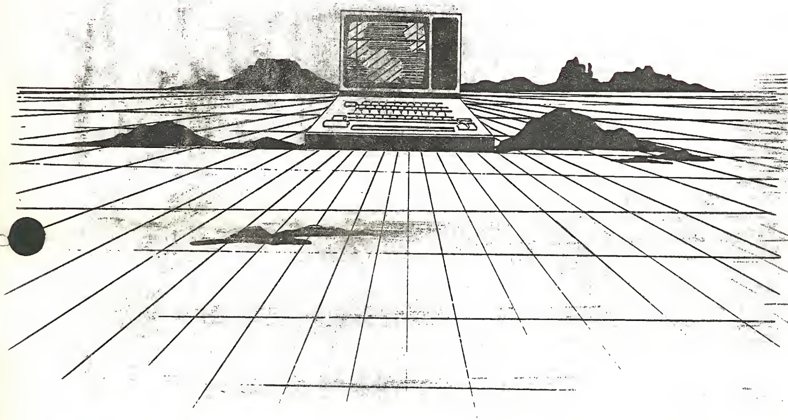


Geographic Information System

TABLE OF CONTENTS

Page

GIS CONCEPT SUMMARY

I. INTRODUCTION

A. Objective

This document will provide BLM employees with a brief overview of

- Geographic Information Systems (GIS) technology
- Bureau's background in GIS development
- Major functional roles
- Recommended approach for Bureauwide implementation

B. Definition

A Geographic Information System (GIS)

stores
displays
retrieves
and
ANALYZES

Spatial data

It is similar to other automated information systems except that it handles spatial data instead of just words and numbers. Since spatial data can be tied to specific geographic locations, the system can model or simulate land uses and resource values.

II. MANUAL VERSUS AUTOMATED GEOGRAPHIC INFORMATION SYSTEMS

A. Manual Systems

The BLM manages geographically distributed natural resources such as

- Vegetation
- Minerals
- Soils

on 342 million acres of public land, and over 732 million acres in which the government has mineral rights. To locate and manage them, the BLM uses manually prepared maps and map overlays.

MANUAL SYSTEM		
Store	Retrieve	Display/Analyze
• map files • storage cabinets	• memory • card catalog • looseleaf binder or other system	• conventional cartography • hand planimeter • grid-cell sampling • visual evaluation of maps and overlays

The amount of information on maps and overlays now exceeds our ability to effectively manage and analyze it.

The wide array of resource values, land uses, restrictions, alternatives and other criteria frequently prevents thorough analysis and evaluation.

Today, much of BLM's resource inventory data is not available for decision-making or planning processes without major commitments of workmonths. Data handling and updating activities are sometimes performed at the expense of sound resource management because current methods are time consuming and have a great potential for error.

B. Automated Geographic Information Systems

An automated GIS is more than a sophisticated filing system for maps. It is most valuable as an analytical tool to assist decision makers. Typical analyses performed are

- calculation of area
- overlaying and compositing
- calculation of proximity

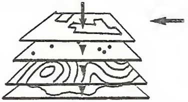
These types of analyses distinguish a GIS from simpler computer mapping systems.

Most computer analyses of geographic data bases involve combinations of

- search
- measurement
- data comparison

SEARCHING	is the capability to read an entire file of geographic data and retrieve any required data by location, attribute or value. EXAMPLE: The scanning of a resource area for all water sources.

MEASUREMENT	is the most frequently performed manipulation. It includes calculation of area, perimeter, distance, direction, etc. EXAMPLE: Calculating the acreage of specific vegetation types.
COMPARISON	is the most powerful capability of the GIS. It is used to identify relationships between data.



A comparative technique, called "compositing" allows the system to overlay different layers of data to examine areas of coincidence.

EXAMPLE: Locating areas where a particular vegetation type, soil, ownership, mineral, etc., occur together.

Past BLM automation efforts have eased the burden of managing resource information, but they do not provide geo-referencing, with the graphics and analytical capabilities of a GIS. Much of the data in existing BLM information systems can be used in the GIS.

III. STATUS OF GIS TECHNOLOGY DEVELOPMENT

A. GIS Software

GIS software has moved from research and development to the point where it is ready for extensive application in resource management.

THE MAP OVERLAY AND STATISTICAL SYSTEM (MOSS) IS THE ACCEPTED STANDARD FOR PUBLIC DOMAIN GIS SOFTWARE IN THE U.S.

Other users include the FWS, BIA, USGS, SCS, NPS, and USFS (See Appendix C).

B. GIS Hardware

The data storage requirements for millions of acres of BLM-managed land, and the various attributes which describe the land's resources, will require very large data storage capabilities.

As a result, it is unlikely that a central GIS computer system would be adequate. Therefore, each state must provide central GIS support to its districts and resource areas.

The Bureau, FWS, BIA, and other agencies are now working on a multi-year competitive computer hardware procurement beginning in FY 1985 to provide states with the means to build their GIS computer facilities.

C. BLM Development and Application

It has long been recognized in BLM that...

> computer technology is needed to assist our complex, dynamic and widely distributed multiple resource management tasks. Although a great deal of interest in GIS technology has been expressed in the Bureau for several years, no concerted, systematic implementation effort has been undertaken.

States vary widely in their current GIS capability, from zero to minimal. While some states have made significant strides in developing GIS capabilities none is fully equipped in either personnel, hardware, or software to fully implement the technology. At present, only a few states are making regular use of GIS technology, most with limited in-state hardware. Only Colorado and Alaska have near-adequate equipment in place.

GIS systems are generic in the sense that...

> they can support a wide array of user applications. In BLM these applications include
>
> - resource inventory
> - monitoring
> - minerals leasing
> - operations
> - planning
>
> for virtually all resource values on the earth's surface or underground.

Another important BLM application is digital cartography, which will permit the construction of custom made maps and combinations of maps very quickly. This technology could render series mapping at fixed scales for resource management purposes obsolete.

Another significant GIS application in the near future will be the graphical display and analyses of records from ALMRS data bases.

IV. FUNCTIONAL ROLES

A. Service Center

The Service Center's role includes:

- the transfer of GIS technology to field users
- continuing support in new systems, applications and software development
- support to resolve software problems, make enhancements, adapt to new hardware advances
- responding to user requirements
- coordination with private vendors

B. States

States will:

- implement GIS technology at their own pace as justified by needs and available funds
- localize GIS operations as much as possible
- develop the capability to provide operational support to their district offices and resource areas
- coordinate GIS data base management
- provide statewide policy and program guidance for GIS technology application

C. Headquarters

BLM Washington office will provide...

policy and budgetary guidance, as with other Bureau operations.

V. RECOMMENDED APPROACH TO GIS IMPLEMENTATION

Bureauwide implementation will be...

a logical and incremental "phase-in" which relies on assistance from the public and private sectors, and in-house resources.

A. Funding and Personnel Constraints

GIS implementation will probably have to be funded from...

> the existing Bureau base and full-time equivalent ceilings. This will require the allocation of scarce resources to cover start-up costs with the knowledge that the short-term investment will result in significant cost savings in the long-term.

B. Implementation Plan

Prior to actual implementation of GIS technology, each state should:

- develop a GIS implementation plan to insure that their specific requirements will be met.
- consider the configuration of the GIS, hardware needs, data communication needs, conditioned ADP facilities needed (space requirements) and staffing and organizational needs.
- call on Service Center personnel if assistance is needed for implementation planning.

C. Cost Estimates

Start-up costs for the initial implementation phase will represent a significant expenditure of funds:

- for state hardware, between $300,000 and $750,000 for the purchase option,
- and between $100,000 to $225,000/year for the lease option for each state.

Funding requirements for data entry of all resource data into the GIS could also be substantial considering the volume of resource data needed. Data entry (digitizing of map data) will be a big job in all states. But...

- it is a one-time cost; the GIS data bases will be permanent.
- it is anticipated that the majority of initial data entry be provided by contractor (rather than with in-house personnel).
- the majority of entry should be done by the states.
- large scale data entry funding will be limited with externally funded projects accommodating most of the digitizing activities.

INTRODUCTION

This GIS Implementation Concept Document was produced by a workshop attended by the following Service Center and State personnel, July 17-19, 1984:

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This document will attempt to merge all the diverse considerations which must be addressed for successful implementation of GIS technology in the Bureau of Land Management. It is intended primarily as an information document for all interested BLM employees.

1.0 INTRODUCTION TO GEOGRAPHIC INFORMATION PROCESSING

1.1 Processing Spatial Data and Information

GIS technology, under development for at least 20 years, has advanced substantially in the past 6 to 8 years. Although its subject matter is often simple, the computer systems required are complex and demand the latest advances in computer technology. As usual with new technologies, much misunderstanding has resulted from an abundance of new terminology and a lack of documented definitions. The glossary (Appendix A) will define terms used in this document.

To describe a GIS as a system for handling "map-based" information is convenient but misleading. GIS technology can be used to manipulate spatial information and data whether derived from a map or any other source.

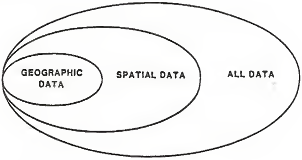

Fig. 1 - Relationships between data of all types, spatial data, and geographic (earth-referenced) data.

For example, the technology has been used to record characteristics of the moon's surface from lunar photography and to display the structure of living cells at the microscopic level. Any surface or volume with physical dimensions can be handled with the technology. The term "spatial" is used because such phenomena are distributed in space.

Unfortunately the term "Geographic Information System" could be interpreted to infer that spatial information is merely stored and retrieved much like alpha-numeric (words and numbers) information in a conventional data bank. A GIS does include an automated filing system for maps but is most valuable as an analytical tool, its major benefit to the Bureau of Land Management.

1.1.1 Manual

In the BLM, geographic information is all around us. BLM's work largely involves management of geographically distributed natural resources and other phenomena. As a result, we have had to evolve a number of manual procedures, using maps of various scales and many map overlays to manage our geographic information.

Although the procedures for using this geographic information might vary from office to office, the requirements for handling it are usually similar. They include data gathering, provisions for data storage and retrieval, and preferably some means of combining, analyzing, displaying, and reproducing the data.

Manual geographic information storage can involve simply map files or storage cabinets, from which we retrieve data by memory (often the case) or with card catalog or looseleaf binder systems. To combine, analyze, and display such information, we've been forced into time-consuming manual cartography and drafting, hand planimetering (measuring of areas), grid-cell sampling, and visual evaluations of problems and planning.

1.1.2 Automatic

Often, the amount of information we need to use on maps and overlays surpasses our ability to manage it. One map can have numerous overlays which present too many options and alternative actions from which the resource specialist or planner must make a decision.

An Automated Geographic Information System (GIS) can help solve this problem by allowing the resource manager to rapidly examine numerous alternatives and management options, recall information without depending solely on his own memory, (and which is never "lost"), and conduct analyses which were not possible using manual procedures.

Points, Lines, and Polygons are the fundamental data elements of an automated GIS.

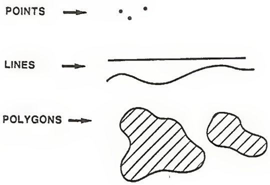

Fig. 2 - A GIS stores information in three forms: points, lines, and polygons (areas).

These data elements are discussed below.

Points have specific geographic locations which are included in the GIS data base. Some examples of point data include weather stations, borehole sites in geological exploration, oil wells, archeological digs, and nodes in a transportation network such as road intersections and airports.

Whether a geographic entity is mapped as a "point" or an "area" depends on the resolution of the source maps to be used and how the information will be used. An airport can encompass notable area in a city or county data base but appears as a point on a state or national map.

Lines in a GIS represent linear features such as streams and rivers, power transmission lines, railroads, highways, and contours. The degree to which lines can be accurately located and their shapes characterized geographically, is a function of the geographic encoding system, the cost trade offs between data storage and preparation, and the desired precision.

Polygons in a GIS represent areas. Examples include: lakes, land cover zones, political entities such as towns, counties and states, land use zones, soil types, and vegetation zones. The precision with which areas can be represented is also a function of the compromises made between the costs of data acquisition and storage, and the desired accuracy.

The attributes of the data are the actual names or descriptive labels of the geographically referenced points, lines, and polygons. A point could represent an oil well and its attributes could describe ownership, production, depth, etc.

A line could be a land ownership boundary, road, or stream, all of which could have a variety of descriptive attributes.

A polygon could be a section of forest land with attributes describing forest type, timber volume, production, etc.

The range of attributes and values which can be related to a single point, line, or polygon is obviously very broad.

1.2 GIS State-Of-The-Art

GIS technology is far ahead of its applications by users. This is not to say that the ultimate level of GIS technology has been reached. To the contrary, as more users apply GIS techniques, more opportunities for use, modification, and enhancement are discovered. User feedback to system specialists is a critical element of GIS implementation.

Until recently, computer hardware constraints placed limits on the use of GIS systems on wide areas of land, such as those managed by BLM. New advances in systems and digital data storage technologies, however, have largely eliminated these limits. In essence, both the hardware and the software have now caught up with BLM's considerable and unique demands.

Major systems require continuing, long-term support for computer software development and applications. In the computer world, software "support" means a permanent service, usually supplied by the software developer/vendor, to fix problems, make enhancements, adapt to new hardware advancements, respond to changing user needs, and make the software more "friendly," faster and "smarter."

Based on the available GIS software, this document recommends formal adoption of the most advanced public domain software, the MOSS family of systems. This approach will avoid long-term Bureau dependence on a particular private company for software but could eliminate the usual source of continuing software support, the private software vendor. To fill the gap, the Denver Service Center is expected to be the Bureau's GIS software support organization. As a result of its statutory responsibilities regarding public land surveys, resource management, and records management, the job of developing, adapting, and improving GIS software for operational applications logically rests with the Bureau.

1.3 Status Of GIS Implementation In The BLM

1.3.1 History of GIS Implementation

Although much interest in GIS technology has been expressed in the Bureau for many years, no concerted, systematic implementation effort has yet materialized. In fact, the Bureau has not produced a clear, comprehensive policy on the subject. The closest thing to a policy statement was an information memo in July 1981 (IM 81-543) which stated in part "...(the ADS/MOSS) system is....the endorsed graphic system for BLM users. However...it will also be Bureau policy to seek out...various graphics systems in or out of BLM."

The memo established the Service Center Director as "broker" of state requests for GIS support, but did not mention GIS implementation in states or districts.

The Bureau has long recognized that computer technology must assist in its complex, dynamic, widely distributed multiple resource management jobs. The 1976 Strategic Plan for Information Resources Management is an example of the foresight in the Bureau at that time. The implementation challenge is, however, awesome and pushes the technical state of the art, calling for new types of personnel and expertise, and proposing new ways of conducting some traditional Bureau activities.

To date, Bureau GIS implementation has been informal and sporadic. It has been pushed along by a few individuals in various offices in an ad hoc fashion, gleaning support from whatever programs were willing to provide it.

As a result, the states vary widely in their current GIS capability. While a few states have established GIS capabilities and are actively involved in applications, no state is adequately equipped with people or hardware to fully implement the technology.

STATE	SYSTEM CAPABILITY: Large mini-computer	Small mini-computer	Link to another facility	PRIMARY APPLICATION: RMP	EA/EIS	Activity Plans	Leasing & Permit. Convey.	Resource Evaluation	KGS	Drainage	Defacto With-drawals
Alaska	●	●		○	○	○	●	○	○	○	○
Arizona			●	○	○	○	○	○			
California		●		○	●	○	○	○	○	○	○
Colorado	●			●	○	○	●	○	○	○	○
Eastern States			●	○	○	○	●	○	○	○	○
Idaho			●	●	○	○	○	○			
Montana				○	○	○	○	○	○	○	○
Nevada			●	○	○	○	○	○			
New Mexico		●		●	○	○	○	○	○	○	○
Oregon		●		○	●	○	○	○			
Utah			●	●	○	○	○	○	○	○	○
Wyoming		●		●	●	○	●	○	○	○	○

● Potential ○ Existing

Fig. 3 - Status of BLM state office computer hardware for GIS application.

1.3.2 State Office Status

At present, only Alaska, Colorado, New Mexico, and Wyoming are making substantial use of GIS technology. Of these, only Colorado has near-adequate centralized equipment in place, a result of oil shale-related support. Utah is remotely using Colorado and DSC facilities. Alaska, New Mexico, and Wyoming are using their own computer systems, all of which are reported to be inadequate to meet demands. Alaska recently received approval to purchase a new computer for GIS applications in FY '84. State plans for GIS hardware procurement in FY '85 indicate several plan to augment their capabilities considerably (Appendix B).

1.3.3 Current DSC Status

The Denver Service Center is currently ill-equipped to proceed with GIS implementation support. Its small Data General computer lab is similar to those in most states with Data General equipment (except Colorado). The DSC (D-400) has recently reorganized some key elements to devote more resources to GIS-related activities. New personnel have been added, and DSC is requesting substantial improvement of its hardware capability in FY '85 (Appendix B).

