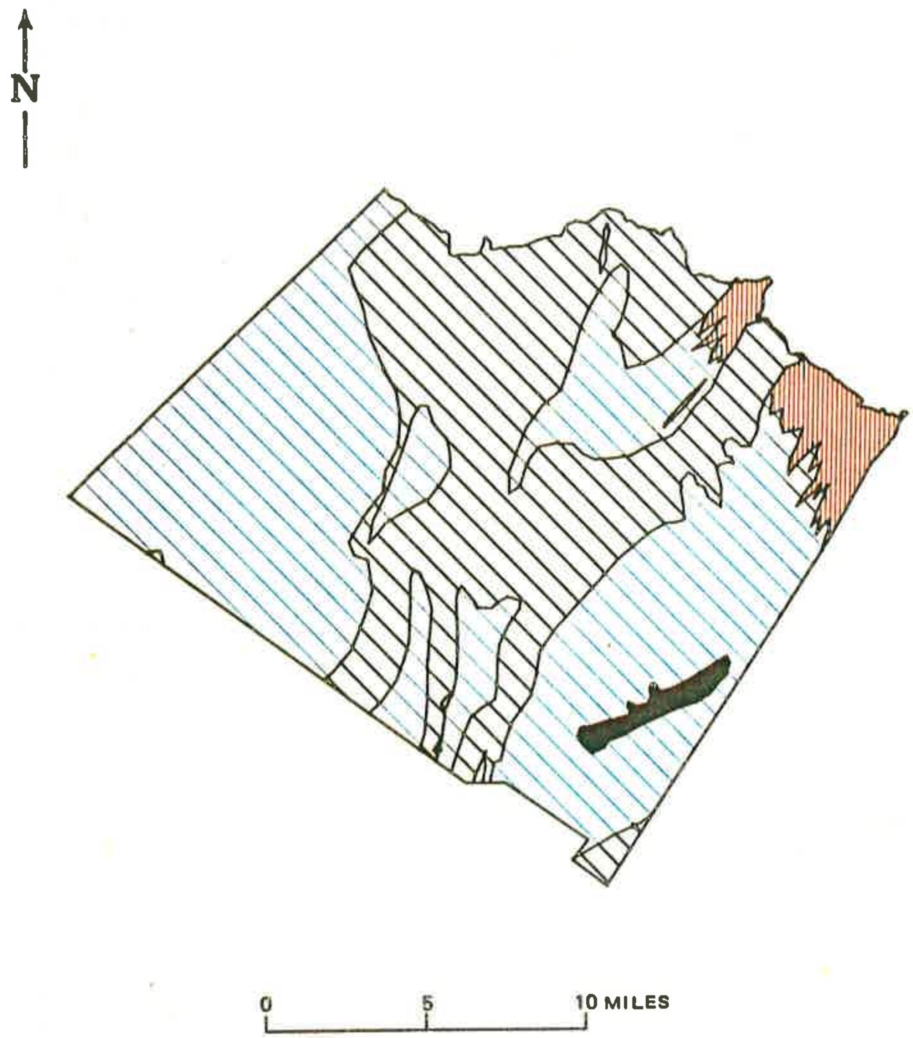

Figure 38. Map of Walton County showing geology as digitized from 1:500,000 geologic map of Georgia (this is the same as Figure 33).

TABLE VI

GENERAL ELEMENTS OF A QUALITY ASSURANCE PLAN FOR GIS DATA

Categories of Accuracy:

Data bases that are entered or digitized into EPD's GIS fall into three categories of accuracy. These, in order of decreasing accuracy, are:

Category I - This indicates a data base that the original source as well as the processed data have both undergone and met quality assurance review. These data bases, therefore, can be assumed to be reasonably accurate. Examples include data bases that have been purchased (e.g., the DLG data bases, the Land Use/Land Cover data bases, the Zip Code data base, etc.) or were derived from peer reviewed sources (e.g., the Most Significant Recharge Area Map) and subsequently cross-checked by an EPD manager (or his designee).

Category II - These include those data bases where the original source has undergone and met quality assurance procedures or was derived from a peer reviewed source but the processed data had not been cross-checked by an EPD manager (or his designee) for quality assurance purposes. An example of these is the Geologic Map derived from the 1:500,000 State Map. The primary errors that would occur in a Category II data base are those of incorrect data entry.

Category III - These are those data bases, mainly derived from non EPD sources, that have not undergone quality assurance checks. For the most part, these data are entered just as they are reported. Examples of these include National Forest boundaries and the Surface Water Impoundments.

Decision-Making:

EPD should only use Category I data bases for environmental decision-making.

Quality Control Review:

Step One: Make decision as to whether or not the original data source meets Category I, II or III level.

Step Two:

(A) If Category I, the data base should be so identified (e.g., for example, the directory in the computer might be labled C-I). Upon doing this the data base is acceptable for use.

TABLE VI (Continued)

(B) If Category II, the data should be entered/digitized. Upon completion of entry, a ten percent sample should be checked for accuracy. If ninety percent of the ten percent sample is correct, when compared to the original source, the data may be upgraded to Category I and are acceptable for use. At this point the data base can be assumed to be about 90 percent accurate. If less than ninety percent of the ten percent sample is correct, all of the entered data should be verified. Verification should continue until ninety percent of a separate ten percent sample are correct.

(C) If Category III, the original data base should be verified. This may require field checking or resolving information via written or oral communications (for example, calling up a facility to verify information). Until the original source data has been verified, entry or digitization should not be initiated. Once the original source material have been verified, the data are at Category II level and are ready to be entered or digitized. In the event, the data base has been entered or digitized at Category III level, it should be so identified and not used until the original data source has been verified and upgraded to Category II.

Responsibility:

For data bases generated by EPD, the Branch responsible (or being the most logical user) for the original source material should have the responsibility to make sure that the data base is at Category I level (e.g., the Water Protection Branch would be responsible for insuring that all wastewater discharges were accurately located and the attribute data are correct and current).

For data bases not generated by EPD, the Geologic Survey should be responsible for insuring that the original source material and the data base are at Category I level.

DECISION SCENARIOS

GENERAL STATEMENT

Four environmental decision-making scenarios are provided in this section of the report. For the purposes of illustration, all of these will be restricted to Walton County.

Each of the scenarios will be performed in a step-wise manner. This means that each figure will represent a sequential step, thus providing a data base in map format for that step; the later figures, in turn, will be maps presenting additional data bases. Therefore, the figures, as presented, will more or less duplicate, in the same sequence, the images that appear on the computer monitor.

One additional point needs to be noted; namely, it is beyond the scope of this project report to provide a comprehensive explanation of how a sanitary landfill, non-point source pollution, or hazardous wastes may affect water resources. Rather the emphasis of this discussion is directed at demonstrating the applicability of integrating GIS data bases so that environmental information can be presented in an understandable manner.

SITING A SANITARY LANDFILL

EPD is continually called upon to perform site suitability studies for proposed sanitary landfill locations. Basically, this means that EPD will assess a candidate site's hydrogeological characteristics; and if the site is not flawed and possesses generally favorable characteristics, the agency will issue a letter of site acceptability. Once the letter of site acceptability is issued, the applicant (typically a county or municipality) retains a consultant who develops a design and operation plan compatible with the site's hydrogeology and other regulatory requirements.

One of the difficulties that EPD faces, however, is that the applicant, not EPD, chooses the site. Typically "low-priced," rocky, swampy or steep sloped land is selected; and upon performing hydrogeological studies, EPD often rejects the site. In the Coastal Plain, for example, rejection rates currently approach fifty percent. Obviously, having EPD return over and over to a single county or municipality is counterproductive because other applicants have to be postponed. With the above in mind, EPD needs a method of reducing rejection rates without compromising environmental protection. One method that could be useful in achieving this would be to provide local governments a map showing those areas where the possibility of locating a viable sanitary landfill site is poor. With such a map, efforts could then be directed to more "favorable" areas.

A comprehensive site investigation with borings, nevertheless, may indicate that a site in a "favorable" area is not suitable. This determination will continue to be made on a case-by-case basis; but with "unfavorable" areas not being considered, the chances of rejection should decrease.

Siting criteria for sanitary landfills in Georgia have been defined by EPD (Georgia Geologic Survey, 1982). Basically, before any letter of site acceptability can be issued, the following hydrogeological considerations must be made.

(1) Distance to point of water use
(2) Depth to the water table (e g., areas where leachate can readily enter the ground-water regime)
(3) Water-table gradient (this consideration is site specific and can only be developed from borehole data)
(4) Topgraphic setting (e.g., slope)
(5) Geologic setting including depth to bedrock
(6) Hydraulic conductivity
(7) Sorption and attenuation capacity of underlying soils
(8) Distance to surface water

In addition to the above, EPD recognizes that, if possible, sanitary landfills should be sited away from populated areas.

Using ARC/INFO, the following data bases, relevant to siting a sanitary landfill and the aforementioned hydrogeological considerations, were integrated for Walton County:

(1) The county outline from the County Boundaries Data Base and the surface water and ground-water withdrawal sites with a two-mile buffer from the Water Use Sites Data Base (Figure 39).*

(2) Significant recharge areas (refer to Figure 32). These data identify those areas where leachate could most readily enter the bedrock aquifer.

(3) Areas having a slope in excess of fifteen percent from the Slope Data Base (refer to Figure 29).

