THE DEVELOPMENT OF A GEOGRAPHIC INFORMATION SYSTEM FOR ENVIRONMENTAL MONITORING ON THE CAPE PENINSULA, AND AN ASSESSMENT OF THE USE OF SPOT IMAGERY FOR VEGETATION MAPPING

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Submitted in fulfilment of the requirements for an M.Sc degree in the Botany and Surveying Departments, University of Cape Town

January 1991

ABSTRACT

This thesis concerns the establishment of a Geographic Information System for the Cape Peninsula and the use of SPOT satellite imagery to map land cover classes. The former is seen as a necessary tool to promote judicious conservation management decisions for the fragile "Fynbos" ecosystem, and the latter as a convenient means of acquiring up-to-date information concerning the environment, and to monitor change.

ACKNOWLEDGEMENTS

I wish to thank Prof. E.J.Moll of the Botany Department for initiating the project and for co-supervising my thesis, together with Mr C.Martin of the Department of Surveying. Mr Martin was responsble for introducing me to the Siemens GIS system and gave me invaluable support throughout the project. Miss A. Tredigda often came to the rescue in dealing with the Siemens mainframe and I thank her for her tireless effort.

The CSIR/FRD Remote Sensing programme was responsible for funding the project. I am grateful for the opportunity to participate in the programme.

Finally, to my collegue Liz Ashton and the staff and postgraduate students of the Botany and Surveying Department who assisted me, thank you.

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INTRODUCTION

The aims of the project were two-fold:

1. The establishment of a Geographic Information System (GIS) for mapping and monitoring the natural environment, specifically the Cape Peninsula, and
2. To investigate the feasibility of utilizing SPOT satellite imagery as a means to acquire information on land cover, particularly vegetation.

These two aims are complementary, since one of the basic inputs to the GIS is information based on the vegetation. The interpretation of the satellite imagery can be further facilitated by the analysis of other environmental data stored in the GIS. For GIS to be accepted as a tool, natural scientists need to be educated with respect to its uses with appropriate real world examples. Hopefully this thesis goes part way to achieving this. Because this thesis is of a bi-disciplinary nature, and being supervised by the Botany and Surveying departments, it was necessary to explain some of the technical terms, however, a basic understanding of GIS and Botany is assumed.

The thesis is divided into four main sections. The first is concerned with GIS theory, the second looks at how and why remotely sensed data are incorporated into a GIS. The third section deals with remote sensing of vegetation, specifically using SPOT satellite imagery to map the landcover of the Cape

Peninsula. The fourth covers the establishment of the Cape Peninsula GIS at the University of Cape Town, its aims, structure and use. In conclusion, I will look at how GIS can be used for conservation management, indicating its strengths and weaknesses. The order of the chapters, although placing the Cape Peninsula GIS (the main topic) at the end, seemed to result in the most logical flow. Also it enabled this chapter and its associated appendices to be closer. In the list of references I have included all material consulted rather than just those quoted in the text, as the number of text books on GIS is very limited and this may go some way to provide a list of GIS source material.

The GIS was initiated on a Siemens mainframe computer operated by the Department of Surveying at UCT. However, by 1991 the system was phased out and replaced by an ARC-INFO system run by the Information Technology Services at UCT. For this reason a postscript describing the conversion of the database to the new system has been included, to inform potential users of the GIS of this development.

CHAPTER 1

GEOGRAPHIC INFORMATION SYSTEMS

1.1 THE NEED FOR GIS

Why do we need a GIS? What can GIS do that conventional cartography cannot? The following quotes express some of these reasons:

"Knowing where things are and how they relate to one another is crucial for management planning and investment decisions taken within both public and private sectors" (Department of the Environment 1987).

"We spend vast sums on collecting geographical data, but we are only scratching the surface in getting added value from these data by using the tools which are now at our command. Technology is the easy part...the problem is getting the managers and decision makers to use this capability" (Chorley 1988).

"As worldwide shortages of natural resources become more apparent and demand for resources rises, there is little doubt that managers will need to better acquire, organize and manipulate environmental data for decision making purposes" (Hill 1983). The necessary data have become increasingly quantitative and the supply of statistical information has outgrown the capacity of conventional cartography to present it before it becomes seriously out of date. Thus, as Hackman (1972) states, planners have turned to computers and the specific tool available to planners is the GIS.