2.0 BLM NEEDS FOR AUTOMATED GEOGRAPHIC INFORMATION PROCESSING

Ease of use of geographic based natural resource information is essential to provide timely, accurate data to field managers for carrying out the basic BLM mission. This "truism" is voiced at all levels of our organization, technical and managerial. BLM's current methods for collecting, manipulating, analyzing and using such information for planning and decision-making need to be simplified to make them applicable at the field level.

Current base mapping and overlay procedures used for land use planning are conducted "by hand" as are calculations of needed statistics. Resource inventory data, collected in large volumes, are not readily available for daily decision-making in field offices and are not transferable to planning or other processes without a major commitment of work months. Data handling and updating are performed by high grade professional employees at the expense of resource management. Additionally current methods are cumbersome, time consuming, likely to produce inaccurate data, and serve as a source of frustration to field professionals.

Excluding ongoing GIS efforts in BLM, automation efforts of past years have served to ease the burden, but these efforts also represent outdated technology. Of equal importance, they are not geographic-based systems.

BLM's present GIS efforts are scattered and no state has a full capability with over half the states having no capability. Our GIS efforts have no central management to capitalize on the gains being achieved in the few states with ongoing efforts, and little central capability exists to provide assistance to state efforts. The Bureau simply does not have the capability (hardware, trained personnel, data collection, telecommunications) to advance further in its current GIS activities or use the current approach to GIS implementation.

Current and potential cutbacks in funding and workmonths are likely to aggrevate today's data handling problems, as fewer resources will be available to continue current manual data handling methods.

The situation described is not unlike the circumstances that resulted in the Bureau's decision to automate its land and mineral records. In fact, the automation of our resource management data needs will proceed concurrently with the land and minerals records automation project. The systems will rely upon each other and interchange data to provide the comprehensive, geographic-based resource data management system envisioned by the 1976 Strategic Plan for Information Systems Management.

The need to take direct, coordinated, management action is even greater in today's resource management environment, where the demand for quick access to reliable data for daily field office use is critical. Many such requests require electronic transmission of data. Such demands can no longer be met by use of our current manual reporting processes.

Existing BLM data bases provide detailed descriptions of resources which could be analyzed and portrayed in a GIS. Tying these data bases to a GIS will provide for coordination in selecting areas to be studied, identifying the types of data needed, and establishing technical considerations for data acquisition. A properly constructed GIS will also solve some of the problems created by having different data bases for the same resource. For example, four different data bases for forest inventory are now in use. GIS technology will provide the means to combine these data bases geographically, and provide the flexibility needed to handle various types of data across areas and states. An automated GIS can build on existing manual methods, which will integrate data and significantly enhance the capabilities of automated systems with the least impact on field operations.

Remote sensing data of all types, whether low level photography or Landsat imagery can also be displayed and tied to other data within a GIS. This capability increases the utility of remotely sensed data and allows it to be readily compared and combined with data from other sources.

2.1 Mapping/Cartography

Department Manual 757.3.3 defines "cartography" as:

> "The art and science of expressing graphically or digitally by the use of maps, charts, or other displays, the known physical features of the earth or extraterrestial bodies, usually including the works of man and his varied activities."

"Mapping" is defined as

> "The process of collecting and preparing data on spatially relatable features for presentation in graphical or digital form."

Mapping is pervasive in the process of managing natural resources, and occurs at all levels of the organization. To paraphrase a past associate director "show me a resource manager who doesn't need maps, and I'll show you a man who doesn't understand the management of natural resources."

You can seldom walk through an office of a Bureau resource manager or specialist and not see maps, in most cases produced or modified by the Bureau. Most U.S. Geological Survey maps with manually colored land status, Unit Resource Analysis overlays, site maps, recreation maps, state maps, environmental impact statement maps, transportation maps, cadastral survey plats, wilderness maps, 1:100,000 land status maps, and many others are not current because most were prepared manually.

GIS technology can reduce the number and cost of maps needed in routine Bureau operations, while at the same time reducing the cost of analysis. The number of maps needed will be less because the comparisons between maps, compilation of map combinations, and analysis of map quantities (areas, for example), can be done inside the computer.

For many BLM activities a GIS could significantly reduce the need for manually drafted paper maps, replace many manual procedures, and provide the user with the latest information through a variety of displays. GIS's have the potential of being even more pervasive than our current manual mapping.

2.2 Planning

One of the Bureau's major tasks is to prepare planning documents to aid in making and implementing resource management decisions. The collection of baseline resource data for these planning documents has made it necessary to develop automated systems to store, analyze, and portray this data. The graphic displays for these planning efforts, however, are for the most part still manually generated and revised. The following are some of the basic plans for which the graphics are manually generated:

- Land use plans (planning unit or resource area). Management Framework Plan (MFP) updates and Resource Management Plan (RMP) development

- Activity plans (grazing management, wildlife habitat, wild horses and burro management, watershed, forest management, wilderness area, recreation, minerals management)

- Project plans (range improvements, right-of-way, mines, transportation, plant sites (e.g. power plants)

- Known Geologic Structure (KGS) determinations and drainage

- Fire protection plans

- Application for Permit to Drill (APDs)

All of these planning efforts require to use maps, overlays, graphs, and charts, which are now produced manually. Revisions, updates, and additions, some of which are extensive, are also accomplished with more costly manual techniques.

2.2.1 Graphics

The following is a list of information types which may be portrayed graphically and should be considered or used in most planning efforts:

A. Lands (This could be part of Automated Land and Mineral Record System (ALMRS) input)

1. land ownership and status - with complete PLSS Landnet including all corners and legal parcels
2. administrative boundaries (allotments, planning units, resource area, district)
3. ROW's, withdrawals
4. land use classifications
5. land use potential or land use suitability

B. Climate

1. precipitation zones
2. temperature zones
3. wind patterns

C. Topography

1. slope and aspect
2. elevation

D. Geology

1. stratification
2. processes

E. Soil

F. Vegetation

1. major vegetation types
2. ecological sites

    a. existing conditions
    b. potential

3. threatened or endangered species areas

G. Water Resources

1. surface water
2. ground water

H. Transportation

1. roads and trails
2. railroads
3. pipelines
4. utility lines

I. Cadastral Survey - extent and type of monumentation

J. Minerals

1. by type of mineral, both developed and undeveloped (locatable, leasable, and saleable)
2. mineral status
3. mineral leases
4. active and inactive mines
5. well locations
6. KGS

K. Forestry

1. forest inventory classification

   a. commercial
   b. non-commercial
   c. wood products
   d. other vegetation products

2. Forest management opportunities

   a. stand improvement
   b. reforestation
   c. protection

L. Watershed

1. watershed areas
2. erosion condition and trend
3. flood potential
4. water uses
5. watershed opportunities

   a. improvement
   b. protection

M. Wildlife (by species or groups of species)

1. Integrated Habitat Inventory Classification System (IHICS)
2. animal use areas (herd units)
3. habitat condition and trend
4. habitat improvement opportunities
5. threatened and endangered species

N. Recreation

1. present and potential situation (developed and general use areas)
2. visual resource classification
3. recreation management opportunities

O. Livestock Grazing Management

1. present conditions
2. improvement potential
3. grazing pressure
4. projected conditions

P. Wild Horse and Burro Management

1. band and herd units
2. present conditions
3. improvement potential

Q. Wilderness Areas

1. present classification
2. potentials
3. management considerations

R. Archaeological and Cultural Areas

1. protection areas or known sites
2. potential sites

S. Improvements (fences, seedings)

1. Job Documentation Reporting System (JDR) input
2. potential improvements

T. Fire Management and Planning

1. fire protection classification
2. fire hazard classification (Alaska has a fire-related GIS now)

Most of this information is or should be used in the planning and decision-making processes, e.g. land use plans, activity plans, environmental assessments, and project plans.

2.2.2 Benefits of an Automated GIS to Planning Process

Increased Quality of Planning and Management Decisions

Having the ability to store and process geographic information will make it possible to be more accurate, quantitative and rational in making natural resource management decisions. Users are required to employ explicit decision criteria, thus ensuring that the reasons for decisions will be stated clearly, in detail, and usually in a quantitative manner. GIS use will also permit accurate modeling of potential and alternative decisions to detect conflicts, impacts, and other adverse results of land management scenarios. The result will be better thought-out decisions and better quality plans, and management actions.

Increased Availability and Utility of Graphics

As the saying goes "a picture is worth a thousand words." A GIS is designed with graphic outputs in mind. We will be able to produce rough and final graphic outputs (for example, maps, projection drawings, graphs and charts) for Bureau and public purposes. Such graphics will aid in showing the total picture, and in depicting plans and intended actions in public meetings. The ready production of effective graphics is an important feature which will add a professional quality, appearance, and credibility to Bureau presentations.

Ability to Deal with Large Areas

GIS technology will provide for the analysis of many data layers (types) over large areas simultaneously in a rapid, efficient manner. This will free the planner or specialist to devote energy and time to the nature of problems faced and their solutions, while the computer does the tedious analytical work which now has to be done manually.

Ability to Analyze Alternatives

In trying to solve nearly any natural resource problem, many alternative approaches should be considered. Current methods limit the number of alternatives which can be effectively considered because of time and funding constraints. A major advantage of computer analysis coupled with a geographic information base is that many ideas and approaches to problems or alternatives can be examined and tested using real data. Thus good ideas can be evaluated and incorporated into planning and management with unworkable alternatives rapidly discarded. The time and costs of pursuing unfruitful alternatives can thus be saved.

Common Frameworks for Analyses

The use of a common framework and methodology by all resource specialists will enable them to better focus their attention on the problems to be solved. Because ideas must be expressed in a common language and deal with a common data base, planning becomes interdisciplinary and comprehensive. Additionally, this common framework will improve coordination between BLM offices and between BLM and other agencies. It will provide for data consistency, uniformity, and more efficient use of technical expertise and funding.

2.3 Environmental Assessment

Environmental analyses can vary from a negative declaration to an environmental assessment or environmental impact statement, all of which require analysis of potential impacts and conflicts. To conduct these analyses and present the results to the public, various graphic products are generated such as graphs, charts, and maps, most of which are still generated manually.

A GIS has obvious benefits to the completion of environmental assessments. The ability to compare resource conflicts rapidly and efficiently will greatly speed up the process and add to the consistency and quality of analysis. The variety and number of action or management alternatives being considered can also be increased.

2.4 Cadastral Survey

For nearly 200 years the cadastral survey has been surveying the public lands of the United States. The results of these surveys are monuments, plats, notes, and geographic coordinates. The monuments are the physical, on the ground markings of the location of the public lands. The plats are a graphic representation of the survey. The field notes describe what the surveyor did and found.

Geographic positions of the corners of the Public Land Survey System (PLSS) have long been a part of the survey but are now becoming more important. They are cornerstones relating locations of natural resources to land status in information systems. The Secretary has assigned lead agency responsibilities to the Bureau for the production and maintenance of PLSS data, a base category for the National Digital Cartographic Data Base (NDCDB).

The primary processes of a cadastral survey are investigating and planning, ground surveying, and documenting. During the investigating and planning phase, surveyors must search through the records of the Bureau, other agencies, and state and local governments for historical information. They examine survey records and the history of land ownership, including maps and aerial photographs; spatially relate the data obtained; and then analyze the data to determine probable location of corners and develop a plan of survey. This is a manual process, but the equipment used for ground surveys is electronic and in many cases produces digital information. In preparing documents, surveyors use computers for computations. In most cases the preparation of map-like documents--the plat and other graphics portraying the PLSS--and the drawing of the map is done by hand.

A comprehensive geographic information system would increase the efficiency of the investigation and planning phase and the production of the graphics phase, plat drafting and the merger of cadastral data with other types of data.

A related question concerns the importance of survey data to GIS applications. Since PLSS positions are cornerstones in the GIS, the GIS output is only as precise as the PLSS data. The PLSS data has varying degrees of spatial precision (not to be confused with the legal location of a PLSS corner).

There are PLSS corners for which the survey has very precise spatial coordinates; for example, the corners positioned for the Piceance Basin RMP. The townships within the RMP unit were resurveyed using precise measuring techniques. In other locations, primarily surveys made before 1910, the positions of the PLSS may not be known to the nearest half mile.

A misunderstanding of PLSS peculiarities have resulted in attempts to represent it as a mathematically perfect 1-mile square grid, which is incorrect. The result is that the location of ownership relative to the resource may be misrepresented. In some management applications, this precision is not critical, however, in others, such as investigating mineral trespass or oil and gas drainage, precision is very important.

2.5 Resource Applications

2.5.1 Potential GIS Applications In Resource Management

Some typical problems and analyses for which automated GIS techniques can be used are:

- Evaluating resource management alternatives
- Planning for reclamation of disturbed areas
- Planning for regional development, including transportation, recreation, preservation, mining, and power plants

- Geophysical investigations for petroleum and minerals
- Location analysis for siting waste disposal areas
- Locating power plants and siting transportation corridors
- Planning for the development of a major watershed
- Projecting likely air pollution levels near major project proposals
- Flood simulation and protection planning
- Mapping of sensitive ecological systems and areas of critical environmental concern
- Planning, managing and tracking forest stand improvement, reforestation, and harvesting
- Tracking water use and water rights filing
- Tracking and updating erosion conditions and improvement or degradation
- Environmental assessment of proposed development projects or management actions
- Evaluating Application for Permit to Drill (APD)
- KGS determinations and associated drainage
- Estimating coal and mineral reserves
- Mineral and energy leasing
- Range condition mapping and reporting
- Range improvement planning and reporting
- Mapping wildlife herd management areas, migration routes, and critical habitat areas (breeding, calving, cover)
- Mapping wild horse management areas, migration routes, etc
- Cadastral Survey
- Developing Resource Management Plans (RMP)

2.5.2 GIS Support To Decision Processes

As plans and management decisions are implemented, the base information needs to be constantly updated. For example, when a planned timber harvest is accomplished, the base information needs to be updated to show the area as cut-over rather than harvestable. Such work is now accomplished manually, and often the data base is not kept up-to-date. With the automation of the data base in a GIS, the revision and updating of the base can be easily and rapidly accomplished. Managers will be able to respond and act quickly with confidence when new situations or proposals arise on which they must make decisions.

2.5.3 Land Management

The management of public lands and resources is an important continuing activity. Because such activity is land related, spatial relationships are a key to the accuracy of our transactions. Because the other party in most of these transactions is the public, timeliness is of great importance. Automated Land and Mineral Record System (ALMRS) case recording and processing without geographic (spatial) data should improve timeliness. But to accurately relate land to its attendant resources and to identify possible conflicts, precise processing of accurate geographic locations is critical. A GIS would provide the mechanism to perform this function.

2.5.4 Public Information/Service

The Bureau performs many public information or service functions, from providing recreation and general information maps to the interaction of the public with our records. In addition, graphics are generated to provide information on an ad-hoc basis, e.g., public hearings. GIS technology can produce custom, single-use graphics and maps, as well as volume production of graphics for printing and mass distribution.

2.5.5 Minerals

GIS systems have a number of potential applications in minerals activities that can improve the quality of decisions. In site selection, leasing and various permitting activities the resource specialist can compare mineral locations with any map theme including land status and other themes including works of man, environmental features, along with other characteristics of the land. The specialist can review different plans for extraction and reclamation by creating perspective views of the resulting terrain. During extraction, GIS techniques can help monitor production on or next to public lands. Minerals related activities most likely to benefit from GIS technology include the following:

- GEM Assessment--The geology, energy and mineral (GEM) resources assessment is at the base of most other mineral programs. This program gathers the minimum necessary data for all mineral resources and classifies the land as to its potential for GEM resources. A GIS would support this program by sorting and organizing the data which could also be used by other mineral programs. It could also be used for analyzing the data, integrating two or more sets of data, and in producing the maps which show the potential for GEM resources. KGS, KGRA, KRCRA and other similar determinations may likely need additional data than what is available in the GEM assessment. For example, well log data from Petroleum Information Corporation or from other sources, which need to be sorted, interpreted and integrated with existing data so that the respective determination can be made. A GIS would facilitate this process.

- Leasing--GIS methods were used extensively in Colorado's Piceance Basin RMP development, a result of emphasis generated by potential additional oil shale leasing. The project was a prototype and cost much more than an operational project. However, it demonstrated the value of GIS techniques for integrating the myriad data types, land use alternatives, and lease tract considerations in minerals planning.

In a similar manner, coal and oil/gas leasing can benefit from the applications of GIS methods by evaluating potential tracts on a regional or site-specific basis in terms of physical, biological, legal, or institutional restrictions to development. These evaluations can also include cumulative environmental or socio-economic impacts and reclamation requirements.

- Resource Evaluation--A GIS can assist in the storing, accessing, integrating, and analyzing of coal and other bedded mineral data for evaluating mineral resources prior to lease sales. The GIS can store and retrieve boundary maps such as mineral ownership, land status, coal PRLA's, known leasing areas, and cadastral survey boundaries. The GIS also has the capability to generate maps for use in resource evaluation, such as isopach and structure maps, and in mining economic considerations, such as mining ratio maps and overburden maps. Methods are available and can be tailored to the specific needs of the Solid Minerals staff to calculate reserves within a tract.