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* A sanitary landfill located downstream from a public water supply's water intake structure would have little, if any, adverse impact. However, for the purpose of this screening scenario, it was deemed prudent to have a two-mile buffer around <u>all</u> public water supplies. Such conservation appears reasonable as either the intake structure or the landfill may be moved in order to increase capacity. For example, as the original landfill site approaches capacity, an adjacent property, closer to the intake structure, may be the most viable for the proposed expansion. The two-mile buffer, therefore, provides space for future growth.

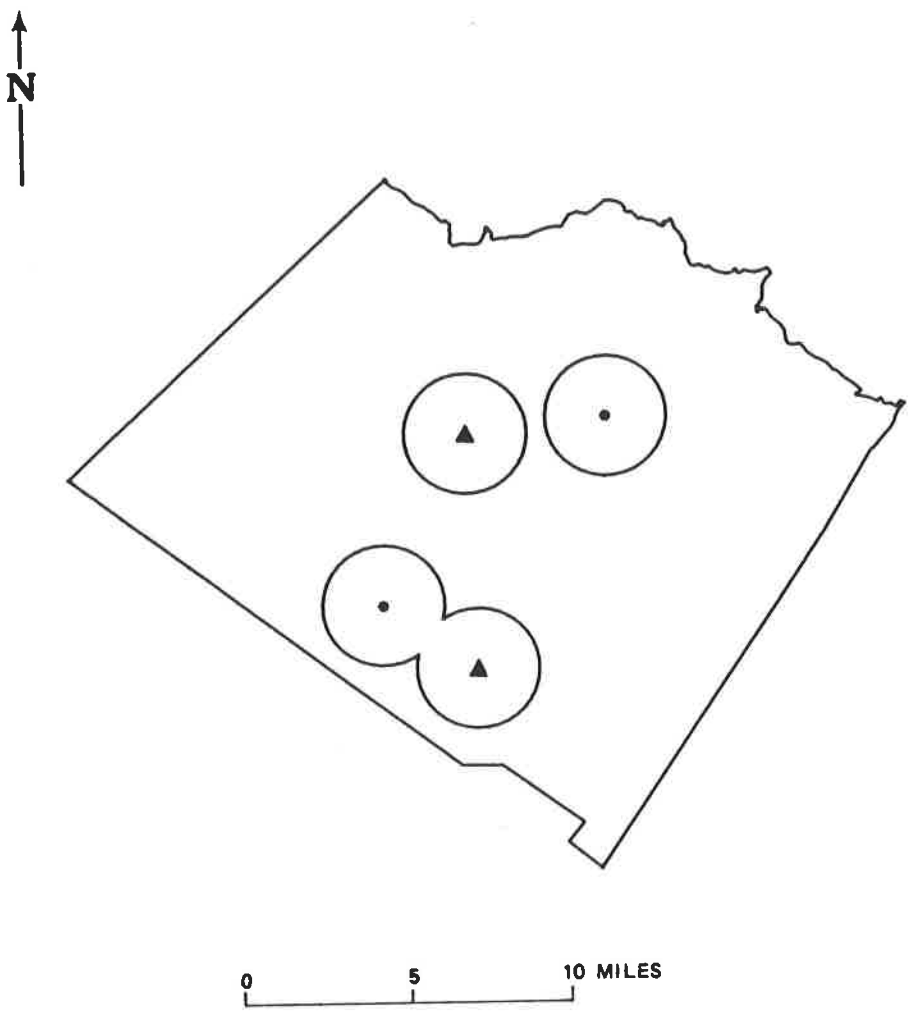

Figure 39. Map of Walton County showing surface-water (triangles) and ground-water (dots) withdrawal sites with two-mile buffer.

(4) Areas underlain by shallow bedrock from the 1:500,000 Geologic Map Data Base (Figure 40). This is the outcrop area of Lithonia Gneiss.

(5) Areas underlain by alluvial or terrace soils from the 1:250,000 DNR Soils Data Base (refer to Figure 36). In the Georgia Piedmont, the alluvial and terrace soils are transported; hence these two soil categories are characterized by high hydraulic conductivity and poor sorption.

(6) Surface water bodies, including wetlands, from the DLG Data Base and the Land Use/Land Cover Data Base (Figure 41).

(7) Urban and built-up land from the Land Use/Land Cover Data Base (refer to Figure 30).

All of the above data bases identify generally unfavorable considerations for a sanitary landfill. Thus those areas, having the above characteristics, have a lesser potential for viable sanitary landfill sites than areas not having the above characteristics.

Figure 42 is an example of the final map, which could be given to local governments. The areas colored in red represent an integration of the above data bases. In other words, the red areas should be considered as generally "unfavorable for a sanitary landfill." Using this map (with the major roads superimposed for reference) local governments, in turn, could direct their site selection efforts to more appropriate areas; thereby, reducing the potential for EPD to reject a candidate site.

In the above analysis, areas underlain by shallow bedrock were considered as unfavorable; however, this need not always be a site limitation. While most sanitary landfills involve excavation of trenches into which the wastes are placed, area fill represent an alternative disposal method. In the area fill method, the wastes are placed above ground and then covered daily with soil. Commonly, this method is employed where bedrock is shallow and excavation of trenches is difficult. Figure 43 is similar to Figure 42 and was derived by integrating the same data bases except shallow bedrock was not considered. Comparing Figure 43 with Figure 42 indicates that the potential "favorable" areas are much greater in Walton County if the area fill method is considered.

With the above in mind, these maps reflect nationally occurring conditions. Many areas shown as being unfavorable could be engineered to overcome various adverse conditions. For example, liners with leachate collection systems could be used to minimize the potential for ground-water pollution in recharge areas.

PRIORITIZING HAZARDOUS WASTE FACILITIES

There are almost 1,600 RCRA facilities in Georgia that either generate, treat, store, transport or dispose hazardous wastes. The majority of

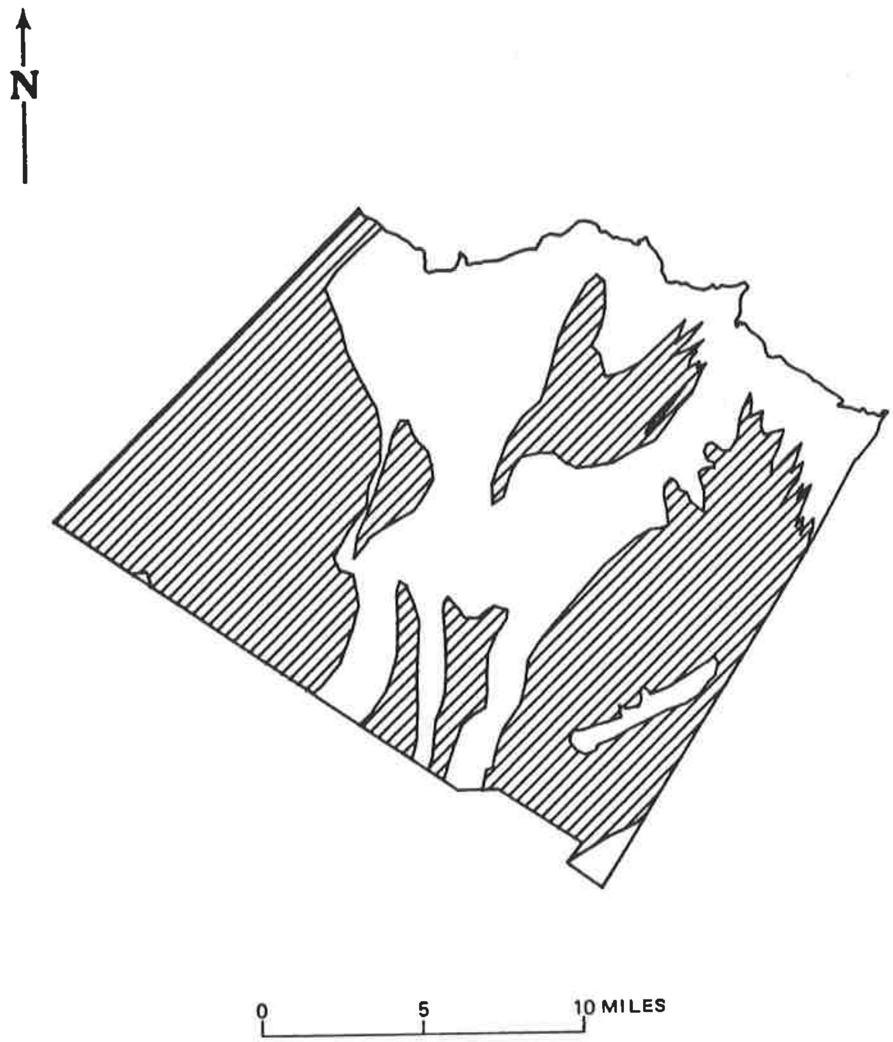

Figure 40. Map of Walton County showing outcrop areas of Lithonia gneiss. This rock unit typically is characterized by pavement outcrops with only a thin veneer of soil.