"Canadian society is now entering an era in which a dominant public issue will be the thoughtful and careful stewardship of the land, and the more intensive use and management of its existing resource stocks. This in turn will require, and indeed already is requiring, a re-examination of the procedures and strategies for providing information about the land. Increasingly the question being asked at very senior levels in both government and private resource sectors, is whether there will be available this information, in place, in time and in the form that will be required by resource planners, managers and policy makers" (McLaughlin 1985).

The same is true for South Africa, particularly in the Cape Peninsula where the conflict between urban expansion and recreation on the one hand, and the conservation of the scenically beautiful landscape with its cover of unique "Fynbos" (for definition see ch4 p2) ecosystem on the other, is growing. The latter two being non-renewable resources of the tourist industry. In the context of the Cape Peninsula the aims of developing a GIS are twofold:

a) to facilitate better and more timeous environmental management plans by providing a comprehensive spatially referenced, and continually updated database;

b) to aid in the interpretation of remotely sensed imagery by providing overlay capabilities for ancillary data, e.g. landcover boundaries derived from the imagery can be depicted by the computer simultaneously, and at the same scale, with one or more sets of ancillary spatial data such as geology or soils.

1.2 DEFINITION OF GIS

In the literature, many definitions of GIS exist, a few are listed below:

"A GIS is an automated tool for the efficient storage, analysis and presentation of geographic data" (Dangermond 1983).

GIS systems provide "an analytical tool box enabling managers to address complex issues in entirely new ways" (Dangermond 1986).

"A system which uses a spatial database to provide answers to queries of a geographical nature" (Goodchild 1988).

From the above definitions it is obvious that the information stored within a GIS is of a geographic nature and has two basic characteristics:

1) The actual phenomena or entity;

2) Its spatial location.

However, there is a third important characteristic, time. Those variables that change over time, be they seasonal or more permanent in nature, need to be monitored and recorded if a GIS is to be efficient and useful. The relationship between these three components in a GIS context is shown in Figure 1.

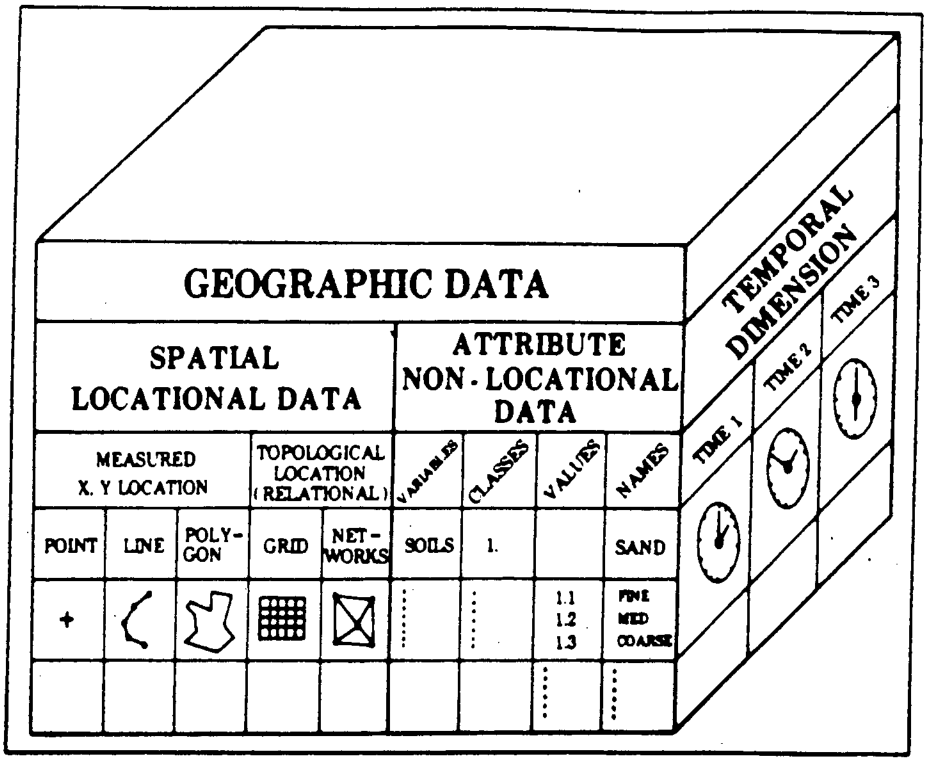

FIGURE 1. The conceptual components of a GIS (Dangermond 1983).