- Permitting--The review of Applications for Permit to Drill (APD's) requires review of a variety of environmental and legal parameters which can be very time consuming and expensive. The use of GIS technology can greatly expedite the process by automatically displaying to the APD reviewer the exact terrain under review, complete with all necessary geologic, environmental, political and administrative information. Not only can the review be accomplished faster but also it can be more complete and systematic.

- Known Geologic Structure (KGS) Determinations--Wyoming and Eastern States Offices are presently using GIS technology to integrate Petroleum Institute (PI) data and well data from other sources to produce oil/gas base maps. Boundary data can also be stored and retrieved in the GIS so that the well location map can be overlayed with such boundary maps as existing KGS boundaries, oil and gas unit boundaries, land status and mineral ownership to determine what action must be taken on newly drilled wells. After it is determined that action must be taken to outline a new KGS boundary or to extend an existing KGS boundary, GIS methods can be used to generate isopach and structure maps of the producing horizons. Algorithms in the GIS can be tailored to the needs of the Fluid Mineral staff to handle situations from simple interpolation of data values to kriging.

- Drainage--GIS capability exists to flag wells that should be investigated for potential drainage of Federal lands. This can be done by having the GIS generate a zone of a specified distance around KGS boundaries to determine if there are any wells that may cause potential drainage of the KGS, or by using the circle method to determine drainage around the well location. Map themes such as boundaries of oil and gas units, KGS boundaries, and mineral ownership can be integrated with the encircled well location map to determine how much drainage of Federal land is occurring within the circle in terms of acres and percentage. The radius of the circle can be easily adjusted in the GIS to meet the various acre-spacing units set by the States.

- Defacto Withdrawals--GIS technology can be used to inventory areas that are restritced to mineral exploration and development in BLM lands by management decisions, so-called defacto withdrawals. These areas can be stored in the GIS along with such stipulation boundaries as:

  1. Critical raptor habitat
  2. Sage grouse strutting grounds
  3. Raptor nest buffer zones
  4. Bald eagle habitat
  5. Migration routes
  6. Winter ranges
  7. T & E plants
  8. T & E trout
  9. Known coal areas
  10. KGS boundaries
  11. Oil shale, open pit or underground mining
  12. Land status
  13. Mineral ownership, etc.

  Using GIS methods for map overlaying, the defacto withdrawal areas can be inventoried and maps generated at suitable scales with summary tables showing acreage totals.

2.5.6 Specific BLM GIS Applications Examples

The following GIS uses were made in Colorado using data originally prepared for the Piceance Basin RMP.

Suitability Analysis

Potential water-based recreation sites were identified by selecting BLM surface ownership, overlaying them for intersection with major rivers and lakes, then zoning the identified sites to determine which were located within one mile of existing major transportation routes.

Site Analysis, Locational Analysis

On a site-specific or large-scale basis, the GIS can take any given criteria within a data base and identify locations of occurrence of each. For instance, a road route was determined by the GIS, given preferred slope, vegetation and soils types, orientation, and distance from endangered species populations.

Predictive Modeling

The potential for occurrence of cultural sites was determined by studying site factors such as slope, vegetation type, nearness to water, stream ranking, relief, soil type, and orientation. Statistical analysis was performed, and a map produced to locate areas most likely to yield archaeological finds.

Composite Mapping

Wildlife priority areas were determined by ranking and assigning relative values to species and habitats, then mathematically adding the layers with an intersection overlay. Locations where the resulting values were greatest were of most importance for wildlife management.

Surface Zoning for Protected Wildlife

Areas of mandatory protection for raptors (bald eagles, red-tailed hawks, and golden eagles) were determined by identifying roosts, nests, and high concentration feeding and use areas to establish a seasonally restricted use zone. Surface occupancies were not allowed on the sites, delineated with the GIS, based on firm biological criteria.

Area Calculation

The GIS can automatically compute and assemble acreage tables for all the classes of data. Also available is the capability for interactive calculation of acreage. The user simply designates areas of interest on the computer terminal screen, and acreages are displayed. The area analysis feature was used in the RMP process and subsequently to document magnitudes of allocations, impacts, and inventoried resources.

Many other applications could be cited in Wyoming, New Mexico, Oregon and Alaska. As BLM users become more familiar with the technology, its applications will undoubtedly expand.

2.6 Basic Considerations In GIS Implementation

2.6.1 User Needs Assessment

To determine the real needs for information, the functions of each resource group to be using the system or the information in the system should be reviewed. The reviews would include those specialists involved in the following management activities:

- minerals management
- livestock grazing management
- wild horse and burro management
- wildlife management
- watershed management
- forest management
- cultural management and protection
- recreation management
- wilderness management
- fire management and protection
- land resources
- land use planning and environmental assessment

With each group the review should begin by identifying what information is currently used, how it is processed, and what are the needed products. In particular, the reviews should uncover how the information can be used in decision-making. Actual, mandated needs for information should be separated from "wants" or "things that would be nice to have." Information used to influence decisions should be differentiated from information for reports that may or may not be read and used. It should be noted that most of the information will be shared between users reducing the costs, i.e., surface water for industrial development, wildlife, range, etc.

In addition to resource specialists, managers and decision makers should also be involved in identifying user needs. Managers often have a different perspective on what they need to make resource decisions.

2.6.2 Analysis of Data Sources

All relevant data sources need to be analyzed by characteristics such as format, scale, source, form, accuracy, currency, ease of access, access speed, ease of interpretation, ease of maintenance, and ease and cost of updating. To ensure consistency in making this evaluation, plans should be developed with standards set for what needs to go into the analysis.

2.6.3 Data Base Design

A number of factors must be kept in mind in the design of data bases: user needs, decisions the data will influence, existing data availability, new data needs, etc. The design must also deal with questions such as mapping scales, mapping resolution, projection, frequency of updating, classifications, and format specifications. A plan must be developed to designate how these factors will be determined. Included in this plan should be methods for collecting, reformatting, automating, creating files, and updating data.

2.6.4 Conversion To Automation

Of primary importance, the use of GIS technology must build on existing manual methods rather than overturn them. Such a practice will help make the transition from manual to automated systems somewhat easier and separate the activities suitable for automation from those that are not. This approach will also aid in gaining acceptance of the technology and minimize the least amount of disruption to ongoing operations.

3.0 Components Of The Geographic Information System

3.1 GIS As An Automated Information System

A Geographic Information System (GIS) is a computer system designed to store, process, and analyze spatial data. In some respects, geographic information systems are similar to other automated information systems in that they involve the following:

- Data acquisition, the collection and gathering of data;
- Data compilation, for plotting data onto a coordinate correct base, i.e., map or orthophotoquad;
- Data capture, for the collection of data, their transformation into machine readable form, and their storage and organization within the computer;
- Editing updating and reclassifying of the data files;
- Manipulation, analysis, synthesis, and retrieval of data for used defined areas;
- Generation of a variety of outputs and reports;
- Consideration of data management and system security.

But the ways in which these functions are performed are for the most part very different from other information systems--a result of the most significant characteristic of the GIS, location. Data in a GIS is of spatial or geographic nature, and must be geo-referenced, that is, tied to locations on the surface of the earth.

3.2 Major GIS System Functions

The major GIS functions cover data capture, editing, analysis, output, and management.

The efficient integration of data base management, data capture, vector and raster processing, automated cartographic techniques and spatial analysis routines results in a unified GIS.

This section describes the functional components of a unified GIS and is meant to provide background information on some of the unique aspects of a GIS.

3.2.1 Data Capture

Data for geographic information systems can be gathered from a variety of sources: maps, aerial photographs, field surveys, range studies, assessor's records, image processing and census tapes. Geographic data can be divided into two basic classes: quantitative and qualitative. Quantitative data include the geographic location, size, and shape of a unit of data, while qualitative data refer to the characteristics or attributes of the unit, such as land use codes, soil types, and vegetation categories. One physical unit of data may have one or several attributes to describe it. The geographic location of a unit of data can be represented horizontally with an (x,y) coordinate or some other geo-referencing system. In addition, a third coordinate (z) can represent elevation to provide a vertical reference.

Geo-referencing Systems

Four major geo-referencing systems have been used in geographic information systems:

Universal Transverse Mercator (UTM)
state plane coordinates
latitude and longitude coordinates
Public Land Survey System (PLSS).

Each system has advantages and disadvantages.

UTM coordinates are used throughout the world, but the distortion of the projection away from the central meridians creates calculation problems across zones.

The state plane coordinate systems use either the Transverse Mercator or Lambert Conformal projections to reduce distortions within a state, but the coordinates between states and between zones within large states differ, making calculations across state boundaries difficult. Several changes to the State Plane system are pending due to the new North American datum adjustments.

Latitude and longitude coordinates are potentially the most accurate and most easily transformed, but distance and direction computations are difficult because spherical trigonometry must be employed.

The U.S. Public Land Survey System (PLSS) based on Township and Range descriptions has been widely used in field surveys and resource records, and would be useful in systems using this information. In practice, however, the survey pattern deviates from a square grid making grid-based calculations difficult and is often geographically inaccurate.

The choice of a particular geo-referencing system depends upon the user's requirements and objectives and the data sources. A number of conversion subroutines have been developed which convert most coordinate systems to UTM, making it possible to use several geo-referencing systems within the same GIS.

Data Accuracy

Data accuracy can be measured by validity or resolution. Validity refers to the correctness or quality of the data and largely depends upon the quality of data collection and editing procedures, and the inventory and map compilation process. The degree of validity depends upon the requirements of the system's users. A land registration system containing data for legal and tax purposes would require a higher degree of validity than a regional land use planning inventory containing aggregate land use classes. The degree of validity required will affect the cost of the data collection phase of the system. Accuracy requirements in BLM are greatly influenced by the end user and available funds. Higher accuracy is associated with higher cost.

Data resolution refers to the smallest data unit that can be identified and is limited only by the resolution of the data entered into the system. The resolution level required depends upon the requirements of the system's users. If several agencies use the same system, data should be entered at the largest scale or at the greatest detail needed for the most demanding user. Data can be aggregated after they are entered into the system. Data collected at a certain map scale, however, cannot be transferred to a larger scale without a loss in accuracy because of cartographic generalization. The resolution level will affect the data transformation process, the storage requirements of the system, the data collection process, graphic output requirements, and most important, the data cost.

Another type of accuracy is spatial or geographic accuracy which can be defined in an absolute sense as the locational accuracy of map features true location on the earth's surface. In its relative sense geographic accuracy refers to the accuracy of map features in relation to each other. These potential accuracy problems can be a result of many factors including but not limited to projection and registration.

The seemingly inconsequential fact that maps are the common input medium is often overlooked in terms of accuracy. For example, maps printed on paper are subject to size changes due to changes in humidity and temperature and physical deterioriation. Mylar or other stable based mediums retain spatial accuracy better than paper.

Data compilation, i.e., the transfer of field or photo-interpreted data to a spatially correct medium (map) is an integral part of data conversion and entry. This process is necessary to obtain geographic coordinates on resource data. It can be the direct inventory and mapping of data to an orthophoto or topographic map, or using photogrammetric transfer procedures.

Data Conversion and Entry

Once data have been collected, they must be converted into machine readable form for input into the system. Quantitative data are digitized manually or in some cases, automatically.

Digitization is the process by which quantitative or spatial data are converted into machine readable form so that they can be stored and processed by the computer. Each geographic location or point on the map is identified by an (x,y) coordinate relative to a predetermined (0,0) point called the origin. Digitizing can be done by an operator either manually or with an electromagnetic digitizer, or automatically with an automatic line-following digitizer or a scanning device.

Digitizing manually

Electromagnetic digitizers are the most commonly used devices. The digitizer consists of a flat table with an internal (x,y) matrix and a cursor. The cursor registers (x,y) coordinate positions on the digitizing table through electric sensors. Once a map is placed on the digitizing table and a point of origin is established, the cursor is used to trace an area of interest. When the cursor is placed over a point that is to be recorded, the operator pushes the "record" button on the cursor and the coordinates of that point are coded on a magnetic tape or recording device.

Automatic line following (ALF) digitizers operate very much like an electromagnetic digitizer. The ALF traces the lines by sensing the reflectance or transmittance difference between the line and the background material. Scanning devices automatically convert the printed material into a machine readable matrix form by sensing different intensities of reflected light. Generally such systems are most effective when "clean" map overlays are available.

Data Structure

The geographic data structure is a dominant aspect of a system and provides the basis for classifying a GIS. The data structure refers to the organization of the data stored in the computer. Structure influences the way data are collected, resolution and validity, data volume, and the types of analyses, the types of products that can be produced.

Geographic data can be broken down into points, lines, and polygons. Points are used to identify locations of features that have no areal extent (waterfalls, wells, section corners, etc). The data structure is usually a list of (x,y) coordinates with whatever descriptive data (attributes) are associated with the points.

Lines are used for linear data like streams, stream networks, roads, and road networks, assuming that these variables have no areal extent. Lines are described by strings of (x,y) coordinates with the beginning and ending points of the line segments called nodes. Descriptive labels are assigned to the line segments between nodes.

The most useful geographic data is referenced as areas, i.e., land use types, forest and vegetation types, soils, census districts, and counties. There are two major structures for areas: grid and polygon systems and polygon loops and arcs (chained arcs). Some systems may use more than one structure.

Grid Systems

The uniform grid structure was one of the first to be implemented, and is still widely used. It is easily understood and relatively easy to program. An example of a uniform grid structure is the MAP package developed at Yale University.

In systems with a uniform grid, a rectangular (typically square) grid is superimposed over an area and the attributes are assigned to each grid cell are entered into the system based on the attribute of the area being covered. Grid cell centroids can be mathematically transformed into one of the geo-referencing systems previously described. It may be possible to associate one or several attributes (soil, landcover, age class) with each grid cell. Some coding schemes enter primary and secondary classes per attribute (predominant soil class, secondary soil class) but the most common practice is to enter only the predominant class.

The resolution of the data in the system is a function map scale and the grid cell size. If a high level of resolution is required, the grid cell size will be small. Conversely, if resolution requirements are not high, it is possible to use a large grid cell. Figures 5 through 8 are examples of what may happen when the grid size and the grid referencing (registration) is changed.

Grid systems have a number of advantages. The data is that of a common two-dimensional matrix (rows and columns). There are many algorithms for manipulating this structure, and most programming languages have capabililties for matrix manipulation. Digitizing coordinates may not be required. Output is usually on a standard line printer with gray tones produced by overprinting characters.

Grid systems also have disadvantages. Coding of the cells was originally a manual process, which could be time consuming if many cells must be coded. (Progress has been made, however, with automated techniques.) Separate overlays containing one variable are most often used for coding. Registration among the different overlays is hard to maintain when maps of different scales and projections are used for coding. Many political or resource boundaries do not conform to grid cells and must be approximated.

When only one class of a variable is assigned to a grid cell, important information may be lost. For example, if a particular cell contains 60 percent Douglas fir and 40 percent western hemlock, the data for the western hemlock will be lost because the entire cell will be coded as Douglas fir. Even when both percentages are encoded, the exact location of the Douglas fir and the Western hemlock are lost.

If one class covers a number of cells, the storage requirement for the grid may be higher than that required in a polygon system because each grid cell must be stored.

Parcel systems permit the collection of data within naturally or politically defined areas rather than within uniform cells. Parcel referencing schemes include census tracts, township and range sections, and political subdivisions. The parcel record may or may not include (x,y) coordinates for the physical location of the parcel. Often the record will include the attribute values and a geo-locater to reference data to a map. The geo-locator value may be a zip code, township and range number, the UTM coordinates of the centroid, or an arbitrary (x,y) value.

Parcel systems share some of the advantages and disadvantages of uniform grid systems. Parcel systems are relatively easy to develop, and file overlays can be overlaid simply and efficiently. Parcel attributes, like grid cell attributes, cannot be broken down into finer detail than the original parcel input. Unlike grid cells, parcel boundaries correspond to natural or political boundaries that preserve some of the geographic relationships. Most data, particularly resource data, are collected by parcel-referencing schemes and consequently can be easily entered into a parcel system without any loss of accuracy or detail.

If map output is desired, the actual coordinates for the parcel boundaries must be digitized and linked to the descriptive data by the geo-locater, or the user must refer to a reference map. Parcel systems are designed for users mainly interested in retrieving, aggregating, and tabulating data, not in obtaining cartographic output.

Raster Systems

Imagery from satellites can be an important input to a GIS, and some systems, such as the DSC IDIMS system, were originally built solely around LANDSAT. LANDSAT comes in a raster-based digital format, which is analogous to the way a television displays its image. The individual cells are called pixels (picture elements). Pixels are essentially grid cells, and an image is a matrix of pixels. The structure of raster systems is similar to that of grid systems--a two-dimensional matrix. Conventional photography as well as maps can be transformed to raster format through use of scanning digitizers. Systems that use raster data from LANDSAT or arc scanned photography usually have software for rectification. A tilted photograph or skewed image is transformed mathematically so that the geo-coordinate references are consistent across the photograph or image.

