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INTRODUCTION

Natural resources and environmental management of military lands is becoming increasingly complex and diverse. As military missions change and new equipment is fielded out training lands become increasingly more restricted due to environmental, logistical, and financial constraints. We must become better stewards of the land if we are going to continue to train troops to meet the next mission.

GIS is a powerful tool for military trainers, environmentalists, and natural resource planners. This paper will discuss the applications of GIS in military training and environmental/natural resources management. It will also discuss the use of map layers in the analysis of Endangered Species Habitats, Cultural Resource Surveys, Soils, cover types, wetlands, and others.

WHAT IS A GEOGRAPHIC INFORMATION SYSTEM (GIS)?

- An information system that is designed to work with data referenced by spatial or geographic coordinates. In other words a GIS is both a database system with specific capabilities for spatially-referenced data, as well as a set of operations for working (analysis) with the data.
- A system for capturing, storing, checking, integrating, manipulating, analyzing, and displaying data which are spatially referenced to the Earth.
- Automated systems for the capture, storage, retrieval, analysis, and display of spatial data.
- A system of hardware, software, and procedures designed to support the capture, management, manipulation, analysis, modeling, and display of spatially-referenced data for solving complex planning and management problems.
- An integrated package for the input, storage, analysis, and output of spatial information, analysis being the most significant.
- GIS are simultaneously the telescope, the microscope, the computer, and the Xerox machine of regional analysis and synthesis of spatial data (*GIS World Magazine,* 1996).

WHAT ARE TYPES OF GIS SYSTEMS, HARDWARE/SOFTWARE IN USE TODAY?

Geographic Resources Analysis Support System (GRASS)

Land managers and training planners at Army installations face the complex tasks of (1) facilitating optimal training use of available range and maneuver areas; (2) maintaining current lands in a condition suitable for long-term training use; (3) protecting valuable natural and cultural resources; and (4) accommodating secondary land uses, including forestry, grazing, hunting, and recreation. Furthermore, land management problems have become more complicated because new, highly sophisticated weapons require larger maneuver and training range areas. To fulfill these complex land use planning and management requirements, tools are needed to store, combine, analyze, and display multiple map elements.

The U. S. Army Construction Engineering Research Laboratories (USACERL) developed the GRASS to provide these management tools to Army environmental planners and land managers. GRASS also has many applications for Civil Works project planning and design. GRASS has many capabilities, including the handling of different data representations such as raster (or grid cell) data, vector (or line) data, point data, and imagery (satellite or aerial photographic) data. The ability to link to a data base management system for additional data storage or definition is also present.

GRASS is run through the use of standardized command line input and can be under the X Window System™. This is an internal language that allows users and programmers to create application and demonstration models and to link GRASS with other software packages. Users can input new data through digitization or the use of a scanner, with a screen pointing device, from a floppy disk, or from computer tapes.

New data can also be created by selecting data elements from existing files for analysis. Outputs include statistical tables, text files, and maps that can be displayed on a color monitor or printed on several types of hard copy printers and/or plotters.

Hardware configurations vary from table-top to rack mount machines, depending on the platform available and the needs of the users. A minimum configuration would include a display device capable of 256 simultaneous colors, a processor running UNIX or a similar operating system, at least 8 megabytes of system memory, at least 140 megabytes of disk space (300 to 600 megabytes is recommended), a line printer, graphics library, a ¼ inch or ½ inch tape drive, and a mouse pointing device. Other options include a digitizer for map input, and several color printers for hard copy output or pen plotters and modems and/or network connections to communicate with other machines.

Current GRASS workstations include SUN, Intergraph, MacIntosh II, CDC 4000 machines, PC-386's and 486's, DEC, Tektronix 88K, Silicon Graphics IRIS, Data General, IBM RISC and PS/2, Hewlett Packard, and AT&T 3B2. Ports to other machines are being developed.

GRASS allows Army environmental planners and land managers to analyze, store, update, model, and display landscape data quickly and easily. Data files can be developed for large or small geographic regions at any scale desired within the limits of the original source documents and the storage capacity of the hardware. Analysis and display operations can be performed for an entire geographic region or for any user-defined area within this region (Goran, 1993).

ArcView

ArcView is a powerful, easy-to-use tool that brings geographic information to desktops. ArcView gives the power to visualize, explore, query, and analyze data spatially.

ArcView is made by Environmental Systems Research Institute, Inc. (ESRI), the makers of ARC/INFO®, the leading geographic information system (GIS) software. They have been helping people solve spatial problems with computers for over 20 years.