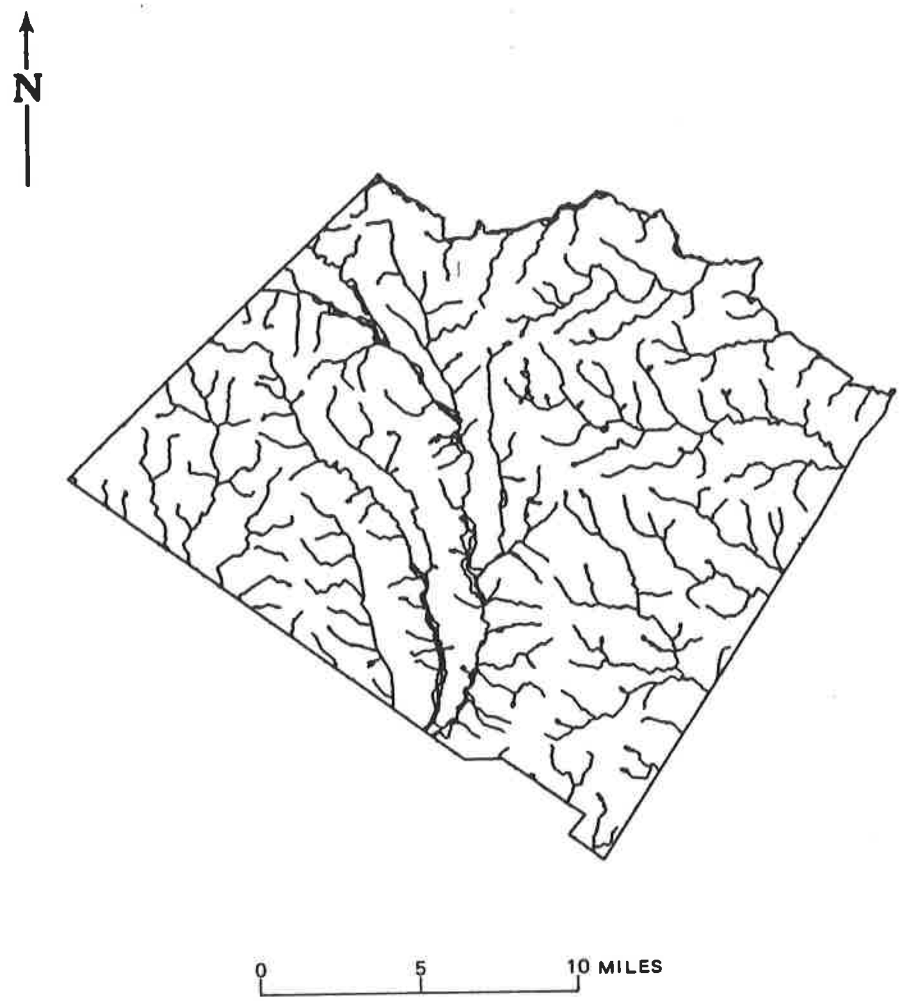

Figure 41. Map of Walton County showing surface water bodies, including wetlands.

Figure 42. Map of Walton County showing those areas (in red) generally unfavorable for sanitary landfills involving trenches. As shown on Figure 43, some of the areas shown in red would be favorable for area fill sanitary landfills. The major road network is shown in black.

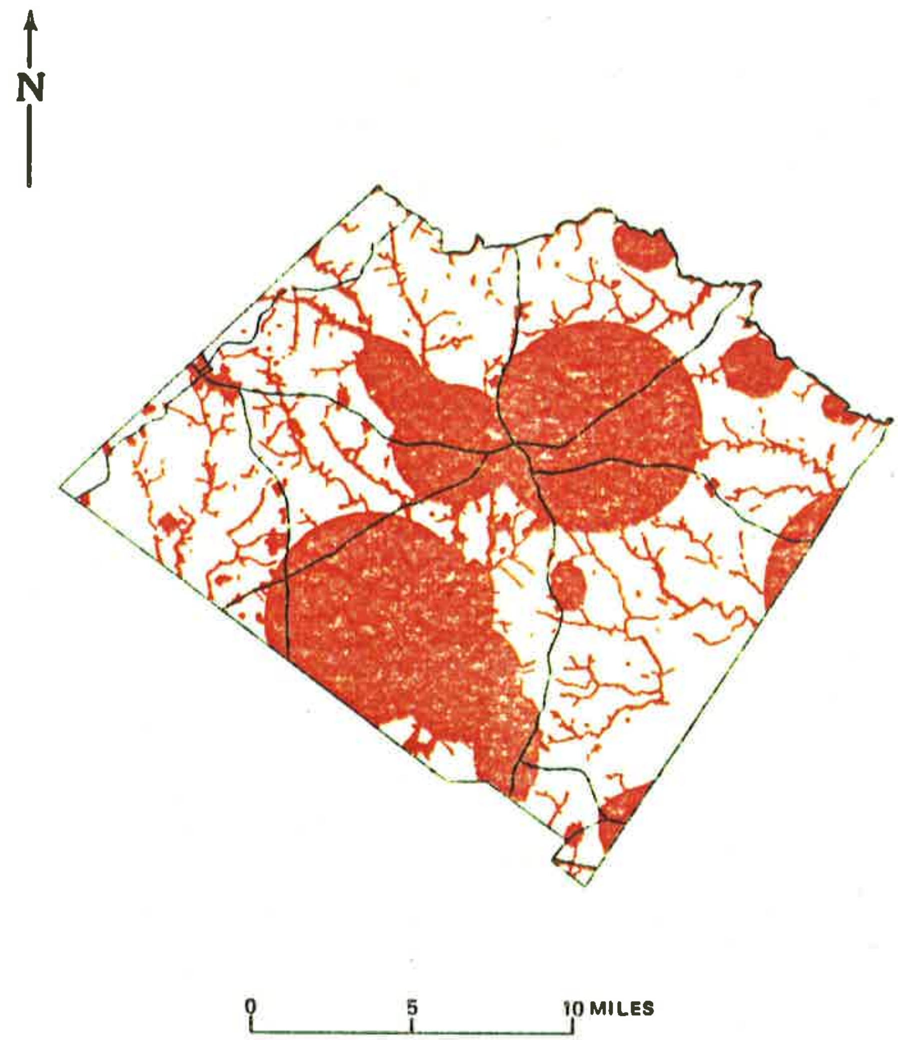

Figure 43. Map of Walton County showing those areas (in red) generally unfavorable for all types of sanitary landfills. The major road network is shown in black.

these are generators, who operate and have operated in the past without incident. Nevertheless, EPD needs to identify which of these facilities has the greatest potential to adversely affect the public, primarily by polluting sources of drinking water. With this type of information in hand, EPD then would be in the position of being able to direct its attention to those facilities where the pollution potential was highest. Then, at a later date, when the higher potential or priority facilities had been adequately regulated, EPD could assess those facilities with lesser potential to pollute water supplies.

EPD, like virtually all environmental agencies, simply does not have the resources to assess or remediate every potential environmental danger. Therefore, by prioritizing facilities on the basis of potential pollution danger, the agency should be able to protect the environment as resources will be directed to the most appropriate or most needed areas.

While there are a number of criteria that can be used to prioritize a hazardous waste facility's potential to threaten human health or the environment, they generally can be grouped into two broad categories; namely (a) proximity criteria and (b) hazard criteria. Proximity criteria indicate the potential pathways of exposure and the receptor population at risk. Hazard criteria indicate the potential of actual threat of a release and the hazard posed by the release (e.g., toxicity, carcinogenic effects, etc.).

Data from both categories can be stored in the GIS, however; because of their spatial character, proximity criteria are most readily analyzed*. Hazard criteria, on the other hand, typically involve an evaluation of specific facility information. For example, the potential for a release would range from almost none for a small quantity generator operating in compliance to very significant for a land disposal facility. Similarly, the threat posed by a release of material that is hazardous due only to ignitability would be much less than the release of a highly toxic chemical.

For this scenario, six imaginary TSD facilities were selected as occurring in Walton County. Two of these, Nos. 4 and No. 6, were arbitrarily selected to be land disposal facilities, with No. 4 being a leaking landfill and No. 6 a non-leaking lined landfill. Using those data bases currently in the GIS, the following proximity criteria were developed:

(1) Those TSD waste facilities that occur within significant recharge areas.

(2) Those TSD waste facilities that are in proximity to (e.g., 2 miles) and upgradient from a public water supply well.

(3) Those TSD waste facilities that are in proximity to (e.g., 2 miles) and upstream of a surface water intake structure.

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* Examples of some proximity criteria are provided in Table VII.

TABLE VII

PROXIMITY CRITERIA FOR HAZARDOUS WASTE FACILITIES

The following proximity criteria are used by the Land Protection Branch of EPD. Those marked with an asterisk were used for the prioritization scenario presented in this report.

- Proximity to recharge area*
- Depth to ground water
- Proximity to ground-water withdrawal sites*
- Soil characteristics
- Ground-water flow direction
- Proximity to surface water bodies, including wetlands
- Stream classification and flow rate
- Proximity to surface-water withdrawal sites*
- Population/Land Use*
    - density
    - potential for domestic wells

(4) Those TSD waste facilities that are in proximity to a populated area (e.g., there are more potential receptors [people] in a populated area).

Using ARC/INFO, the following data bases, relevant to prioritizing the six imaginary TSD hazardous waste facilities on the basis of proximity to recharge areas, proximity to sources of drinking water and proximity to receptors were integrated for Walton County:

(1) The county outline from the County Boundaries Data Base, the significant recharge areas and the six imaginary TSD facilities (Figure 44). Three TSD facilities occur within significant recharge areas; three do not.

(2) Surface water and ground-water withdrawal sites from the Water Use Sites Data Base with a two-mile buffer and RCRA facilities from the RCRA Data Base (Figure 45). Three TSD facilities occur within an induced recharge area; none are upstream from a surface water withdrawal site.