Satellite imagery has a number of advantages. Each image initially is acquired in digital form. Each LANDSAT satellite records an image for a given area every 18 days, providing up-to-date coverage and making change detection possible.

However, there are several disadvantages associated with LANDSAT. The unclassified tapes contain much data that requires a great amount of computing power and data storage. High-quality output for human interpretation requires expensive hardware. Most important, LANDSAT's sensors record reflectance values, but classification schemes used in many GIS applications cannot be determined by spectral reflectance values alone, because classification criteria may not be related to spectral reflectance. This problem has been largely responsible for LANDSAT's failure to satisfy the vegetation mapping and analysis requirements of the BLM and other resource agencies. The utility of LANDSAT data may be increased by the integration of LANDSAT with other auxillary data, the focus of a number of research projects. Furthermore, future satellite systems, technically advanced over LANDSAT, may solve some of these problems in the long term.

Polygon Systems

Polygon structures provide the most accurate representation of geographic data because the systems store the actual location and spatial form of data. They do not just assign data to an arbitrary grid. The boundary of any areal feature can be digitized and entered into the system regardless of the shape or extent of the feature. Consequently, data can be entered initially at the finest resolution of the source.

The grid structure, as mentioned, is that of a two-dimensional matrix, a common structure used in computer programming. Polygon systems require more complex structures, which are probably unique to a GIS. The relationship between the cells is inherently given: row 2 follows row 1, column 2 follows column 1, etc., however, this topological relationship has to be constructed with polygon data.

Polygons are represented by a series of (x,y) coordinates representing straight line segments. Because lines are represented by two end points or nodes, polygon systems can handle point and line data effectively. Overall accuracy is increased when the line nodes are closely spaced, at the expense of computer storage. The volume of data required can quickly approach unmanageable proportions. This problem of data storage has been a barrier to the development of regional polygon systems, but it has stimulated research into polygon structures. The storage problems are not unique to a GIS, the computer industry is seeking new methods to store large amounts of data (e.g., bubble memory).

Polygon loop (true polygon) systems represent the first generation of polygon systems. Each polygon is digitized separately and stored as an individual record. Consequently, the boundaries of adjacent polygons are digitized twice. Since it is almost impossible to exactly duplicate the line each time it is digitized, slivering occurs. Slivering can be corrected by several editing processes, each of which has advantages and disadvantages.

With the arc (chained arc or area bounding) structure, only the boundaries between polygons are digitized, and the left and right polygon labels are entered at the digitizing stage. Since each line is digitized only once, slivering is not a problem. The arc structure maintains topological validity and seems to have gained acceptance over the loop structure in the design of new polygon systems. Each structure can take advantage of automatic line following digitizers and optical scanning devices.

3.2.2 Editing and Updating

Geographic data can be classified by their persistence. Certain types of data, such as geologic features, natural vegetation, and soil classifications are fairly stable and, once entered accurately, can remain unchanged for long periods of time. Dynamic data includes such things as mine boundaries, urbanization land use and weather samples. The updating/revision frequency has to be considered in the design phase of the system so that it will meet the requirements of the system's users. Data editing can be conducted on the data entry system or the analysis system but preferably in the data entry system.

Editing, like data entry, can be done in batch or interactive mode. In a batch process, all of the changes are made sequentially, and there is no intermediate interaction between the operator and the system. Batch editing is inexpensive but time consuming.

Interactive editing is an interactive process in which the operator can engage in a dialogue with the computer. Interactive editing uses more on-line storage because it requires direct access to the data files, but operator time is decreased relative to batch editing.

Interactive editing capabilities should include the following:

- Point data editing capabilities

  a. delete point
  b. replace point

- Arc data editing abilities

  a. delete complete arc or part of arc
  b. add new arc
  c. delete node
  d. change node

e. add new node
f. change arc label
g. dissolve area and merge areas

- Polygon data editing

  a. delete polygon
  b. change portion of polygon
  c. add polygon
  d. change label of polygon

- Grid data editing

  a. delete single or multiple cells
  b. change characteristics of single or multiple cells
  c. replace single and multiple cells

- Textual data editing

  a. add, change, delete, replace characters
  b. move sets of characters
  c. delete, add, replace character strings
  d. search for string

There are editing checks that can be performed automatically by the software which include:

- Deleting duplicate or unnecessary points, arcs, polygons, grid cells, or points in arcs and polygons;
- Locating logical errors, including missing arcs and polygon descriptors in arc files;
- Automatically closing polygons (since digitizing the same point twice exactly, as with the starting and ending nodes, is difficult, automatic closure is necessary);
- Displaying errors for correction.

Polygon files can be updated in several ways:

- Creating a new file by resurveying;
- Changing old files by dropping out or erasing the changed polygons, digitizng the changes, or
- Changing areas by digitizingd and running an overlay against this alternative, however, this procedure creates slivering problems, which will be discussed in the following section.
- Matching edges of adjacent maps.

Normally in grid systems, the boundaries do not change because the cell size is constant. The file is updated by reassigning the attribute values to the cell, i.e., residential land use to commercial land use. Some changes that occur, however, may not be reflected in a grid system. For example, the residential land use class would be assigned to a cell 80 percent residential and 20 percent commercial.

A change to 55 percent residential and 45 percent commercial would not be apparent in a system in which only the dominant value was assigned.

Careful attention must be given to the registration of the new source material to the original file in both systems. If the overlays are not exactly registered, a great deal of error may be introduced.

3.2.3 Data Retrieval and Analysis

Analysis of data is the primary function of a computerized computerzed GIS. Typical analyses might include calculation of area, overlaying and compositing, or calculation of proximity. These types of analyses distinguish a GIS from a computer mapping system. With any analysis, the locational data are manipulated in concert with the descriptive data that correspond to that location. With a grid structure, the attributes are stored within the matrix and the geographic location is inherent in the structure of the matrix. Due to this, most manipulations are performed more efficiently with the grid structure, since polygon structures explicitly store both attribute and location.

Data Extraction

In terms of minimum data functions, no standard definition of a GIS exists. A GIS can be differentiated from a computer mapping system by its analytical capabilities. If the manipulative techniques of search, measurement, and comparison are not needed, a GIS is not needed. These manipulation techniques are more powerful when the results can be retrieved and displayed with a GIS for human evaluation. Most queries on a geographic data base will involve combinations of these three components and can range from very simple to very complex.

Searching is the capability to read the entire file of geographic data and retrieve any required data by location, attribute or specific attribute value. The following are examples of search queries:

- "Locate all water bodies" - simple search on an attribute (water bodies).
- "Locate all reservoirs" - simple search on a specific attribute value (man-made water bodies).
- "Locate reservoir with smallest area" - same as previous query except the location data are specified by area, a measurement technique.
- "Locate any reservoir within 1 mile of a specific archeological site" - this time the search criterion is based on the attribute and location from another

data set (archeological sites). The specification of a search radius (measurement of distance) is called proximity.

- "Locate all reservoirs with high recreation potential" - search based on criteria from multiple data sets. For instance, recreation potential might compare the calculation of travel times from a road network with the distances from population centers.

Though these do not include all the possible types of queries, they show how queries are built using the search capability, measurement, and comparison techniques.

Measurement is one of the most frequently performed manipulations. Location measurement functions include counting of points, lines, nodes or arcs, and calculating of area, perimeter, distance, and direction.

Comparison

Comparison is probably the most powerful capability of a GIS. It is defined as the use of descriptive or location data to determine relationships based on criteria from one or both types of data. The two basic comparative techniques are overlaying/compositing and inferential statistics, i.e., regression and correlation. These two techniques, combined with techniques from the search and measurement capabilities, lead to the creation of new data sets and sophisticated model building, such as the above example where "high recreation potential" was determined.

Although the definitions of overlaying and compositing are slightly different, their concept is essentially the same. Conceptually, compositing is the ability to overlay different layers of data on top of one another. Compositing is analogous to peering down through numerous map overlays to examine areas of coincidence. The computer allows any combination of data sets to be composited without the inherent visual restrictions of the human eye.

Most systems also have a statistical analysis subsystem that performs a variety of statistical operations. Of these, spatial correlation or the degree to which one data set corresponds to another is used most often. For example, the correlation between changes in land use and changes in water quality in a given area might be determined.

Other Functions

Some of the more common manipulations involving combinations of search, measurement and comparison with some examples listed below:

- Intervisibility: From a given point, determine the extent of the visual landscape. Used in viewshed analysis.

- Interpolation: From a sample of points, determine points or lines of equal value. Used for contouring maps.

- Corridor delineation: From a number of criteria, find a cooridor for a power line, road, or other linear feature.

- Slope: Determine degree of slope associated with different land units.

- Aspect: Determine directional orientation of the slope for a land unit.

- Aggregation/disaggregation: Aggregation involves the reclassification of data into broader categories. For example, soil types might be combined into soil association categories. Soil types may also be grouped according to their drainage characteristics. Disaggregation involves the reclassification of categories into finer detail. For example, land cover classified as "coniferous" might be redefined as Douglas fir or western hemlock. Disaggregation is possible only if the more detailed classes were entered when the data were created.

- Projection and scale change: During the entry stage, map projection and scale may have to be transformed to match that of the data base. During the retrieval stage, the map may be drawn at a specified projection or scale.

- Centroid allocation: Calculation of a single point, usually at the center of the polygon, to represent the polygon in various manipulations. Problems occur when the polygon is concave such as arc-shaped reservoir, because the machine may position the centroid outside the polygon.

- Line smoothing and simplification: Points are added to lines in smoothing to give the appearance of smooth, manually drawn lines for output. Points are deleted from lines in simplification. This is important for eliminating clutter and merging lines when the scale of the plot is much smaller than the scale of the digitized source.

- Windowing: The ability to extract data from boundary coordinates, which is often used on display terminals to modify or zoom in on a particular portion of a data base.

- Embedded polygons: If one polygon encloses another polygon, the system has to recognize this embedded polygon (island). This is a fairly complex task, which can be handled in several ways.

- Data Structure Conversions: The most common conversions are point to grid or point-to-polygon, which involve determining which polygon or grid a given point falls within. It is essential for arc systems to transform the arcs to polygons. As mentioned in the section on comparison techniques, (3.2.3.2) polygon systems may convert to grids, then reconvert to polygons for compositing.

3.2.4 Data Output

Line Printers

High-speed line printers are most often used for output of both maps and text. Their overriding advantages are speed, low cost, and widespread availability. Their major disadvantage is that maps produced are generally too crude to be used for presentation. Fixed carriage typewriters, e.g., IBM ball-type Selectrics, and daisy-wheel printers, however, can be interfaced with the computer, improving the overall appearance of maps over a line printer product, by making character blackness and spacing between characters consistent.

Line Plotters

The flatbed plotter consists of a table, an arm that moves along the length of the table, and a drafting head that moves along the arm or width of the table. A number of tools can be attached to this drafting head: felt tip pens, ball point pens, wet ink drafting pens, scribing tools for directly producing photographic negatives, or a point light source for exposing photographic negatives on top of the line models. Colored inks can be used with the pens.

Drum beltbed plotters have a fixed arm, a movable drafting head, and a rotating drum that holds the drafting material.

These plotters produce output of extremely high quality but can only accomodate capabilities associated with felt tip, ball point and liquid ink pens.

Excellent linework can be produced with the aid of the plotter, precise linework that rivals or exceeds that of a skilled cartographer and most computer installations have plotters.

Raster (Electrostatic) Plotters

Electrostatic plotters and printers are devices that produce images by a matrix of small, closely spaced nibs that can electrically charge small areas on a piece of paper. This paper is then passed through a special ink which adheres only to the areas that have been charged. These plotters are excellent for area shading, but linework appears stepped like a staircase under magnification and is not as precise as that of a line plotter. These plotters can produce at very high speeds and most often are used to generate black and white graphics, however, they can be used to produce high qualtiy color products. The cost of good color plotters, however, remains high.

CRT Displays

There are two types of cathode ray tube (CRT) displays: the refresh tube and the storage tube. Refresh tubes are like a conventional television in that they produce images at regular intervals (the refresh cycle). Images can be selectively added or erased and the image can be animated. Storage tubes produce images by exciting an electrically charged phosphorous screen. Information can be added and displayed on a storage tube, but cannot be erased without having to redraw the entire image. Lower cost CRT displays allow for interactive map design, an area of great interest to cartographers. CRT displays can also be interfaced with plotters or electrostatic printers for a permanent image.

Report Generation

The attention given to the map in a GIS should not overshadow the importance of simple graphics and report generation. Although maps might be the most demanded item from a GIS, reports are probably the most used by the greatest number of people. Graphs and charts include such things as histograms, frequency curves, and scattergrams. A GIS should produce these products as well as bi- and multi-variate line and bar graphs. Diagrams can be drawn on all of the mapping devices and are usually of high enough quality for presentation.

Beyond simple program listings, a report generating program can provide the following:

- Summaries of system status (tables of descriptive and locational data, size of data base, use statistics, update information)

- Statistical tables

- User guides

- Reports for presentation to planning boards, interest groups, and other users.

A variety of users will place output demands on a GIS, and thus the types of reports needed and their format should be flexible. A well-designed program that generates reports should enable the user to:

- Designate titles, labels, sources, and page numbers

- Save the report as part of the system

- Output the report to a line printer, fixed carriage typewriter, CRT, or other device

- Request standard formats.

Human Interaction In Output Production

A discussion of output would be incomplete without considering how the user requests this output, i.e., how the user interacts with the system. The user has a right to expect an understandable interface through which he/she uses the system. This interface should include the following:

- The overall conceptual model of the system provided by various user manuals and program descriptions.

- The command language used.

- The feedback from the system (the explanatory messages and output).

- Adequate display of the information the user is manipulating (for interactive systems).

With a poorly designed interface a user could spend hours deciphering an obscure user manual, submitting a request to the computer, and waiting a day for a plotter-drawn map that contains no information other than his user number and the date. Though this is an extreme example, it shows how detrimental to a system a poorly designed interface can be. This particular user probably would abandon the use of GIS capabilities.

This is not to say that a user should sit down at a CRT and type "I want a map" and expect a response (although it would be nice). Rather, the interface should:

- Be logical and consistent throughout, employing concepts familiar to the user.

- Allow the users to understand the system as opposed to masking them from it.

- Allow sophisticated users to bypass the explanatory dialogue that novice users need - to let the user "grow" with the system.

An analyst-operated system is used by a person who has knowledge of the system's programs (some programming may be required) along with knowledge of the end user's wants and needs. In many cases, the analyst may also be the end user. In the BLM, the end user is the planner or resource manager who requires little instruction to sit down at a terminal and within a short time receive satisfactory output.

3.2.5 Data Base Management

Data can be stored on a number of devices: keypunch cards, paper tape, magnetic tape, disk, drum, or in the computer's memory at execution time. All these devices vary in cost, but disks and drums are more expensive because they are technically complex and allow data to be randomly accessed.

Any data base system has to maintain a back up data base in the event of system "crashes" in which the entire data base may be lost. The traditional method is to maintain a magnetic tape archive so the current data base can be reconstructed.

Past GIS systems have paid little attention to protection of sensitive data, relying on standard system checks such as passwords and charge numbers. As more and more geographic data are generated, ethical considerations of privacy will probably have to be considered. Such protection may include decisions as to who can see what files and what files cannot be combined for analysis.

3.3 BLM's GIS Components

The Bureau's GIS is based on the MOSS "family" of systems (Figure 4). This family of software includes compatible data capture, edit, update, retrieval, analysis, output, and data base management systems. It also includes numerous reformatting and data conversion programs.

The MOSS family has grown from the original systems developed by the U.S. Fish and Wildlife Service, Western Energy and Land Use Team, to the most advanced public domain GIS software in existence. It is currently being used by the USFWS, BIA, USGS, DOE, MMS, SCS, and USFS, in addition to BLM, (Appendix C).

3.3.1 Data Capture

The Bureau Geographic Information System has functional components for data capture, edit and update. The two data entry subsystems available to state offices are ADS (Automated Digitizing System) and AMS (Analytical Mapping System). Several reformatting programs are also available to enter digital data from other sources.

Automated Digitizing System (ADS)

The ADS data entry system is an interactive point/vector digitizing system that provides the capability to capture thematic map data as well as other graphic data. ADS supports two-dimensional data base construction by performing a transformation of table digitizer coordinates to map coordinates. ADS can capture information in point or stream mode.

Topologic formation of polygon areas is performed after the line data has been captured. Labeling map features is conducted interactively by the user after the digital outline of the map has been captured and verified. This sequence increases the speed at which digitizing is conducted. ADS can also be used to assign point and line symbols during the data entry process providing an excellent mechanism for standardizing map symbology. Edge matching between digitized maps is done interactively by the user. Digital map coordinate values are carried as digitizing table coordinates until converted to a map projection for entry to MOSS.