A user doesn't need to know how to create geographic data in order to use ArcView. ArcView comes with a useful set of ready-to-use sample data. Additional geographic data sets are available from ESRI and from various third parties to suit almost any requirement. Plus, organizations using ARC/INFO format data already will be able to use ArcView immediately to access all these resources, including vector coverages, map libraries, grid images, and event data.

ArcView can be used by anyone who wants to work spatially. A key feature of ArcView is that it is easy to load tabular data, such as dBase® files and data from database servers, into ArcView so that users can display, query, summarize, and organize this data geographically.

Users will be working with your data in a completely new way, seeing patterns not seen before, understanding geographic relationships that were previously hidden, gaining new insights, and achieving new results for organizations.

<u>Key tasks that can be accomplished with ArcView</u>:

- Display ARC/INFO data.
- Display tabular data on a view.
- Import tabular data and then join in to the data in a view to display it geographically.
- Use SQL to retrieve records from a database and display them on a view.
- Geocode tables containing addresses and display them.
- Find the attributes of any features.
- Classify features with different symbols according to their attributes.
- Select features according to their attributes.
- Select features based on their proximity to other features.
- Find places where certain features coincide.
- Summarize and generate statistics on the attributes of features.
- Create charts showing the attributes of features.

- Lay out a map and print it.
- Lay out a map and export it for use in another application.

(Environmental Systems Research Institute, Inc., 1994)

AutoCAD

AutoCAD is a general purpose Computer Aided Design (CAD) program for preparing two-dimensional drawings and three-dimensional models. It is not a true GIS system. It can be used in conjunction with other GIS systems. It provides a full range of drafting tools that let you create accurate and realistic images that meet the ANSI standards for drafting. Users can retrieve and analyze the information in their AutoCAD drawings to generate reports, bills of material, cost effectiveness studies, numerical control data, and much more. Drawings created in AutoCAD can be translated to other CAD applications via the IGES, DXE, and SLD formats. In addition, AutoCAD provides add-on applications that let users create and analyze solid models, render models to realistic, shaded images, and analyze data stored in external bases. AutoCAD is fully customizable, enabling the automation of tasks, and creating custom menus, hatch patterns, line types, and so on. A variety of third-party applications are available to help and further customize AutoCAD. Furthermore, AutoCAD provides programming tools that let you create add-on applications. AutoCAD can run on a variety of computers and operating systems; on both stand-alone and networked setups. AutoCAD supports a wide range of video displays, pointing devices (mice and digitizers) and plotters (Autodesk, Inc., 1993).

POTENTIAL USES AND APPLICATIONS

GIS have been developed independently for a wide variety of purposes and the future of GIS will depend to a large extent on the degree to which these various needs can be integrated and met by one type of product. The growth of GIS in recent years has been led by developments in a number of areas and there have been distinct differences in the forms that development has taken and in the meaning attached to GIS (R. F. Tomlinson, 1987).

Forestry

Forestry has been responsible for a significant growth in the use of GIS in the past five years. Ideally, GIS technology would be used for the updating and maintenance of a current forest inventory and for modeling and planning forest management activities such as cutting and silviculture, road construction, and watershed conservation. In other words, the true advantages of GIS accrue only when emphasis is placed on the manipulation, analysis, and modeling of spatial data in an information system. In practice GIS have often been used for little more than automation of the cartography of forest inventories, because of limitations in the functionality of software or resistance to GIS approaches on the part of forest managers.

In a typical North American forest management agency the primary cartographic tool for management is the forest inventory. It is prepared for each map sheet in the agency's territory on a regular cycle, which requires flying and interpreting aerial photography, conducting operational traverses on the ground, and manual cartography. In one such agency the number of sheets is 5000, and the cycle of updating is 20 years. Events which affect the inventory, such as fire, cutting, and silviculture, are not added to the basic inventory.

The earliest motivation for GIS in forestry was the ability to update the inventory on a continuous basis by topological overlay of records, reducing the average age of the inventory from the existing 10 years to a few weeks. More sophisticated uses include calculation of marketable timber, modeling outbreaks of fire, and supporting planting management decisions. Every significant forest management agency in North America either has now installed a GIS, or is in some stage of acquisition. No agency is known to have rejected GIS in the past few years.

Several forms of de facto standardization have emerged in various parts of the industry. In New Brunswick the private and public sectors have coordinated efforts by acquiring identical systems. The U. S. Forest Service is in the process of determining a coordinated approach to GIS for its 10 regions. Emphasis is expected to shift increasingly to analytic rather than cartographic capabilities, so that there will be a growing replacement of simple systems by those with better functionality. This will be an expensive change for some agencies who will find that their early systems or databases cannot be upgraded, often because of the lack of topology in the data structures.

