PHILMONT SCOUT RANCH ROUTE NETWORK:

AN APPLICATION OF GIS TECHNOLOGY

IN RESOURCE MANAGEMENT

By

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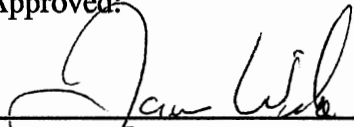Beijing, P. R. China

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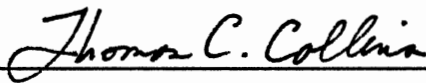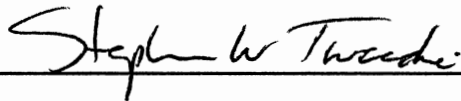the Degree of
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CHAPTER I

INTRODUCTION

Today, managers at the Philmont National Scout Ranch
must quickly respond to complicated problems involving a
wide variety of geographically referenced data sets.
Administrative, programming, and maintenance
responsibilities assigned to the managers have placed
tremendous pressure on their existing information delivery
systems. As Guptill (1988) noted, the traditional methods of
acquiring, storing, and analyzing spatially referenced data
are proving to be too costly and inflexible in meeting the
information needs of modern society.

During the last two decades, computer-based systems for
handling space-time data have grown from tentative
implementations to commonly used tools in many areas. The
common basis for these applications has been a set of tools
for the input, storage, and retrieval; manipulation and
analysis; and output of spatial data. This tool kit is
generally known as a "geographic information system (GIS)"
(Marble, 1984). In the past ten years, rapid developments in
both hardware and software (leading to cheaper and more
sophisticated systems) particularly in the field of micro-

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based computer systems, are affordable to an increasingly wider audience (Sliuzas and Vugt, 1988; ESRI, 1990). Small resource management agencies such as the Philmont Scout Ranch are among these potential users. A microcomputer-based geographic information system designed for them is very likely to be a perfect solution to many administrative and maintenance problems.

Study Objectives

In 1990, the Philmont Scout Ranch began a cooperative project with the Department of Geography at Oklahoma State University, to develop a microcomputer based geographic information system that would assist in the management of land resource and camping activities. The object of this research is to develop a route network using currently available GIS software packages. This network is intended to be a part of a larger system and can also exist as a unit by itself. The main purpose of this network is to assist the manager in finding the optimum route for emergency evacuation of injured campers. Philmont search and rescue operations, referred to as "Philsars" by staff members, locate injured campers, provide first aid assistance, and evacuate them (Wikle, 1991). This network can be very helpful to Philsar operation. PC ARC/INFO GIS software package was selected as the geographic information system to be used in the project.

This system could also fulfill many other needs of

different departments of the Ranch. In fact, almost every problem that has to do with trails and roads can be solved using this system. For example, for the Program Department, the system can develop and display a graph showing the changes in elevation for each trail section; it can determine and display all possible trails routes between camp A and camp B; furthermore, it can be used to plan itineraries to insure an even distribution of campers throughout the backcountry (the only restriction is the limitation of the software); for the Ranch Department, it can display all roads at different scales with every detail; and for the Maintenance Department, it can display all trails and roads that can be used to fight fires.

Study Area

The study area of this research is the 137,493 acre Philmont Scout Ranch located near Cimarron, New Mexico (Knutson, 1985). The ranch covers a region of mountains and canyons ranging in elevation from 6,400 feet at the ranch headquarters to the 12,441 foot summit of its highest peak (Figure 1). Philmont is the Boy Scouts of America's premier "high adventure" base. As a multiuse primitive recreation area it is intensively managed to maintain balance among a variety of activities (Wikle, 1991).

According to Knutson (1985) and Willwerth (1990), every summer Philmont plays host to an average of 15,000 to

Legend

☐ State	— Creek
— Border	▲ Mountain
▬ Highway	• Point of Interest

Miles
0 1 2 3 4 5

Philmont Scout Ranch

New Mexico

Scout Ranch
Detail see right

Middle
Cottonwood Canyon
Chase Canyon
North Ponil
Baldy Mountain ▲12441
South Ponil
Ponil Canyon
Hart Peak ▲ 7978
Ponil Creek
Dean Canyon
Canyon
Ute Creek
Ute Park
Cimarroncita
Cimarron
Sawmill Creek
Ute Creek
Creek
Cimarron
Cimarroncito Peak ▲10468
Gulch
Nash Gulch
Cimarroncito
Creek
Bear Mountain 10663▲
Camping Headquarters
Training Center
Black Mountain ▲10892
9003▲
Tent City
Museum
Rayado
North
Tooth of Time
Nairn Place
Urraca Creek
Buck Creek
Trail Peak 10242
South Urraca Creek
Agua Fria Creek
Bonita Creek
Rayado
Creek

Figure 1. Location of Philmont Scout Ranch

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17,500Boy Scout and Explorer campers and their leaders in a camping season of almost 70 days. The ranch has 24 staffed and 61 non-staffed camps strategically located in the backcountry and linked by more than 300 miles of constructed trails (Figure 2).

The trail and road system of Philmont consists of four different types of roads. Roads types include a state highway, unimproved roads, and jeep trails. Backpacking trails are also included. The USGS 1:24,000 scale 7.5 minute topographic maps of this area can be used to register all the trails and other relevant data.

Summary

Effective resource management requires a system capable of processing many diverse types of information. Such a system can best be established as a geographic information system. This research describes the development of the Philmont Scout Ranch routing network as a simple geographic information system, which was designed for emergency response planning. Chapter II discusses general literature that addresses geographic information systems, GIS networking, and applications of GIS. Chapter III discusses the methodology used in developing a emergency response route planning system for Philmont using a GIS. Chapter IV examines the development and operation of the network. Chapter V offers conclusions to the study.

Philmont Scout Ranch
Roads and Camps

Legend

——	Highway
•••••	Public Access Road
——	Service Road
- - -	Jeep Trail
•••••	Backpacking Trail
——	Border
▲	Camp
●	Town

Miles

0 1 2 3 4 5

Ute Park
Cimarroncita
Cimarron
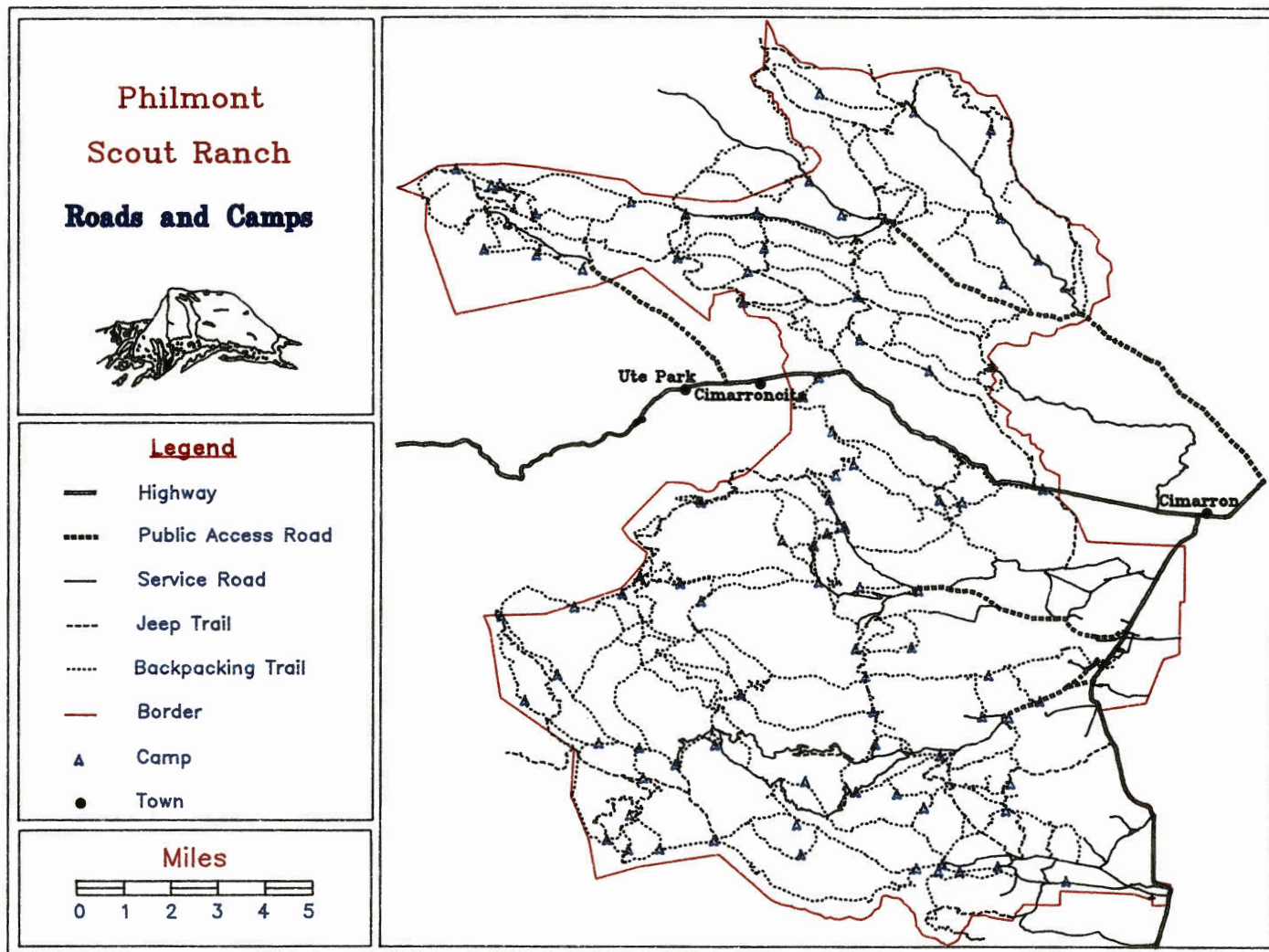
Figure 2. Roads and Camps of Philmont Scout Ranch

CHAPTER II

REVIEW OF THE LITERATURE

The sections that follow will group the literature related to this thesis into similar topical categories for discussion. The following discussion describes the major focus of each article and, where appropriate, its relationship to this paper.

Geographic Information Systems

A vast amount of current literature exists which describes the hardware, software, and operational considerations of GIS. References described which report on the nature, operations, benefits, and application within GIS serve as the organizational topics for the review of the literature. Because the route network was pre-digitized from topographic maps, topics such as the determination of user data requirements and data acquisition will not be discussed in this paper.

Nature of Geographic Information System

The function of an information system is to improve one's ability to make decisions. An information system is

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the chain of operations that takes us from planning the observation and collection of data, to storage and analysis of the data, and finally, to the use of the derived information in some decision-making process (Calkins and Tomlinson, 1977). A geographic information system (GIS) is, therefore, an information system that is designed to work with data referenced by spatial or geographic coordinates (Star and Estes, 1990). Guinn and Kennedy (1975, pp. 867) described such systems as "primarily concerned with the manipulation of data which can be associated with points, lines, or areas below, on, or above the earth's surface." In other words, each bit of information in a geographic information system is referenced to a specific location.

As Star and Estes (1990) have suggested, a geographic information system can either be manual (analog) or automated (based on a digital computer). Although manual GISs have played an extremely important role in resource management and planning activities, computer-based GIS will be the focus of this discussion whether the phase "computer-based" is mentioned or not.

Sliuzas and Van Vugt (1988) note that the term 'Geographic Information System' is used for a wide variety of configurations of hardware and software which are designed to store, retrieve and process spatially related data. As Marble and Peuquet (1983) stated, all complete or full geographic information systems perform the following major functions:

Data Input: normally consists of a mixture of manual and automatic digitizing operations together with associated data editing activities.

Data Storage and Retrieval: initial creation of the spatial data base together with subsequent update operations and query handling.

Data Manipulation: creation of composite variables through processing activities directed toward both spatial and non-spatial attributes of system entities.

Report Generation: creation of both tabular and cartographic reports reflecting selective retrieval and manipulation of entities within the data base.

Beyond its various functions, Star and Estes (1990) suggest that "data integration" is the philosophical basis for modern GISs. This would suggest that the essence of a GIS is its integration of many different kinds of information that describe spatial objects in an area. A geographic information system is the tool for integrating different technologies that are used in gathering, analyzing, and assessing spatial data. GIS is especially significant as a tool that has the ability to efficiently handle spatial relationships within large data volumes.

Geographic information systems have been implemented in many resource management situations. Despite the diversity of applications, the physical structure of most systems are similar. The following sections briefly describe the data structures and functional operations currently utilized in GIS.

Data Structure

There are several different ways to organize the data inside a geographic information system. GIS can generally be distinguished by the spatial character of its data. The choice of a particular spatial data structure is one of the important early decisions in designing a geographic information system. Although the data structure in this research is predetermined by the design of the selected software package, it is still useful to have some knowledge of the data structures.

Spatial data is stored and manipulated as a means of subdividing the earth's surface into meaningful entities or objects that can be characterized. Besides spatial data, there are equally important non-spatial data (attribute data) that maybe necessary for spatial analysis. Attribute data can be any characteristic related to the object except its geodetic location. Each different type of spatial data in a GIS is referred to as a data layer. Hydrology, vegetation type, land use, roads, etc..., can each be a layer. In each of these data layers there are three primitive types of geometrical entities to encode: points, lines, and polygons (Peucker and Chrisman, 1975). Most geographic information systems have specialized capabilities for storing and manipulating attribute data in addition to spatial information (Star and Estes, 1990).

Two major choices of data structure formats are

commonly utilized in geographic information systems: 1) cell encoding, resulting in the storage of grid data, also known as <u>raster data structure;</u> and 2) line or point encoding, resulting in the storage of polygon data, best known as <u>vector data structure.</u> Each data structure fits certain types of data and applications better than the other. Once the structure is determined, conventions and procedures used in that geographic information system can be determined accordingly (Wikle, 1990).

<u>Raster Data Structure</u>

Raster, or cellular organization of spatial data, is one of the simplest data structures. It is developed by converting geographic units into an array of grid cells. The array of data cells in a grid information system is constructed by overlaying the desired map with a grid. Each grid cell is then compared with the map to determine which geographic entity occupies the majority of the cell's area. All the cells that occupy the same geographic entity are then assigned the same value. The value of the geographic unit is then applied to the entire grid cell (Figure 3). The degree of detail of the resulting map is dependent on the size of the grid cell utilized. The concept of resolution is involved; a smaller grid cell results in greater spatial detail but also larger a data base (Tomlin, 1990).