(3) Urban and built-up land from the Land Use/Land Cover Data Base and RCRA facilities from the RCRA Data Base (Figure 46). None of the TSD facilities occur in urban/built-up land.

At this point, and viewing the computer monitor, each of the imaginary Walton County TSD facilities was given a rating point whenever that facility met one of the aforementioned four proximity criteria.

Rating points for hazard criteria were given as follows:

(1) Generators and transporters were not given a rating point.

(2) TSD facilities were given one rating point.

(3) Land disposal facilities were given an additional rating point (e.g., one point for being a TSD facility and one point for being a land disposal facility).

(4) TSD facilities having a documented release were given two rating points (e.g., since a release had occurred to the environment, this hazard criteria warranted increased consideration).

(5) TSD facilities handling toxic wastes (as opposed to ignitable, corrosive or reactive wastes) were given one rating point.

The distribution of rating points for the six imaginary TSD facilities in Walton County, as calculated from the proximity criteria and hazard criteria, are provided in Table VIII. Summarizing Table VII, it is apparent that facility No. 4, which received a rating of six, would warrant first consideration.

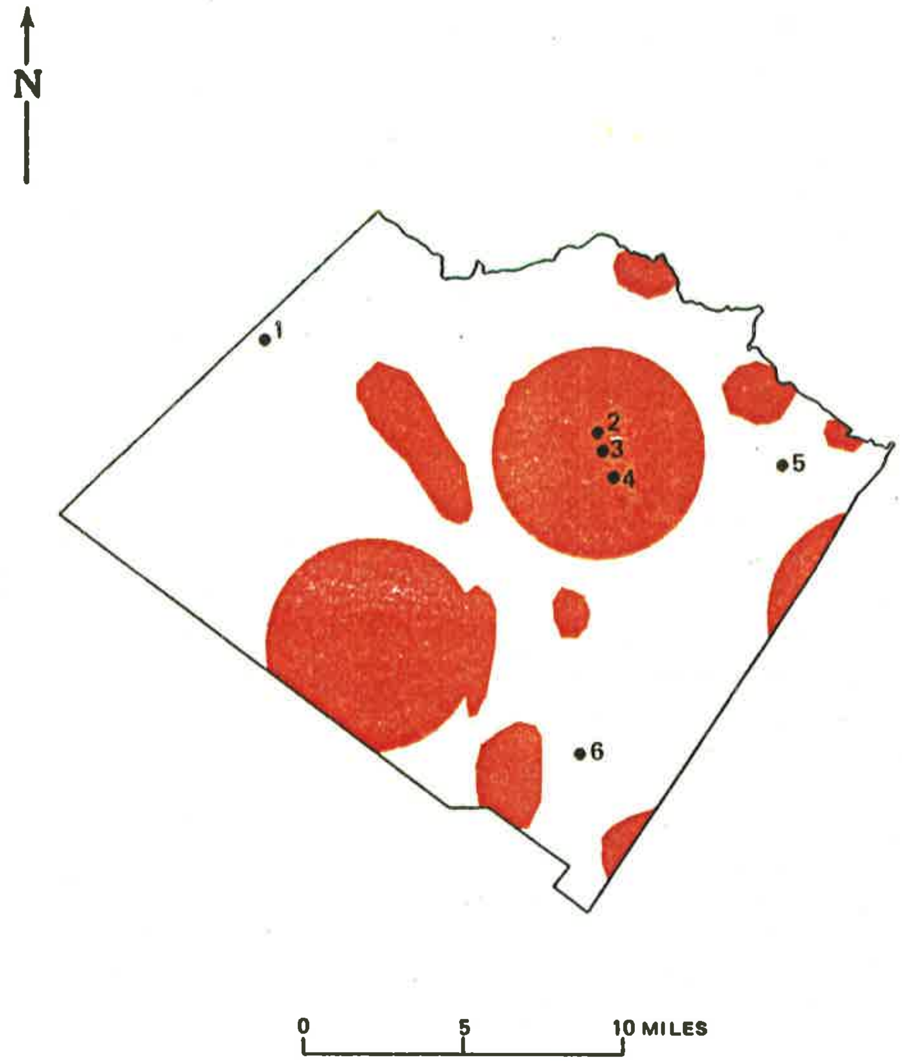

Figure 44. Map of Walton County showing six imaginary TSD facilities in proximity to significant recharge areas.

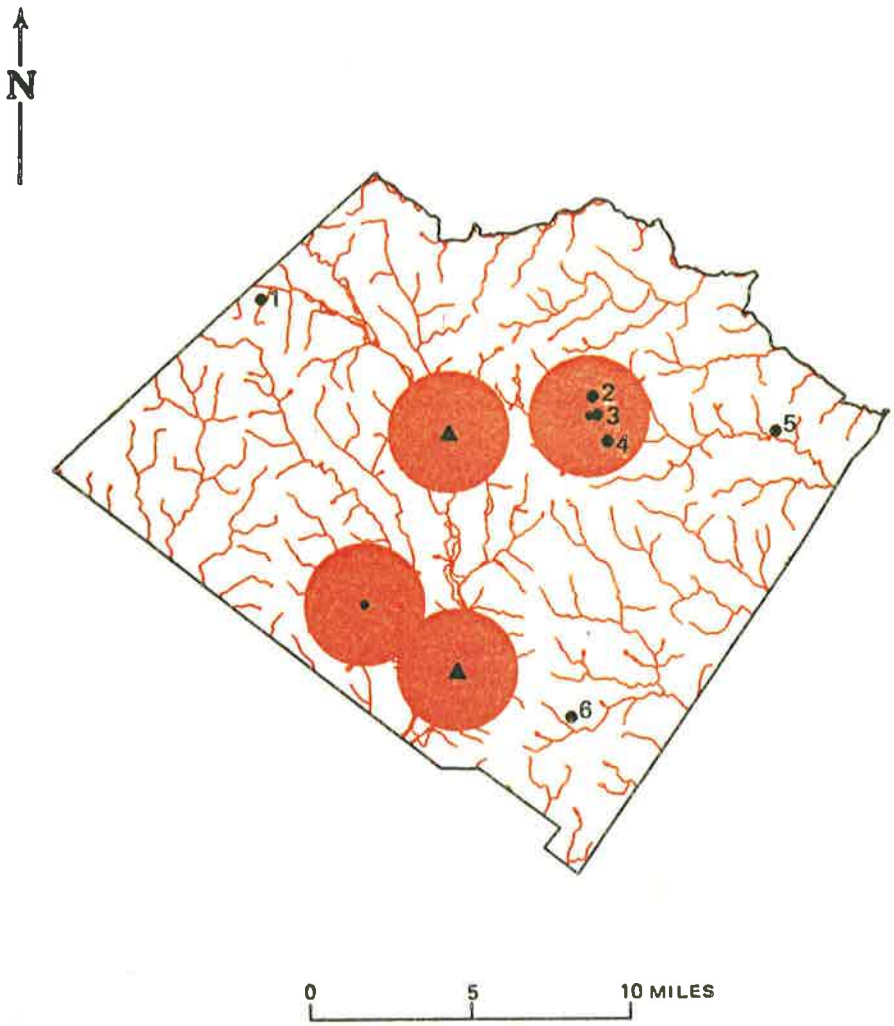

Figure 45. Map of Walton County showing six imaginary TSD facilities in proximity to surface and ground-water withdrawal sites.

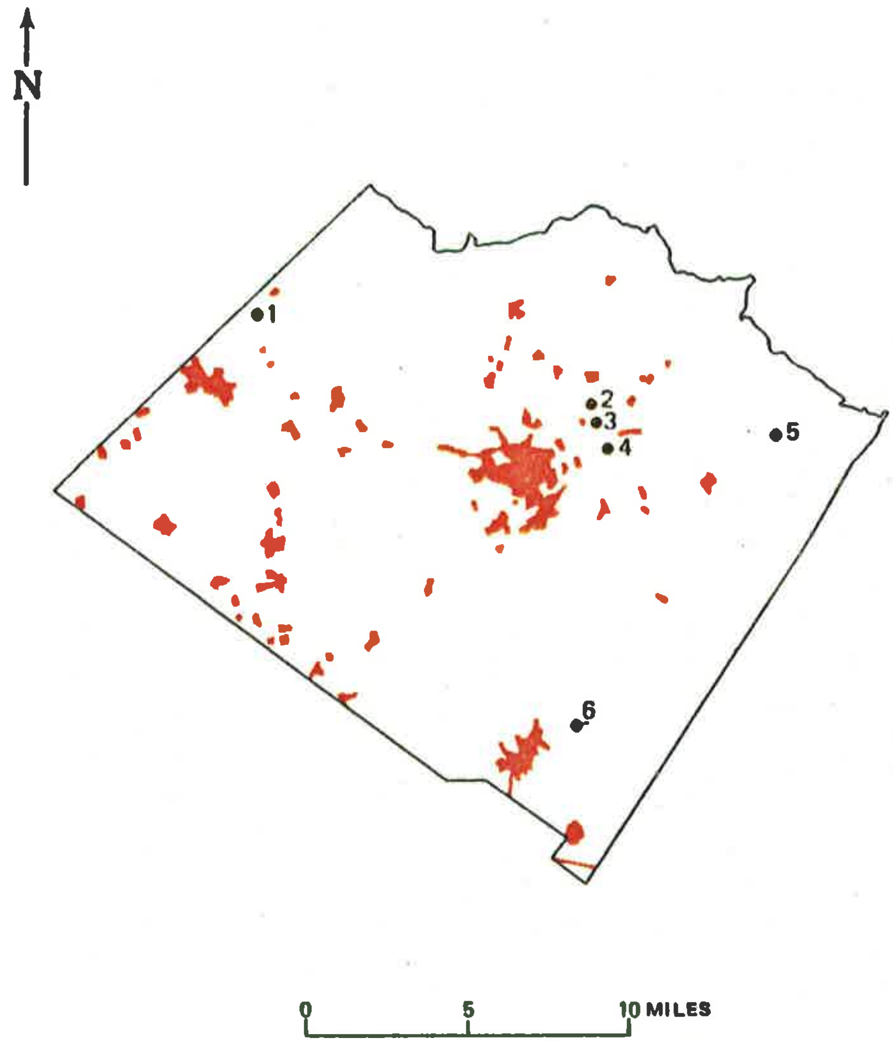

Figure 46. Map of Walton County showing six imaginary TSD facilities in proximity to urban and built-up land.