The typical U. S. National Forest has a mandate to manage not only the forests in its area, but also the wildlife, mineral, and recreation resources. Management objectives must also allow for the need to conserve as well as to extract. The typical Forest Service GIS will be used to manage road facilities, archaeological sites, wildlife habitats, and a host of other geographical features. The relative emphasis on each of these varies greatly from forest to forest.

Several factors account for the recent very rapid growth of GIS activity in the forest industry. First, effective forest management has been a significant societal concern and has attracted government funding. Secondly, GIS technology is seen as an effective solution to the problem of maintaining a current resource inventory, since reports of recent burns, cutting, and silviculture can be used to update a digital inventory immediately, resulting in an update cycle of a few months rather than years. Thirdly, a GIS is attractive as a decision tool to aid in scheduling cutting and other management activities. Finally, because of the multi-thermatic nature of a GIS database, it is possible to provide simultaneous consideration of a number of issues in developing management plans (Tomlinson, 1987).

Property and Land Data

The acronyms LIS and LRIS (Land Information System and Land Related Information System) are often used in this sector, reflecting the relative importance of survey data and the emphasis on retrieval rather than on analysis. Most major cities and some countries have some

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experience in building parcel systems, often dating back to the earliest days of GIS, but state or national systems have not generally been considered in North America because land registration is usually a local responsibility. Fragmentation of urban local government is also a problem in the U. S. and in some Canadian provinces.

The functions needed in a LIS are well short of those in a full GIS. In many cases all that is needed is a geocoding of parcels to allow spatial forms of retrieval: digitizing of the outlines of parcels is useful for cartographic applications. It is unlikely that many municipalities will advance to the state of creating a full urban GIS by integrating data on transport and utility and developing applications in urban development and planning at least in the next five years. In summary, automated cartography and retrieval will probably remain the major concerns of such systems in the immediate future and confidentiality and local responsibility will remain barriers to wider integration. It is likely that these needs will be met initially by vendors of automated cartography systems and Database Management Systems, although there will be a steady movement towards GIS capabilities as urban planners and managers demand greater analytic capabilities. It is unlikely, however, that many municipalities will reach the stage of giving the digital data legal status as a cadastre because of problems of accuracy and confidentiality (Tomlinson, 1987).

Utilities

Telephone, electric and gas utilities operate in both private and public sectors in North America, and it is useful to distinguish between applications at large and small scales. Large-scale applications include monitoring the layouts of pipelines and cables and locations of poles and transformers, and as in the case of land parcel systems, combining needs for cartography and spatial retrieval. Small scale applications include planning of facilities and transmission lines to minimize economic, social and environmental costs, and demand forecasting. Some utilities have built large databases for such purposes, and also make use of digital topographic data. In the long term as GIS software stabilizes and develops, it is likely that the advantages of better capabilities for easy exchange of data formats will make such systems an attractive option for these applications. Developments in this arena have not yet reached the beginning of the growth curve, but a significant proportion of this market will probably move away from existing automated cartography systems in GIS in the next 10 years, and several vendors appear to have anticipated this trend (Tomlinson, 1987).

Transport, Facility, and Distribution Planning

In addition to both public and private sector transport agencies, much of the work in this sector is carried out by contractors, such as market research firms and university staff. Although market research frequently calls for sophisticated forms of spatial analysis, such as site selection and modeling, vendors of GIS have not made any significant penetration of the market. Instead, most companies rely on a combination of standard statistical packages. There is every indication that this sector will be a major growth area for applications of GIS in the next 10 years. Software for these forms of analysis is at present rudimentary but developing rapidly. There is a pressing need for the ability to handle multiple formats of geographical data, scales and types of features, and hierarchical aggregation of features in processing socio-economic data, and in combination with advanced forms of spatial analysis and map display. The potential market includes retailers, school systems, transport and distribution companies and other agencies who need to solve problems of routing and rescheduling on networks, and the direct mail industry (Tomlinson, 1987).

Civil Engineering

A major use of digital topographic data is in large-scale civil engineering design, such as cut and fill operations for highway construction. The first digital developments in this field derived from the photogrammetric operations, which are the primary source of data. There are multiple systems installed in civil engineering firms and government agencies. Rapid growth is occurring in both Canada and the U. S. in the significance of digital topographic data for defense, because of its role in a number of new weapons systems, including Cruise, and because of the general increase of defense budgets in the industrialized world. This work has drawn attention to the importance of data quality, and the need for sophisticated capabilities for editing topographic data as well as for acquiring them. These needs are presently being met by enhancements to automatic cartography systems (e.g., Intergraph) and it is not yet clear whether they will lead to any significant convergence with GIS (Tomlinson, 1987).