Original Map

Grid Overlay

Columns

Rows

1 2 3 4 5 6 7 8 9 10

Grid Cell Map

Grid Cell File

Row	Column	Value
1	1	1
1	2	1
1	3	1
1	4	1
1	5	5
1	6	5
.	.	.
.	.	.
.	.	.
8	5	6
8	6	7
8	7	7
8	8	7
8	9	7
8	10	7
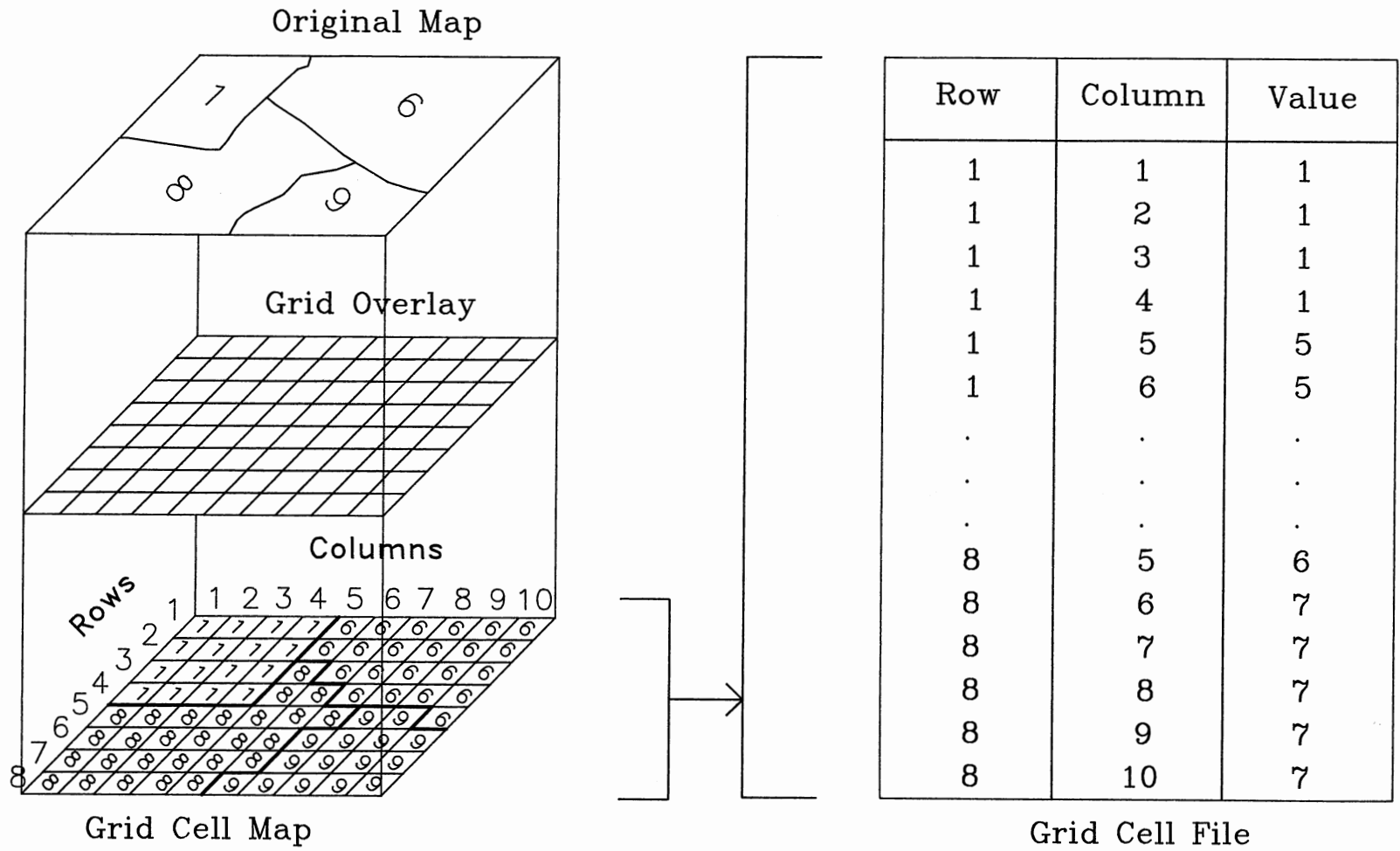
Figure 3. Raster Data Structure

Vector Data Structure

Contrary to the raster data structure which is based on the "decomposition" of the layer, vector data structures are based on elemental points whose locations are known to an arbitrary precision. When storing a line in a vector data structure, a line would be recorded by its start and end point and a code that specifies it is a line. In this example, vector structure is more efficient in terms of the amount of data required, as well as more precise (Star and Estes, 1990). For spatial data in most GISs, the coordinate data is encoded, and after input processing, is stored as some combination of points, lines, and areas or polygons (Peucker and Chrisman, 1975; Peuquet, 1977). There are several forms of vector data structures in common use. Spencer and Menard (1989) noted that vector GIS systems have many inherent characteristics largely applied to provide "intelligence" to vector data. The intelligent vector GIS provides excellent information content that is particularly applicable for geographic analysis and decision support. "What if" and "ad hoc" questions can be answered by system's query, search, and retrieval capabilities especially when relational database technology is present.

Raster Versus Vector

Vector and raster technologies differ fundamentally in how they store data and what information each can represent

to users. The traditional advantages and disadvantages of raster versus vector spatial data structures include issues about data volume (or storage efficiency), retrieval efficiency, data manipulation (or processing) efficiency, data accuracy, and data display. These questions have been discussed by many scholars (Kennedy and Meyers, 1977; Durfee, 1974). Star and Estes (1990) argue that in modern GIS applications, some of these differences are less important. They, along with others, suggested that modern GISs should be able to utilize both types of data. In this way, different types of data (a road system or an image from remotely sensed data) could be stored in their "natural" form to both optimize geographic specificity and minimize conversion costs and attendant bias. Meanwhile, different kinds of analytic procedures operated on different data structures could keep their highest efficiency and accuracy.

Data Structure of ARC/INFO

ARC/INFO is a set of tools for creating, analyzing, displaying, and managing computerized maps in vector format. ARC/INFO is composed of two subsystems:

A.ARC is the set of tools for managing map coordinate data (for example, geographic features). But it should be noted that ARC alone has the ability to manage thematic data.

B.INFO is a generalized relational Data Base Management System (DBMS) for managing attribute information (for example, socio-economic and other thematic data). All ARC/INFO attribute files are in INFO readable formats which allow INFO to be employed for processing a coverage's thematic data. (Marble, Calkins, and Queteut, 1984. pp 4-45)

The type of vector data structure ARC/INFO used is called arc-node structure. In an arc-node data structure, objects in the database are structured hierarchically. In this system, points are the elemental components as shown in Figure 4 (Star and Estes, 1990). Arcs are the individual line features forming networks or borders of polygons. An arc is defined by a from-node and a to-node and additional vertices in between. Nodes are the ending point of arcs. In many cases, the end of one arc marks the beginning of another, so nodes also mark the point of intersection between arcs. There are also points that are not associated with lines. Take arc II in Figure 4 for example, node one and node two are its from- and to- node respectively. There are four vertices in between. Node one is also the to- node of arc I.

Arc-node structure is more efficient when encoding geometric data. A polygon is not represented by a new set of data, rather by a series of arcs surrounding it. Several different kinds of attributes can be included in an arc-node database. Data attribute values are also stored with topographical information. Some thematic information is required to be stored in the coverage together with geometric data, such as spatial information (e.g., polygon area, arc length) and numbers used to keep track of the features (and to link information to the features, i.e., features' internal number and user ID) (Marble, Calkins, and Queteut, 1984). PC ARC/INFO also allows thematic information

```
        1|              II         2|
   _____|      _____|         __|_____ Birch St.
         |     |       |           |
      I  |     | Smith |           | III
         |     | Estate|           |
   _____|_____|_____|_____|_____ Cherry St.
         |                         |
      4  |         IV              | 3
         |                         |
```
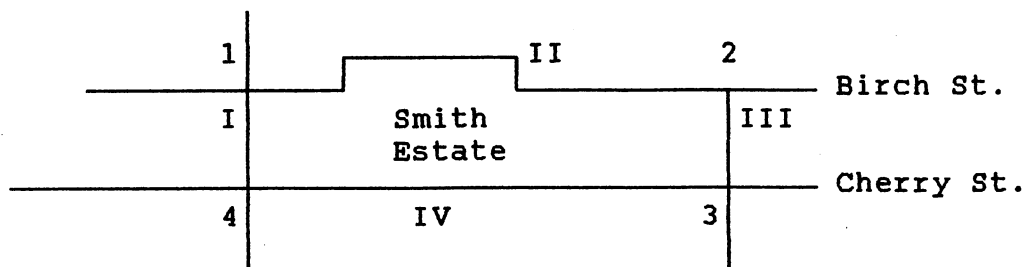
Nodes:

			Traffic	
Number	Easting	Northing	Control	Crosswalk
1	126.5	578.2	Light	Yes
2	218.6	581.9	Sign	Yes
3	224.2	470.4	None	No
4	129.1	471.9	Sign	No

Arcs:

	From	to		Pavement	
Number	Node	Node	Length	Condition	Lanes
I	4	1	106.3	Good	4
II	1	2	92.2	Fair	4
III	2	3	111.6	Fair	2
IV	3	4	95.1	Fair	2

Polygons:

Name	Owner	Arcs	Perimeter	Area	Zoning
A34	J. Smith	I,II,III,IV	405.2	10203	R-4
A35	R. white	III,VI,VII,XI	478.1	01562	R-4

Source: Star, Jeffrey, and John Estes, 1990. Geographic
        Information System: An Introduction.Prentice-Hall,
        Inc, Englewood Cliffs, New Jersey. (revised)

Figure 4. Arc-node Data Structure.

to be stored outside the coverage in another INFO file and kept separately from topological information. As described earlier, these attributes are stored in a relational database management system, and are related to features via their feature ID.

Operation of A Geographic
Information System

Nearly all geographic information systems, regardless of their intended applications, perform the same basic database functions. These common functions include: 1) data input 2) data storage and retrieval, 3) data manipulation, and 4) report generation. Each of these database functions will be briefly discussed in the following section.

Data Input, Storage and Retrieval

All geographic information systems must have the capability of accepting mapped data as input, and storing such data in a easily retrievable form (Lewis, 1972). Mapped information can be entered into a geographic information system in either a format or vector data format. The choice of data format depends upon individual system capabilities, characteristics of the mapped data, and the intended data applications.

Most of the spatial data available today are not in computer-compatible formats. These include maps of many kinds and scales, printed manuscripts, and imagery.

Converting these analog source data into a digital format
compatible with a computer-based geographic information
system can be very expensive and time-consuming. In 1983,
Marble and Pueqeut noted that "...most of the time and
recourse required to create a GIS are ... concentrated in
the data-input phase (pp. 925)." The initial data capture
for a geographic information system is still a constraint to
GIS implementation (Skiles, 1988; Star and Estes, 1990; and
Antenucci, 1991).

Techniques of data input vary from system to system.
The converting of maps and other graphic data to a digital
format is usually referred to as "digitization."
Digitization can be performed either manually or
automatically. Manual digitization is done by using a
digitizing tablet. This allows for interaction between the
human eye and mind to be incorporated in the process.
Automatic digitization is usually done by optical scanner or
scanning desitometers (Marble and Pueqeut, 1983). The main
problems in using a manual digitizing tablet arise because
the digitizing process is inherently slow and manual
digitization involves human labor. High costs and numerous
errors being generated are associated with the presence of
an operator and are two major problems when humans are
involved in digitizing (Lightfoot, 1986).

Data Manipulation

An important function of geographic information systems

is the manipulation of stored data. Without data
manipulation functions, a GIS would serve only as a
computer-based library designed to store maps. Any given GIS
must be capable of performing a series of manipulations upon
the spatial data being held. Each system contains a specific
set of these procedures, determined by the requirements of
the users of the system (Marble and Pueteut, 1983).

According to research conducted by Tomlinson and Boyle
(1981), the following is a set of typical manipulation
capabilities:

  Data Manipulation

  Reclassify - attributes
  Generalization
     Dissolving and merging
     Line smoothing
     Complex generalization
  Interpolation
     Centroid allocation
     ContouringScale change
  Distortion elimination - linear (rubber sheeting)
  Project change

  Generation

  Points
  Lines
  Polygons
     Simple five-sided polygons
     Irregular polygons with islands
     Circles
     Grid cell nets
     Latitude and longitude lattices
     Corridors (along linear features)
     Other

Data extraction

  Search and identification
     Attributes
     Shapes
  Measurement
     Number of items
          Distances (straight line between points, along

convoluted lines)
>   Size of areas
>   Angel direction
>   Volume (cubic measure)

>   Comparison

>   Intersection - overlay
>   Point-in-polygon

>   Polygon-on-polygon (grid cell on polygon, circle on
>   polygon)
>   Other
>   Juxtaposition (proximity)
>   Shortest route
>   Nearest neighbor
>   Line of sight
>   Contiguity
>   Connectivity
>   Complex space-attribute-time correlation

>   Interpretation

>   Determination of optimum location
>   Determination of suitability
>   Determination of desirability

PC NETWORK is a specialized product designed to provide network modeling and address matching capabilities for PC ARC/INFO (ESRI, 1990a). Interconnected lines in this network permit movement from one location to another. ROUTE is a network modeling program that can help a user to find the optimum path between two or more points. ALLOCATE is another network modeling program that can assign and evaluate the distribution of resources between centers and their surrounding arcs.

Attributes along with each arc form the basis for network modeling and address matching. The attribute chosen as the impedance item influences the way programs find the optimum path. For a user who wants to find the shortest path, the "length of the arc" must be specified as the

impedance attribute; to find the quickest path, "the time traveled through the trail" must be specified as the impedance attribute. Users can also give other characteristics, such as the number of students, to specify the resource demand that will be picked up along each arc (ESRI, 1988).

Report Generation

The last important data base function of geographic information systems involves the retrieval and display of stored data. Storage and manipulation functions have little meaning unless the products derived from such functions can be viewed and used for further analysis. A geographic information system must include software for displaying maps, graphs, and tabular information on a variety of output media.

Report generation capabilities vary from system to system, depending upon the availability of stored data, retrieval programs, and display devices (Shelton and Hardy, 1974). An important output products of a geographic information system are maps which clearly display the spatial distribution of various kinds of phenomena. The output of tabular lists of non-spatial information as the result of spatial analysis can also be valuable to certain audiences (Star and Estes, 1990).

Typically, maps in a final report should be able to be displayed either on a graphic monitor or on paper through

printing or plotting. Hard copy of non-spatial numerical data should also be easily obtained.

Geographic Information System
Networking Applications

Geographic information systems can be used to support the decision-making processes of an organization. There are a large variety of applications for GIS, and numerous systems have been developed on different levels to support various users all over the world. In most cases, networking is incorporated in large regional geographic information systems. The Geographic Information Management System (GIMS) of San Bernardino County, California, is a perfect example. One of three parts of this centralized regional GIS is a comprehensive street network. The GIMS users cover a wide range of municipal services. County schools have active systems for analyzing attendance and developing pupil transportation plans. New GIS applications are also being developed for pavement management (Star and Estes, 1990).

The level of GIS/LIS technology is such that real-time, life-dependant applications are now being seriously investigated. In 1989, the GIS section in the Emergency Health Services Branch within the Ontario Ministry of Health, together with ESRI Canada examined the possibilities of utilizing a GIS in an ambulance dispatch environment. According to Schwarz (1989), the objective of this project was to lower emergency vehicle response times. To achieve

this goal, GIS was employed in three capacities: automated geo-referencing and routing; automated mapping; and planning and analysis.

Beriwal and Mazzei (1990), on the other hand, studied the role of computer graphics in simulating evacuation over a large, complex network in and around the city of New Orleans, Louisiana. Here the need for GIS was emphasized by the complexity of both the spatial distribution of population and transportation networks. The available computer graphics made the display of the simulation run of the region's network very simple. Though there were still some problems with the system, the result proved that computer-aided GIS can be successfully applied in evacuation planning.

Summary

Geographic information systems have the potential for improving our understanding of the world around us. Yet these systems do not lessen the need for quality data, nor will these systems do the work for us. The work we can do with a GIS is clearly dependent on the quality of data it contains. Thus, care must be taken to understand the potential sources and relative magnitudes of errors which may occur when gathering and processing spatial data. In addition, one must be cautious concerning the potential for misinterpretation of the information output from a GIS. In interacting with a geographic information system, the user

must not only understand the application, but also the
characteristics of the tool and the system itself.

CHAPTER III

RESEARCH METHODOLOGY

A methodology with a structured design should proceed
the development of any geographic information system
(Calkins and Tomlinson, 1977). This process is extremely
important because errors occurring in system design and
specification can be very costly to correct later in the
development process. Additionally, detailed design
methodology can be a time saver while maintaining
consistency throughout the whole design process.