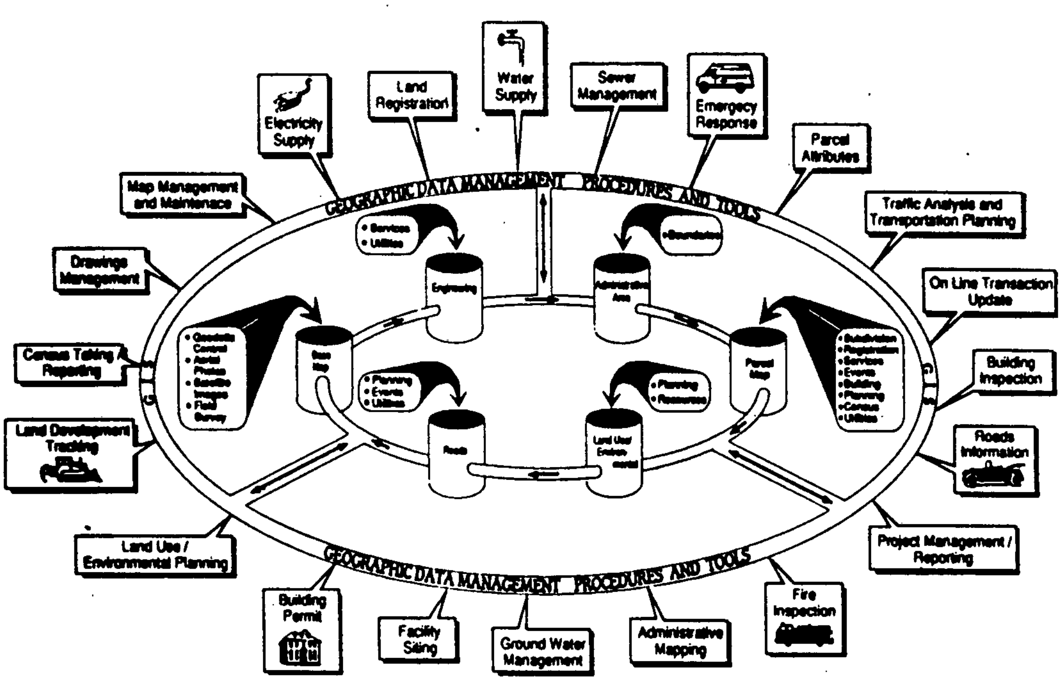

FIGURE 2. Areas of application for a GIS (Allam 1989).

A GIS can be broken down into its components to provide a better definition (modified from Carter 1988):

1) "System" in GIS is the orderly arrangement of components inter-connected and inter-related to perform specific tasks;

2) "Information system" in GIS is the need to organize information so that it is useful when subsequently retrieved, accessed efficiently and updated regularly;

3) "Geographic" in GIS makes this type of information system unique in that it is primarily concerned with spatial phenomena.

These definitions can be divided into four categories; the process-oriented approach, the application approach, the toolbox approach, and the database approach, each of which are seen to have some disadvantages (Cowen 1988). First, the process-oriented approach assumes that several integrated subsystems help convert geographic data into useful information, but this definition is so broad that even an altas could be included. Secondly, the application approach categorizes GISs according to the type of information handled, but this does not distinguish it from other forms of automated geographic data processing. Thirdly, the toolbox approach provides a list of computer-based procedures for handling spatial information, however this is not a viable definition. Finally, the database approach refines the last definition by stressing the interaction of the tools with a database, though this is still not conclusive. Cowen (1988) concludes in his article on the definition of GIS that it can best be described as "a decision support system involving the integration of spatially referenced data in a problem solving environment".