Agriculture and Environment

The use of GIS approaches can be traced to the need to measure the area of land resources, to reclassify and dissolve prior to display, and to overlay data sets and to compare them spatially. These remain among the most basic justifications for GIS technology. GIS technology is of considerable interest in land management, particularly of national parks and other federal, state and provincial lands, and has been adopted in both the U. S. and Canada. In agriculture, the main issue arises from the critical importance in farming of changes over time and season. Although much research has been conducted on the interpretation of agricultural data from remotely-sensed imagery, there remain the conceptual problems of classification and interpretation. Marine environmental monitoring and climatology are good examples (Tomlinson, 1987).

MILITARY HISTORY OF USE

Problems of maintaining military lands in support of the training mission, while dealing with environmental compliance and land stewardship issues, have become increasingly complex for military and civilian personnel. Many of the environmental laws and regulations that have been passed in the past two decades affect our military training lands.

To achieve compliance, protect valuable natural and cultural resources, prevent incompatible land uses and support the training mission, military installations need a program that integrates training mission requirements with effective land management practices (Severinghaus & Goran, 1991).

This program is called Integrated Training Area Management (ITAM). One of the primary tools to display and analyze data is its GIS system. As discussed earlier, the military developed GRASS for this purpose. Currently the military is converting its systems over from a GRASS UNIX system in most cases to a DOS ARC/INFO system. These systems are more user friendly and compatible with systems and is utilized by various federal and state agencies.

GIS systems are used extensively by the military to assist decision makers in numerous natural resources and environmental compliance issues. GIS has become so ingrained into the NEPA process it would be deficit to analysis and display data without this tool.

Other Uses

GIS and automated geographic information systems are rapidly expanding. The following areas are a summation:

- Engineering mapping (all disciplines)
- Automated photogrammetry
- Land planning
- Tax mapping
- Highway mapping
- Utility mapping and management
- Geodetic mapping
- Event mapping (accidents, crime, fire, facility failures, etc.)
- Census mapping
- Statistical mapping
- Environmental impact studies and assessments
- Natural resource mapping and management
- Transportation mapping and management
- Urban planning and management

(Dangermond, 1983)

USE INHIBITING FACTORS

The wider use of GIS technology is inhibited by a number of factors. Some are the lack of large-scale digital base mapping and no projection for one in the near future. The access and availability of data has been a significant factor. Digitization and the cost of implementing local use base data are cost prohibitive for all but larger agencies. Software is very important. Because of the limited use and small market the cost and development of software remains a prohibition. Reductions in the costs of hardware, storage and peripherals will continue and cost will eventually decline.

User awareness is an extremely important factor, along with other behavioral considerations. Information about GIS has tended to be disseminated through personal contacts, reports, and meetings rather than through formal organizations, journals, and textbooks. There has been no systematic approach to GIS in the educational system. The term is encountered in courses in departments of geography, surveying and forestry – in other words, primarily in applications of GIS by students with little or no technical background.

The only effective way to implement a total educational package would be a complete and comprehensive study of functional requirements with the full cooperation of the director of the agency. Another possible alternative would be to ensure that all staff were introduced to GIS as part of their basic education, whatever their application area. If this were possible it would take decades to achieve. In short, the greatest obstacle to greater use of GIS will continue to be the human problem of introducing a new technology (Tomlinson, 1987).

INTERCOMPATIBILITY AND EXCHANGE OF DATA USES

To understand how GIS can be used in conjunction with other systems the recorder must have a rudimentary understanding of the differences between Geographical Information Systems (GIS), Computer Aided Design Systems (CAD), and Data Base Management Systems (DBMS). All this must be understood with the slant towards spatial definition and analysis.

Data capture - GIS is spatial maps in digitized form. Maps are two-dimensional representations of the earth's surface. Therefore, there exists a direct translation of all geographic entities into equivalent elements of planar geometry. Map digitization is an exercise in translating these geometric representations into the computer as machine readable. Geographic entities therefore can be captured from maps or images and subsequently represented as points, lines, polygons, or a matrix of numbers. The most important question is how data capture relates to scale, resolution, and the efficient storage and retrieval of spatial entities (Cowen, 1988).