The general objective of the information system design
process is to do everything to insure the success and
utility of a system. This involves the processing of data as
efficiently as possible and extending its useful life as
long as possible. However, unlike the original system
design which requires the system designers to develop almost
all of the software and the data base, the present design
situation becomes a combination of designing and developing
new components and integrating existing components into a
viable system. Numerous existing GIS packages provide a
wide variety of choices to establish the system (Calkins,
1983), and there even spatial data bases such as USGS's

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topographic quadrangle are series available in digital format. Therefore it is important to assess the quality of the existing hardware and software components and the degree to which they can contribute to satisfy the functional requirements of the system.

This chapter examines the procedures used within this study to design a GIS routing network for the Philmont Scout Ranch. The development of this network involved the following interrelated phases:

1. Determination of goals and objectives
2. Determination of hardware and software component
3. Data collecting
4. Data input
5. System operation
6. Design of user interface
7. Testing the database

Goals and Objectives

The first task in this design process involved the determination of objectives for system (i.e. users of the system and their needs). The Philmont National Scout Ranch Geographic Information System was designed for use by managers of various departments. A questionnaire was used to determine the GIS needs of managers at Philmont Scout Ranch. Among the most important functions identified was locating the best possible routes for evacuating injured scouts or adult leaders by foot, four-wheel drive vehicle, or, if

needed, helicopter. This problem was the primary focus of this study. To accomplish this task, a routing network was developed. The primary application of the Routing Network will be to support Philsars - Philmont search and rescue operations. Besides these activities, the network can be used as the transportation network layer of the larger geographic information system. Related problems also can be solved in or with this network.

Hardware and Software

The rapid development of the computer industry has made micro-computer based geographic information systems a valuable tool for solving real world problems. Compared to the situation several years ago, computers with very high computation abilities can be afforded at very low prices. More important to geographers, computer display monitors now have the ability to display graphics at very high resolutions. Similar changes have happened in the software industry. More powerful GIS packages have appeared in the market with greater data processing and analyzing abilities. These rapid changes have made inexpensive GIS applications possible to relatively small organizations such as Philmont Scout Ranch.

Hardware

The basic hardware components of the proposed system will include a 386-based micro computer, a mouse, a printer

with the ability to produce graphics, and a digitizer. A multi-pen plotter or a color laser printer can enhance the output capabilities of the system. Portable computers could be a real help for the people on the road since desktop systems are difficult to operate inside a vehicle. According to the recent report from PC Magazine (Seymour, 1991), notebook size PCs with desktop power are now available at relatively low prices.

When designing the system in the Department of Geography at Oklahoma State University, researchers used 386 and 486 based personal computers. Topograhic data were entered manually from a table-size digitizer. Graphic output was displayed by an 8-pen plotter, and the text output was printed by a printer.

Software

As mentioned earlier, a major task in the development of GIS involves writing the software package which will provide the capability for data input, storage, and manipulation for various applications, and will facilitate the production of output products. With the rapid development of the software industry, numerous types of geographic information system programs became available. The design task became a procedure to first select one or a combination of the most suitable software package(s) to finish the work, and then to assemble them into one integrated system.

The researcher selected Atlas*Draw (designed by Strategic Mapping Inc., San Jose, California) as the primary data input tool. The package was selected based on its simplicity. In addition to this, there is no need to provide special training to personnel involved in data entry using this package. Finally, the product is compatible with popular database and other GIS software. A database management program, dBase, and a spreadsheet program, Quattro, were selected to enter attributes associated with the geographic features of the database. Quattro was selected as a bridge to convert data from Atlas*draw and other sources to dBase format. PC ARC/INFO is the core program for the routing network. Through careful research, it was determined that PC ARC/INFO (distributed by Environmental Systems Research Institute, Inc.) was the most suitable GIS package to deal with Philmont routing problems. PC ARC/INFO stores its data files in dBase format. To finalize the system design, a user interface was designed using Simple Macro Language (SML) provided by PCARC/INFO.

The final hardware/software environment includes the ARC/INFO package working on 386-based personal computer, a digitizer to enter spatial information, and a plotter or graphics printer to produce output. PC ARC/INFO will be capable of updating both spatial and attribute information.

Data Collecting

The selection and acquisition of data is a very

important task in the development of a geographic
information system. The utility of any information system
depends upon the relevancy of the stored data. The selection
of data should be based on the initial system objectives.
Because this research was carried out through PC ARC/INFO
software's PC NETWORK module, the selection of data also was
based on the types of data required to operate within the PC
NETWORK module.

To establish the Philmont Route Network, currently
available trail and road information was obtained at a scale
of 1:24,000 from US Geological Survey topograhical maps.
These maps display road types, elevations, and campsite
information. This information provides the source of the
spatial information used in the network. To gain an
understanding of the types of relational attributes needed
and how to create ARC/INFO data sets that accurately
represent the actual network, it is necessary to know what
PC NETWORK's data sets are, and how they perform their
operations.

According to ESRI's PC NETWORK Users Guide (1990), "A
network is a system of connected linear features through
which resources flow. The flow of resources, however,
depends on more than the linear conduits of movement.
Movement between connecting lines is affected by other
elements and their characteristics in the network" (ESRI,
1990 pp.2-11). Elements of a network data set in this
research are "links," "turns," and "stops." Simply stated,

as previously shown on Figure 4, "links" are lines (arcs) used as the conduits of resource movement in the network; "turns" are the possible turns for resource flow at each node where links connect. "Stops" are node locations where resources are to be picked up or dropped off along "links" through the network.

Each of the above elements is represented by a coverage feature having a set of special feature attributes used to facilitate network modeling and analysis. The primary network data set is an arc coverage with the topology of line coverage.

All of the above network elements have one or more characteristics that are important parts of the network. Among those attributes, "impedance" is the most important one for routing.

"Impedance" measures resistance to movement. Only arcs and turns have this attribute. Arc impedance is the amount of resistance required to traverse the arc from one end to the other. Suppose the length is the impedance; the longer the length, the larger the impedance, and consequently the more resistance to movement. For routing purposes, the impedance could be the time-of-travel along arcs, or the length of arcs. Every arc may be traversed in two directions: moving from the from-node to the to-node, and moving from the to- node to the from-node (Figure 5). Each direction can be assigned an impedance which is not necessarily the same, depending on the real world situation.

Directional impedance items are stored in the coverage

(ROUTE is the name of the coverage) AAT (Arc Attribute

```
              <—— To-from impedance ——
   1 +————————————————————————————+2
        ————From-to impedance ——→
```
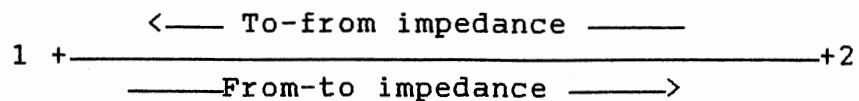
Figure 5. Impedances of arcs

Table) (see Table I). The unit of the impedance could be
feet, miles, or minutes, whichever specified by the network
designers or users.

TABLE I

STORAGE OF IMPEDANCE INFORMATION

FROM NODE#	TO NODE#	LENGTH	ROUTE#	ROUTE_ID	FROM-TO IMPED	TO-FROM IMPED
1	2	100	5	2	30	40

ROUTE.AAT

Turns also have impedance attributes. They measure the

amount of resistance to move from one arc, through a node,

or onto another arc. Turn impedances will vary according to

the conditions at the intersection of the two arcs. In PC NETWORK, all of the impedance information is stored in a turntable. A turntable is an INFO data file which can be created within the PC NETWORK. The amount of impedance varies with the characteristics of the node, such as the angle of the turn, whether traffic must stop, locations of overpasses, and so on. An especially important factor is that all arc and turn impedances in a network must always be in the same units to insure compatible calculations. Table 2 from the PC NETWORK's Users Guide shows a few examples of the angle and time impedance to make turns where certain conditions

The purpose of impedances is to simulate conditions along arcs and turns in real networks. The results of route analyses differ according to the impedances assigned to elements in a network data set. The optimum path is the path of least resistance (in other words, lowest impedance). The arc and turn with the lowest positive impedance will always be assigned first.

Unfortunately information about time-of-travel on each segment of the trail is not available to us, so this information was estimated from the calculated distance information and estimated travel speeds, provided by Philmont managers.

TABLE II

SAMPLE OF TURNS AND THEIR TURNTABLES

Actual	Description	Turntable		0 = No Impedance -1 = No Turn	

U-turn

		NODE#	FROM ARC#	TO ARC#	ANGLE	TIME IMPEDANCE (seconds)
U-turn	U-turn moves from Arc 6 to node 20, then back to arc 6. This is a 180 degree angle with a time impedance of 20 seconds to make the turn.	20	6	6	180	20

Stop sign

		NODE#	FROM ARC#	TO ARC#	ANGLE	TIME IMPEDANCE (seconds)
Stop sign	A stop sign slows down movement from arc 6 onto all adjoining arcs - straight onto arc 7, left turn to arc 8, and right turn to arc 9. The table shows the time impedance for each.	20	6	7	0	15
		20	6	8	90	20
		20	6	9	−90	10

Overpass/Underpass

		NODE#	FROM ARC#	TO ARC#	ANGLE	TIME IMPEDANCE (seconds)
Overpass/Underpass	Overpasses permit straight movement without delay, as from arc 6 to arc 7 and from arc 9 to arc 8. However, they prohibit turns (e.g., from arc 6 to arc 8). A negative impedance value of -1 is assigned to prevent other turns.	20	6	7	0	0
		20	6	8	90	−1
		20	6	9	−90	−1
		20	9	8	0	0
		20	9	7	−90	−1
		20	9	6	90	−1

No right turn

		NODE#	FROM ARC#	TO ARC#	ANGLE	TIME IMPEDANCE (seconds)
No right turn	A right turn from arc 6 to arc 9 is prohibited, so a negative impedance value is assigned. The other possible turns to arc 7 and arc 9 have positive impedance values.	20	6	9	−90	−1
		20	6	7	0	5
		20	6	8	90	10

Data Input

The traditional map sheet has been designed to create a complex product which represents an extremely high density storage medium for spatial data as well as a complex visual display device for the same data. This mixture of functions, although serving its initial purpose, makes manual efforts to capture this data into digital format slow and error prone (Marble, Lauzon, and McGranaghan, 1984). Ever since the early stages of GIS, data input remained a major problem. Although more and more digital databases are becoming available, many current operations must deal with the complex analog to digital conversion processes by which map sheets are changed into clean, useable, digital files.

This transformation is accomplished by either manual or automatic digitization. Early in 1984, Peuquet and Boyle pointed out that mass automatic digitization is economical only for very large volumes of data and practical only when the map documents being scanned have been prepared according to a strict set of specifications. This is still true in many cases.

Although topographical maps in digital format are available from the US Geological Survey, budget restrictions prevented their use in this research. Manual digitizing was the primary method for entering map data into the geographic information system.

Information that was required to be digitized from the

base map included the complete road and trail systems and the location of all the camp sites. At the 1:24,000 scale, Philmont Scout Ranch covers 11 map sheets. It was anticipated that trails and camps would be digitized separately into eleven files. Upon completion of all eleven parts, a complete map will be generated by combining them. In practice, a detailed error check and correction of each file was carried out; after all identified errors had been corrected, one file was then created by merging two sheets together. Another series of error checks were then performed to ensure the validation of the newly merged file. At this point, extra attention was given to the connectivity of the routes. For a perfectly connected route network, all intersections should be points that shared by all intersecting arcs. Bad connections often caused by crossing arcs do not actually have an intersection point. After all map segments were combined into the database and put through the editing phrase, the database was ready for its final editing. The above procedures were carried out within Atlas*Draw. Spatial data was than translated into PC ARC/INFO for further manipulation and analysis.

PC ARC/INFO's ARC CONVERSION module provides a tool to convert files in Atlas*Draw format directly into ARC/INFO format. Using tools provided in the ARC EDIT module, the writer could display errors on the screen, or print them on paper. Errors that could be displayed at this point were the type of connectivity among trails and the phony

intersections of trails (intersecting trails without intersecting node). The correction of errors was carried out either within PC ARC/INFO's ARC EDIT module or through Atlas*Draw. After ARC EDIT, error-free data files still needed to go through a topology building procedure.

After the spatial database has been established, relational attribute data can then be entered. For routing needs, the time-of-travel is a very important impedance attribute needed in the final database. Unfortunately, this information was not available from Philmont managers. An estimated alternative was therefore calculated by the researcher:

$$Time = Distance / Speed$$

In the formula, "Time" is the time used traveling through a section of trail; "Distance" is the length of this section of trail; "Speed" is the maximum speed that a vehicle or a person can travel on the trail. The speeds of moving on different types of roads were obtained from actual road test: traveling speed on state highways is 60 miles per hour, on improved roads 30 miles per hour, on unimproved roads 15 miles per hour, on jeep trails 6 miles per hour, and on hiking trails 3 miles per hour.

Because the true distance between two points on the earth is influenced by the elevation change along the road, the information about the true distance between two points (in this research, length of each segment of trail) cannot

be obtained directly from the topographical map. Therefore
it also needed to be estimated. Here the calculation used
another simple formula:

Length=Square root[(Length on the map)^2+(Elevation change)^2]

In the formula, "Length" is the supposed actual distance
between the starting and ending points of a trail segment,
"Length on the map" is the length of this piece of trail
calculated by the computer using coordinate information of
the starting and ending point of the trail; "Elevation
change" is the different of the starting point and the
ending point in elevation.

It should be noted that traveling speeds are different
when traveling uphill as opposed to traveling downhill.
However, because there were several estimates causing the
uncertainty, it seems that distinguishing uphill from
downhill speed is not that important to the final result of
routing analysis. Therefore in this research, the to-from
impedance is the same as the from-to impedance.

The impedances of every turn were also calculated since
there was not enough information on the condition of all the
crossings. Table 3 shows detailed impedance assignments of
turns in different situations.

In order to generate the attribute data, data needed to
be obtained for the elevation of starting and ending points
of each route segment. The elevation information was taken

TABLE III

TURN IMPEDANCE ASSIGNMENT

Imped (in min.) Type or type / Road Change	Left Turn	Right Turn	U-Turn	Going Straight
From highway to others roads	0.25	0	0.5	0
From pubic ace-ess road to HYW	0.25	0.1	0.5	0.2
From PAR to the rest of road	0.25	0	0.5	0
From dirt road to PAR and HWY	0.25	0.1	0.5	0.2
From dirt road to jeep trail	0.25	0	0.5	0
From jeep trail to other roads	0.25	0.1	0.5	0.2
From trails to other roads				
From other road to trails	0	0	0	0
From trails to trails				

Note:
    Imped.   Time impedance, unit in minute
    PAR   Public Access Road
    HWY   Highway, both US interstate and state highway

directly from the base map. The remainder of data entry and calculation was completed through the spreadsheet software called Quattro. The final attributes that were incorporated into the database included "time impedance of arcs," "length," "elevation change," and "turn impedance." Although "time impedance of arcs" is enough for creating a routing network, it had to be considered that the network would eventually be a layer used in the larger Philmont GIS. The "length" was included because it can be an arc impedance when routing criteria is the shortest distance but not the shortest time. Table 4 shows a section of the actual data file.

System Operation

Data manipulation functions and models are an important part of any information system. Typically, decisions are based upon the structured manipulation of pertinent, stored data (Haseman, Holsapple, and Whinston, 1976). Data manipulation functions used by the Route Network of Philmont Scout Ranch's GIS were provided by PC ARC/INFO's PC NETWORK module.