TABLE VIII

PRIORITIZING SIX IMAGINARY HAZARDOUS WASTE FACILITIES IN WALTON COUNTY

FACILITY NUMBER	PROXIMITY CRITERIA				HAZARD CRITERIA				TOTAL SCORE
	Recharge Area	Ground Water	Surface Water	Receptors	TSD	Land Disposal	Release	Waste Type	
1	0	0	0	0	1	0	0	uk	1
2	1	1	0	0	1	0	0	uk	3
3	1	1	0	0	1	0	0	uk	3
4	1	1	0	0	1	1	2	uk	6
5	0	0	0	0	1	0	0	uk	1
6	0	0	0	0	1	1	0	uk	2

uk means unknown

IDENTIFYING RECHARGE AREAS SUSCEPTIBLE TO NON-POINT SOURCE POLLUTION

In Georgia, non-point source ground-water pollution (e.g., pollution that cannot be attributed to a single source) comes from two principal sources; namely:

(1) effluent from domestic septic systems; and

(2) applications of agricultural chemicals to cultivated fields.

Ground-water monitoring by EPD (Barber, et al, 1986; Davis and Turlington, 1987 and 1988) suggests that urban runoff and nitrates from animal wastes, which are known to cause ground-water pollution in other states, are not significant contributors in Georgia.

Domestic septic systems are particularly common in residential areas outside of municipalities. Generally, within municipalities, wastes are sewered to treatment facilities and then, upon treatment, properly discharged to a surface stream or by land application (e.g., spray irrigation. Agricultural chemicals (mainly herbicides, insecticides and fertilizers) are applied to cultivated lands throughout the State, but primarily in the Coastal Plain (Figure 47).

In general, non-municipal residential areas and cultivated fields overlying significant recharge areas represent those areas that would be the most susceptible to non-point source ground-water pollution. Here, septic effluent and agricultural chemicals could reach aquifers with minimal attenuation.

Using ARC/INFO, the following data bases relevant to identifying recharge areas susceptible to non-point source pollution, were integrated for Walton County:

(1) The county outline from the County Boundaries Data Base and municipal boundaries/city limits as digitized from Georgia DOT County Highway Maps (Figure 48).

(2) Agricultural lands from the Land Use/Land Cover Data Base (Figure 49).

(3) Urban and Built-up land outside of municipal boundaries from the Land Use/Land Cover Data Base (Figure 50). Here, urban and built-up land within municipal boundaries was "subtracted" from the data base shown in Figure 30.

(4) Significant recharge areas (refer to Figure 32).

The above four data bases were integrated into the final map (Figure 51) which shows (1) urban and built-up land (outside of municipalities) occurring within significant recharge areas as well as (2) agricultural land occurring within significant recharge areas. It is these areas where non-point source ground-water pollution is considered to have the greatest

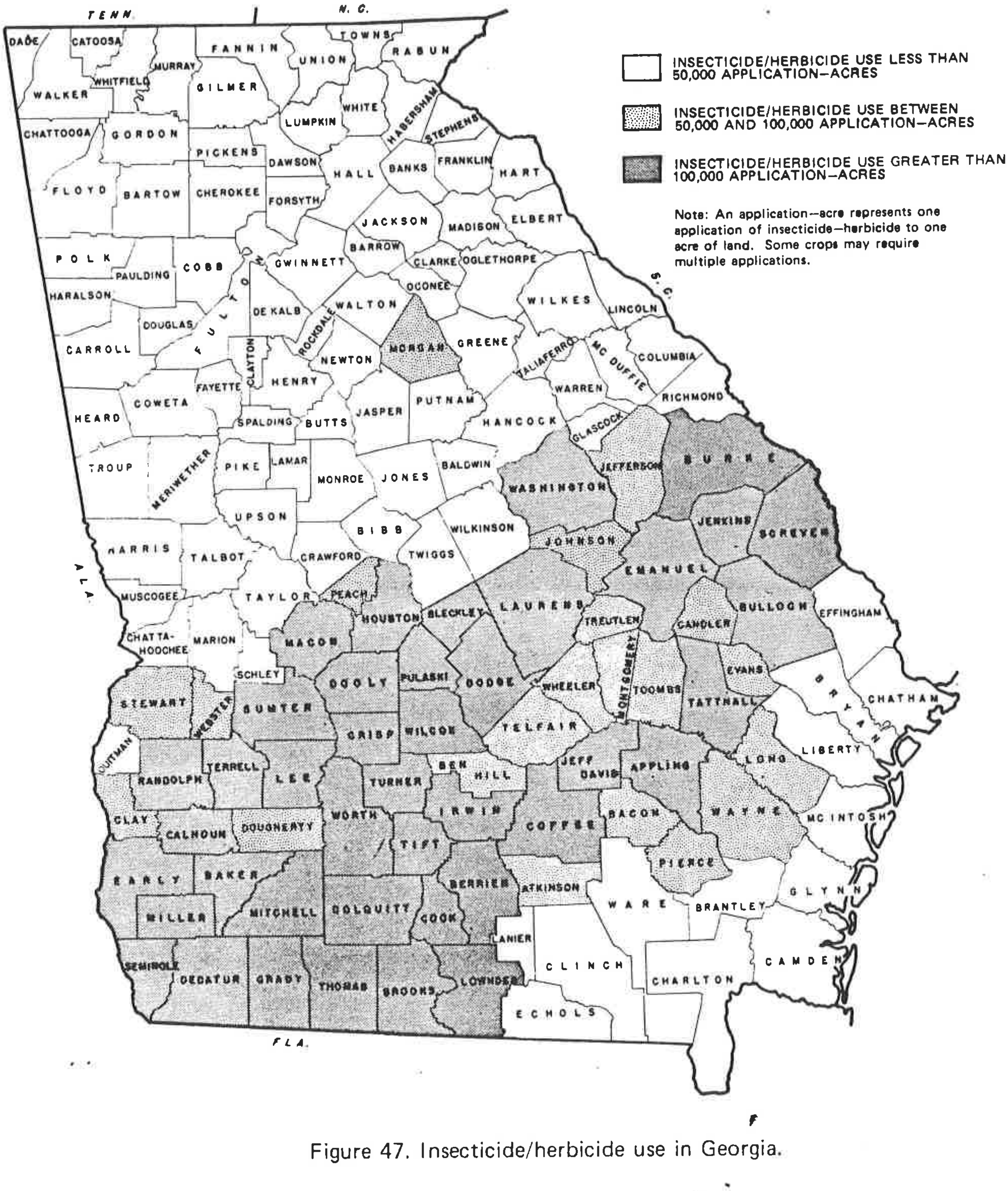

Figure 47. Insecticide/herbicide use in Georgia.