Although GIS started as early work in computer mapping the field is greatly expanded. The original work at the International Geographic Union Commission on Geographical Data processing and sensing resulted in a two-volume report. Tomlinson stated GIS is not a field by itself but a pattern of a common ground between information processing and the many fields utilizing spatial analysis techniques (Tomlinson, 1972). Based on a 1986 definition of GIS as "computer assisted systems for the capture, storage, retrieval, and analysis of spatial data," it would appear that in the minds of many, GIS is simply a catchall for almost any type of Computer Automated Geographical Data Processing (Clarke, 1986). Cowen argues that such vague definitions do a great disservice to the field by allowing the label of GIS to be applied to any software system that can display a map. Four general approaches to defining and understanding GIS follow:

1. *Process Oriental Approach* - based on the idea that an information system consists of several integrated subsystems that help convert geographic data into useful information.

2. *Application Approach* - a modification of the process-oriented approach yields a definition which categorizes GIS according to the type of information being processed. For example, Pavidis' classification scheme includes natural resource inventory systems, urban systems, planning, and evaluation systems, etc. The field of Forestry may cut across several of these categories, but is primarily concerned with inventory, planning, and management. While defining GIS on the basis of application may help to illustrate the scope of the field, it does not enable one to distinguish GIS from other forms of automated geographical data processing.

3. *Toolbox Approach* - the toolbox definition of GIS derives that such a system incorporates a sophisticated set of computer-based algorithms for handling spatial data. Typically, these tools are organized according to the needs of each process oriented system (e.g., input, analysis, and output). The tool box definition implies that all these functions must be present and should work together efficiently to enhance the transfer of a variety of geographical data. Therefore, even though they are important components of automated geography, neither digitizing, image processing, nor automated mapping systems qualify as GIS because they do not possess all the necessary tools and do not provide the overall integration of functions.

4. *Data Base Approach* - refines the toolbox definition by stressing the ease of interaction of other tools with the database. A GIS must start with an appropriate data model. The success of a GIS will be determined by the efficiency that the data model provides for retrieval analysis and display of information. While the technical issues surrounding database design are the most critical ones facing the field today, the data base approach does not provide any better basis for defining the field than does the tool box. A GIS is best defined as a system which uses a spatial database to provide answers to queries of a geographical nature. The generic GIS thus can be viewed as a number of specialized spatial routines laid over a standard relational database management system (Goodchild, 1985). The confusion then, regarding the distinctions among differing computer-based geographic processing systems, may be abasted by examining the functions that such systems provide. The most appropriate way to accomplish this objective is to scrutinize the flow of data through the system and review the types of questions the system is able to respond to (Cowen, 1988).

CAD - A GRAPHIC APPROACH

A surprising amount of digital cartography is merely electronic drafting. For cartographic applications graphical entities are often traced electronically from existing maps only to be selectively redrawn with additional annotation and other embellishments. In short, CAD systems handle geographic data in the same manner as photographic separations are used for topographic maps. CAD systems proving more versatility in forms of display functions than do their photographic counterparts are beneficial for editing and updates.

CAD systems have several limitations for analytical tasks. For example, it is difficult to link attributes in a database to specific geographical entries and then automatically assign symbology. For example, a CAD system could be used to create a graphical representation of a subdivision consisting of all property lines. CAD would generate smooth curves for radiuses and would form all lines perfectly. The system would enable the cartographer to point to a particular parcel and then shade it with a pattern. CAD could not, however, automatically shade each parcel based on values stored in a tax assessor's data base containing information regarding usage or value. In other words, CAD is merely graphic (Cowen, 1988).

THE UNIQUE SCOPE OF GIS

Fundamental Operations

Cartensen's (1986) recent investigation of the needs of a local government provides a basis for pinpointing the unique capabilities of a GIS. He approached the selection of an automated system on the basis of each candidate system's ability to determine which parcels of land met a set of six criteria for industrial site selection. All of the information needed to select such a site could have been gathered from maps and searches at the appropriate local offices. The important question from the standpoint of geographic data processing and the field of GIS is the determination of whether the information could be generated automatically from digital representations of the relevant maps (Cowen, 1988).

If the information for each parcel of land already existed in a database, then a standard database management system (DBMS) would have been able to deliver a list of addresses of the parcels that met all criteria. A computer mapping system could have retrieved the same parcels and generated a map. It is interesting to note that the street addresses might very well have been more useful in the decision process than a map. However, for even a moderate size area, either of these solutions would have required more manual effort to build the database than would have been justified for this single problem (Cowen, 1988).