ADS produces pen plotter maps to assist in data entry verification and quality control. ADS can be configured

	1. Data Entry	2. Data Analysis	3. Data Output
Software (computer programs)	1. ADS (Automated Digitizing System). 2. AMS (Analytical Mapping System). 3. Numerous programs for insertion of digital data from outside BLM (USGS, SCS, PI, USFS, DMA data, etc.)	1. MOSS (Map Overlay & Statistical System) 2. MAPS (Map Analysis & Processing System)	1. COS (Cartographic Output System). 2. ADS, AMS, MOSS (Limited output capabilities).
Functions	1. Map Digitizing (conversion of mapped information to forms usable by computer). 2. Editing (process of cleaning up messy or erroneous data). 3. Georeferencing (associating data with its location on the ground). 4. Updating (adding new or deleting old information).	Over 100 commands perform numerous complex data analysis operations. A few examples are: - Find, retrieve and display full or partial maps from storage - Compute acreages, distances, perimeters, widths, etc. - Compute and display topographic slope and aspect. - Create buffer zones around areas, points, corridors, etc. - Generate contours of elevation density, structure, etc. - Overlay multiple data themes on base maps - Create composite maps by adding components - Compute statistical characteristics of mapped features. - Calculate geographic locations of stored information	1. Complete cartographic design for automated map production. 2. Color, shading, rotating, textue selection. 3. Labeling with user designed or standard symbols, letter styles.

Figure 4 - Basic BLM GIS Components

for remote access to a central computer from a local field office using one data communications line making it more desirable to offices that require remote data entry facilities

Automated Mapping System (AMS)

The AMS data entry system is an interactive arc/node digitizing system that allows for the capture of spatial data from either maps or aerial photography. AMS provides point, stream, and curve mode digitizing.

AMS supports full three dimensional data bases and has been developed in conjunction with a Stereo Analytical Plotter (APPS) for direct entry of digital data. A photogrammetrically rigorous system is also available for digitizing data directly from a single aerial photograph using an x,y digitizing table. AMS also does full edge matching and topological verification.

The automatic topological procedure is part of the arc/node data entry subsystem. The procedure checks the following conditions:

- Missing arcs
- Non-valid node junctions
- Duplicate arcs
- Spikes
- Gaps
- Bad attributes
- Loops in an arc
- Edge match with adjacent geounits

The verification process forms polygons from an arc/node file and assigns islands to the appropriate polygons. If any errors are detected, the user is informed and an interactive edit can be used to correct the problem.

AMS interactive edit functions include:

- Attribute edit
- Delete arc
- Add arc
- Delete polygon (and all associated arcs)
- Drop node in arc (split arc)
- Identify arc by pointing
- Identify polygon by pointing
- Identify node by pointing using the cursor

The first consideration in AMS is that the data entry latitude/longitude is its locational reference. This enforces a common geographic reference system for the entire data base. Secondly, digitizing occurs in terms of geographic coordinates, rather than table coordinates, ensuring that the new data are immediately referenced to the data base. Thirdly, the geographic data base is subdivided into discrete logical units of fixed size called geounits.

AMS also uses the concept of edge nodes to tie features together that cross geounit boundaries. Data entry personnel are able to perform edge match as an interactive procedure during the initial digitizing process, rather than as a subsequent editing step.

AMS produces pen plotter maps as well as acreage summaries. AMS currently requires more than one data communications line for remote use.

Digital Data Entry Programs

In the MOSS GIS family, BLM has additional programs available to enter the following digital data:

- USGS 1:24,000 Digital Line Graph (DLG) data base
- USGS 1:24,000 Digital Elevation Models
- DMA Digital Elevation Terrain Data (DETD)
- DMA Digital Feature Analysis Data (DFAD)
- IDIMS Image processing files
- ELAS Image processing files
- U.S. Forest Service RIDS interchange files
- U.S. BLM ADS digitizing system files
- U.S. BLM AHDS digitizing system files
- Soil Conservation Service primary sample unit files
- Petroleum Information Corp. well data

The following is a list of projections which can be accommodated:

- Geographic (Latitude/Longitude)
- Universal Transverse Mercator
- State Plane
- Albers Conical Equal Area
- Lambert Conformal Conic
- Mercator
- Polar Stereographic
- Polyconic
- Equidistance Conic
- Transverse Mercator
- Stereographic
- Lambert Azimuthal
- Azimuthal Equidistance
- Gnormonic
- Orthographic
- Vertical Near Side Perspective

- Sinusoidal
- Equirectangular
- Miller Cylindrical
- Van Der Grinter 1
- Oblique Mercator

3.3.2 Data Retrieval and Analysis

Background

Data retrieval and analysis are available in the MOSS and MAPS systems. The DSC also has the IDIMS system for specialized raster processing which can provide high quality but more limited data products to state offices.

MOSS (Map Overlay and Statistical System) is an integrated package for storing, retrieving, analyzing, and displaying digital map data. Work was initiated on MOSS in 1977 when a detailed user needs assessment was performed. This assessment focused on data needs, analysis needs, display requirements, and data characteristics of resource inventory/management in the Bureau of Land Management and Fish & Wildlife Service.

Based on the User Needs Assessment, a detailed functional specifications document was developed and reviewed by the potential user community. This document detailed the types of data base management, retrieval, analysis, and display functions required by the user for resource management applications.

Once the functional specifications were reviewed, a detailed design document was developed. This document suggested languages for user interaction, data structure, coding standards, program logic flow, and a variety of other information related to actual software implementation. Before any coding was initiated, however, a review of the existing geographic information system (GIS) technology was performed. Information on both proprietary and public domain software was collected. Over 100 systems were identified of which 54 had adequate documentation for a detailed review.

At this point, several decisions were made. First, proprietary systems were removed from further consideration because BLM and FWS felt that 1) local modifications requiring source code was mandatory, and 2) being tied permanently to one vendor/contractor was not in the long-term best interest of the government's user community. Second, since no public domain system met even half of the stated functional requirements, the decision was made to combine the best portions of existing public domain systems, and write new language interfaces for the user, drivers, and DBMS software. In 1977, there were no adequate DBMS's available for properly handling GIS-related applications.

In the Fall of 1977, the actual coding of MOSS began. By the summer of 1978, a prototype system was available for demonstrations on a CDC mainframe. In 1979, the Fish & Wildlife Service decided to convert the fledgling GIS to a Data General Eclipse minicomputer. This conversion was completed in July of 1979. During the same period, MOSS was interfaced to AMS, a fully rigorous arc/node digitizing package.

In recent years, a number of enhancements have been made to the MOSS "family" of GIS software. Over 50 new vector and raster processing functions were added; interactive color graphics was implemented; a number of the data structure components were upgraded; and the concept of "fast files," auxilliary files that decrease execution time by an order of magnitude in some cases, was introduced. Also, interfaces were developed for accepting data from USGS DLG and DEM files, Forest Service RIDS files, Census DIME files, DMS DFAD and DETD files, and SCS AMS files.

System Status

Two recent events characterize the current status of the MOSS family:

(1) The first National MOSS User's Conference was held in 1983 bringing together representatives from different agencies now using MOSS. The Conference provided a forum for individuals from a variety of agencies to talk about their GIS work, problems, and enhancements they require. The general consensus was that MOSS does the job, but projects were getting too diversified and too large for the original design model to be valid. The general feeling was that 1) MOSS needs an arc/node data structure, 2) MOSS needs an interface to a relational DBMS, 3) MOSS must allow users to operate on more than one map at a time, and 4) MOSS and MAPS should be fully integrated.

(2) The MOSS system was recently converted to a DEC VAX computer system, a first step toward spreading the whole MOSS family from Data General to other hardware environments.

Literally hundreds of MOSS applications projects have been successfully completed. Over 50 user groups have been using the MOSS family of software (Appendix C). There are currently 95 user available functions (commands) and 28 utilities in MOSS, (Appendix D). MOSS itself now is operational in both the Data General and DEC environments, and also runs on the DG desktop computer. (The remainder of the MOSS family, including MAPS, however, is only operational on Data General systems.)

As computer technology and the demand for it continues to accelerate, so do user requirements. MOSS is in need of some major overhauls if it is to meet the needs of resource managers in the future. Several steps have already been initiated in this direction. First, in 1983, a new raster processing system was designed, modeled after the Yale University MAPS package through coordinated efforts between BLM and FWS. The MAPS package was first used for projects in late 1983, and its use and functional capabilities increased considerably during 1984. There is now an effort underway to more closely integrate MAPS into MOSS. The goal is to replace many of the existing raster commands in MOSS with MAPS capabilities and to enhance a number of the existing MOSS raster commands that are not part of MAPS. This integration task, funded by SCS, is expected to be completed by January 1, 1985.

Another major development, being funded by the U.S. Navy, is the design and implementation of an IGES (International Graphics Exchange System) interface. This will allow the MOSS family to "communicate" map data with any of the major CAD/CAM vendors. This work is also to be completed by January 1, 1985.

Perhaps the most important new development will be the implementation of an arc/node data structure in MOSS. A design effort, funded by USGS, will begin in October, 1984. This effort will provide both a functional specification as well as a detailed design document for implementing a topological data structure. This design will be based on years of experience with topologic and spatial data structures as well as recent "super state-of-the-art" studies done by the MOSS development/support staff on topological and attribute data structures. This detailed design document will also address the relational DBMS interface problem.

One final key aspect of current MOSS trends is that the military has included MOSS in several key mapping systems currently being developed. These systems, while unique to the military, have and will continue to provide significant overflow of some new capabilities into the civilian version of MOSS.

Data Retrieval Capabilities

Data Retrieval Operations

- Retrieve entire map
- Retrieve single feature map

- Retrieve by single attribute in map
- Retrieve by single attribute for multiple maps
- Retrieve using one or more attributes with boolean and relational criteria
- Retrieve based on feature size/length criteria
- Retrieve based on juxtaposition criteria
- Retrieve based on all data except a specified subject, attribute or item

Mathematical and Logical Analysis

Vector operations:

- Polygon on polygon overlay (and, or and not)
- Polygon on line overlay
- Polygon on point overlay
- Find all points, lines or plygons within a given distance of a point set
- Find all points, lines or polygons within a given distance of a line set
- Find all points, lines or polygons within a given distance of a polygon set
- Zone generation about point, line and/or polygon data sets (Buffer).
- Area calculation
- Perimeter calculation
- Centroid calculation
- Vector map merge
- Divide polygon into smaller polygon
- Vector to raster format conversion (for single and multiple attribute files)
- Move centroid
- Re-project coordinate data
- Generalization (merge polygons)
- Distance between points
- Distance along a line
- Juxtaposition analysis (contiguity)
- Common edge analysis
- Corridor analysis
- Modeling multiple attribute file (boolean searches)
- Networking functions involving lineal data
- Area size selection criteria

Raster Operations:

- Logical and arithmetic compositing
- Raster zone generation
- Raster modeling (most commonly referred to as cartographic modeling)
- Area reports
- Pixel query
- Slope calculations
- Aspect calculations
- Profiling

- Three-dimensional block diagrams
- Two contouring algorithms
- Interpolation and isoline generation, i.e., contours
- Viewshed analysis

Isolines may be generated from a grid of z values using one of two algorithms. The grid of z values may be created either using point-to-grid interpolation functions, or may be entered from an external source. Isolines may be labeled and stored in the data base for use with other data.

3.3.3 Data Output

ADS, AMS and MOSS have limited graphic output capabilities. Therefore, full cartographic design is performed with the Cartographic Output System (COS). Users can define their own mapping symbols, and up to 128 per font may be created. There are 128 available fonts: 22 are already pre-defined. There are 36 pre-defined line styles and 80 pre-defined point symbols. Polygon shading (cross hatching) is supported on the system as either default or user specified shade types. Shading texture, rotation and color are correlated to each map attribute. Windowing and scaling are also supported.

Plot annotation occurs in two modes. In the first mode, any feature may be labeled with its attribute information. This is done automatically by the plotting software, although the user can move label positions in MOSS prior to plotting in COS since they are stored in the data base. In the second mode, the user uses MOSS to interactively create, edit, and update a layer of information containing only text. This text can be displayed in any one of the 22 text fonts, any number of colors and angle, any height-to-width ratio, and any line weight in MOSS or COS.

COS supports the following hardcopy devices:

- CALCOMP (any size) pen plotter
- ZETA (any size) pen plotter
- Houston Instruments (any size) pen plotter
- GERBER pen, scribe, and photohead plotter
- Versatec (any size) electrostatic plotter

Work has been initiated on developing independence through implementation of the Graphics Kernal System Standard (GKS). It uses its own library of graphics routines, and requires only device initialization and device vector move and draw.

3.3.4 Data Base Management

MOSS can store the following types of spatial or geographic data:

- Point data sets
- Lineal data sets (roads, streams, etc.)
- Full polygon data sets (where the arcs have been linked together to form full polygons)
- Discrete raster data sets (such as LANDSAT or data sets rasterized from vector files)
- Continuous raster data sets (such as digital elevation models)
- Text annotation layers

The coordinate data for vector data sets may be either two-dimensional (x,y) or three-dimensional (x,y,z).

MOSS has no limitations on the number of cartographic levels that can be stored in the data base. In terms of analysis, the number of levels that can be handled at any one time depends on the function being used. Typically, the number of allowed levels ranges from one to twenty, although some functions can manipulate up to forty maps at one time.

MOSS has a file handling system that allows the user to maintain references to maps on disk while the maps themselves are on tape. All map data is stored on a map sheet by map sheet basis (although multiple maps may be searched during a given data retrieval query). The data entry system automatically targets a map sheet by using the Latitude/Longitude of the map sheet center. The analysis and display system uses map sheet names.

Updates to the data base may be done either interactively or in batch mode. The only inconvenience to the user is that the map being updated is locked until the update is complete. This prevents a data base read/write lock condition during update.

Attribute data may be entered either interactively during data capture process, interactively during data base construction, automatically if sequential numbering is required (range can be specified), or as a batch process after spatial data base construction. Currently, MOSS supports integer, floating point, character and x,y attributes. The precision of numbers is dependent on the precision of the computer. Attributes may be up to 64 characters in length, and up to 200 attributes can be used in a multiple attribute file to describe a single map feature.

A summary of MOSS data base size limits are:

- Up to 32,000 map sheets in one project
- Up to 16,000 features (points, lines or polygons) in one map
- Up to 32,768 points defining a line or polygon
- Up to 353 islands in one polygon
- Up to 210 attributes per feature
- No limit on the number of project data bases
- Up to 20 keys for an attribute search
- A single map file may be up to 8,388,352 bytes in length

A number of techniques are used in MOSS to facilitate efficient data retrieval from geographic data bases. These include the following:

- All files are fixed length random access files
- Binary searches are used
- Both explicit and implicit pointer structures are used to form data bases relating all spatial, topologic, and cartographic information.
- Both static and runtime structures are used to provide very quick access to data that has already been retrieved.
- Data compaction is used for both coordinate data and attribute data.

The attribute data is stored in a random access format in compacted form. The attribute data files are easily expanded without rebuilding the entire data base. MOSS supports a wide variety of qualitative and quantitative multiple attributes.

The report generation functions available in MOSS are:

- Map status information
- Area reports
- Perimeter reports
- Frequency reports
- Multi-column attribute reports
- Single map feature reports
- Complete feature reports
- Complete data dump
- Histograms (raster or vector data).
- Descriptive statistics (raster and/or vector data).
- Bi-variate cross tabulations with Chi-square (raster data only)

MOSS also provides a number of security levels. The first level requires each user to have a valid MOSS password. If the user enters a password which is not valid, MOSS cannot be executed. The second level, incorporates read and write locks for each map file in the data base. Finally, a number of data base management functions, such as master map deletion, require an additional password.

3.4 Software Operation and Maintenance

The component subsystems of the GIS require permanent maintenance and operational support. These efforts are corrective, preventive, adaptive, and perfective maintenance.

3.4.1 Corrective Maintenance

Corrective maintenance is performed in response to problems or "bugs" in the system. Large and complex systems are never completely error free in logical design or implementation. As Dr. Edgar Dykstra points out - "There is no program without bugs, only those that no bugs have been found in".

These kinds of problems can elude formal and rigorous test procedures when there are few constraints on the number of data paths and data ranges a process must accommodate. Most errors can be corrected by revising the logic or data flow for a program. Other errors require a different algorithm or problem solving approach.

3.4.2 Preventive Maintenance

Preventive maintenance is an investment in time and effort to ensure greater reliability of the software. Revising the structure of programs or data formats to provide simpler logical constructs or fewer data paths helps to decrease the complexity of the software, thereby increasing its maintainability. The use of software engineering techniques such as structured programming, algorithm verification, and modular testing are preventive maintenance activities. Preventive maintenance commits the time and effort to methodically replace cumbersome, unstructured code with clean, structured code. The GIS subsystems were developed as prototype operational systems in several cases without the benefit of structured techniques. A software improvement program for these subsystems would replace unstructured FORTRAN 66 code with structured FORTRAN 77, Pascal MC code on a module by module basis.