The operation of routing was a relatively simple task when the database was ready. PC NETWORK's Route module could find the optimum path between any two or more points with ease. When starting the routing session, it is necessary to first choose the desired impedance information. In this network, to-from impedance and from-to impedance are the

TABLE IV

SAMPLE OF DATABASE: AAT

(ARC ATTRIBUTE TABLE)

F_NODE	T_NODE	L_POLY	R_POLY	ROUTE_ID	ROUTE_ID	ROADTYPE	ELEVATION	ELEVCHANGE	LENGTHFEET	LENGTHFEET	TIME_IMPED
1	2	0	0	1	US64_1	Highway	7183 6780	403	19144.24	3.62682	3.62682
3	4	0	0	2	NM204_8	Public Access	7150 7120	30	902.1	0.17089	0.341789
4	5	0	0	3	NM204_7	Service Road	7150 7150	0	177.9	0.03369	0.13476
5	6	0	0	4	NM204_9	Service Road	7175 7150	25	1447.22	0.27414	1.096564
6	7	0	0	5	NM204_11	Service Road	7220 7175	45	2265.45	0.42908	1.716339
5	8	0	0	6	SPonilRd2	Service Road	7150 7120	30	352.48	0.06676	0.267049
9	10	0	0	7	SPonilrd1	Service Road	7720 7265	455	11419.07	2.16272	8.650874
11	12	0	0	8	Cntr_SMil3	Service Road	7680 7570	110	1543.92	0.29244	1.169774
12	13	0	0	9	Cntr_SMil4	Service Road	7748 7680	68	1248.85	0.23645	0.945805
13	14	0	0	10	Cntr_SMil2	Service Road	7748 7725	23	259.82	0.04921	0.196853
14	15	0	0	11	Cntr_SMil1	Service Road	78207725	95	2361.91	0.44726	1.789049
15	16	0	0	12	Cntr_SM4w9	Jeep Trail	8264 7820	444	5087.41	0.96358	9.635784
16	17	0	0	13	Cntr_S4wl0	Jeep Trail	8745 8264	481	15877.29	3.00638	30.063813
17	18	0	0	14	Cntr_SM4w1	Jeep Trail	9150 8745	405	4771.22	0.90376	9.037628
18	19	0	0	15	Cntr_SM4w8	Jeep Trail	9295 9150	145	2917.61	0.55258	5.525832
19	20	0	0	16	Cntr_SM4w5	Jeep Trail	9690 9295	395	4517.3	0.85558	8.555788
20	21	0	0	17	Cntr_SM4w6	Jeep Trail	10080 9690	390	3065.91	0.58072	5.807193
22	23	0	0	18	DeanCan4w4	Jeep Trail	7570 7310	260	10663.17	2.0206	20.206005
24	25	0	0	19	DeanCan4w6	Jeep Trail	7780 7780	0	425.2	0.08052	0.8052

same. Either time or length must be read twice, first time as to-from impedance and the second time as from-to impedance. After displaying the network on the screen, optimum routes are displayed by the system between designated starting, ending points and necessary stops.

The final products of the routing can be presented in hardcopy in two forms. First, the map of the best route and surrounding network can be printed or plotted on paper so users will be able to take it along as a graphic guide during a search and rescue operation; second, for this route, a list of directions on how to traverse it can also be provided in paper format. This list can show the name of every piece of arc, the time or distance needed to travel on it, and the turning direction of every intersection crossed.

The implementation of this system was difficult because of the limited information about the road network at Philmont. It is expected that this research will serve as the basis for future implementation when more data becomes available.

User Interface

As Chong and Dudley (1988) noted, the wider acceptance of GIS technologies into the workplace has created a new class of problems with which the system designer must deal. With the increasing complexity of GISs, potential operators may have to spend more and more time in training before any output can be expected. However, today's working environment

does not permit this time allowance. Instead, what are demanded are systems which will allow a new user to begin producing tangible output within a matter of weeks or days. "A Key element in the satisfaction of this demand is the quality of the interface between the user and the GIS" (Cassel and Parker, 1989. p. 538).

The PC ARC/INFO package is the only software that managers and rangers at Philmont will have direct contact with. The PC version of ARC/INFO has a command language and macro interface that is not very user-friendly. It requires the user to type commands and sometime specific parameters at different prompts. In an experienced operator's hand, the program can be very powerful because of its flexible commands. The disadvantages of this command driven program include the substantial training requirement, the increased retention demanded of the user, and the greater number of keystrokes often necessary to execute a command.

Among other interactive methods available, "menu" was selected to be the interface for this system. Menus provide the user with a list of possible actions from which one is selected. Following this selection there maybe a secondary menu, a data fill-in form, or the execution of a specific action.

The menu used in the system appears at the top of the screen. There are several reasons for selecting menus. Menus offer advantages such as a reduced learning time, fewer required keystrokes (and therefore lessened mistakes),

and the imposition of structure upon the decision making process (Sheiderman, 1987). Menus can be appealing to novice or infrequent users of a system who want to get information either into or out of a system but don't have the time to learn or relearn complex commands. Despite these advantages, menus may become an encumbrance to experienced users.

The menu used with the Philmont GIS Route Network is very straightforward. In order not to have too many menus to confuse users (this may happened when menus go too deep and are not very carefully thought out) some display choices were sacrificed. Therefore, it is highly recommended that when the system is put into operation at Philmont, at least one operator should be familiar with the commands.

Creating a user interface is a cyclical process that begins with a design phase, proceeds to a coding phase, and then a testing and debugging phase. At any point, it may be necessary to return to the design phase to allow the application to be modified (see Figure 6).

In the design phase, the requirements of the interface are identified. Problems such as determining the operations to be performed, and identifying the type of the output the system will have were solved in this stage.

The coding phase converts the design requirements of the application into an actual program. Numerous mistakes often appear at this phase, and to correct them requires constant redesign of certain parts of interface.

Reevaluate design

```
        ┌─────────────────────────┐
        │                         │
     \  │  /
   ┌─────────┐     ┌─────────┐     ┌─────────┐     ┌──────────────┐
   │ Design  ├──?─ │ Coding  ├──>─ │ Testing ├──>─ │ User Interface│
   └─────────┘     └─────────┘     └─────────┘     └──────────────┘
                     /  │  \
                   ┌─────────────────┘
```

Bug fixing
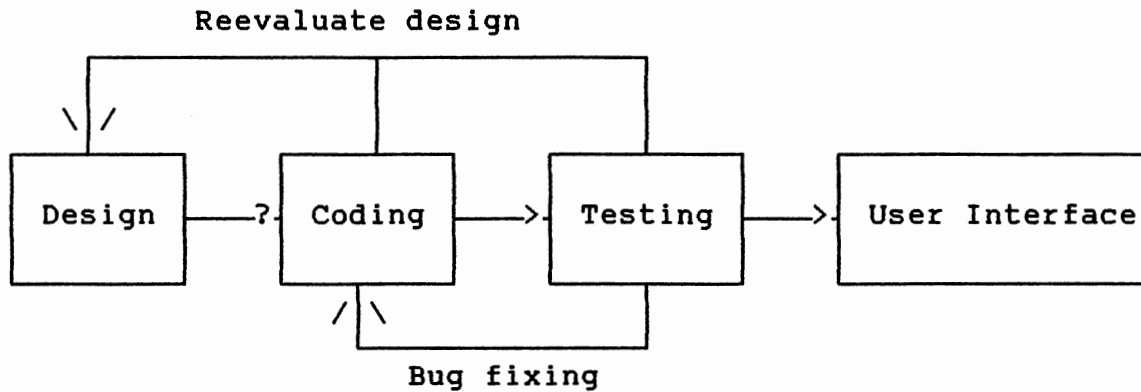
Source: ESRI, 1990. <u>Understanding</u> <u>GIS:</u> <u>The</u> <u>ARC/INFO</u> <u>Method.</u>
Environmental Systems Research Institute, Inc.
Redlands, California.

Figure 6. User Interface Design Model

The program is written by SML - Simple Macro Language -
provided by PC ARC/INFO software for users to customize
their system.

SML is a highly flexible language. The host operating
system (like DOS), ARC/INFO, and SML elements can be
combined together to perform complex operations. A SML
program is an ASCII format text file which can be created
using DOS commands and edited in many wordprocessing
programs. SML programs can be run from any prompt once PC
ARC/INFO is running. They can also be employed inside
another SML program to perform multi-level operations and
data transfer. SML is similar to many high-level programming

languages. However, it is an interpreted language. Every command line, either entered from the keyboard or SML file, is interpreted by the SML processor, which performs variable substitution, logical branching, and looping operations before the command is executed by the current PC ARC/INFO program.

The last step is testing and debugging the program. This is one of the most important steps in developing the user interface. For the system to be effective, it must be bugfree. Sometimes correction of one bug may require additional design and coding work.

The functions of the interface for the Route Network include:

1. <u>DISPLAY</u> the route network: allows a user to zoom in and out the map on the screen, and move around freely.

2. <u>ROUTING</u> the network: allows a user to find the fastest route between two of more stops; show all the routes currently in the network; and delete routes that are no longer needed.

3. <u>REPORT</u>: allows a user to display the directions of the selected route; print the directions on paper as well as maps of a selected route.

Testing the Database

The Philmont Scout Ranch Geographic Information System will be developed for planning and managing Philmont's recreation programs and conservation activities. It is very

important to maintain high standards for the accuracy of the system and at the same time make the system highly functional.

After finishing the basic development of the network, an extensive connectivity test was performed. The best way to do this test was to use the route module to find optimum routes. The more test points, the better the accuracy of the system. The next test was the road test. For every route the module determined, there is an associated total time or distance of travel. A sample route test may help determine the accuracy of the system.

CHAPTER   IV

DEVELOPMENT AND OPERATION
OF THE ROUTE NETWORK

The development of the Philmont GIS Route Network required the use of four IBM compatible software packages. These programs provide the capability to input and store data, manipulate it for final applications, and then produce display products. PC ARC/INFO provided programing tools for customizing a user interface. Though there is still a major task that needs to be completed involving the development of the database, the implementation of these routines made the design of this network a very simple task compared to similar tasks just several years ago. This chapter examines the entry of data into the PGIS Route Network, the system capabilities for data manipulation (demonstration of routing practice), output, and the design of the user interface.

Data Entry

The primary source of data for the network were USGS 1:24,000 scale topographic maps. The development of map coverage, with its respectively linked attributes, has proven to be a major task in the overall network planning

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process. The enormity of this task cannot be over stated by the GIS literature. The time, effort, and cost involved in building a complete, accurate, and up-to-date GIS database is often greater than anticipated (Butler, Ludeke, and Palmer, 1990).

Spatial Data Input

As Marble and others noted (1984), the transfer of data from analog map documents to digital form represents one of the most time consuming and costly steps in creating a geographic information system. As demonstrated by this research, much of this encoding activity involves a human operator who is interacting with instrumentation which transforms two-dimensional analog data into precise digital coordinates. The goal of the map encoding process is to create clean and useable digital files. Therefore, manual digitizing must be followed by editing operations which check the digital data against the original analog document and correct measurement errors introduced by the human operator. It is often true that the editing process requires a more substantial amount of human interaction and use of checking routines than is necessary for data input. Obviously, failure to properly edit the input data will cause substantial downstream errors in GIS operating and can consequently cause misconceptions or mistakes in interpretation of GIS products.

There were a total of eleven 7.5 minute USGS

topographic quadrangles used to cover the study area.
Trails were digitized by a research assistant at the OSU
Department of Geography. The data entry workstation
consisted of a 386SX personal computer and a large Hitachi
digitizing tablet. The program used to transform the data
was Atlas*Draw (AD) published by Strategic Mapping Inc.
When AD registers spatial information, it allows users to
give two names to every geographic entity. Each trail was
given a unique second name to distinguish it from every
other and a first name to indicate its type. There are five
different types of roads in the study area. They are
"highway," (interstate and state highway); "public access
road," (improved dirt road); "service road," (unimproved
dirt road); "jeep trail," (those roads that only open for
emergency vehicles); and "trail," (backpack trails).

To edit the digitizing output, each portion of the
digital map was checked with its corespondent base map.
Some missing trails were added, some road type mistakes
corrected, and some mistakenly digitized trials redigitized.

The second step required more time. It involved
splitting some of the trails into two or more segments.
Because it was necessary to know the elevation change of
each trail, in order to calculate the real length of each
piece, it was necessary to keep each trail either going
uphill or downhill, but not both. In cases where trails
meandered along at a similar altitude, no splitting was
performed. Also when trails' elevation changes were less

than 5 feet, elevation was kept constant.

Step three involved piecing together all eleven parcels into one integrated map coverage. Maps were put together one at a time. When two maps were joined, related edges were joined and missing trails were added. It should be pointed out that PC ARC/INFO software provided a tool to automatically match mismatched arcs along two map edges. However because of the specific detail of the digital map, it was decided not to automate the process.

The final step was to bring Atlas*Draw files into PC ARC/INFO and then check the connectivity of the digital map. Connectivity in a network means that for every intersection, every crossing route should share the common point that makes the intersection. ARC/INFO PC CONVERSION module provides a command "ATLASARC" to convert map files in Atlas*Draw format to ARC/INFO coverage. Once in PC ARC/INFO, the "BUILD" command was applied to build coverage topology. Then the "CLEAN" command was used to intersect crossing trails that did not have that overlaping node. After that, the commands "RENODE," "MNODE," and "BUILD" were used to rebuild the correct topology. Finally a check of connectivity was carried out to compare the map generated by "EDITPLOT" with a checklist containing information about nodes that may have problems. The command "ERRORNODE" could provide such a list. After the final correction, the map was ready to use. However, without attribute information associated with each trail, such as trail length and turn

impedance, the network system was not able to perform any analyses.

Attribute Data Input

As stated earlier, "Elevation" is a basic element used to generate the relational attribute database, although elevation is a spatial element. Because the number of trails was quite large (677), it was difficult to identify each trail and add elevation changes to them in PC ARC/INFO. Therefore, Atlas*Draw was used complete this task. Atlas*Draw's "BOUNDARY-NAME-TYPE" routine can easily and quickly identify the correct trail and then change its name correspondingly. Only the first name was replaced during this step with the elevation change in feet. For example the trail whose second name is "US64_1" was given the first name "7183-6780." Atlas*Draw's sister program, Atlas*Graphics can extract first names of geographic entities of a boundary file and export them into an ASCII format for popular database and spreadsheet programs. This study employed a spreadsheet program called Quattro to process the exported elevation data. Two variables were created, one representing the elevation (high and low, same as the first name); the other one to represent the numeric value of the actual elevation change in feet. These two items were then combined into PC ARC/INFO's Arc Attribute Table (AAT.DBF) which is a dBase file. The horizontal length of each trail is readily available either from Atlas*Draw or from PC

ARC/INFO. Using PC ARC/INFO's TABLES module, "length of trails," "time impedance of trails" can then be calculated. Part of the actual attribute database is shown in Table VI.

"Turn impedance" was calculated within a turn table which was generated by the command "TURNTABL." There are 4006 turns in this network. The impedance of each turn was assigned according to information shown on table 3.

After the spatial data and their relational attribute data were ready, the design of the system was nearly finished. After a series of tests, the database proved to be working properly and was ready for a real world test.

Practice Use of the Route Network

The Philmont Geographic Information System Route Network can be applied to a wide variety of management situations involved in transportation networking. The stored data can be utilized as a library of data or processed by the data manipulation functions, such as the routing module, to produce answers to a variety of questions. Although actual applications must be determined by the managers and rangers who ultimately use the information system, the following examples should demonstrate the types of applications that are possible.