The dependency on manual creation of a database provides the basis for distinguishing a GIS from a computer map system. One could expect a full featured GIS to support entire creation of the database, as well as storage, retrieval, analysis, and report generation required to select the appropriate subset of geographic entities. For example, by utilizing GIS, the size of each parcel would have been calculated automatically from the boundary coordinates, the type of zoning for each parcel would have been determined from the overlay of a zoning map, and the ownership status would have been updated automatically from transactions at the assessor's office. Inclusion in a flood-prone area would have been determined by another overlay created from maps of water bodies and topography. The same sources would have been used to determine the slope. Finally, the distance to different types of geographical entities could have been calculated from existing map inputs. In every case, variables or attributes relating to each parcel would have been created from other layers of geographical information. Most significantly, the GIS previously encoded information. This ability to both automatically synthesize existing layers of geographic data and to update a database of spatial entities is the key to a functional definition of a GIS (Cowen, 1988).

Spatial Search and Overlay

It is important to note that of all of the operations that commonly are included in GIS toolboxes, spatial search and overlay are the only ones unique to GIS. Furthermore, it can be illustrated that most spatial searches are merely special forms of the overlay process. For example, in order to identify all of the parcels located within a mile of heavy duty roads, one would generate a buffer zone, or polygon, one mile wide around each such road. A polygon overlay algorithm would then be used to identify which parcels fell within these polygons. The emphasis of the GIS operations must be on the integration of different layers, not their creation. Concentration on the integration process results in the classification of the digitizing step as one that simply preprocesses maps into machine readable formats. Cartographic systems reverse the digitizing process by converting digital information into an analog format. Whereas digitizing is an essential part of the GIS process, the cartographic output subsystem of a GIS is often a convenient by-product (Cowen, 1998).

GIS as a Decision Support System

Geographic information systems have sometimes been called decision support systems. Most of the work on GIS system design emphasizes this approach. Calkins and others stress that the first stage of any assessment of user needs must involve an identification of the decision makers, and analysis of the objectives of the system, and an outline of the organization's decision making system (Calkins & Tomlinson, 1977). A successful GIS must support the management of some resource or some problem-solving process. If it does neither, it will fail. Because decision making is a broader term that encompasses the full scope of resource management, one could conclude that a successful or operational GIS must serve as a decision support system. Furthermore, it would appear that a successful GIS must exist within an organizational setting that is capable of providing it with proper support. A GIS is best defined as a decision support system involving the integration of spatially referenced data in a problem solving environment. The most important part of this definition is the emphasis on integration. In other words, GIS provides the tools, particularly polygon overlay, that we have always needed to truly synthesize disparate sources of spatial information. Earlier forms of automated geography that simply retrieved, manipulated, or displayed predefined geographical features lacked the ability to combine maps with remotely sensed data and other types of data (Cowen, 1988).