3.4.3 Adaptive Maintenance

Adaptive maintenance converts existing capabilities to new hardware and/or operating system environments. The system must also become easily transportable to other operating systems and hardware configurations to accommodate requirements for competitive procurement and to take advantage of advances in hardware technology.

3.4.4 Perfective Maintenance

Perfective maintenance refers to enhancing existing system capabilities in response to identified user needs for extended or new capabilities.

The GIS system must adapt to new BLM user requirements to retain a high degree of usefulness over a broad range of applications.

4.0 Recommended Approach TO GIS Implementation

The following discussions present major points to be considered by the Bureau as it implements GIS technology. This is not an implementation plan, but an implementation approach. An implementation plan, based on individual state plans, will follow.

4.1 Implementation Objectives

4.1.1 Basic Objective

The basic objective of GIS implementation is to capitalize on the efficiencies and cost savings of GIS automation in the BLM as soon as practical. What is practical will vary by state, primarily as a result of budget considerations.

4.1.2 GIS Computer Hardware Implementation Objective

Recent technical analyses coupled with consideration of the Bureau's organization structure indicate GIS technology should be implemented at the state level. Under this scenario, each state office would provide computer support to its own field offices and there would be no Bureauwide mainframe computer for GIS use.

Therefore, the hardware objective is:

> To install independent, but standardized GIS computer hardware in each state office on schedules determined by each state director.

District and area hardware configurations will vary, but must be fully compatible with their state offices at all levels. Likewise, all state offices must be standardized with each other and with the Denver Service Center. States should perform all direct support for computer operations and field applications.

4.1.3 GIS Applications Software Implementation Objective

As with all large, complex software systems, the Bureau GIS must have a source of permanent support (Section 1.2). Lacking private vendor support, the DSC is the logical software support organization. As a corollary to the Bureau's need for long term system support, it will be necessary to ensure that all Bureau GIS software installations are identical, or nearly identical. It would not be possible to support different GIS software in each state, an inevitable result of non-standard systems.

Therefore, the software objective is:

<u>To install the Bureau-standard GIS software in all states, and some districts, centrally supported by the DSC.</u>

4.1.4 GIS Infrastructure Objective

GIS infrastructure is composed of the people, organizations, and facilities necessary to implement the hardware and software of GIS technology. In many ways it is more difficult to obtain than the systems, because it involves talents, attitudes, and institutions which cannot be simply purchased.

It is preferable that the infrastructure preparations in each state begin well in advance of actual GIS implementation. For example, as existing vacancies are filled, the skills required for GIS applications must be kept in mind and position descriptions prepared accordingly.

GIS technology is sure to have long term profound effects on resource management, including BLM operations. It will create new ways of "doing business" in many ways, but the technology is new, complex, and not likely to be picked up by casual association. GIS technical support personnel, especially in the DSC and state offices, therefore, should be professionals with formal education in those skills for which they are hired, and field organizations should be staffed to address all aspects of GIS implementation.

Thus, the objective regarding infrastructure is:

<u>To strive for technical excellence and provide professional attention to all aspects of GIS technology implementation in personnel placement and configuration of GIS-related organizational elements.</u>

4.2 Implementation Plan

Each State Office will need to develop a GIS Implementation Plan to meet its own specific requirements. These state plans will in turn be used to develop the necessary Bureauwide plans, software development and support, equipment procurement, etc.

Some states have already produced plans for GIS applications and these can provide a basis for the implementation plans. Since the implementation will involve concepts and technologies unfamiliar to many Bureau personnel who must contribute to them, selected DSC and State Office staff with operational experience will be available to assist state planning efforts, on request. Formal requests for such assistance have already been received from some states. An outline for a typical state GIS Implementation Plan is provided as Appendix E to this document.

The Service Center will produce a Bureauwide GIS Implementation Plan, based on the input it receives from state offices. This may be conducted through a GIS advisory committee having state representation. This plan will be a dynamic document, frequently updated to reflect changing state plans. Each state will implement GIS technology on its own schedule according to funding constraints and opportunities. Thus, a state may have no specific plans in this year, but evolve a very detailed effort a year or two later. The Bureau's GIS Implementation Plan must accommodate these changes.

In addition, the DSC will prepare an Operating Plan which reflects how and when it expects to respond to state GIS implementation support needs. This plan will also have to be dynamic, and will use computer project management planning techniques. Project tracking mechanisms will produce running schedules, milestones, and progress reports on DSC support of state implementations, all of which will be regularly distributed to the relevant state offices.

4.3 GIS Hardware Implementation

The hardware implementation objective calls for standardized GIS computer hardware. Standardization does not simply mean "compatibility." Compatibility in computer terms can refer to communications, meaning two systems can talk to each other, or it can refer to the ability to run the same software. Unfortunately, "software compatibility" rarely assures what it infers, that different makes of computers can run exactly the same software.

It is true that most major computer systems can use approximately the same user language, e.g., FORTRAN, COBOL, etc. But they may use different versions of the same language, or different combinations of statements from the same language may be required to execute the same operations. In short, "software compatibility" does not ensure that the same software programs will perform exactly alike on different hardware. Computer manufacturers appear to be moving toward true, 100% compatibility, but that event will occur in the future, if it occurs at all.

Given these concepts on compatibility, the Bureau has no choice but to employ the same basic hardware for all its GIS installations. The alternative would be to recommend different GIS software in each state, the inevitable result of having different hardware. That posture would be untenable because:

- it would require each state to have its own software support staff, a mini-DSC for each system
- the interchange and consolidation of data would be difficult or impossible; national statistics and analyses would be difficult or impossible
- national statistics and analyses would not be possible
- users would have to be retrained when they changed states

- the expense of maintaining GIS technology Bureauwide would be many times higher.

These same benefits could be realized across the Department of Interior with appropriate directions and support.

4.3.1 State Hardware

The exact system configuration of each state will be determined by its own requirements. Although each state's central processing units and certain related hardware must be the same, there is room for flexibility in the selection of peripheral hardware such as plotters, terminals, and workstations. In FY'85 the DSC will begin evaluating certain devices and hardware combinations which have significant potential benefits in overall GIS implementation. For example, stand-alone data entry stations, optical disc storage, microcomputer-based GIS work stations, advanced digitizing techniques and similar technical advances will be examined. As new devices become available and are determined to be operational, they will be recommended to states for use. As a result, not all states, districts, or resource areas will use the same peripheral hardware. They will vary depending on when hardware is purchased, and what needs are specified. It will be up to the DSC, working with each state's GIS/ADP personnel to insure that all such advances do not threaten Bureauwide GIS standards.

By Spring of 1985, the BLM expects to participate in the award of a competitive hardware procurement with the U.S. Fish and Wildlife Service and Bureau of Indian Affairs (Appendix F). This will be a 5-year contract with sufficient optional quantities to permit all BLM state offices to purchase state-of-the-art, virtual memory, 32-bit minicomputers, and related 16-bit microcomputers. Another procurement is planned to be executed at the same time, to provide for the purchase of GIS-related peripheral equipment over the same time period. These procurements are intended to give states the flexibility of acquiring GIS hardware gradually, according to demand.

State cost of GIS computer hardware will vary for several reasons:

(1) Some states already have a computer and peripheral equipment which may be usable with the new Bureau standard CPUs.

(2) Potential state GIS workloads, for renewable resources, minerals and planning, are highly variable.

(3) The number of districts and resource areas which should be GIS-equipped varies.

(4) Minerals states will have a greater GIS-related workload than non-minerals states (except Alaska).

(5) ALMRS-equipped states will have need of GIS support for automated records graphics production.

For these and other reasons, the initial GIS hardware cost may be expected to vary from about $300,000 to $750,000 per state, for the following basic computer hardware, located in state offices:

1 Central Processing Unit

2 Magnetic Tape Drives

2 Magnetic Disk Drives (approx. 200 megabytes each)

1 Line Printer (300 lines per minute)

1 Pen Plotter (Line)

1 Electrostatic Plotter (Raster)

2 Terminals (operators)

6 Microcomputers (16 bit - 32 bit)

4 Digitizing stations (including terminals)

Not all these devices would be initially needed at all states, although some states may need more. In addition, district and resource area hardware may or may not be needed. It is strongly recommended that DSC GIS hardware engineers be consulted on specific configuration alternatives as state GIS Implementation Plans are developed.

4.3.2 <u>DSC Hardware Configuration</u>

The computer graphics hardware configuration required at the Service Center will serve two significant purposes. The first is to perform the centralized software support needed for operation, improvement, and long term maintenance of the ADS, AMS, MOSS, MAPS, and COS systems, and the related library of programs needed to operate them on a Bureauwide basis. Second, the DSC intends to provide limited GIS operational support to states requesting it, as an interim measure pending in-state GIS hardware implementation. This support will necessarily be short-term and subject to availability of DSC computer resources. Some limited long term support may also be provided.

The Service Center's basic hardware requirement is the same as the basic state office package listed above, in addition to its existing hardware. In addition, the DSC will require a certain amount of developmental hardware to assist in the development of new techniques and systems for state use. DSC will also require certain specialized processing and output devices for centralized

Bureau support. These may include oversized flatbed plotters, large film writers and color electrostatic plotters.

4.3.3 Washington Office Hardware

The Washington Office GIS hardware requirement is understood to be small although it could easily grow as new GIS uses are discovered. As now planned, all large processing requirements and demands will be supported by the Eastern States Office GIS organization. A number of graphics terminals, microcomputers, and plotters, however, may be desirable in Washington offices to provide rapid access to and display of national data bases on line at the ESO office or by telecommunications with other offices for rapid action items.

4.4 GIS Software Implementation

The Bureau's GIS software consists of many different programs and sub-programs, totaling almost 500,000 lines of code. These include the major programs that constitute the MOSS family, (Section 3.3) as well as numerous smaller programs written for specific purposes.

As mentioned previously, most DOI agencies, plus the USFS, SCS, and some state agencies, are now using MOSS-based GIS software. As a result, each has a stake in further MOSS development and long-term support. The Bureau (W.O. and DSC) is now participating in several interagency committees and working groups with the intention of coordinating and sharing the cost of further GIS development.

In FY'85, the DSC will initiate procedures for soliciting, evaluating, and acting on user needs for further software system enhancement. Some of the resulting development work will be done by DSC in-house, some will be contracted out directly, and some major developments will be submitted for consideration by the USGS as a requirement on which that agency, as the government's mapping organization, should act. One such major development, an arc-node data structure for MOSS, is now underway by the USGS Eros Data Center, in cooperation with BLM.

Implementation of the Bureau's GIS software will be done systematically as states acquire the necessary hardware. An effort will be made to keep all states on the same versions of each major system, so that all users can benefit from fixes and enhancements as they are implemented. All state office system managers will be asked to participate, either through the existing IRM-TAC or other body yet to be organized, in the establishment of Bureau standard system operating procedures. These will include file management and access procedures, disk utilization, and related procedures which will be necessary for software installations to run as intended. States will be responsible for their own system management, of course. But without adherence to a minimal set of basic operating standards, successful software implementation and support would be impossible.

4.5 Data Communications Implementation

The combination of State Offices, Districts, Resource Areas, the Service Center, and the Washington Office could require the full spectrum of data communications protocols (synchronous and asynchronous), speeds (300 BPS through 19-2K BPS), and media (microwave, satellite, and land lines) to apply the GIS on a Bureauwide basis. A phased implementation schedule, coordinated with each state's GIS hardware installations will be followed for procuring and installing the needed data communications equipment and circuits, for in-state networking between state, district, and resource area offices. The design of a Bureauwide GIS communications network must await analysis of Bureauwide (interstate as opposed to intrastate) GIS requirements, if any. GIS could share some of the large networks that are currently operational in some states.

4.6 Physical Facilities

Most state offices occupy space that can be modernized or expanded to accommodate new GIS equipment. Some states have existing space that is adequate for accommodating computer equipment. In other cases, new space with power and air conditioning will be needed to support the GIS equipment.

The area required to house the typical GIS configuration is approximately 1,000 square feet of computer room environment (raised floor, power, air conditioning). Additionally, data entry office space of about 75 square feet per station would be. The computer space should be prepared in the fiscal year before procurement and installation of the GIS equipment. District and area office space requirements will vary; however, it should approximate 125 square feet.

4.7 Organizational Considerations

4.7.1 Personnel Requirements

Successful implementation of GIS technology requires hardware, software, and personnel resources. Personnel resources make up the single, most important element. Acquisition of GIS personnel resources, however, poses special problems because in many cases, no single job category is adequate. For example, a general ADP background will not suffice in filling a "systems manager" job because a combination of skills is needed to fill the systems manager position. Likewise, cartographic skills must be combined with ADP skills in data entry supervision. We will thus be developing and filling new kinds of jobs for which existing personnel classification and qualification standards are lacking or difficult to find and to apply. At the same time, Bureau managers responsible for organizing and staffing GIS units will be managing new, different kinds of operations, elements of which will be foreign to them.

Because of these factors, guidelines and assistance must be provided to the states in developing organizational structures and job configurations, qualifications analysis, training of new and existing staff, and recruitment activities. This assistance can be provided from a combination of DSC and State personnel.

These guidelines and assistance are only that - guides and offers of assistance. The initiative and final decisions determining organization, personnel, and location are vested in the State Director. The abilities of those skilled and knowledgeable in GIS, however, are expected to be tapped and used both in the implementation and operational phases.

To provide the necessary guidelines and assistance, several actions must be taken. As a minimum the following tasks need to be accomplished:

1) A definition of the minimum desirable skills/positions needed at the different organizational levels at which GIS action takes place--State, District and Resource Area. Such a definition should be as specific as possible, describing essential skills, knowledges, and abilities needed and relating these to the functions to be performed at several levels.

2) An inventory of the skills, knowledges, and abilities existing at the level where implementation is to begin.

3) Immediately after Task 1 is completed, a working group of technical experts in the field, personnelists, and organization specialists should be assembled to prepare standardized (model) position descriptions for all key jobs, e.g., systems manager, GIS specialists, data entry technicians, etc. The jobs would then be properly classified and provided to states for use and/or modification (combining tasks or functions) within the organization.

4) States would be provided access to GIS technical experts, personnel, and organization specialists to assist them in their implementation efforts individually or as a team.

5) Recruitment methods to obtain the types of people required to fill GIS vacancies need to be explored. Permanent support contracting for specific work functions or skills also needs to be examined. Specific actions needed are:

   a.) Pursue normal internal government advertising.

   b.) Use external but specific recruitment notices for specific jobs geared to the several knowledges and abilities required in the job at specific locations, as opposed to recruiting from existing lists geared to only one type of skill e.g., ADP skills. Such efforts should include paid advertising and recruitment visits.

   c.) Agreements should be arranged with specifically identified colleges and universities to provide internships for students studying in fields directly related to GIS work. In addition, faculty appointments should be used for temporary, short-term, problem-solving, or development needs. These appointments could be for actual work accomplishment or to train BLM employees.

   d.) Development of natural resource college curriculum additions to encourage inclusion of GIS methods in undergraduate and graduate degree programs, thus building a talent pool to meet future BLM GIS-trained personnel requirements.

   e.) Use co-op students to develop a source of qualified college graduates for projected jobs.

   f.) Use volunteers for short-term peak workloads such as data entry efforts.

   g.) Identify BLM employees who can learn new skills and who have base knowledge of a technical area related to GIS application.

4.7.2 Typical Staff Complement

A typical, basic state office GIS staff might be composed of the following nine positions. These may or may not all be within the same state office organizational unit, and the list would probably be modified to fit existing state circumstances.

Title	# of Positions
Systems Administrator	1
Computer Operator	2
Cartographic Data Entry Operator	4
GIS Coordinator	1
User Representative	1

4.7.3 Training

Training opportunities will be identified to develop and maintain skills in GIS work. Courses will be available not only for users/operators but also for managers. These courses include BLM offered courses and those offered at outside institutions or other government agencies. Technical experts in the field will be used to assist BLM in identifying and developing training resources. The required training will be developed to supplement existing courses, by teams comprised of State Office, Service Center, university and contractor personnel. Training will be conducted in phase with the implementation of GIS hardware, software, and data communications implementation, as scheduled by each state.

Specific training opportunities which may be provided include:

1) DSC courses on GIS for users in general: What GIS is; how GIS is used; why used, etc.

2) DSC courses on GIS for managers: Decision-making based on GIS analyses; cost efficiencies of GIS automation; personnel technical development opportunities, etc.

3) Specific BLM GIS Users' Courses: GIS/RMP procedures; GIS use in range management; GIS procedures applied to minerals leasing; minerals operations; records applications, etc.

4) University-based cooperative courses on GIS technology in-depth, for state office ADP personnel.

5) Headquarters program leader training on GIS philosophy of operations; budgetary implications of bureauwide implementation; interagency GIS development and cooperation, etc.