Example 1

This is the situation that the system is specifically designed for:

The manager at the base camp received a call for help from a ranger who has an injured camper needing medical attention as soon as possible. The system operator first determines the location of the camper on the map, and then adds this information as a stop in the computer; he then tells the computer the starting point (where the rescuers are, usually the camping headquarters) and the ending point (the newly added stop) of the route. The computer will then calculate and display the fastest route, considering time spent on the run and at stops (intersections). The operator may then print the map and the directions for the emergency response team to bring along as references. Figure 7 shows the shortesst path in time from the Camping Headquarters to the accident site. Table V shows the directions in time and Table VI shows the directions in actual distance. In comparison, Figure 8 shows the shortest path in distance between the two points. Table VII and table VIII show the directions in time and in distance, respectively.

Note that in the Table 5, the trail's Name was used as a street name to show the direction. These names was given by the researcher arbitriraly. As a matter of fact, every variable shown in Table IV can be used to replace it for whatever reason.
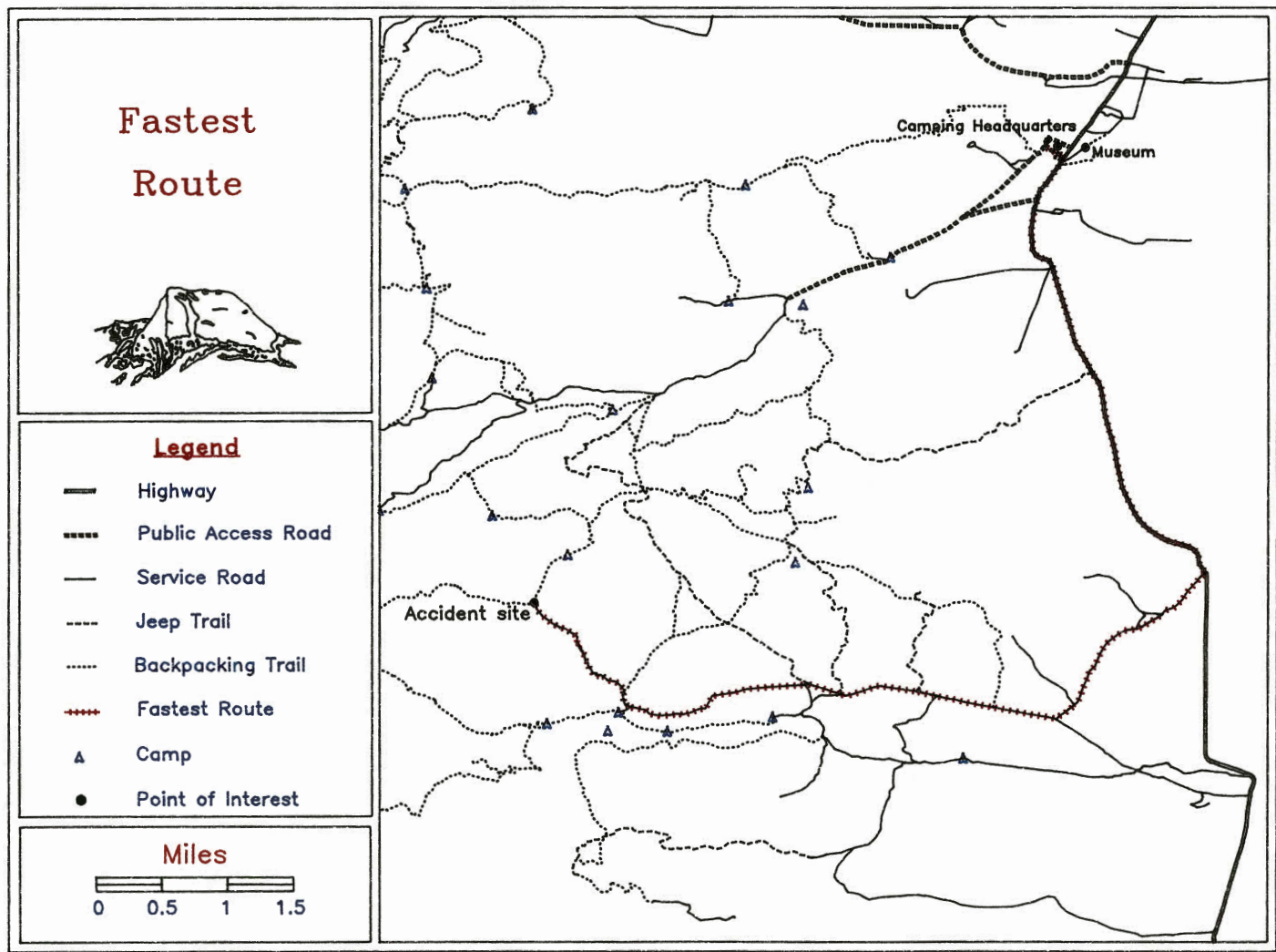
Figure 7. Shortest Route in Time

TABLE V

SHORTEST ROUTE IN TIME MEASURED IN TIME

Directions for route	2

Start at CHQR1					
Travel	0.37 minute	Turn right	to	NM21_16
Travel	0.03 minute	Go straight	to	NM21_21
Travel	0.04 minute	Go straight	to	NM21_13
Travel	0.38 minute	Go straight	to	NM21extra
Travel	0.11 minute	Go straight	to	NM21_5
Travel	0.63 minute	Go straight	to	NM21_2
Travel	1.03 minute	Go straight	to	NM21_9
Travel	2.20 minute	Turn right	to	UrracaR7
Travel	2.09 minute	Go straight	to	UrracaR8
Travel	0.95 minute	Go straight	to	UrracaR5
Travel	3.67 minute	Go straight	to	UrracaR3
Travel	0.78 minute	Turn right	to	ZastroR5
Travel	1.99 minute	Go straight	to	ZastroR6
Travel	1.77 minute	Go straight	to	ZastroR4
Travel	0.62 minute	Go straight	to	ZastroR2
Travel	2.42 minute	Go straight	to	ZastroR8
Travel	1.08 minute	Turn left	to	RayadoR14
Travel	0.10 minute	Go straight	to	AbreuRd
Travel	5.86 minute	Go straight	to	AbreuStnT2
Travel	3.64 minute	Turn left	to	AguilCmpT3
Travel	25.19 minute			

Total=	54.95 minute

TABLE VI

SHORTEST ROUTE IN TIME MEASURED IN DISTANCE

Directions for route		2			
Start at CHQR1					
Travel	0.18 mile	Turn right	to	NM21_16	
Travel	0.03 mile	Go straight	to	NM21_21	
Travel	0.04 mile	Go straight	to	NM21_13	
Travel	0.38 mile	Go straight	to	NM21extra	
Travel	0.11 mile	Go straight	to	NM21_5	
Travel	0.63 mile	Go straight	to	NM21_2	
Travel	1.03 mile	Go straight	to	NM21_9	
Travel	2.20 mile	Turn right	to	UrracaR7	
Travel	0.52 mile	Go straight	to	UrracaR8	
Travel	0.24 mile	Go straight	to	UrracaR5	
Travel	0.92 mile	Go straight	to	UrracaR3	
Travel	0.19 mile	Turn right	to	ZastroR5	
Travel	0.50 mile	Go straight	to	ZastroR6	
Travel	0.44 mile	Go straight	to	ZastroR4	
Travel	0.16 mile	Go straight	to	ZastroR2	
Travel	0.60 mile	Go straight	to	ZastroR8	
Travel	0.27 mile	Turn left	to	RayadoR14	
Travel	0.02 mile	Go straight	to	AbreuRd	
Travel	1.47 mile	Go straight	to	AbreuStnT2	
Travel	0.18 mile	Turn left	to	AguilCmpT3	
Travel	1.26 mile				
Total=	11.38 mile				
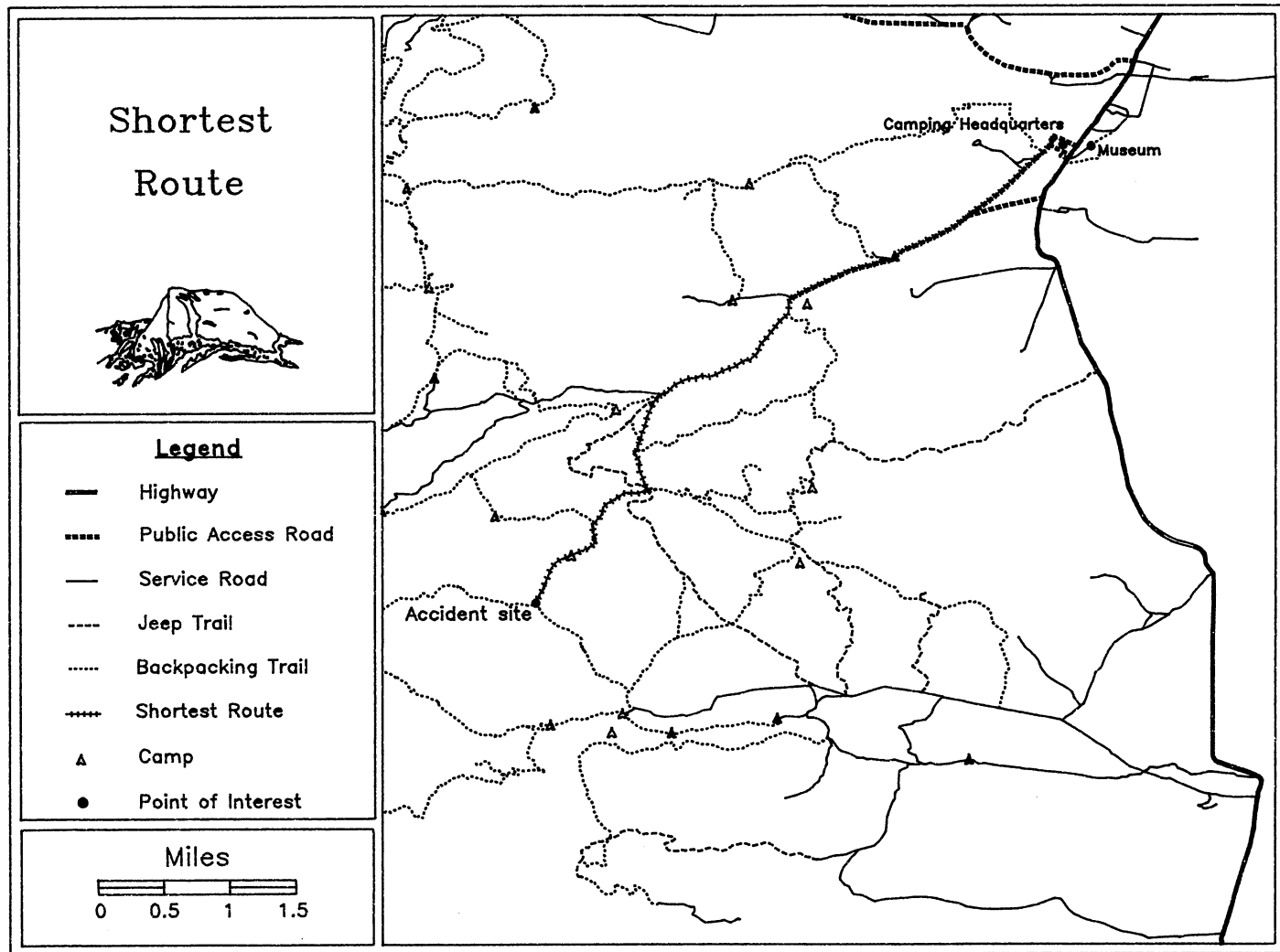
Figure 8. Shortest Route in Distance

TABLE VII

SHORTEST ROUTE IN DISTANCE MEASURED IN TIME

Directions for route		1		
Start at CHQR3				
Travel	0.14 minute	Turn right	to	CHQR10
Travel	0.20 minute	Go straight	to	CHQR8
Travel	0.27 minute	Go straight	to	CHQR9
Travel	1.23 minute	Go straight	to	LoversR3
Travel	1.42 minute	Go straight	to	LoversR2
Travel	1.69 minute	Turn left	to	LoversR1
Travel	0.61 minute	Turn right	to	LoverLeapR
Travel	5.23 minute	Go straight	to	StonWalPR2
Travel	0.19 minute	Turn left	to	StonWal4w1
Travel	0.63 minute	Turn left	to	LoverStnW3
Travel	7.42 minute	Go straight	to	LoverStnW2
Travel	2.08 minute	Go straight	to	LoverStnW1
Travel	7.63 minute	Go straight	to	StonWlP4w2
Travel	0.57 minute	Turn right	to	AguilCmpT2
Travel	12.11 minute	Turn left	to	AguilCmpT1
Travel	19.20 minute			
Total=	60.63 minute			

TABLE VIII

SHORTEST ROUTE IN DISTANCE MEASURED IN DISTANCE

Directions for route 1					
Start at CHQR3					
Travel	0.07 mile	Turn right	to	CHQR10
Travel	0.10 mile	Go straight	to	CHQR8
Travel	0.13 mile	Go straight	to	CHQR9
Travel	0.61 mile	Go straight	to	LoversR3
Travel	0.71 mile	Go straight	to	LoversR2
Travel	0.84 mile	Turn left	to	LoversR1
Travel	0.15 mile	Turn right	to	LoverLeapR
Travel	1.31 mile	Go straight	to	StonWalPR2
Travel	0.05 mile	Turn left	to	StonWal4w1
Travel	0.06 mile	Turn left	to	LoverStnW3
Travel	0.37 mile	Go straight	to	LoverStnW2
Travel	0.10 mile	Go straight	to	LoverStnW1
Travel	0.38 mile	Go straight	to	StonWlP4w2
Travel	0.06 mile	Turn right	to	AguilCmpT2
Travel	0.61 mile	Turn left	to	AguilCmpT1
Travel	0.96 mile			
Total=	6.53 mile			

Example 2

The stored data sets can be used to supply information in situations requiring simple mapped data. For example, a ranger may need to know how elevation changes along a route of his or her choice. The route may contain several segments of trails. Once the route is selected, an operator simply uses the "DIRECTIONS" command, replacing the trail's Name with elevation change. This provides the elevation change along the route (Table IX). For example, the selected route started from elevation 6691, went uphill to elevation 6700, then uphill to altitude 6719, and went on to the destination at the altitude of 8555. If the user only wants to get information for some disconnected trails, he or she can always use the "IDENTIFY" command to point at the desired trail segment. The computer will display all or selected attributes of that trail on the screen, depending upon the request.

User Interface

The objective of the user interface is to provide a tool that a new user of the geographic information system or PC ARC/INFO software can use to explore the Route Network. This requires the operator to have at least some knowledge concerning how to use a mouse or a keyboard to move the

TABLE IX

ELEVATION CHANGES

Directions for route	1			

Start at 6700 6691				
Travel	0.07 mile	Turn right	to 6719	6700
Travel	0.10 mile	Go straight	to 6735	6719
Travel	0.13 mile	Go straight	to 6816	6735
Travel	0.61 mile	Go straight	to 6930	6816
Travel	0.71 mile	Go straight	to 7110	6930
Travel	0.84 mile	Turn left	to 7115	7110
Travel	0.15 mile	Turn right	to 7480	7115
Travel	1.31 mile	Go straight	to 7480	7480
Travel	0.05 mile	Turn left	to 7480	7440
Travel	0.06 mile	Turn left	to 7500	7440
Travel	0.37 mile	Go straight	to 7595	7500
Travel	0.10 mile	Go straight	to 7873	7595
Travel	0.38 mile	Go straight	to 7885	7873
Travel	0.06 mile	Turn right	to 8355	7885
Travel	0.61 mile	Turn left	to 8555	8195
Travel	0.96 mile			

Total=	6.53 mile			

cursor around on the screen. This menu provides mimimum

operation of the system. However, it is highly recommended

that users be familiar with the actual commands so they can

utilize the full potential of PC ARC/INFO.