In order to better understand what comprises a GIS, it is perhaps enlightening to look at what a GIS does. "The aim of Land Information Systems (LIS) is to simplify access to information relating to land, and to facilitate the manipulation of data held within the system in order to produce new information, such as relationships between various types of data" (Groom 1988).

What becomes clear from the literature is that GISs are many things to many people, however, some unique features emerge:

1. The ability to create new information by the integration of different layers of information;
2. A problem solving capability and the ability to ask "what if?" questions in a spatial context;
3. The presence of automated linkages between data (non-graphic records) and their location.

Each system will of course have its own characteristics based on its purpose, user, and expertise of persons organizing and managing the GIS. Figure 2 indicates not only the vast array of areas of application for a GIS, but also how many different disciplines can be integrated into a GIS.

1.2.1 GIS VERSUS LIS, WHAT'S IN A NAME?

In an endeavour to try and create a standard in 1981, the Fédération Internationale des Géomètres (FIG) at Montreux,

approved a definition for Land Information Systems (LIS);
"A Land Information System is a tool for legal, administration and economic decision making and an aid for planning and development which consists on the one hand of a database containing spatially referenced land-related data, and on the other hand of procedures and techniques for the systematic collection, updating, processing and distribution of the data. The base of a LIS is a uniform spatial referencing system for the data in the system, which also facilitates the linking of data within the system with other land-related data" (Hamilton and Williamson 1985). The FIG definition includes all other spatially-related information systems, including GIS, under the LIS umbrella. However, Marble (1985) suggests that LIS is a discipline-specific application of the GIS concept. Rhind (1989) criticizes writers for distinguishing between GIS and LIS in terms of scale, saying there is no such dichotomy, as they are synonymous terms. Parker (1988) concurs with Rhind and sites synonyms for GIS from various authors as follows: Geo-base Information Systems, Spatial Information Systems, Geographic Data Systems, Land Information Systems and Multipurpose Cadastre. I **accept the synonymity of the terms and will henceforth refer to them as Geographic Information Systems (GIS)**, thereby following the nomenclature adopted by the University of Cape Town.

1.3 ADVANTAGES OF GIS OVER CONVENTIONAL CARTOGRAPHY (modified from Dangermond 1983)

1) Data are maintained in a physically compact format, i.e. magnetic tape or computer disc, as opposed to numerous maps,

images and colour separations, and files.

2) Data are maintained and extracted at lower cost per unit of data handled than by conventional methods, because a part of a map can be retrieved and updated as opposed to the whole.

3) Data are retrieved with greater speed.

4) Data are readily manipulated, the integration of different types of data is possible and new themes of information can be stored in the database.

5) Graphic and non-graphic data can be merged and manipulated simultaneously.

6) It is possible to analyze change over time more easily and more quickly than via conventional means. Groom (1988), for example, suggests that the "Greenhouse effect" could be monitored, via the encroachment of sea level on a flat low-lying coastal area using a GIS. Gelinas (1985) explains the use of a GIS for land use monitoring in Canada.

7) Output in the form of automated multi-coloured map production, at any scale on any size paper, is possible.

8) Because the data can be accessed, transformed and manipulated rapidly and interactively in a GIS, it can serve as a testbed for studying environmental processes, or for analyzing the results of trends, or anticipating the possible effects of planning decisions.

As opposed to the conventional cartographic means of resource assessment which is static and where any re-evaluation is tedious, the GIS approach is dynamic, and the parameters used in an assessment can be altered and the results known in a comparatively short time. Not only does the computer technique have sophisticated overlay capabilities, but once a "hybrid" map (via intersection or generalization for example) has been produced this becomes a new layer within the database that can be further interrogated. "The full value of digitally stored land data is not evident until two or more sets of information are superimposed and analyzed to determine relationships, and these relationships can then be used as information in their own right. This new information can then be used to answer the 'what if?' questions often asked by scientists and natural resource managers" (Groom 1988).

1.4 DISADVANTAGES OF GIS

1) The high costs and technical problems converting existing geographical records into computerized databases.

2) The large technical and financial overheads necessary to maintain automated files.

3) The high cost of the initial acquisition of the system.