6) Courses given in cooperation with other agencies such as the current effort between DSC and the FWS.

All user training courses will be designed by DSC and other agencies in cooperation with university and contractor personnel, and with major input from BLM field disciplinary specialists. Standing user committees from states, districts, and resource areas are planned which will serve as training program advisors in specific GIS applications areas. The same user committees will provide advice to GIS software system specialists on system fixes, enhancements, and other improvements that could make the technology more useful in specific applications.

4.8 Data Base Development

The construction of digital geographic data bases will be driven by state office and program priorities and constrained by funding to such projects.

4.8.1 Alternatives

There are several alternatives available for implementing digital data bases covering specific geographic areas. Digital data may be available for specific thematic layers from other agencies, e.g. USGS, SCS, FWS merely for the cost of duplication. When digital data are not readily available, contract in-house, contracted, or cooperative digitizing with other agencies are alternatives. With the rapidly growing use of GIS technology by federal, state, and private resource management organizations, opportunities for joint digitizing projects are increasing.

It is also important to realize that much of BLM's resource data is not in a "clean" format, ready for digitizing. Although standards exist for resource mapping and are intended to facilitate digitizing, they have not been uniformally followed. Most resource data, therefore, will require reworking to resolve discrepancies. These efforts will require additional inhouse work and hinder the use of contract digitizing as an alternative for data entry.

4.8.2 Digitizing Cost

The average cost (in cents per acre) for digital thematic data is estimated to be:

Data Category	Duplicate (other agency) Original	In-House Digitize	Contract Digitize
Administrative	1.8 Cents	3.0 Cents	4.7 Cents
Abiotic	4.6 Cents	15.6 Cents	30.0 Cents
Biotic	4.6 Cents	15.6 Cents	30.0 Cents
Climatic	3.0 Cents	9.4 Cents	25.0 Cents
Physiographic	2.0 Cents	3.6 Cents	6.3 Cents
Totals	16.0 Cents	47.6 Cents	96.0 Cents

The cost estimate for a data category includes all the thematic map overlays within that category.

It is important to realize that, although digitizing can be an expensive process, it is permanent. Once a data base is established, it is never lost. After all, the vegetation, topography, hydrography, soils, geology, etc., do not change significantly unless disturbed by man. All that needs to be added to the permanent data base is updated information to keep it current, mainly in terms of land use changes. As new, updated GIS output products are needed, such as recreation or wilderness maps, they can be produced for little more than the cost of running the computer.

4.9 Funding Approach

GIS implementation requires allocation of scarce resources to cover start-up costs with the expectation that short-term investments will lead to efficiencies and cost savings in the long term. In BLM, our responsibilities as stewards of the public lands are becoming more complex while our real dollar appropriation will remain constant if not shrink during the remainder of the decade.

Regardless of program priorities at any given time, certain staffing and equipment requirements must be funded to operate and maintain a GIS program. This base program with equipment and personnel should be funded from all potentially benefitted activities. Not only has it been shown that most activities benefit from use of a GIS when available, but as program change, benefits to all programs have a tendency to balance.

Establishing organizations to develop, operate, and maintain GIS capabilities should be approached with the view that a certain base level of staffing is definable as the minimum acceptable level. Growth beyond that level must be supported by activities requiring the service and must consider the need to maintain fiscal flexibility to meet changing conditions.

Funding requirements for establishing GIS capabilities vary greatly among the states, as do the skills of employees within the organization. Though certain technical elements of the GIS program must be standard or compatible from State to State, each State Director should be permitted to proceed with implementation at a pace consistent with the requirements and resource issues of that organization. Maximum flexibility to operate GIS's to meet local demands should be maintained.

APPENDIX A

A Glossary of Terms and Acronyms in Geographic Information Processing

Access	The act of fetching an item from or storing an item in any computer memory device.
Accuracy	The degree to which a measured value is known to approximate a given value.
Address	An identification, represented by a group of symbols, that specifies a register or computer memory location.
Algorithm	A finite set of instructions which, if followed, accomplish a particular task.
Alphanumeric	A set of characters with letters, numbers, punctuation marks and special symbols.
Assembler	A computer program that translates instructions written in a source language directly into machine language.
Auxiliary Memory	Any computer memory or memories used to supplement main memory.
Batch Processing	A method in which a number of data items or transactions are coded and collected into groups and processed sequentially.
Bit	Acronym for Binary Digit, the smallest unit of information which can be stored in the computer.
Boundary	General term for the division between two mapped areas.
Buffer	The internal portion of a data processing system which serves as an intermediate storage between two different storage or data handling systems with different access times or formats.
Byte	A group of adjunct bits that are operated on as one unit.
Card Image	A representation in computer storage of the hole patterns of a punched card. The holes are represented by one binary digit and the spaces are represented by the other binary digit.

Cathode Ray Tube	An electronic tube with a screen that is used in computer terminals to display input and output data. Also referred to as a CRT.
Cell	The smallest region in a grid.
Central Processing Unit	The central processing unit, or CPU, of the computer is that portion of the computer which is used to control the components of the hardware system.
Centroid	The center point of a mass or polygon.
Chain	A synonym for a string, e.g., "a chain of coordinates."
Character	A letter, digit, or other special symbol used for the representation of information.
Compiler	A computer program that converts a source language into an object language.
Coordinate	An ordered set of values that specify a location.
Core	The most accessible information storage of a computer.
Cursor	A movable part of an instrument that indicates (x,y) coordinates to the machine.
Data Base	A set of data files organized in such a manner that retrieval and updating can be done on a selective basis and in an efficient manner.
Data Structure	The arrangement and interrelationship of data.
Data Tablet	A flat tablet which will output the digital position of a pointer placed at any position on its surface.
Digitization	The process of converting analogue or graphic data into digital form. Manual digitization involves the transformation of data by an operator with or without mechanical computer processors, while automatic digitization requires the use of an automatic device, i.e., scanner, pattern recognition, character recognition.
Digitizer	A device which converts maps into a digital format for computer input.

Direct Access	Interactive systems employ direct or random access in which the access time is not related to the location of the data in the computer memory, i.e., data does not have to be serially or sequentially searched.
Editing	The detection and correction of errors.
Encode	The process of applying a set of unambiguous rules to transform data from its original form to some coded representation, usually digital.
Field	A group of characters that is treated as a unit of data.
File	A variable number of records grouped together and treated as a main division of data.
Fixed Length Record	Relates to a number in which various records must contain the same number of characters.
Format	The specific arrangement of data in a record or file.
FORTRAN	An acronym for FORmula TRANslation, a procedure-oriented computer programming language.
Geocoding	The geographic coding of the location of data items.
Geographic Base File	A coded network.
Geographic Coordinates	A spherical coordinate system for defining the position of points on the earth.
Geo-referencing System	Planimetric coordinate system which identifies points on the surface of the earth. Systems include latitude-longitude, universal transverse mercator, stable plane coordinate and land survey systems, etc.
Grid Coordinates	Euclidean coordinate system in which points are described by perpendicular distances from an arbitrary origin, usually on an (x,y) axis.
Hardware	The physical components of a computer and its peripheral equipment.
Hard Copy	Printed or paper copy of computer output. Commonly a paper copy of the information displayed on a computer video terminal.

Information Retrieval	Methods and procedures used for storing and retrieving specific data and/or references based on the information content of documents.
Interactive Mode	Allows users to directly interact with the information system to input and/or manipulate and retrieve information in a real time framework.
Interface	The junction between components of a data processing system.
Intersection	The region containing all of the points common to two or more regions or polygons. See also union.
Light Pen	A device the size of a ballpoint pen which is used for pointing to a location on a CRT screen. One of several types of interactive positioning devices include a mouse, joystick and tracking ball.
Line Printer	An output device for computers which prints one line at a time. It can be used as a high speed listing or, by spacing symbols, as a plotting device.
Machine Language	Instructions written in a code that can be understood by the computer without further translation.
Magnetic Disk	A computer memory device on which data is available by random access.
Magnetic Tape	A computer memory or storage device which will store a large amount of data, but this data is only accessible in a sequential search.
Memory	An organization of storage units (bits, bytes) retained primarily for information retrieval.
Minicomputer	An inexpensive CPU with limited core capacity.
Natural language	A user-oriented language which can be used to search the computer files by operators who have no programming experience.
Network	A connected set of segments and nodes.
Node	A point which is common to two or more segments.
Object language	A machine language that is output from a compiler.
Off-line	Processing is not directly under the control of the central processing unit.

On-line	Processing is directly under the control of the central processing unit. All interactive systems operate on-line.
Optical Character Recognition	The process by which printed characters are read by light sensitive devices for computer input. Also referred to as OCR.
Overlay	The superimposition of one map or digital image over another of the same area in order to determine data combinations or intersections and unions.
Peripheral	Input and output equipment used to transmit data to and receive data from a CPU.
PL/1	A computer language intended to combine the most useful features of the scientific (FORTRAN) and business (COBOL) languages.
Plotter (line)	A mechanical plotter controlled by a computer, generally for the recording of location or spatial information. Lines are drawn as a series of vectors, usually by pens. Scribing tools and photoheads are also available as accessories.
Plotter (raster)	A plotter which prints an array of tiny dots to draw the material being plotted. Device is usually electrostatic (xerox principle), although systems using ink jet technology are also available.
Polygon	Plane figure consisting of three or more vertices (points) connected by line segments or sides.
Program	The implementation of a procedure by the use of a computer programming language. A program consists of a set of instructions which direct the CPU in the performance of a specific task.
Random Access	The process of obtaining information or data from a computer storage device where the time required for such access is independent of the location of the information most recently obtained.
Raster Scan	A line-by-line sweep across a display surface to generate or record an image.
Real Time	Processing which appears instantaneous to the person or the device controlling a computation.
Remote Sensing	The acquisition of information without physical contact. Includes visual, photographic, and electronic data-gathering methods.

Resolution	Measure of the ability of an imaging system to separate the images of closely adjacent objects. Also, the smallest area at which data can accurately be identified.
Software	The set of programs used to instruct the computer in problem solving; consists of the operating system programs and applications programs.
Spatial	Referring to a phenomenon distributed in space and therefore having physical dimensions.
String	A consecutive sequence of characters.
Terminal	A device used to input or output data from a computer, often from remote sites.
Time Sharing	A concurrent use of a computer system by more than one user or program by allocating short time intervals of processing to each active user. The response time is usually so fast that each user is given the impression that the computer's resources are totally designated to his task.
Uniform Grid	Square, rectangular, or hexagonal lattice grid coordinate system for recording geographic data.
Union	The region containing all of the points in two or more regions or polygons. See also intersection.
Variable-length	Relates to a file in which the various records may contain a different number of characters.

ACRONYMS

ADP	Automated Data Processing
ALF	Automatic Line Following
ALMRS	Automated Land & Mineral Record System
AMS	Automated Mapping System
AOS	Advanced Operating System
APD	Application for Permit to Drill
ASLD	Arizona State Land Department
BIFC	Boise Interagency Fire Center
CAD	Computer Aided Design
CAD/CAM	Computer Automated Drafting/Mapping System
CAM	Computer Aided Manufacturing
CDC	Control Data Corporation
COM	Computer Output on Microfilm
COS	Cartographic Output System
CPU	Central Processing Unit
CRT	Cathode Ray Tube
DBMS	Data Base Management System
DOD	Department of Defense
DEC	Digital Equipment Corporation
DEM	Digital Elevation Model
DFAD	Digital Feature Analysis Data
DLG	Digital Line Graph
DMS	Degree Minute Second
DSC	Denver Service Center
DTED	Digital Terrain Elevation Data

FY	Fiscal Year
GIRAS	Geographic Information Retrieval & Analysis Sytem
GIS	Geographic Information System
GKS	Graphics Kernel System
IGES	International Graphics Exchange System
IHICS	Integrated Habitat Inventory & Classificaiton System
JDR	Job Document Reporting System
MAPS	Map Analysis & Processing System
MOSS	Map Overlay & Statistical System
NDCDB	National Digital Cartographic Data Base
ORNL	Oak Ridge National Laboratory
PAYPERS	Payroll/Personnel System
PLSS	Public Land Survey System
RIDS	Resource Inventory Data System
RIPS	Remote Image Processing System
SCS	Soil Conservation Service
TGS	Technicolor Government Services
USBM	US Bureau of Mines
USBOR	US Bureau of Reclamation
USGS	US Geological Survey
UTM	Universal Transverse Mercator
WELUT	Western Energy and Land Use Team

APPENDIX B

Planned FY 85 GIS Hardware Procurements

Office		Item	Quantity
AK	*	MV 10,000 Hardware and Software Add-Ons	1
	*	DG MV 4000 computer plus peripherals	1
CO	*	DG 30 16-bit microcomputers	5
ESO	*	DG MV 4000 computer plus peripherals and software	1
	*	DG 20 16-bit microcomputers	2
UT	*	DG MV 10,000 plus peripherals and software	1
SC	*	DG C-330 Upgrade	1
	*	DG MV 10,000 plus peripherals and software	1
		DG Tape Drive	1
		DG 20 15-bit microcomputers	5
NM	*	DG MV 10,000 plus peripherals and software	1
OR		Tektronics 4054 terminals with software and peripherals	6
		Winchester Fixed Disk with Controller for DG M600	1
		DG Dasher Terminal	1
WY	*	DG Tape Drive	1
	*	DG 20 16-bit microcomputers	9

* To be part of Bureauwide FY 85 Graphics Procurement to be conducted with Fish & Wildlife Service.

APPENDIX C

MOSS USER GROUPS

Institution	Agency/Firm	Application
Federal	Army Corps of Engineers, Mobile, Alab.	Dredging Studies, Gulf of Mexico Wetlands Change Detection
Federal	Army Corps of Engineers, Omaha, Neb.	Flood Plain Work
Federal	Bureau of Indian Affairs, Hoopa, Calif.	Resource Management and Inventory
Federal	Bureau of Indian Affairs, Washington, D.C.	Land Records
Federal	Bureau of Indian Affairs, Yakima, Wash.	Resource Management and Inventory
Federal	Bureau of Indian Affairs, Alaska State Office	Land Records Master Title Plats
Federal	Bureau of Land Management, Colorado State Office	Oil/Gas/Coal Tract Leasing Studies
Federal	Bureau of Land Management, Denver Service Center	User Support Special Studies
Federal	Bureau of Land Management, Meeker Resource Area Office	Resource Management Plans
Federal	Bureau of Land Management, New Mexico State Office	Land Records Resource Management Planning Oil and Gas Development Records
Federal	Bureau of Land Management, Oregon State Office	Grazing Environmental Impact Statements

Institution	Agency/Firm	Application
Federal	Bureau of Land Management, Wyoming State Office	Resource Management Plans Coal Tract Leasing Alternatives
Federal	Bureau of Reclamation, Arizona	Mensuration Using APPS-IV Photogrammetric Studies
Federal	Central Intelligence Agency	ORWELL -- Special Studies
Federal	Los Alamos National Lab, DOE	Planning Facilities Management
Federal	National Park Service, Big Thicket	Park Management
Federal	National Park Service, Santa Fe, N.M.	Archeological Studies
Federal	U.S. Army Engineering Topo. Lab., Ft. Belvoir, VA	Interface to Intergraph, Studies Using Graphics Superposition Studies Using Panoramic Optical Bar & Radar Cross-Country Movement Models Pershing II Study Fort Management Plan Studies Vertical Obstruction Data Base Study Special Studies
Federal	U.S. Fish and Wildlife Service, Alaska	Refuge Management
Federal	U.S. Fish and Wildlife Service, Ft. Collins, CO	Wildlife Management Resource Inventory Support Services
Federal	U.S. Fish and Wildlife Service, Slidell, LA.	Refuge Management Wetland Studies Oil Spill Impact Modeling Dredge Disposal Studies

Institution	Agency/Firm	Application
Federal	U.S. Fish and Wildlife Service, St. Petersburg, Florida	National Wetlands Inventory
Federal	U.S. Forest Service, Nicholet	Timber Management Resource Planning
Federal	U.S. Forest Service, Pest Management	Pest Management and Impact Studies
Federal	U.S. Forest Service, Sawtooth Forest	Timber Management
Federal	U.S. Geological Survey, Eros Data Center, SD	Federal Lands Mineral Studies
Federal	U.S. Geological Survey; Reston, VA	DEM Validation DLG Validation Product Generation
Federal	U.S. Soil Conservation Service, Ft. Collins, CO	Special Studies
Federal	U.S. Soil Conservation Service, Wash., D.C.	Special Studies
State	Dept. of Geophysical and Geochemical Services, Alaska	Mineral Exploitation and Exploration
State	Dept. of Natural Resources, Alaska	Land Use Planning
State	Dept. of Fish & Game, Alaska	Wildlife Management
State	Louisiana Dept. of Natural Resources	Resource Management
Local	Platte River Trusteeship	Whooping Crane Preservation
Local	Winnebago County, Wisconsin	Tax Mapping Land Use Planning
Local	Johnson City, Tennessee	Land Use Planning Facilities Management

Institution	Agency/Firm	Application
Private	Greenhorne & O'Mara	Subdivision Planning Floodplain Studies Landuse Planning Management
Private	Hammon, Jenson, Wallen, & Assoc., Calif.	Forest Applications
Private	Nortec, Inc., Alaska	Oil and Gas, Land Records Resource Management and Planning Environmental Impact Statements
Private	Technicolor Government Services, Colorado	Support Services for Digitizing
Private	ZIA Corp., Los Alamos, N.M.	Facilities Management
University	University of Gratz, Austria	Land Use Planning

APPENDIX D

Current List of MOSS and MAPS Commands

MOSS COMMANDS

Command Name	Summary Description
ACTIVE	Produces a table identifying and describing activated maps.
ADD	Adds import/export format vector maps into the master data base.
ARCHIVE	Prepares maps for removal from the data base onto tape.
AREA	Determines area, frequency, and percentage of each subject in polygon or cell maps.
ASPECT	Produces a cell map of aspects from digital elevation maps.
ASSIGN	Pre-sets graphic assignments for maps.
AUDIT	Prints out a detailed summary of all features in a vector map.
BAUD	Changes the default operating baud rate.
BSEARCH	Performs complex boolean retrievals from associated attribute files.
BUFFER	Creates a buffer zone of user-specified size around any feature in a vector map.
BYE	Terminates the session.
CALCOMP	Produces a file for output to a plotter.
CBUFFER	Creates a buffer zone around features in a cell map.
CLI	Temporarily allows the user to exit MOSS and access the operating system.
COMMANDS	Lists all commands and their abbreviations.