Basically the interface has three menu levels. The

main menu shown in figure 9 has four choices. When

"DISPLAY", ROUTING", or "REPORT" are selected, a secondary

menu will appear as shown in Figure 10, 11 and 12. Only

"REPORT" has a third level menu - "HARDCOPY" shown in Figure

13. "HARDCOPY" could be included in the "REPORT" menu,

however, in order to save time and simplify the programing,

the two functions were separated. After the user makes a

choice and follows the simple suggestions given in the

window, the user enters the parameters of the requested

operation, a series of commands will then be executed

automatically. When a job is done, the main menu will

automatically reappear. A user can select "QUIT" to leave

the program. The menu interface can be activated at any

prompt by typing "EMERGENCY." Figure 14 shows the

relationships between each menu.

Programs used for developing the user interface are

included in the appendix B.

```
┌─────────────────────────────────────────────────────────────────┐
│    Philmont Geographic Information System Route Network           │
├─────────────────────────────────────────────────────────────────┤
│                                                                   │
│  DISPLAY          ROUTING          REPORT            QUIT          │
│                                                                   │
└─────────────────────────────────────────────────────────────────┘
```

Figure 9. Main Menu

```
┌─────────────────────────┐      ┌─────────────────────────┐
│        DISPLAY          │      │        ROUTING          │
│  ─────────────────      │      │  ─────────────────      │
│                         │      │                         │
│   ZOOM IN               │      │   FIND NEW ROUTE        │
│                         │      │                         │
│   ZOOM OUT              │      │   SHOW OLD ROUTE        │
│                         │      │                         │
│   MAP SHIFT             │      │   DELETE OLD ROUTE      │
│                         │      │                         │
│   RESET                 │      │                         │
│                         │      │                         │
│                         │      │                         │
│   RETURN                │      │   RETURN                │
│                         │      │                         │
│                         │      │                         │
└─────────────────────────┘      └─────────────────────────┘
```

Figure 10. Display Menu   Figure 11. Routing Menu

```
┌─────────────────────────┐      ┌─────────────────────────┐
│        REPORT           │      │        HARDCOPY         │
│  ─────────────────      │      │  ─────────────────      │
│                         │      │                         │
│  DIRECTIONS             │      │  DIRECTIONS             │
│                         │      │                         │
│  ELEVATION CHANGES      │      │  ELEVATION CHANGES      │
│                         │      │                         │
│  MAP                    │      │  MAP                    │
│                         │      │                         │
│  HARDCOPY               │      │  CLEAN DATABASE         │
│                         │      │                         │
│                         │      │  BACK TO ROUTING        │
│                         │      │                         │
│  RETURN                 │      │  RETURN                 │
│                         │      │                         │
└─────────────────────────┘      └─────────────────────────┘
```

Figure 12. Report Menu   Figure 13. Hardcopy Menu

```
┌─────────────────────────────────────────────────────────────────┐
│     PHILMONT GEOGRAPHIC INFORMATION SYSTEM ROUTE NETWORK          │
│  ─────────────────────────────────────────────────────────────   │
│     DISPLAY           ROUTING           REPORT        QUIT        │
└─────────────────────────────────────────────────────────────────┘
```

```
┌─────────────────┐  ┌─────────────────────┐  ┌──────────────────────┐
│     DISPLAY     │  │      ROUTING        │  │       REPORT         │
│  ─────────────  │  │  ─────────────────  │  │  ──────────────────  │
│                 │  │                     │  │                      │
│  ZOOM IN        │  │  FIND NEW ROUTE     │  │  DIRECTIONS          │
│                 │  │                     │  │                      │
│  ZOOM OUT       │  │  SHOW OLD ROUTE     │  │  ELEVATION CHANGES   │
│                 │  │                     │  │                      │
│  MAP SHIFT      │  │  DELETE OLD ROUTE   │  │  MAP                 │
│                 │  │                     │  │                      │
│  RESET          │  │                     │  │  HARDCOPY ────┐      │
│                 │  │  RETURN             │  │               │      │
│                 │  │                     │  │               │      │
│  RETURN         │  └─────────────────────┘  │  RETURN       │      │
└─────────────────┘                           └───────────────┼──────┘
                                                              │
                                              ┌───────────────┼──────┐
                                              │    HARDCOPY          │
                                              │  ──────────────────  │
                                              │                      │
                                              │  DIRECTIONS          │
                                              │                      │
                                              │  ELEVATION CHANGES   │
                                              │                      │
                                              │  MAP                 │
                                              │                      │
                                              │  CLEAN DATABASE      │
                                              │                      │
                                              │  BACK TO ROUTING     │
                                              │                      │
                                              │                      │
                                              │  QUIT                │
                                              └──────────────────────┘
```
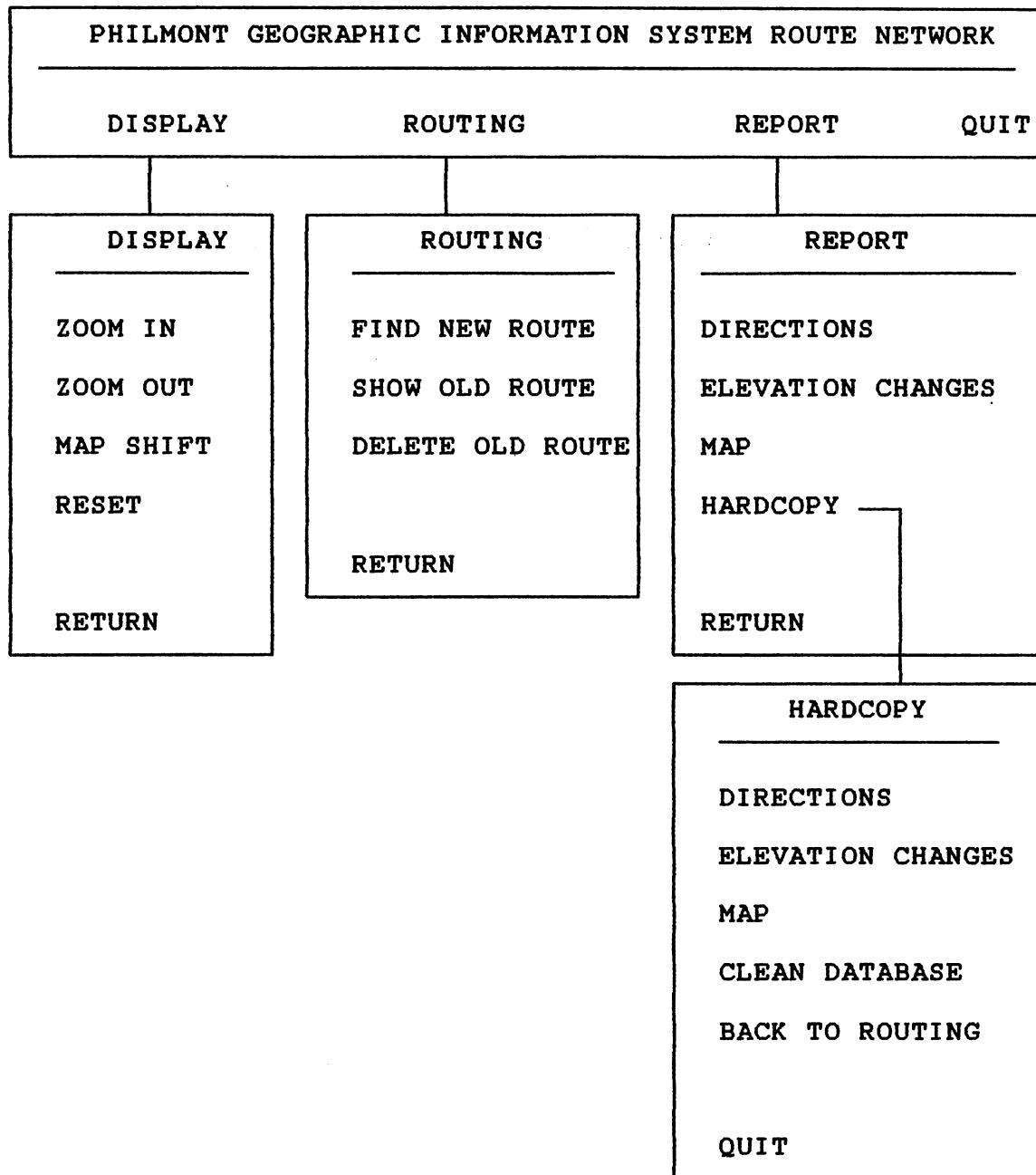
Figure 14. Simplified Menu Chart

CHAPTER V

EVALUATION AND CONCLUSION

The Philmont Geographic Information System's Route Network has the potential to provide valuable information to the managers of Philmont National Scout Ranch. It was designed using the PC ARC/INFO GIS package which allows the input, manipulation, and display of data. Relevant data were determined, acquired, and entered as layers of information. A menu driven user interface was developed to assist occasional users of the system. After the physical construction of the information system had been completed, several trials in the lab proved the system to be effective. The field test was carried out at Philmont from August 8th to August 10th, 1991. This chapter presents a general evaluation of the PGIS Route Network only from the developer's point of view. Such an evaluation is valuable because those who design and construct an information system can often best determine specific applications for the system and features that should be included in the future. The first section in this chapter presents an evaluation of the information system and provides recommendations which might increase the system's utility.

Evaluation of the PGIS Route Network

The Philmont Geographic Information System Route
Network was developed to provide information which would
assist the managers of Philmont Scout Ranch in
decision-making. Because of the nature of the system, a
vector data structure was used. Vector GISs such as PC
ARC/INFO are best suited for the determination of perimeter
and length measurements. PC ARC/INFO also provides a
relational database which permits rapid exchange of data
with spreadsheet programs. In addition, the relational
database allows for a large number of attributes to be tied
to each feature, facilitating many types of analyses
(Johnson, Johnston, and Pastor, 1988). It should be noted
that there were several estimates that could potentially
influence the accuracy of the system. Fortunately the
managers at Philmont, especially Mr. David Bates, provided
data which list exact times needed to travel on roads
between different points. Though not all roads have been
covered yet, the data provided a basis from which the
implementation could begin.

Data input consisted of a very large portion of the
work of GIS designing. All routes were digitized manually
and carefully checked. In order to compare the speed of
manual digitizing with that of automated digitizing, a
simple test was carried out. The sample area was a 5 inch
by 8 inch area on a 1:24,000 scale USGS topographic map.

The automatic digitizing was performed by first scanning the sample area. A raster to Vector converting program was then used to convert the scanned image. Finally the vector file was edited. It took almost the same amount of time performing the digitizing either way. Therefore, if the road system (but not the whole map including the contour lines) is the only thing needed to be digitized, manual digitizing is a far more efficient method.

The road system may change over time, so it is important for the Route Network to have the ability to edit the Network when changes occurs. The PC ARC/INFO software has the ability to make changes on the digital map or on the attribute file. Updating was not included in the user interface to assist the managers to maintain the system. When the whole GIS is put into operation, all update processes will be done by experienced system managers at OSU.

The output products from the Philmont Geographic Information System Route Network should be of considerable value to Philsar operations. Maps of selected routes can be rapidly viewed on a computer monitor. Hardcopy maps can be obtained either from a multi-pen plotter or graphics printer. Directions of how to access to a designated point can be printed very quickly through a printer. These maps and instructions can be taken on the road and utilized as a field guide for finding injured campers. Maps of the route network can also be produced for various applications.

With the help of the user interface, the data manipulation, display and report generating capabilities of the PGIS Route Network can be utilized by individuals who have limited prior experience in the use of computer information systems. User inputs are generally prompted in plain English. Instructions are given only where they are necessary. Such user-oriented attributes allow quick familiarization with all system capabilities and are important in assuring the widest possible utilization of the information system.

Future Recommendations and Conclusion

Future Recommendations

The Philmont Geographic Information System Route Network should not be regarded as a finished product with immediate applications to all routing situations. It can be improved in several areas. The recommendations discussed in this section will hopefully provide directions for future system implementation.

Data accuracy was a problem mentioned throughout the paper. Several different data sets could be improved in terms of accuracy. Firstly, "time impedance" can be replaced by field tested travel time instead of calculated estimations. Secondly, special attention should be paid to this "real traveling time" because weather and road conditions change over time. There should be different sets of data available based on the changing conditions.

Thirdly, elevation change along roads and trails could be registered more accurately. As discussed in Chapter IV, not all elevation turning points have been split. Also, it would be ideal if the whole network could be digitized and displayed three-dimensionally. Finally, the accuracy of data sets that can be derived from the digitized digital maps could also be improved if the quality of manual digitizing was better controlled. Scholars have suggested that errors introduced by manual digitizing can cause significant differences on total line length and polygon area (Keefer, Smith, and Gregoire, 1988).

When the data sets become final, there is a need for intensive road tests. The test results should then be compared with the data to determine the margin of the error to measure the degree of inaccuracy of the system.

The user interface is another system component that could be improved. It is often difficult to explain things in just one or two lines of text. Therefore, a "help" option could be added to the system. Help should be able to list directives that describe functions of different menus, ways to interact with the computer, and required input formats. Users should be able to get "help" at any point in the program. It is very important to design an effective user interface because, "the acceptance and success of a GIS in today's workplace will depend largely upon the nature of its interface" (Chong, and Dudley, 1988, pp. 671).

The PC ARC/INFO software itself applies some

restrictions to the performance of the Network. The best printout of the directions of routing should contain information on mileage of each route segment, time required to travel on it, turning situation, route name, and type of route all at the same time. Currently all of this information can be produced provided that the operator to make at least three copies of the different directions.

Conclusion

The PGIS Route Network should provide a database that can efficiently organize the information required for the effective management of route-related activities. A variety of data, considered pertinent to the management of a route network, were collected and entered into the vector based information system. The data included information on roads and trails, campsites, elevation changes, length of route segments, time required to travel on each route segment, time for turning, and etc. The system was designed to work with the PC ARC/INFO software package. The PGIS facilitates the generation of a variety of output products for display and analysis. The products include maps from a plotter or printer (with or without color), and written directions produced on a printer. All of these can also be shown on a computer monitor screen. In its present stage of development, the PGIS Route Network should provide solutions to problems currently facing the ranch managers.

A fully implemented and well-designed GIS can provide

better, more accessible, more flexible information so that decisions can be made based on objective facts rather than surmise. Also, when GIS is implemented organization-wide, many changes will take place in the way the organization functions (Brown, 1990).

A Geographic Information System also should not be regarded as a static management tool. In order to insure maximum effectiveness, an information system, such as the PGIS Route Network, must continually evolve to handle new data needs and user requirements. PC ARC/INFO's database structure permits the addition of new routes and new data layers. Other routing tasks that can be carried out using this program need to be explored. The potential of the Network extends beyond its present capabilities.

The development of a routing procedure for Philmont Search and Rescue Operations is a complicated task and requires careful planning. The Philmont Geographic Information System Route Network should provide a valuable decision-making tool for managers at Philmont, and will hopefully become an integral part of the future Philmont Geographic Information System.

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APPENDICES

APPENDIX A

TRADEMARKS

Throughout this thesis, trademarked names are used. Rather than put a trademark symbol in every occurrence of a trademarked name, the writer state that he is using the names only in an editorial fashion, and to the benefit of the trademark owner, with no intent of infringement on the Trademark. Following are trademarks used in the research.