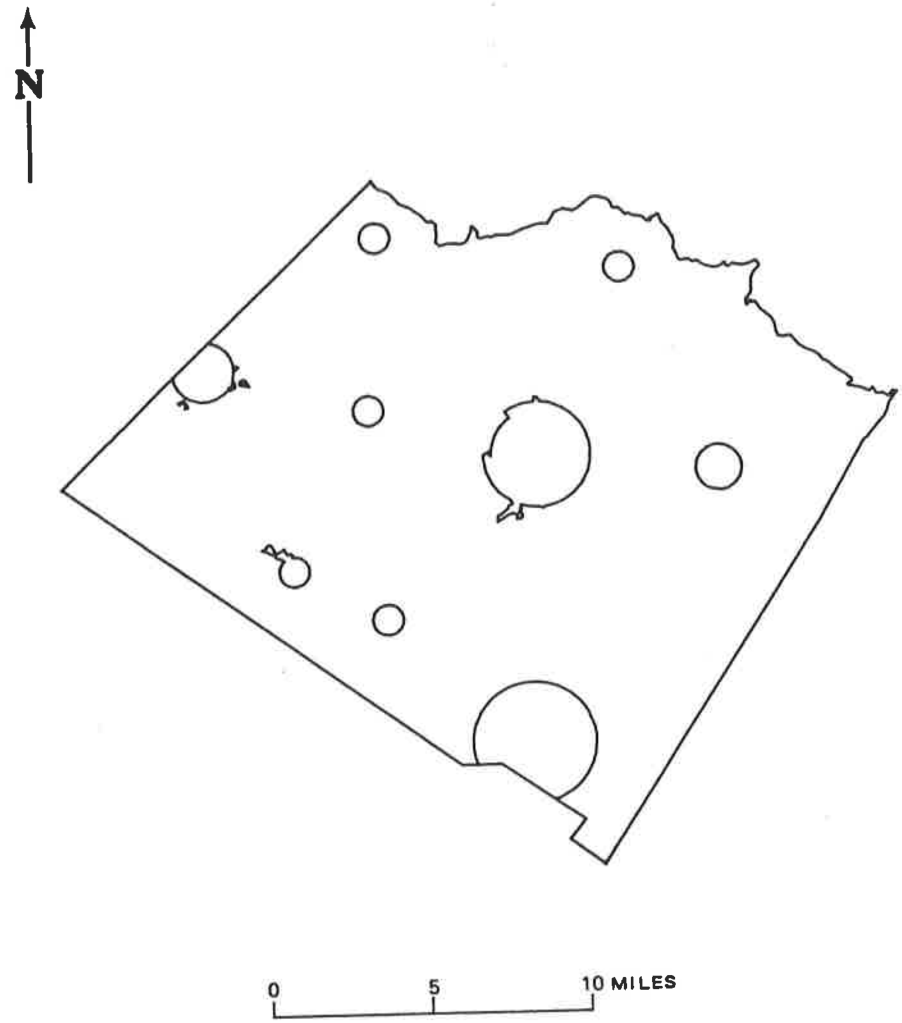

Figure 48. Map of Walton County showing municipal boundaries/city limits.

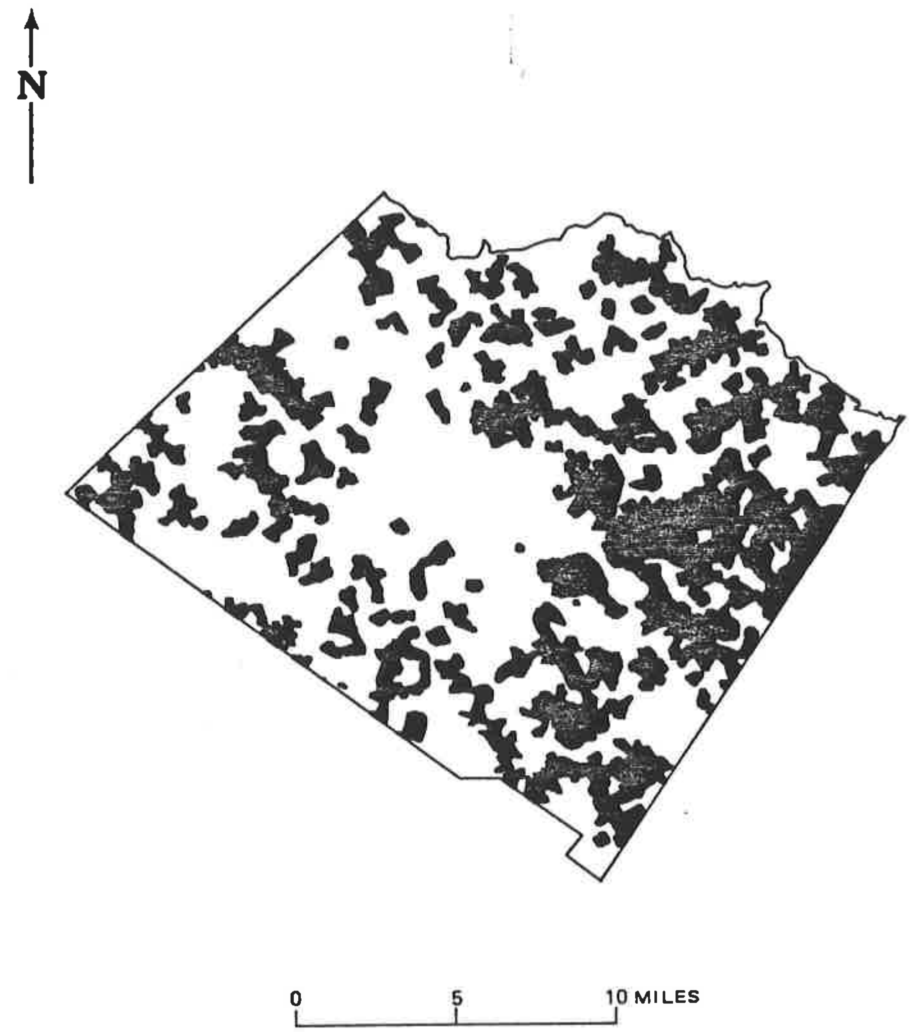

Figure 49. Map of Walton County showing agricultural lands.

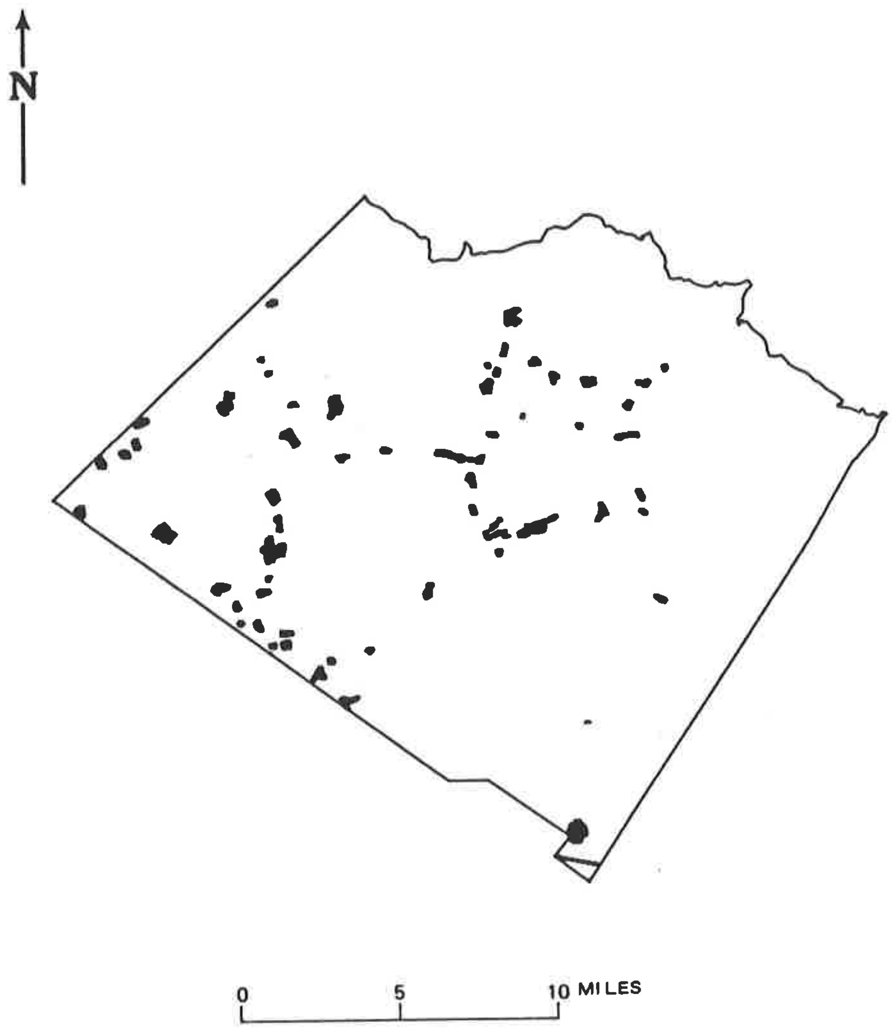

Figure 50. Map of Walton County showing urban and built-up land outside of municipal boundaries.