4) The complexity of the system means that trained personnel are required to operate it.

5) It is foreign to most planners and managers.

In order to establish whether or not a GIS is desirable for a particular organization, a cost-benefit analysis must be carried out. In an article in the Journal of Forestry, Devine and Field (1986a) postulate five separate elements of the cost calculation, namely: purchase price, personnel, digitizing, maintenance and support, management, and product distribution. This is balanced by the benefit calculations including error avoidance, information efficiency, analysis capability and exactness of repetition.

1.5 GIS VERSUS CAD, WHAT'S THE DIFFERENCE? (see Figure 3)

Dangermond (1990) lists the following advantages of GIS over CAD:

1) GIS was developed to support information management and the manipulation of large amounts of spatial data, whereas CAD was developed essentially to draw diagrams;

2) GIS software tools are organized around the GIS database to provide multiple users with their own specific "view" of that database;

3) In GIS the relationship between spatial objects is important i.e. their topological relationships (see paragraph 1.6);

4) GIS is more flexible, for example the user can associate a chosen set of symbols with the cartographic objects, based on the attributes in the database, and is therefore not restrained as in a CAD package where the symbology is set;

5) Unlike CAD, a GIS has tools for developing macros and customizing commonly performed procedures.

A GIS actually has the ability to create new information and explore alternative scenarios. Newell (1990) also makes the point that a GIS must be able to store information about the quality of the data, something that a CAD package cannot do.

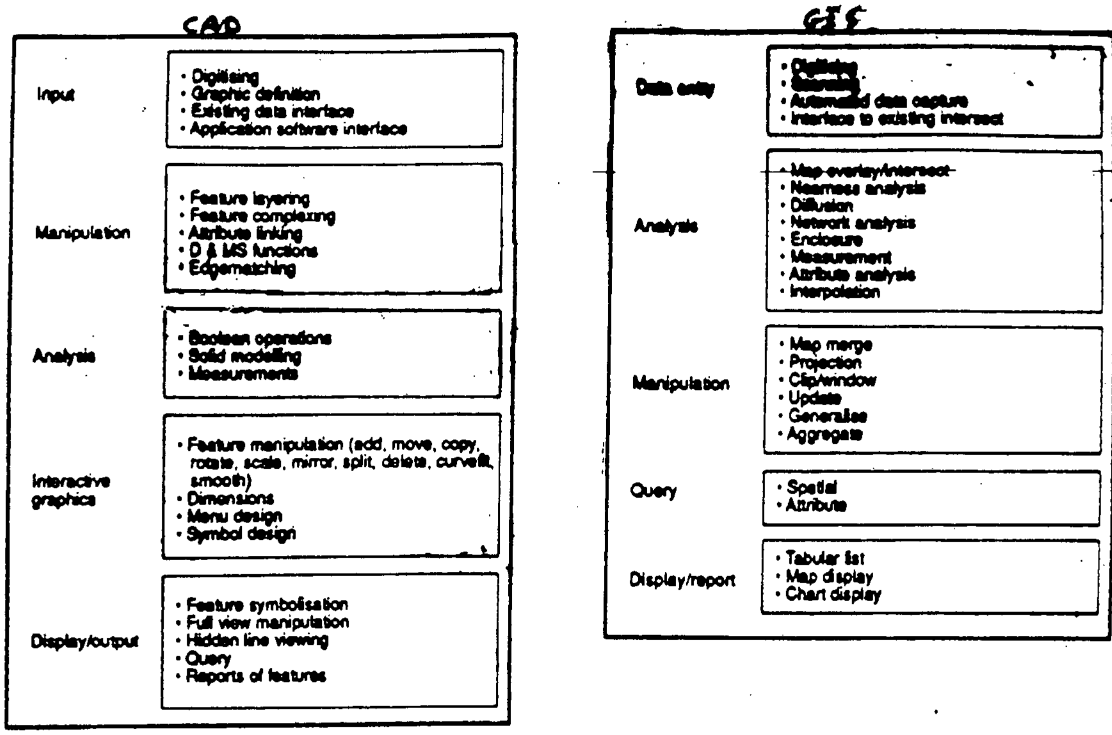

FIGURE 3. A comparison of CAD and GIS software tools.