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Appendix B

SML PROGRAMS FOR

USER INTERFACE

Programs are listed in alphabetic order of their name.

adraw.sml

```
&REM FILE NAME: ADRAW.SM
&REM FUNCTION:  DRAW NETWORK AND ROUTE TO SCREEN

&REM GET THE VARIABLE 5 FROM SAVE PLOT.SML

@SAVEPLOT
DIS 4
MAPEXTENT %5
ARCLINE ROUTE CLASS ROUTE.LUT
ARCS %5
DIS 4 1 6
```

alter.sml
```
&REM ALTER.SML - SML TO CONTROL CHANGING OF COVERAGES
&REM RUN FROM EMERGENC.SML AND RETURN TO THE SAME PLACE

&LABEL INPUT

  &REM POPUP ALTER FORM
  POPUP GCHANGE.MNU SML

  &JUMP %45
  &GOTO OTHERWISE


                    &REM VARIABLE 45 CONTAINS ONE OF THE
BUTTON VALUES

                    &REM (e.g.OK)
                    &REM GO TO THAT LABEL, OTHERWISE
RETURN TO CALLING

                    &REM PROGRAM (WHICH IS EMERGENC.SML).

  &LABEL SEE`THE`LIST
                    &REM IF ? IN VARIABLE 5, THEN LIST
COVERAGES.

                    &GOTO CHOOSE &IF &EQ %5 ?

                &LABEL OTHERWISE
                  &GOTO BAD &IF &EQ %5 " "
                  &GOTO BAD &IF &CN %5 ?
                  &GOTO BADMSG &IF &NF %5
                  POPUP MENU.MNU SML
                  &JUMP END
                  &RETURN

                &LABEL CANCEL
                &SV 43 EMERGENCY
```

```
                        &JUMP END
                        &RETURN

&LABEL CHOOSE
                                        &REM CREATE A LISTING OF
COVERAGES TO POP UP
   &RUN PICKDIR "CHOOSE`ROUTE`OR"
   &JUMP END

                        &LABEL BADMSG
                        @MSG BADROUTE
                        &GOBACK INPUT

                        &LABEL BAD
                        @MSG BAD
                        &GOBACK INPUT

&LABEL END
&RETURN
bad.msg

`The`input`form`contains`a`required`field`which`is`either
`blank`or`contains`a`?.``You`must`either`input`a`valid
`response `or`a`?`and`then`select`the `SEE`THE`LIST`button.

badroute.msg

`Route`entered`does`not`exist.``Please`enter`a`valid`route
`name.

clean.sml

&REM FILE NAME: CLEAN.SML
&REM FUNCTION: DELETE UNNECESSARY ROUTES AND ASSOCIATED
INFORMATION
&REM RUN FROM MENU.MNU, GOING BACK TO MENU.MNU

&RUN PICKROUT "CHOOSE`ROUTE`TO`DELETE`OR"
&RETURN


continue.mnu

&REM 1 2 20 60 3 12
&REM
&REM    CONTINUE
&REM
&REM EOF
&JUMP %1
&RETURN

&LABEL CONTINUE
&RETURN
```

```
&REM 'FILE NAME: CONTINEE.MNU'
&REM 'POPUP MENU MENU FOR TEMPORARY STOP'
&REM 'RUNNING FROM SELECT.SML BY REPORT, GOING BACK TO &REM
'SELECT.SML'


display.mnu

&REM 6 2 1 10 16 13
&REM
&REM    `DISPLAY
&REM `_____
&REM
&REM    ZOOM`IN
&REM
&REM    ZOOM`OUT
&REM
&REM    MAP`SHIFT
&REM
&REM    RESET
&REM&REM
&REM
&REM    RETURN
&REM
&REM EOF
&JUMP %6
&RETURN


&LABEL ZOOM`IN
MAPEXTENT *
DRAWNETWORK
SHOW ROUTES 1
&GOTO DRAWROUTE &IF &NE 0 %1
&RETURN


&LABEL ZOOM`OUT
@ZOOMOUT
DRAWNE
SHOW ROUTES 1
&GOTO DRAWROUTE &IF &NE 0 %1
&RETURN


&LABEL MAP`SHIFT
SHOW MAPEXTENT 30 31 32 33
&CV 34 ( %30 + %32 ) / 2
&CV 35 ( %31 + %33 ) / 2
&TYPE "MOVE THE CURSOR TO THE NEW CENTER OF THE MAP AND
PRESS ENTER"
&GETXYM 36 37 50
&CV 38 %36 - %34
&CV 39 %37 - %35
&CV 30 %30 + %38
&CV 31 %31 + %39
&CV 32 %32 + %38
```

```
&CV 33 %33 + %39
MAPEX %30 %31 %32 %33
DRAWNE
SHOW ROUTES 1
&GOTO DRAWROUTE &IF &NE 0 %1
&RETURN

&LABEL RESET
MAPEX ROUTE
DRAWNE
SHOW ROUTES 1
&GOTO DRAWROUTE &IF &NE 0 %1
&RETURN

&LABEL DRAWROUTE
SHOW ROUTENUMBER 2
&GOTO RETURN &IF &EQ 0 %2
DRAWRO
&RETURN
&LABEL RETURN
&RETURN

&REM 'FILE NAME: DISPLAY.MNU - MENU FOR DISPLAY POPUP MENU'
&REM 'RUNNING FROM DISPLAY.SML, GOING BACK TO MAIN MENU'
```

emergenc.bat

```
@ECHO OFF
CLS

REM BEGINNING OF USER INTERFACE
REM SYSTEM CAN BE ACTIVATED BY TYPING EMERGENCY AT ANY PLACE
REM FILE NAME "EMERGENC.BAT"
REM GET INTO PHILMONT WORKSTATION, THEN RUN ARC/INFO, REM
ACTIVATE EMERGENC.SML

ECHO*********************************************************
* ECHO*                                                    *
ECHO*                   WELCOME TO                         *
ECHO*                                                      *
ECHO*          PHILMONT GEOGRAPHIC INFORMATION SYSTEM
*
ECHO*                                                      *
ECHO*                  ROUTE NETWORK                       *
ECHO*                                                      *
ECHO*********************************************************
*
CD\PHILMONT
ARC EMERGENC
```

emergenc.sml

```
&REM 'FILE NAME: EMERGENC.SML'
&REM 'FUNCTION: 'ENTER IN TO THE ROUTE MODULE AND ACTIVATE
&REM 'ROUTE.SML'
&REM 'RUNNING AFTER EMERGENCY.BAT AND BEFORE ROUTE.SML'
&echo on

&label again

   &JUMP %43

   &LABEL EMERGENCY
   &REM 'START ROUTING SESSION.'
   ROUTE ROUTING
   &RUN D:\PHILMONT\SAVEVAR.SML
   &GOBACK AGAIN

   &LABEL REPORT
   @ALTER
   &GOBACK AGAIN
   &LABEL QUIT
   QUIT
   &return


environ.sml

&REM 'FILE NAME: ENVIRON.SML'
&REM 'FUNCTION: 'FIND OUT THE MAPEXTENT OF THE MAP ON THE
&REM 'SCREEN'
&REM 'RUNNING IN ZOOM-PAN, ARCPLOT...'

&OPENW ENVIRON.SML
SHOW MAPEXTENT 1 2 3 4
&WRITE "MAPEXTENT %1 %2 %3 %4"
&CLOSEW


find.mnu

&REM 7 2 1 23 15 17
&REM
&REM
&REM        'ROUTING
&REM  '_____
&REM
&REM    FIND'NEW'ROUTE
&REM
&REM    SHOW'OLD'ROUTE
&REM
&REM    DELETE'OLD'ROUTE
&REM
&REM
&REM
&REM    RETURN
&REM
```

```
&REM EOF
&JUMP %7
&RETURN

&LABEL FIND`NEW`ROUTE
&REM 'SET GLOBAL VARIABLE 46 TO O'
&SV 46 0
@FIND
&JUMP RETURN
&RETURN

&LABEL SELECTED
&LABEL SHOW`OLD`ROUTE
SHOW ROUTES 50
&SV 47 "show"
&GOTO NOROUTE &IF &EQ 0 %50
SHOW ROUTENUMBER 49
&GOTO NOROUTENOW &IF &EQ 0 %49
LISTROUTE&ASK 49 "ENTER THE ID NUMBER OF THE ROUTE TO BE
SHOWN:"
&GOTO DRAWRO &IF &RN  %49 1 50
&RETURN

&LABEL DRAWRO
SEL %49
DRAWRO
&JUMP RETURN
&RUTURN

&LABEL DELETE`OLD`ROUTE
LISTROUTE
&SV 47 "delete"
SHOW ROUTES 50
&GOTO NOROUTE &IF &EQ 0 %50
SHOW ROUTENUMBER 49
&GOTO NEEDSELECT &IF &EQ 0 %49
&ASK 49 "ENTER THE ID NUMBER OF THE ROUTE TO BE DELETED:"
&GOTO DELETE &IF &RN %49 1 50
&RETURN

&LABEL NOROUTENOW
POPUP NORUTNOW.MNU SML
&GOTO RETURN &IF &EQ %9 CANCEL
&GOBACK SELECTED
&RETURN

&LABEL NEEDSELECT
POPUP NORUTNOW.MNU SML
&GOTO RETURN &IF &EQ %9 CANCEL
&GOBACK DELETE`OLD`ROUTE
&RETURN

&LABEL DELETE
SEL %49
```

```
REMOVEROUTE
&JUMP RETURN
&RETURN

&LABEL NOROUTE
POPUP NOROUTE.MNU SML
&JUMP RETURN
&RETURN

&LABEL RETURN
&RETURN


&REM "NAME OF THE FILE: FIND.MNU"
&REM "FUNCTION: FIND ROUTE, SHOW OLD ROUTE, DELETE ROUTE,"
find.sml

&REM "RUN UNDER MAIN.MNU, GOING BACK TO MAIN MENU."
&REM 'FILE NAME: FIND.SML'&REM 'FUNCTION:  CHECK ROUTES
NUMBER IN THE NETWORK, ADD NEW &REM 'ROUTE.'
&REM 'RUNNING BY FIND.MNU - FIND`NEW`ROUTE'

&echo on

SHOW ROUTES 1
&LABEL TOP
&GOTO A1 &IF &RN 0 %1 49
&GOTO END &IF &EQ %1 50

&LABEL A1
&CV 2 %1 + 1
&ASK 40 "ENTER A ROUTE-ID (NUMBER BETWEEN %2 TO 50):"
&GOTO A2 &IF &NR %40 %1 50
&CV 41 %40 + 1
ADDROUTE %40 %41
POPUP HOWTO.MNU SML
PATH *
&RETURN

&LABEL A2
&TYPE "ERROR: REPEAT USE OF ROUTE-ID,"
&TYPE "CHANGE ROUTE-ID OR DELETE SOME ROUTE"
&GOBACK A1

&LABEL END
&TYPE "YOU REACHED THE LIMITS. ARF/INFO ONLY ALLOW"
&TYPE "50 ROUTES IN ONE NETWORK. ERASE SOME ROUTES TO KEEP
GOING."
&RETURN


first.mnu

&REM 9 2 18 1 5 78
```

```
&REM
&REM          `The`route`added`previousely`wasn't`saved.
&REM          `you`can`save`it`now.
&REM          `Otherwis`you`will`lose`it.
&REM
&REM                         SAVE`ROUTE        DON'T`BOTHER
&REM EOF
&JUMP %9
&RETURN

&LABEL SAVE`ROUTE
POPUP NAME.MNU SML
&JUMP RETURN
&RETURN

&LABEL DON'T`BOTHER
&SYS "DEL A.DIR"
&SYS "DEL A.ELE"KILL A
&RETURN

&LABEL RETURN
&RETURN

&REM 'FILE NAME: FIRST.MNU - MENU FOR ENTERING THE ROUTING'
&REM 'RUNNING FROM EMERGENC.SML BY, GOING BACK TO &REM
'EMERGENC.SML'


gchange.mnu

&REM 45 2 1 1 9 77
&REM `Selecte`a`route`for`which`you`want`to`get`reports
&REM `You`can`enter`the`name`of`the`route`if`you`know;
&REM `Or`you`can`put`a`question`mark`after`the`colon,
&REM `and`then`press`enter`to`pick`the`one`you`want`from
&REM `the`list.
&REM
&REM `Route       :%5
&REM
&REM          OK      SEE`THE`LIST     CANCEL
&REM EOF
&RETURN

&REM `FILE NAME: GCHANGE.MNU.'
&REM `SELECT THE ROUTE YOU WANT TO GET THE REPORT'


howto.mnu

&REM 1 2 1 5 9 73
&REM
&REM `Enter`starting,`ending`stops`by`moving`the`cursor
&REM `on`the`points,`then`pressing`number`key`'1'
&REM `Stops`in`between`can`also`be`added`the`same`way.
```

```
&REM `Or,`you`can`use`the`mouse`if`you`have`one.
&REM
&REM `Press`number`key`'9'`when`finished.
&REM
&REM                                OK
&REM EOF
&JUMP %1
&RETURN


&LABEL OK
&RETURN


&REM 'FILE NAME: HOWTO.MNU'
&REM 'FUNCTIONS: SHOW USERS HOW TO TELL COMPUTER TO FIND THE
&REM 'ROUTE.'

main.mnu

&REM 5 2 1 4 6 69
&REM
&REM      `PHILMONT`GEOGRAPHIC`INFORMATION`SYSTEM`ROUTE`NETWORK
&REM
`_____
&REM
&REM            DISPLAY      ROUTING          REPORT   QUIT
&REM
&REM EOF
&JUMP %5

&REM 'SET GLOBAL VARIABLE 43 TO QUIT'

&SV 43 "QUIT"
&SAVE SAVEVAR.SML 43 43
%5
&RETURN

&LABEL DISPLAY
POPUP DISPLAY.MNU SML
&JUMP RETURN
&RETURN

&LABEL ROUTING
POPUP FIND.MNU SML
&JUMP RETURN
&RETURN

&LABEL REPORT

    &REM 'THE ROUTE ID OF THE CURRENTLY SELECTED ROUTE IS
%49'

SHOW ROUTENUMBER 49

    &REM 'THE NUMBER OF ROUTES IN THE NETWORK IS %50'
```

```
SHOW ROUTES 50
&SV 47 "get`report`for"

                                &REM 'GOTO NOROUTE IF NO ROUTE AT
ALL'

                        &GOTO NOROUTE &IF &EQ 0 %50

                         &REM 'GOTO NOROUTENOW IF NO ROUTE
CURRENTLY SELECTED'

                        &GOTO NOROUTENOW &IF &EQ 0 %49

                         &REM 'GOTO TOOMANY IF THERE IS MORE
THAN ONE ROUTE IN'
                         &REM 'THE NETWORK'

                        &GOTO TOOMANY &IF &NE 1 %50
                        &GOTO NONEED &IF &EQ 1 %46
                        &JUMP NEXT
                                &LABEL NOROUTENOW
                                POPUP NORUTNOW.MNU SML
                                &JUMP RETURN
                                &RETURN

                                &LABEL NOROUTE
                                POPUP NOROUTE.MNU SML
                                &RETURN

                                &LABEL TOOMANY
                                POPUP TOOMANY.MNU SML
                                POPUP FIND.MNU SML
                                &RETURN

&LABEL NEXT
POPUP NEXT.MNU SML
&LABEL NONEED
&GOTO RETURN &IF &EQ %9 CANCEL
DIS 4 1 20
POPUP REPORT.MNU SML
&JUMP RETURN
&RETURN

&LABEL RETURN
&RETURN

&REM 'FILE NAME: MAIN.MNU - MENU FOR MAIN POPUP MENU'
&REM 'RUNNING FROM MAIN.SML, GOING BACK TO MAIN MENU'


menu.mnu

&REM 8 2 1 50 17 20
&REM
```

```
&REM          `HARDCOPY
&REM `_____
&REM
&REM   DIRECTIONS
&REM
&REM   ELEVATION`CHANGES
&REM
&REM   MAP
&REM
&REM   CLEAN`DATABASE
&REM
&REM   BACK`TO`ROUTING
&REM
&REM
&REM   QUIT
&REM
&REM EOF
&JUMP %8
&RETURN
&LABEL DIRECTIONS
&SYS "PRINT %5.DIR"
&JUMP END
&RETURN

&LABEL ELEVATION`CHANGES
&SYS "PRINT %5.ELE"
&JUMP END
&RETURN

&LABEL MAP
&SAVE SAVEPLOT.SML 5 5
@PRINPLOT
@SAVEPLOT
&JUMP END
&RETURN

&LABEL CLEAN`DATABASE
@CLEAN
&JUMP END
&RETURN

&LABEL END
POPUP MENU.MNU SML

&LABEL BACK`TO`ROUTING
&SV 43 EMERGENC
&JUMP END
&RETURN

&LABEL QUIT
&SV 43 QUIT
&SAVE SAVEVAR 43 43
QUIT
&JUMP END
```

```
        &RETURN

        &LABEL END
        &RETURN

        &REM 'FILE NAME: MENU.MNU - MENU FOR HARDCOPY POPUP MENU'
        &REM 'RUNNING FROM EMERGENC.SML, GOING BACK TO EMERGENC.SML
        &REM 'MENU'




name.col

        &REM 1 2 18 1 5 78
        &REM
        &REM `Enter`the`name`to`the`route`you`want`to`save
        :%45&REM `No`number`please.`Press`"Enter"`when`you`done.
        &REM
        &REM                                 DONE
        &REM EOF
        &JUMP %1
        &RETURN

        &LABEL DONE
        &VALUE 41 45
        &RETURN

        &REM 'FILE NAME: NAME - MENU FOR GIVE A NAME TO THE ROUTE
        &REM 'POPUP MENU.'
        &REM 'RUNNING FROM SELECT.SML BY REPORT, GOING BACK TO &REM
        'SELECT.SML'


name.mnu

        &REM 1 2 18 1 5 70
        &REM
        &REM `Enter`the`name`to`the`route`you`want`to`save :%41
        &REM                    `Press`"Enter"`when`you`done.
        &REM
        &REM                                 DONE
        &REM EOF
        &JUMP %1
        &RETURN

        &LABEL DONE
        &SYS "COPY A.DIR %41.DIR"
        &SYS "COPY A.ELE %41.ION"
        RENAMCOV A %41
        &SYS "DEL A.DIR"
        &SYS "DEL A.ELE"
        &RETURN
```

```
&REM 'FILE NAME: NAME.MNU - MENU FOR RENAME ROUTE POPUP
MENU'
&REM 'RUNNING FROM FIRST.SML BY EMERGENC,GOING BACK TO &REM
'FIRST.SML'


next.mnu

&REM 9 2 1 1 6 70
&REM
&REM           `The`route`ID`of`the`current`route`is`%49,
&REM           `Do`you`want`reports`of`this`route?
&REM
&REM                              OK        CANCEL
&REM
&REM EOF
&JUMP %9
&RETURN
.&LABEL OK
@SAVE
&RETURN

&LABEL CANCEL
&RETURN

&REM 'FILE NAME: NEXT.MNU - POPUP MENU FOR CONFIRM
&REM 'THE SELECTION OF CURRENT ROUTE'
&REM 'RUNNING FROM MAIN.SML BY REPORT, GOING TO DIFFERENT
&REM 'PLACES'


noroute.mnu

&REM 9 2 1 1 5 78
&REM
&REM `There`is`no`route`in`the`network.`If`you`want`to`%47
&REM `a`route,`you`need`to`find`it`first.
&REM
&REM                              OK
&REM EOF
&JUMP %9
&RETURN

&LABEL OK
&RETURN

&REM 'FILE NAME: NOROUTE.MNU - MENU FOR NO ROUTE  POPUP
MENU' &REM 'RUNNING FROM MAIN.SML BY REPORT, GOING BACK TO
MAIN &REM 'MENU'
&REM 'NO ROUTE AT ALL'


norutnow.mnu
```

```
&REM 9 2 1 1 5 75
&REM
&REM `There`is`no`route`currently`selected,`If`you`want`to
&REM `%47`a`route,`you`need`to`select`a`route`first.
&REM
&REM                       SELECT`A`ROUTE          CANCEL
&REM EOF
&JUMP %9
&RETURN

&LABEL SELECT`A`ROUTE
@SELECT
&JUMP RETURN
&RETURN

&LABEL CANCEL
POPUP FIND.MNU SML&RETURN

&REM 'FILE NAME: NORUTNOW.MNU'
&REM 'MENU FOR NO ROUTE NOW POPUP MENU'
&REM 'RUNNING FROM MAIN.SML BY REPORT, GOING BACK TO MAIN
&REM 'NO ROUTE CURRENTLY SELECTED'


pickdir.sml

&REM GENERALIZED LIST-DIRECTORIES ROUTINE
&REM VARIABLE 1 - VARIABLE NUMBER TO PUT POPUP CHOICE INTO
&REM VARIABLE 2 - MESSAGE TO PIPE TO FILE TO POPUP
&REM FILE NAME: PICKDIR.SML
&REM RUN FROM ALTER.SML

&LABEL LIST`COVERAGES
   &OPENW D:\ARCEXE\ARCSHELL\T$TEMP\FILES.LST
   &WRITE "`ROUTES`IN`CURRENT`WORKSPACE`-`%1 CANCEL"
   &WRITE " "
   &CLOSEW
   &SYS "L *.* -HLD >>D:\ARCEXE\ARCSHELL\T$TEMP\FILES.LST"
   POPUP D:\ARCEXE\ARCSHELL\T$TEMP\FILES.LST 5 2 1 6 6 68
   &SYS "ERASE D:\ARCEXE\ARCSHELL\T$TEMP\FILES.LST"
   &VALUE 3 5
   &GOTO END &IF &NE %3 CANCEL
   &GOTO BACK &IF &EQ %3 CANCEL


   &LABEL END
                  &SV 1
                  &SV 2
                  &SV 3


   POPUP MENU.MNU SML
   &JUMP STOP
   &RETURN
```

```
&LABEL BACK
POPUP MENU.MNU SML
&RETURN

&LABEL STOP
&RETURN
```