COMPOSITE	Performs cell map overlay using boolean and arithmetic comparison criteria.
CONTIGUITY	Activates all polygons of subject A and B when A and B are spatially adjacent to each other.
CONTOUR	Produces a new line map of contours from digital elevation data.
COST	Summarizes cost, elapsed time, and computer resources used during the session.
DEARCHIVE	Prepares maps for entry into the data base from tape.
DELETE	Deletes maps from the data base.
DEVICE	Allows graphics output to be routed to different devices.
DIGITIZE	Creates a new vector map using a table digitizer.
DISTANCE	Measures distance between any two points along a path or along a straight line.
DIVIDE	Allows large polygons to be split.
EDGE	Creates a new line map based on common boundaries or edges between two or more polygon maps.
EDITATT	Allows for modifications of an associated attributes file.
ERASE	Erases the CRT display screen.
EXPORT	Craetes an import/export format map from an active vector map.
FLOOD	Displays polygon and discrete cell maps with color.
FREE	Removes active maps from the active map table.
FREQUENCY	Determines frequency and percentage of each subject in a vector map.
GCALCOMP	Produces a file for output to a plotter.
GCONTOUR	Generates a contour display of DEM data or makes a new line map.
GENERATE	Creates a new vector map at a graphics terminal using cursor or keyboard input.

GOVERLAY	Creates a new polygon map based on the logical intersection of two polygon maps.
GRID	Performs grid interpolation of an elevation point map to create a new cell map.
HELP	Produces a list of commands within functional groups or a detailed description of a particular command.
LEGEND	Displays a map legend with title and scale, and labels attribute information for vector maps.
LENGTH	Determines length of all lines of each subject in a line map.
LINE	Displays line maps using a variety of possible fonts.
LIST	Prints out name, header, or subjects of maps stored in master data base or workfiles.
LOCATE	Determines coordinates of any point in the viewing window.
LPOVER	Creates a new point or line map from the logical intersection of a polygon map and a line or point map.
MAPS	Accesses the MAPS subsystem.
MERGE	Combines two or more vector maps into one map.
MODELG	Performs boolean and arithmetic overlay on multi-value cell files.
MODIFY	Modifies coordinates of features in a polygon map.
MOVELABEL	Repositions the centroid of vector map features.
MULTIVAL	Creates a multi-value cell file from a single value cell file.
NEWS	Produces a narrative description of recent changes and other information.
NUMBER	Displays feature number, active map number, or area/length of vector maps.
OPEN	Allows access to different master files.
OVERLAY	Creates a new polygon map based on the logical intersection, union, or non-intersection between two polygon maps.

PAGE	Allows the default lines per page to be changed.
PERIMETER	Determines total distance around each subject in a polygon map.
PLOT	Displays maps on a graphics device.
POLYCELL	Converts vector maps into cell maps with a user-specified cell size.
PROFILE	Generates a cross-section diagram between two points using digital elevation data.
PROJECTION	Changes the map projection of vector maps.
PROXIMITY	Activates data from a vector map based on its spatial distance to some point or other map feature.
QUERY	Identifies subject, area/length, feature number, and map name of any position displayed on a vector map. For cell maps, identifies subject, cell frequency, and cell size of any position being displayed.
REPORT	Generates reports from the multiple attributes data base.
RESET	Sets the viewing window to the original coordinates specified by the WINDOW command (i.e., counteracts ZOOM).
SAMPLE	Performs random sampling of features in a vector map.
SAVE	Saves an active vector map as part of the workfile.
SELECT	Activates all, or a specific portion, of any master map or workfile map.
SHADE	Shades polygon or cell maps with cross-hatching on the CRT.
SHOW	Performs a number of commands sequentially including SELECT, WINDOW, PLOT, SHADE, and AREA.
SIZE	Activates polygons or lines from a map based on area or length, respectively, of the features.
SLOPE	Creates a cell map of slopes from digital elevation data.

SNGVAL	Creates a single value cell file from a multi-value file.
SPSS	Prepares cell data for output to a file for later statistical analysis.
STATISTICS (CROSSTABLES)	Produces a two-way frequency table of the contents of any two cell maps.
STATISTICS (DESCRIBE)	Produces descriptive statistics (e.g., mean, variance) on the subjects in a map.
STATISTICS (HISTOGRAM)	Produces a histogram (bar chart) of subjects in a legend.
STATUS	Prints out information on volume and type of data associated with a particular mapfile, map, or session.
SYMBOL	Displays point or polygon maps using a variety of possible fonts.
TESTGRID	Plots a grid of a specified cell size.
TEXT	Creates and positions text in a text file.
THREED	Produces a 3-D display of any digital elevation map.
TRANSLATE	Translates a vector map in x and/or y, rates a map, or rubber sheets a map.
WEED	Thins points in a line or polygon map.
WINDOW	Sets the viewing window to a particular area of the earth's surface and defines the initial study area boundary.
WRITE	Generates output of a cell file for printing on a line printer.
ZOOM	Magnifies a user-specified portion of the viewing window.

MAPS COMMANDS

Command Name	Summary Description
ADD	Adds the cell values of two or more discrete or continuous maps to create a new continuous map.

AGGREGATE	Combines one or more dichotomous maps into a new discrete map.
ARCHIVE	Sets the file status indicator of an existing map to be archived after removal from the data base onto tape.
AREA	Provides an area table showing area by subject value and total area in acres or hectares for a dichotomous or a discrete map.
ASPECT	Computes azimuthal aspect, or direction of surface slope, of a continuous map to create a new continuous map.
AVERAGE	Averages the cell values of two or more discrete or continuous maps to create a new continuous map.
BAUD	Changes the default operating baud rate.
BOOLEAN	Performs logical operations (including AND, OR, XOR, or NOT) on one or more dichotomous maps to create a new dichotomous map.
BYE	Terminates the current session or stops execution of MAPS and returns the user to the MOSS program.
CATEGORIZE	Counts the occurrences of each cell value on a continuous map to create a new discrete map.
CLOSE	Closes the current master data base.
CONSTANT	Assigns a single constant value to every cell in a discrete or continuous map to create a new discrete map.
CONTOUR	Generates a line-drawing of an integer-value continuous map by connecting those cells with equal values and which fall on a specified interval to represent a three-dimensional surface.
COPY	Copies a dichotomous, discrete, or continuous map to create a new, equal, dichotomous, discrete, or continuous map.
COST	Summarizes total units of resources (computer time, units of dsik transfer, clock time, and total cost) incurred up to that point during the current session.
COVER	Combines two or more discrete or continuous maps by covering the cell values from the preceding map with the non-zero values from each succeeding map to create a new continuous map.

CROSS	Combines two discrete or continuous maps using the logical operations AND, OR, ANOT, or ONOT to create a new discrete map.
CUT	Cuts out a portion of a dichotomous, discrete, or continuous map according to the current viewing window or according to specified rows and columns to create a new, smaller dichotomous, discrete, or continuous map.
DEARCHIVE	Sets the file status indicator of an existing map from archived to exposed after entry into the data base from tape.
DELETE	Deletes exposed maps from the data base.
DESCRIBE	Provides a listing of header and projection information for a dichotomous or continuous cell map; or the header, projection, and subject information for a discrete cell or vector map.
DISPLAY	Allows graphics output to be sent to the log-on console or to a specified file.
DIVIDE	Divides the cell values of two or more discrete or continuous maps to create a new continuous map.
ERASE	Erases the console screen.
EXPLAIN	Provides a list of commands within a functional group or provides a detailed explanation of a single command.
EXPOSE	Sets the file status indicator of a map in the data base to exposed which allows that map to be deleted, modified, or overwritten.
EXPONENTIATE	Raises the cell values from a discrete or continuous map by exponential powers represented by the cell values from one or more additional discrete or continuous maps to create a new continuous map.
EXTRACT	Selects specified cell values and ranges of cell values from a discrete or continuous map and allows reassignment to create a new discrete map.
FUNCTION	Performs a mathematical function (square root, logarithm, natural logarithm, rounded integral, truncated integral, absolute value, tangent, sine, cosine, arctangent, arcsine, or arccosine) on the cell values from a discrete or continuous map to create a new discrete or continuous map.

IMPORT	Creates MAPS compatible new maps from existing IDIMS cell maps, MOSS polycelled cell maps, and USGS digital elevation models.
INFORM	Provides a listing of current system status including date and time, working and master project names, read, write, and display files, whether the display window is set, number of soft errors incurred, the last seven commands specified, and total units of resources used.
ISOLATE	Selects those cells with a specified value or range of values from a discrete map to create a new dichotomous map.
LABEL	Allows for entry or modification of header and projection information contained in a dichotomous or continuous cell map or of header, projection, and subject information contained in a discrete cell or vector map.
LIST	Provides an alphabetical listing of the map-name, indicator status, and map-type of maps in the working or master project. Optionally lists by map type or by a range of map names.
MATH	Performs mathematical operations or functions on cell values from one or a combination of discrete or continuous maps to create a new continuous map.
MAXIMIZE	Compares cell values from two or more discrete or continuous maps and selects the maximum value to create a new continuous map.
MERGE	Combines two or more dichotomous, discrete, or continuous maps whose areas may be adjacent or may intersect into a new dichotomous, discrete, or continuous map.
MINIMIZE	Compares cell values from two or more discrete or continuous maps and selects the minimum value to create a new continuous map.
MULTIPLY	Multiplies cell values of two or more discrete or continuous maps to create a new continuous map.
NEWS	Provides a narrative description of recent changes and other system information.
NOTE	Allows for the incorporation of non-command text during a session.
OPEN	Allows access to a different master data base.

PAGE	Allows the default lines per page to be changed.
PLOT	Displays dichotomous, discrete, and continuous maps, or parts of maps, on the console or to a display file.
PRINT	Generates a character image of a discrete map on which may be sent to a line printer or to the log-on console.
PROJECT	Sets the file status indicator of a map in the data base to "protected" which allows the map to be accessed but prevents it from being deleted, modified, or overwritten.
PROXIMITY	Selects those cells from a dichotomous, discrete, or continuous map which lie within, or outside of, a designated distance of cells of a specified range of values to create a new dichotomous, discrete, or continuous map.
QUERY	Provides information on a designated cell, or series of cells, from a dichotomous, discrete, or continuous map including cell value, northing and easting, row and column location and, if available, frequency and attribute descriptor.
RASTERIZE	Converts information from a point, line, or polygon vector map into cell format to create a new dichotomous, discrete, or continuous map.
READ	Allows command-input to be received from the console or from a specified file.
RENAME	Allows exposed work project map names to be changed.
RENUMBER	Assigns new values to specified cell values or ranges of values and retains the old values of the remaining cells from a discrete or continuous map to create a new discrete map.
RESET	Resets the viewing window to that area specified by the most recent WINDOW command which counteracts the effect of previous ZOOM commands.
SCAN	Summarizes values of each cell from a continuous map with a summary statistic (average, total, maximum, minimum, most frequent, least frequent, diversity, deviation, or proportion) of the values surrounding that cell to create a new continuous map.

SCORE	Summarizes values of each cell from a discrete or continuous map with values of similar cells from a second discrete map according to a summary statistic (average, total, maximum, or minimum) to create a new discrete map.
SHADE	Displays a shaded plot of a dichotomous, discrete, or continuous map, or parts of maps, on the log-on scale or to a display file.
SIZE	Counts the number of cells of each value from a discrete or continuous map and assigns these numbers to the cells of a new discrete map.
SLICE	Divides a range of cell values from a discrete or continuous map into an equal number of intervals and assigns each cell a value according to the ordinal position of the interval it falls into to create a new discrete map.
SLOPE	Computes slope of a continuous map in percent rise overrun to create a new continuous map.
SUBTRACT	Subtracts cell values of two or more discrete or continuous maps to create a new continuous map.
VIEW	Displays an existing read or write file on the output console or provides a plot of a display file on a graphics console.
VISTA	Determines visibility of a specified viewing cell(s) with respect to a specified observer cell(s) from a discrete or continuous map to create a new discrete or continuous map of visible or invisible area.
WINDOW	Sets the viewing window to a particular area of the earth's surface represented by one or more specified vector or cell maps.
WRITE	Allows character output to be sent to either the console or to a specified file.
ZONE	Selects cells within a specified distance and range of values from a dichotomous, discrete, or continuous map to create a new discrete map.
ZOOM	Magnifies a specified portion of the viewing window.

APPENDIX E

Implementation Plan Outline

1. Applications Analysis - Identify activities which will benefit by the application of GIS capabilities to determine potential projects and desired information products.

   - Program areas with existing or potential requirements for GIS capabilities (resource management planning, range management, activity planning, minerals management and leasing, etc.).
   - Preliminary workload analysis, by project, over the planning time period (staff hours, data base development, computer time required).
   - Data acquisition and data base construction requirements (map themes, alpha/numeric data, digital data base sizes).

2. Organization and Staffing

   - Types of support personnel

     - Computer operations
     - Data entry
     - In-state user training
     - GIS applications specialists

   - GIS User Liaison and Needs Assessment

     - GIS Applications Committees
     - Systems support representatives, etc.

3. Funding Requirements

   - Workmonth requirements and potential program sources
   - FTE levels
   - Vacancies available (for redescription)
   - Potential for support from major projects

4. Training

   - Schedule required to match hardware equipment
   - Types of training from DSC (to train "trainers")

     - Computer operations
     - Data Entry
     - GIS user applications

5. Hardware Requirements - Consult with DSC GIS computer hardware engineers and specialists to determine hardware requirements to meet state-specified applications needs in state, district, and resource area offices.

   - Central Processing Unit - workload est.; number of users (total, concurrent); etc.
   - Magnetic disc drives - storage requirements
   - Magnetic tape drives
   - Plotters - line plotters, raster plotters
   - Terminals
   - GIS workstations
   - Data entry stations
   - Microcomputers

6. Communications - Estimate level of in-state centralization/decentralization of GIS operations.

   - State/District data entry
   - State/District workstations
   - Stand-alone/central support
   - Numbers of users and locations
   - Existing communications adequacy

7. Space Requirements

   - Main computer lab (environmental control)
   - Data entry workspace requirements
   - Field office requirements

APPENDIX F

Planned Joint GIS Hardware Competitive Procurement

(BLM, FWS, BIA)

The purpose of the Joint Competitive Procurement is to provide a vehicle to purchase mini-computers as well as compatible micros and related peripheral equipment for GIS implementation hardware in each state.

1. The first procurement is a FWS procurement - they are running it, BLM is "piggybacking."

2. For mini-computers and compatible micros (several different sizes, capabilities of minis, i.e., MV 10,000 type, 4000, 2000 plus micros).

3. Second procurement (after award of first) will be a joint procurement for peripherals, i.e., plotters, digitizers, etc.

4. Estimated procurement FWS timeframe: Request for Proposals out by 10/1/84; contract award 4/85; delivery 6/1/85.

5. Estimate of BLM timeframe: BLM could exercise options on award after award is made and after satisfying DOI document/action requirements.

6. The procurement will be effective 3-5 years (negotiable).

7. BLM Lead personnel:

- Contracting - Dan Sedlock (DSC)
- Technical - Eric Strand (DSC)
- States (IRM/TAC) Coordination - Dale Vance (AK)
- Documentation - John Cash (DSC)
- Contracting Officer - Bill Battle (DSC)

WER'S CARD

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R	OFFICE	DATE RETURNED
K	SC-311	KKS
er	SC-344	KKS

(Continued on reverse)