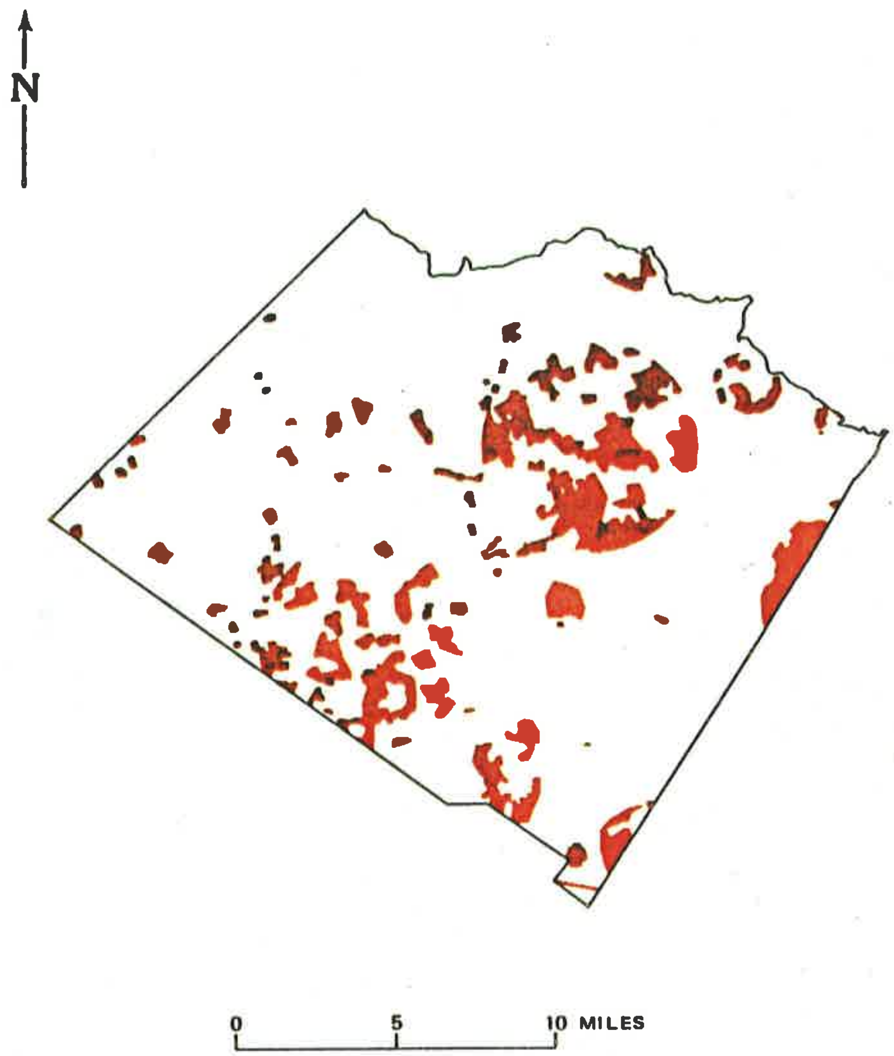

Figure 51. Map of Walton County showing urban and built-up land outside of municipal boundaries and agricultural land occuring within a significant recharge area. These areas, colored red, are considered to have higher potential for non-point source ground-water pollution.

potential for occurring in Walton County. Monitoring, obviously, would be required to confirm if pollution problems actually were occurring; but this type of analysis would be useful in identifying those areas in Georgia where EPD should first search. By reviewing maps similarly developed for all of Georgia's counties, EPD could identify those areas of the State with the highest potential for non-point source ground-water pollution and then target activities, such as educational programs, to those areas.

SITING A REGIONAL WATER SUPPLY RESERVOIR

EPD's 5-year strategy calls for the construction of a number of regional reservoirs throughout north Georgia. The purpose of these reservoirs would be to provide a source of drinking water to augment existing sources during times of drought. Siting criteria for regional reservoirs, developed by the Water Resources Management Branch of EPD, include:

(1) Stream Flow/Drainage Area - must be of sufficient quantity to produce a reliable yield equal to or exceeding water supply demands. For this study, stream reaches having a flow of 5 cfs during the drought of 1986 were deemed to have an adequate flow to supply a regional reservoir.

(2) Proximity to Water User - should not be economically prohibitive to transport raw or treated water.

(3) Land Use - reservoir area and upstream area should not be developed.

(4) Dam Site - Geological foundation should be solid, dam size (length) should be minimized.

(5) Stream Classification - non-trout classification is preferred; secondary trout is acceptable; primary trout is prohibited.

(6) Wetlands should be avoided.

In addition, the reservoir should be upstream from potential pollution sources such as sanitary landfills, hazardous waste facilities and NPDES discharges. This is considered prudent because in the event one of these potential pollution sources were to fail, the water quality in the reservoir would not be compromised.

Using ARC/INFO, the following data bases relevant to siting a regional reservoir, were integrated for Walton County*:

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* Siting criteria 4, 5 and 6 are not particularly relevant to Walton County. The entire county is underlain by crystalline rock, therefore foundation conditions should be generally good; the streams are relatively warm and provide poor habitat for trout; and wetlands are restricted to stream bottoms.

(1) The county outline from the County Boundaries Data Base, the stream hydrography from the DLG Data Base, the 5 cfs 1986 Drought Stream Flow Data Base, and urban and built-up land from the Land Use/Land Cover Data Base (Figure 52). From this integrated map, two candidate sites for a regional reservoir: Site A on the Alcovy River-Beaverdam Creek upstream from the City of Monroe and Site B on the Apalachee River in the eastern portion of the county.

(2) Stream hydrography, the 5 cfs 1986 drought stream flow and the sites of sanitary landfills and NPDES discharges (Figure 53). Evaluation of this integrated map indicates that Site A should be moved to Site A' in order to be upstream from one of the landfills.

(3) Stream hydrography with a circle having a radius of two miles surrounding the City of Monroe's water intake structure (Figure 54). From this map it is apparent that Site A' is only slightly more than two miles from an existing municipal system whereas Site B is isolated.

The above analysis suggests that the Alcovy River-Beaverdam Creek area northwest of Monroe is viable as a potential site for a regional reservoir*. Obviously, before site selection can proceed further, a number of additional features (such as land availability and costs, rerouting of roads and powerlines and new development) need to be considered. Nevertheless, GIS provides a tool whereby an initial screening of candidate reservoir sites can be made and those sites having fatal flaws can be eliminated quickly from consideration.

GENERAL EVALUATION OF THE METHODOLOGY

GIS represents an important tool for environmental decision-making. EPD was able to obtain useful and meaningful results for the four decision scenarios. Properly used by appropriately trained persons, the technology provides a mechanism for managing large and complex data bases by converting them to simple maps and tables.

Moreover, the technology is limited only by the imagination of its practitioners. For example, by combining ARC/INFO with ground-water solute-transport models, maps of industrial facilities showing plumes of contamination and monitoring wells can be constructed easily. And with each monitoring cycle, the change in configuration of the plume can be mapped. By doing this over several monitoring cycles, a "movie" of plume growth or migration can be created on the computer monitor.

* Independent of this GIS analysis, the Water Resources Management Branch identified the Alcovy River-Beaverdam Creek area northwest of the City of Monroe as one of the sites for a regional reservoir.

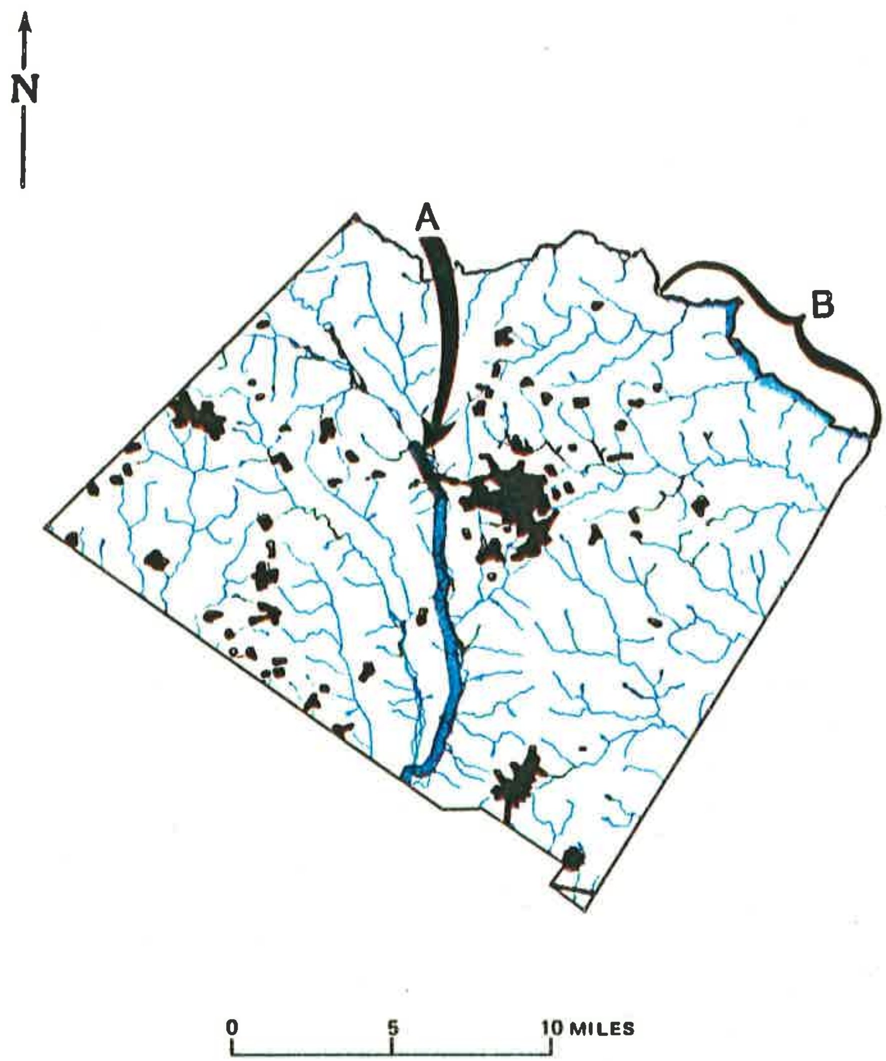

Figure 52. Map of Walton County showing hydrography (with those reaches having a flow of 5 cfs or more during 1986 having a thicker line) and urban and built-up land. Hydrography is shown in blue and urban and built-up land in black. Potential reservoir sites A and B are delineated.