pickout.sml

```
&REM GENERALIZED LIST-DIRECTORIES ROUTINE
&REM VARIABLE 1 - VARIABLE NUMBER TO PUT POPUP CHOICE INTO
&REM VARIABLE 2 - MESSAGE TO PIPE TO FILE TO POPUP&REM FILE
NAME: PICKout.SML
&REM RUN FROM ALTER.SML

&LABEL LIST`COVERAGES
   &OPENW D:\ARCEXE\ARCSHELL\T$TEMP\FILES.LST
   &WRITE "`ROUTES`IN`CURRENT`WORKSPACE`-`%1 CANCEL"
   &WRITE " "
   &CLOSEW
   &SYS "L *.* -HLD >>D:\ARCEXE\ARCSHELL\T$TEMP\FILES.LST"
   POPUP D:\ARCEXE\ARCSHELL\T$TEMP\FILES.LST 5 2 1 6 6 68
   &SYS "ERASE D:\ARCEXE\ARCSHELL\T$TEMP\FILES.LST"
   &VALUE 3 5
   &GOTO END &IF &NE %3 CANCEL
   &GOTO BACK &IF &EQ %3 CANCEL


   &LABEL END
                  &SV 1
                  &SV 2
                  &SV 3

   &SYS "DEL %5.DIR"
   &SYS "DEL %5.ELE"
   KILL %5
   &RETURN

   &LABEL BACK
   &RETURN
```

prinplot.sml

```
&REM FILE NAME: PRINPLOT.SML
&REM FUNCTION: ACTIVATE ARCPLOT AND START ANOTHER SML
&REM RUN FROM MEMU.MNU

ARCPLOT ROUTDRAW
```

repeat.mnu

```
&REM 9 2 1 1 5 78
&REM
&REM `The`name`%41`has`already`been`taken.`Pleas`try`another
&REM    `one.
&REM
&REM                                OK
&REM EOF
&JUMP %9
&RETURN

&LABEL OK
&RETURN
&REM 'FILE NAME: REPEAT.MNU - MENU FOR REPEATED ROUTE NAME'
&REM 'RUNNING FROM MAIN.SML BY REPORT, GOING BACK TO MAIN
&REM 'MENU'
```

report.bat

```
@ECHO OFF
CLS

REM BEGINNING OF REPORT
REM SYSTEM CAN BE ACTIVATED BY TYPING REPORT AT ANY PLACE
REM FILE NAME "REPORT.BAT"
REM GET INTO PHILMONT WORKSTATION, THEN RUN ARC/INFO, REM
ACTIVATE REPORT.SML

ECHO****************************************************************
* ECHO*                                                       *
ECHO* YOU CAN RUN REPORT AT C: PROMPT BY TYPING "ARC
REPORT"* ECHO*                                                *
ECHO****************************************************************
*
@REPORT
```

report.mnu

```
&REM 8 2 1 50 16 20
&REM
&REM
&REM           `REPORT
&REM `_____
&REM
&REM    DIRECTIONS
&REM
&REM    ELEVATION`CHANGES
&REM
&REM    MAP
&REM
&REM    HARDCOPY
&REM
```

```
&REM
&REM
&REM   RETURN
&REM
&REM EOF
&JUMP %8
&RETURN


&LABEL DIRECTIONS
DIRECTIONS ROUTE_ TIME MINUTE
POPUP CONTINUE.MNU SML
&JUMP END
&RETURN
&LABEL ELEVATION`CHANGES
DIRECTIONS ELEVATION TIME MINUTE
POPUP CONTINUE.MNU SML
&JUMP END
&RETURN


&LABEL MAP
DRAWNE
DRAWRO
&JUMP END
&RETURN


&LABEL HARDCOPY
&REM 'SET GLOBAL VARIABLE 43 TO REPORT'
&SV 43 "REPORT"
&SAVE SAVEVAR.SML 43 43
QUIT
&RETURN


&LABEL RETURN
DIS 4 1 6
MAPEX %41
DRAWNE
DRAWRO
&RETURN


&LABEL END
POPUP REPORT.MNU SML

&REM 'FILE NAME: REPORT.MNU - MENU FOR REPORT POPUP MENU'
&REM 'RUNNING FROM MAIN.SML, GOING BACK TO MAIN MENU'


report.sml

&REM 'FILE NAME: REPORT.SML'
&REM 'FUNCTION: 'ENTER IN TO THE REPORT MODULE AND ACTIVATE
&REM 'REPORT MENU.
&REM 'RUNNING AFTER REPORT.BAT AND BEFORE .SML'

POPUP MENU.MNU SML
```

```
ROUTDRAW.SML

&REM FILE NAME: ROUTDRAW.SML
&REM FUNCTION: DRAW NETWORK AND ROUTE TO PLOTTER OR PRINTER
&REM RUN FROM PRINPLOT.SML

&REM GET THE VARIABLE 5 FROM SAVEPLOT.SML

@SAVEPLOT
DIS 1
MAPEXT %5PAGESIZE 14 11
MAPLIMITS 0.3 0.3 10.1 10.8
LINESY 1
BOX 0.1 0.1 13.65 10.9
ARCLINE ROUTE CLASS ROUTE.LUT
LINESY 54
ARCS %5
TEXTSY 41
TEXSI .4 .4
MOVE 10.1 9
TEXTFILE TITLE
TEXTSI .25 .25
KEYBOX .6 .4
KEYSE 0.15 0.25
KEYPOSITION 10.2 6.4
KEYLINE ROUTE.KEY
DIS 4 1 6
QUIT


routing.sml

&REM 'READ NETWORK INTO ARC/INFO, SET UP SCREEN DISPLAY,'
&REM 'MAPEXTENT IS ROUTE, DRAW NETWORK USE LINE SYMBOL 1'

READNE ROUTE TIME TIME
DIS 4 1 7
MAPEXTENT ROUTE
DRAWNE

&REM 'POPUP THE MAIN MENU - ZOOM, ADD ROUTE, AND REPORT'

&LABEL TOP
POPUP MAIN.MNU SML
&GOBACK TOP &IF &NE %5 QUIT
&RETURN


save.sml

&REM 'FILE NAME: SAVE.SML'
&REM 'SAVE INFORMATION ABOUT THE CURRENTLY SELECTED ROUTE'
```

```
&LABEL BEGIN
POPUP NAME.COL SML
&GOTO NEXT &IF &NF %41.DIR
POPUP REPEAT.MNU SML
&GOBACK BEGIN

&LABEL NEXT
DIRECTIONS ROUTE_ TIME MINUTE %41.DIR
DIRECTIONS ELEVATION TIME MINUTE %41.ELE
SAVEROUTE %41
&RETURN
```

savevar.sml

```
&REM 'FILE NAME: SAVEVAR.SML'
&REM 'SAVE INFORMATION ABOUT THE variable 43'

&SAVE SAVEVAR.SML 43 43
&RETURN
```

select.mnu

```
&REM 1 2 20 1 5 70
&REM
&REM 'Enter`the`ID`number`of`the`route`you`want`to`select:
&REM   :%41
&REM                          `Press`"Enter"`when`you`done.
&REM
&REM                                      DONE
&REM EOF
&JUMP %1
&RETURN

&LABEL DONE
&VALUE 49 41
SEL %49
&RETURN

&REM 'FILE NAME: SELCET.MNU'
&REM 'MENU FOR SELECT A ROUTE POPUP MENU'
&REM 'RUNNING FROM SELECT.SML BY REPORT, GOING BACK TO &REM
'SELECT.SML'
```

select.sml

```
&REM 'FILE NAME: SELECT.SML'
&REM 'FUNCTION: SELECT A ROUTE TO GENERATE REPORTS'

LISTROUTE
POPUP SELECT.MNU SML
&RETURN
```

```
toomany.mnu

&REM 9 2 1 1 5 78
&REM
&REM `You`have`to`delete`all`the`routes`except`the`one`you
&REM `need`in`order`to`get`the`exact`report.
&REM
&REM                              OK         CANCEL
&REM EOF&JUMP %9
&RETURN

&LABEL OK
&JUMP RETURN
&RETURN

&LABEL CANCEL
&RETURN

&LABEL RETURN
&RETURN

&REM 'FILE NAME: TOOMANY.MNU - MENU FOR TOO MANY ROUTE
POPUP' &REM 'RUNNING FROM MAIN.SML BY REPORT, GOING BACK TO
MAIN &REM 'MENU'
&REM 'NO ROUTE AT ALL'


zoomout.sml

&REM ZOOMOUT.SML
&REM PRRFORMS A SOFTWARE ZOOM OUT BY ADJUSTING THE
MAPEXTENT.
&REM THE AMOUNT OF MOVEMENT CAN BE CONTROLLED BY ADJUSTING
&REM THE SCALE FACTOR WHICH IS CURRENTLY HARDWIRED TO 4,
&REM IN LINE 12:
&REM &CV 11 ( %7 / 4 )

&TYPE "ZOOMING OUT..."
SHOW MAPEXTENT 3 4 5 6
&CV 7 %5 - %3
&CV 8 %6 - %4
&CV 11 ( %7 / 4 )
&REM ALTERNATIVE &CV 11 ( ( ( %7 * %7 ) + ( %8 * %8 ) ** .5
) / 4 )
&CV 3 %3 - %11
&CV 4 %4 - %11
&CV 5 %5 + %11
&CV 6 %6 + %11

MAPEXTENT %3 %4 %5 %6
&RETURN
```

VITA

JUN GAO

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