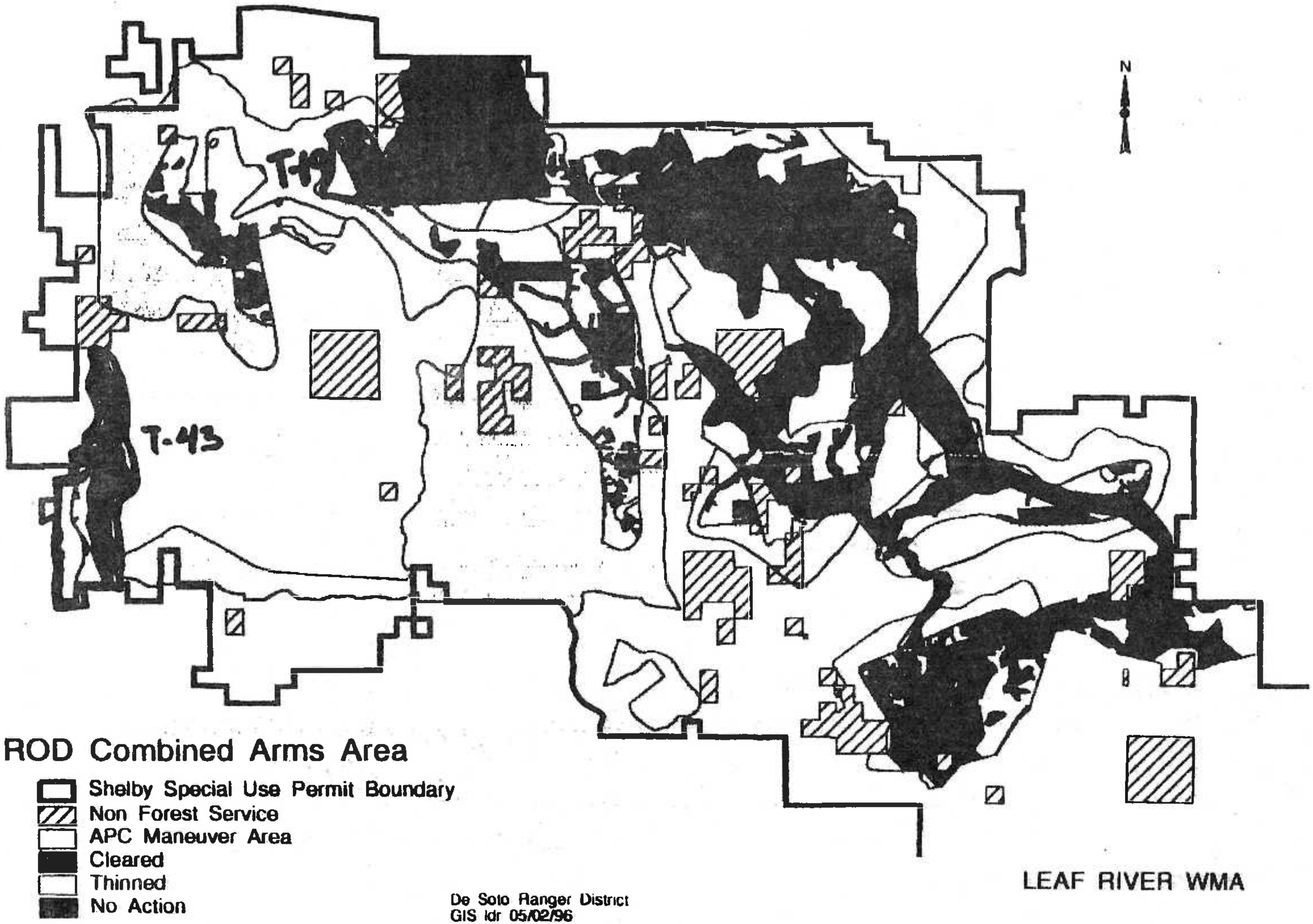
INTERCOMPATIBILITY

In the following sections, we will examine a few of the intercompatibility issues available in conjunction with GIS. Technology such as Global Positioning Systems, CAD, Surveying Equipment and Remote Sensing are just a few compatibility technologies that will support and enhance the use of GIS in the decision support system role. Available in everything from back packs to brief cases, Global Positioning System (GPS) technology continues to play a dominant role in getting fast, accurate information about the world in which we live. While users certainly realize that GPS is not the end-all technology, it does provide some support to GIS. GPS can be used to map and create extended databases for mapping wetlands, surveying, and emergency response. The data that is then produced becomes the framework for all survey design and analysis performed in an agency's other information systems such as GIS programs. Progressive enhancements to GPS software and receivers deliver increasing mobility and accuracy thereby opening the door for extended applications.

One of the most far-reaching effects of GPS to the surveying and mapping community is not its capability as an independent data gathering system but instead a technology partner to other similar systems. These include tools that gather data, such as laser systems, total stations and tools designed to manipulate data such as GIS/CAD (*Engineer News Record,* October 1996).

The opportunity that these tools provide by delivering seemingly unending streams of information in a timely manner will help the GIS market maintain its growth rate. It will be further stimulated by the industry's continued drive to deliver more integrated information exchange between otherwise disparate systems.

Another compatibility issue to watch is the emerging commercial high resolution remote sensing market. Market headers - Earthwatch, Orbital Imaging (ORBIM-AGE), and Space Imaging - are each on the verge of launching the first of a series of high resolution satellites. Once these satellites become operational, extremely detailed images of Earth's surface will boost the availability of data so critical to technology like GIS (*Engineer News Record,* October 1996).