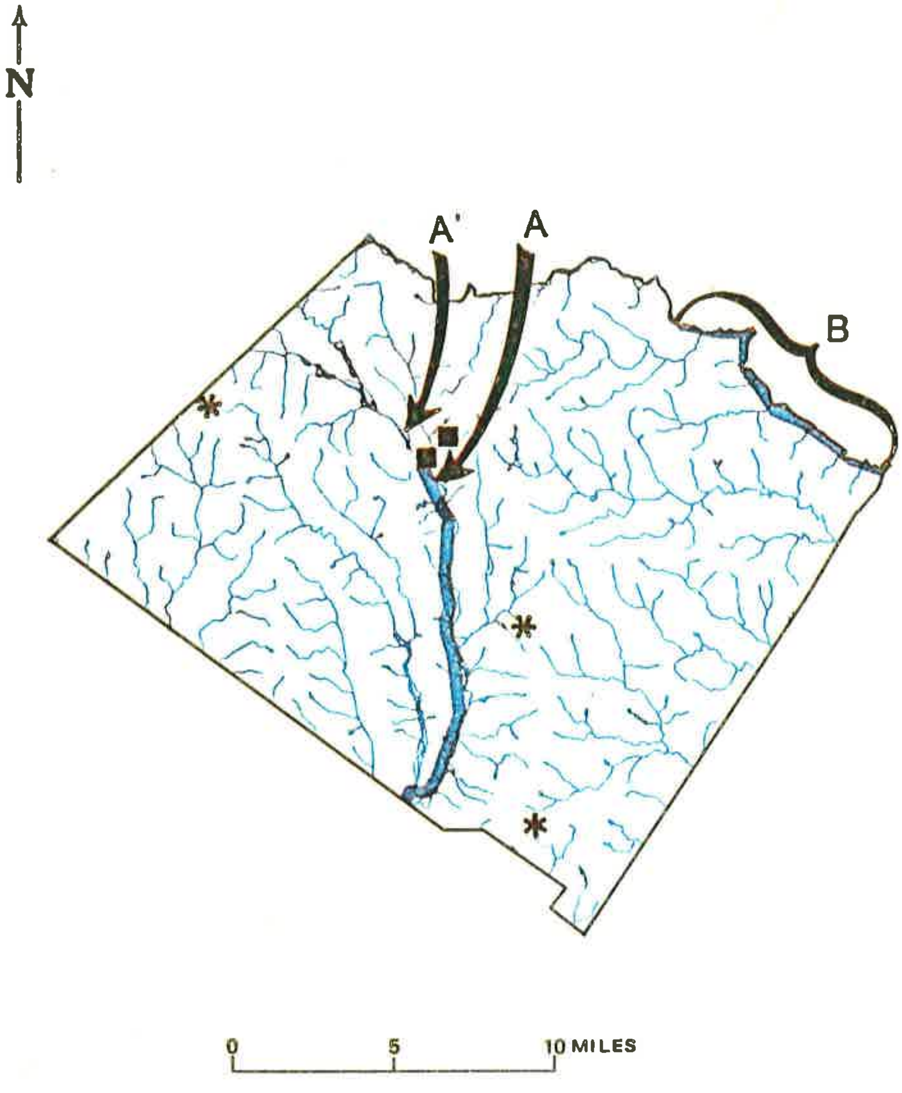

Figure 53. Map of Walton County showing stream hydrography (with those reaches having a flow of 5 cfs or more during 1986 having a thicker line) and sites of sanitary landfills and NPDES discharges. Hydrography is shown in blue and sites are in shown in black. Sanitary landfills are denoted by squares and NPDES discharges by stars. Potential reservoir sites A, A' and B are delineated.

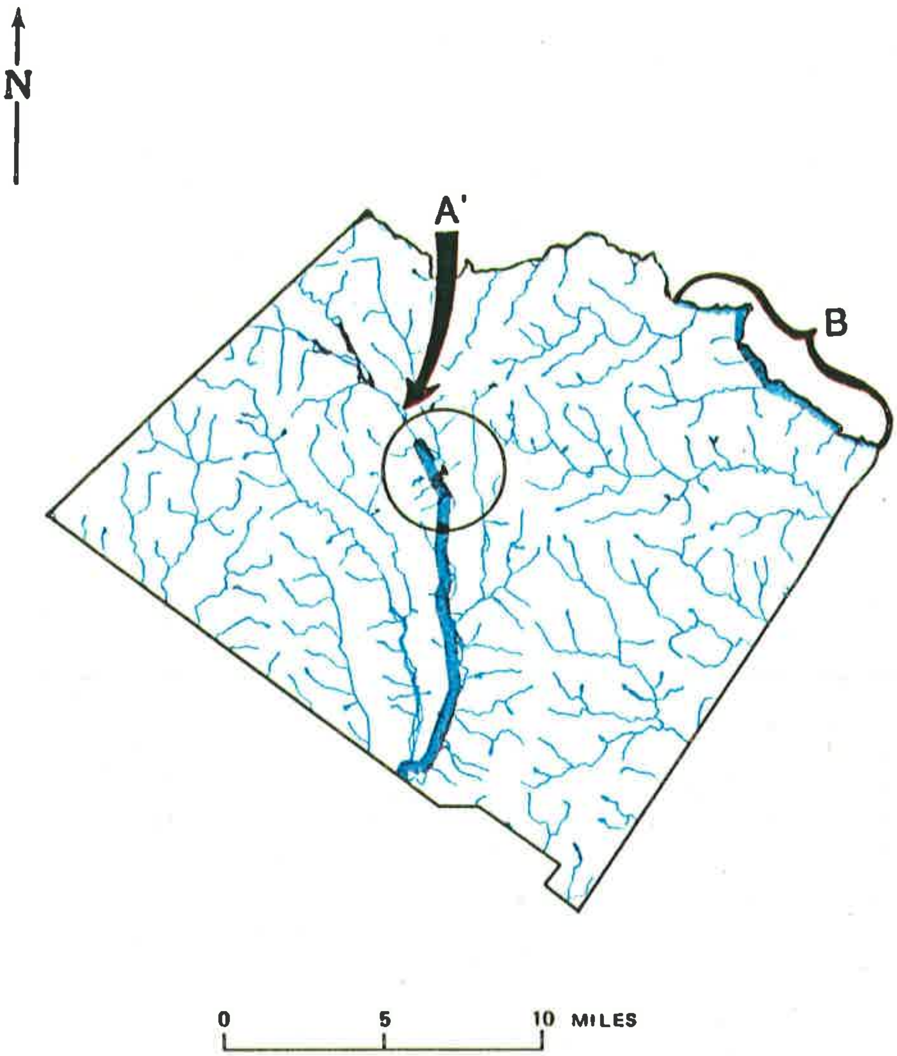

Figure 54. Map of Walton County showing stream hydrography (with those reaches having a flow of 5 cfs or more during 1986 having a thicker line) with a circle having a two mile radius surrounding the City of Monroe's intake structure. Hydrography is shown in blue and the buffer in black. Potential reservoir sites A' and B are delineated.

The technology, however, is somewhat analogous to a child playing with a loaded gun; namely in the hands of inappropriately trained persons the results can be disastrous. An example from the Phase II project serves to document this point. As discussed earlier in the Section dealing with Quality Assurance, the 1:750,000 SCS Soils Data Base does not correlate with the 1:500,000 Geologic Map Data Base. In this regard, it was apparent that, even though the 1:750,000 Soils Map had been digitized, the resultant data base was inappropriate, at the county-level, for the sanitary landfill decision scenario; and therefore, while reasonably useful for statewide maps, the data base should not be used because an incorrect decision could result. In other words, for GIS to be most effective, at least one of the persons performing the analysis has to be able to make the decision as to whether or not the data base is accurate and/or realistic. Decisions based on inaccurate or unrealistic data have the potential to undermine the entire concept of a computer-based GIS technology.

Another issue that needs to be addressed are the costs and commitments necessary for a workable GIS program. As is commonly stated by practitioners, "GIS is not cheap." The technology requires relatively expensive computer facilities as well as the labor of trained persons over a considerable period of time. Without agency commitment, GIS can be little more than a computer "toy."

Some additional issues relevant to using GIS for environmental decision-making, which became apparent during the Phase II project, include:

(1) An effective GIS program will require a multi-talented group of persons working as a team. This team should be made up of:

   (a) at least one person, knowledgeable in FORTRAN and other computer languages, who is skilled in manipulation of the ARC/INFO software;

   (b) one or more persons to digitize new data bases and perform quality assurance reviews;

   (c) one or more persons knowledgeable in the demographics and natural resources of the area to be covered by the GIS; and

   (d) one or more persons knowledgeable of environmental decision-making.

   Obviously some experienced persons probably could perform more than one of the aforementioned functions.

(2) The greater the number of people familiar with the GIS technology, the greater will be the number of useful applications for environmental decision-making. For example, the GIS technology appears to be expecially useful in performing Vulnerability Analyses as required by the Safe Drinking Water Act. This means that personnel from the Water Resources Management Branch, if versatile

in GIS, should be able to perform Vulnerability Analyses in a more timely manner or with fewer people.

(3) Outside organizations should not be relied upon to develop EPD's data bases. EPD probably will have to develop the majority of the natural resource data bases for Georgia. While other organizations will, from time-to-time, develop useful data bases, these organizations typically have their own schedules and priorities, which are different from those of EPD. Therefore, they are unlikely to produce data relevant to EPD's program in a timely manner.

(4) With the exception of those data bases developed under a quality assurance plan, there were considerable inaccurate data. During the course of the Phase II project, EPD developed an Integrated Information Management System (IIMS), which contains accurate and up-to-date information in its Facility ID Module. Data bases from the Module have the capability to be loaded directly into the GIS.

(5) Facility or site data typically are in a state of flux. New facilities are added and old ones closed. Sites continually change owners, products, capacities, etc. Therefore, data bases should be referenced with regard to time. For example, the TSD data in the GIS (the Hazardous Waste Data Base)is current as of March 1988 and should be so noted on all maps and tables.

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