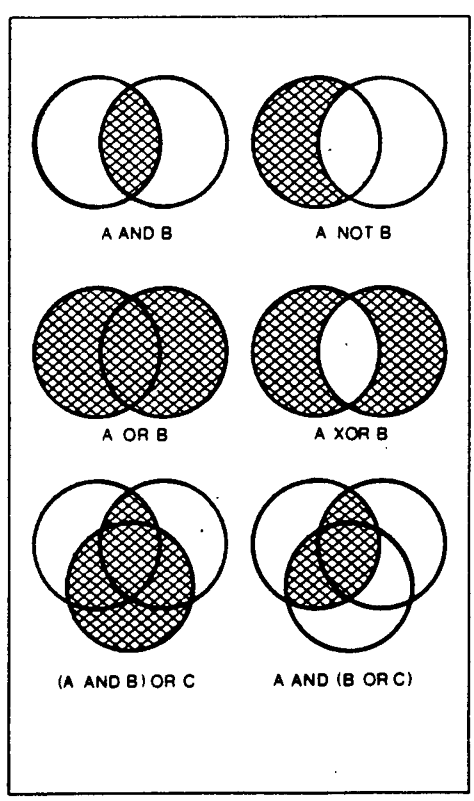

FIGURE 4. Venn diagram showing results of applying Boolean logic to two or more sets (Burroughs 1986).

1.6 GIS SOFTWARE COMPONENTS

In order to use a computer to handle spatial data one needs to impart to it three facts (Parker 1988):

1) the exact locality of each feature in geographical space;

2) a description of each feature;

3) what each feature's spatial relationships are to other features i.e. the topology.

The software necessary to achieve this consists of five main parts, those concerned with the encoding, the management, the retrieval, the manipulation, and the display of spatially referenced data (Smith et al. 1987). There is however, an important sixth component, the user interface, i.e. the means by which the human operator communicates with the system (Guptill 1989).

1.6.1 DATA ENCODING

Within the context of a GIS, each spatial data type, or theme, is referred to as a spatial data layer or data plane. Within each of these spatial data layers there are four possible types of geographic entities which must be encoded: points, lines, surfaces and polygons. Data can be fed directly into the system via tape if it is already in digital form, typed in via the keyboard if it is in numeric form or digitized from an existing paper map.

1.6.2 DATA MANAGEMENT IN GIS

The database management system consists of the combination of the database and the associated software to perform all needed tasks of data entry, storage, retrieval and maintenance.

It is very important to remember that the computer is unable to replicate nature, the real world is too complex. The spatial database is a collection of spatially referenced data that act as a model of reality, just as a map represents a given perspective of the real world.

Data are usually derived from many sources and in many forms, as is the case with the Cape Peninsula GIS. The highest accuracy of any GIS output product can only be as accurate as the least accurate data theme of information involved in the analysis (Walsh et al. 1987). Because GIS data consist of point, line and area data, the "most important issue in designing a GIS is the determination of the appropriate level of spatial and attribute resolution" (Dueker 1979). The prerequisite for effective revision of any geographic database is the observation of all changes in the region, and to recognize these as soon as possible. The responsibility for updating the data should be distributed to those authorities which have the duty to maintain that facility or information (Wilmersdorf 1986).

1.6.2.1 REQUIREMENTS OF DATABASE MANAGEMENT SYSTEM (modified from Simonett 1983)

1) Provide a standardized (uniform) format, and a set of

standards and procedures for recording data.

2) Allow efficient storage and retrieval for all intended data.

3) Provide for data structures that are independent of the programs used to access them. This allows for the revision of the data structure without adversely affecting the programs' ability to access that data.

4) Ensure non-redundancy of the data.

5) Protect the data from accidental loss through hardware failure or human error.

6) Provide ease of system use.

7) Provide economy of system use.

1.6.3 DATA RETRIEVAL

A GIS may be required to locate any of the following; a single feature, a set of defined features, an undefined feature or set of features (browse), features based on defined relationships within the data set, a set of features where the criteria are within another data set, and all features within a given class. For an example from the Cape Peninsula see ch4 p78.