N
T-19
T-43
ROD Combined Arms Area
Shelby Special Use Permit Boundary
Non Forest Service
APC Maneuver Area
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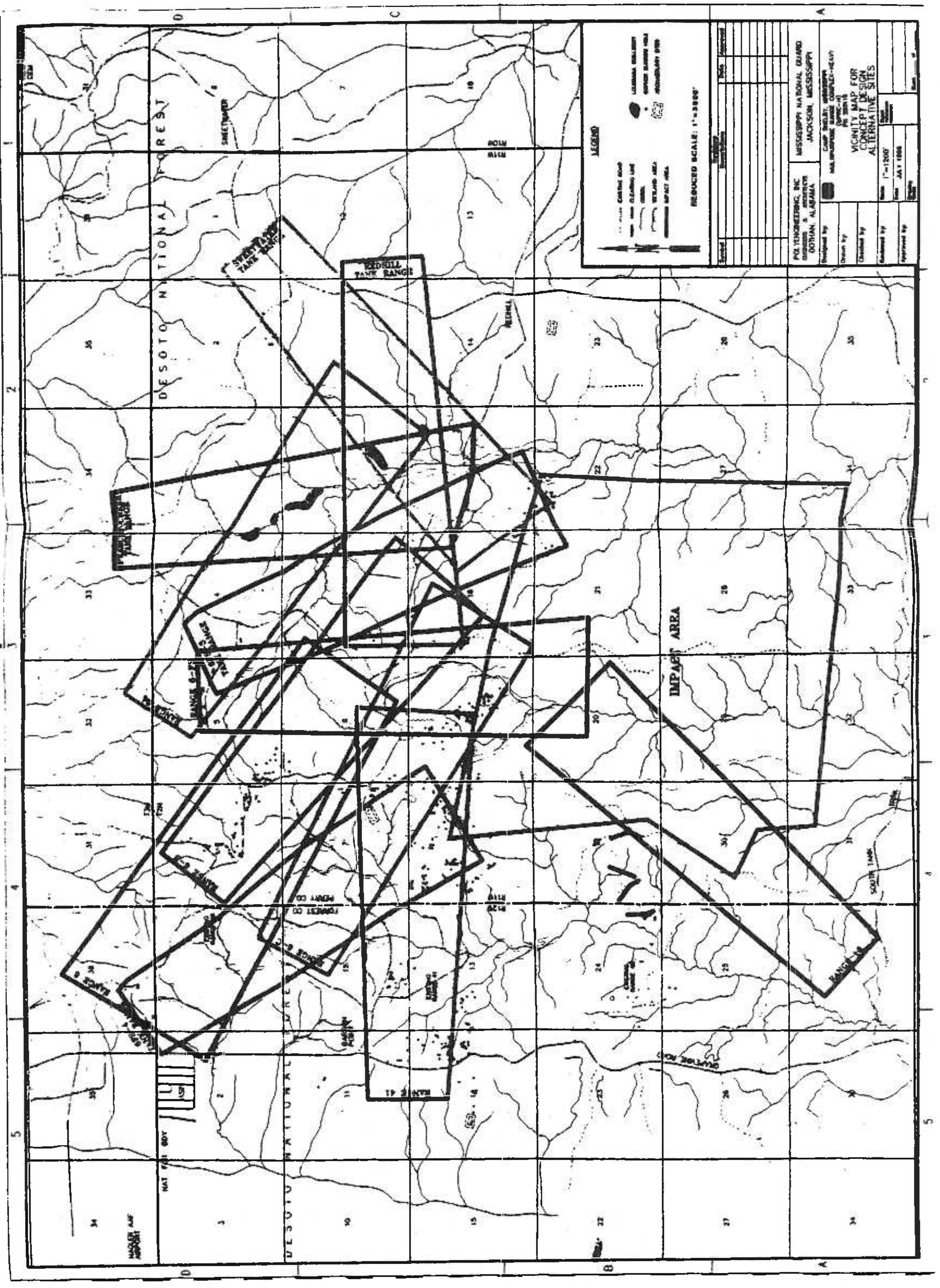
DESOTO NATIONAL FOREST
REDHILL TANK RANGE
IMPACT AREA
LEGEND
POLYENGINEERING, INC
DOTHAN, ALABAMA
MISSISSIPPI NATIONAL GUARD
JACKSON, MISSISSIPPI
VICINITY MAP FOR
CONCEPT DESIGN
ALTERNATIVE SITES

CONCLUSION

The magnitude of environmental issues facing local, state, and federal government agencies is large and becoming greater. From pollution prevention issues, restoration, environmental decision making, engineering decision making and others, the list becomes greater each year. This creates a need for information which outstrips even the Federal Government's fiscal and manpower resources. GIS was, and is, an effective informaiton tool to research cost effective ways of providing solutions to problems. By utilizing GIS in coordination with other base support technologies, agencies can reduce the cost of achieving and maintaining environmental compliance as well as providing a cost effective means of decision making and record keeping. Although the cost of developing, procuring and implementing geographical information systems in agencies appears high it is the most cost effective means in the long run for the use of scarce resources and will help guarantee successful decision making ventures.

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