1.6.4 DATA MANIPULATION

Going beyond simple data retrieval, the rules of Boolean logic can be applied to the dataset, to create subsets (see Figure 4).

The following manipulative capabilities are common to most GISs: (Smith et al. 1987)

a) spatial analyses, including procedures such as polygon overlay, connectivity, and neighbourhood statistics (slope, aspect, profile);

b) measurement of lines and arc lengths, of point to point distances, of perimeters, areas and volumes;

c) statistical analysis including histograms or frequency counts, regression, correlation and cross-tabulation, file generation for interface with a standard statistical package;

d) report generation.

1.6.5 DATA DISPLAY

A GIS should include software for the display of both graphic and non-graphic data in the form of maps, graphs and tables. It is also critical that this output can be reproduced in hardcopy.

1.6.6 USER INTERFACE

It is important that the system be as user friendly as possible, so that non-computer literate persons can access and query the database. However, only competent users should be allowed to modify the core data. This is normally assured by providing different levels of access to different classes of user.

1.7 GIS DATA STRUCTURE

Geographic data is generally stored in a GIS with different themes on different levels or layers (see Figure 5). This is a similar concept to the way in which cartographers have a set of colour separations which together make up a composite map.

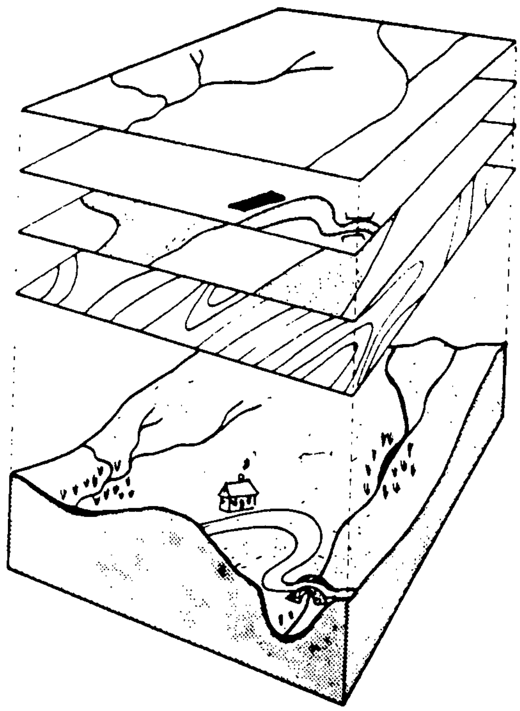

FIGURE 5. Concept of storing different data from the real world on different levels in the database (Burroughs 1986).

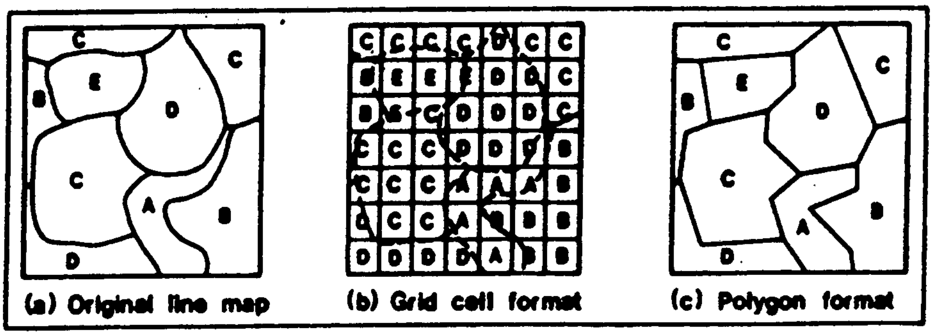

FIGURE 6. Comparison of the grid and polygon approach of data representation (Walsh 1988).

There are two basic approaches to storing geographical data on a computer, the raster (grid) or the vector (polygon) structure.
1) The raster approach involves the use of a grid framework for holding the geographic data. Each grid square is inherently associated with the co-ordinate system and contains information on the presence or absence of a particular attribute.
2) The vector approach involves a string of co-ordinates defining the storage of points, lines or areas. The Siemens system, used for this study, utilizes this vector approach.

The vector structure is philosophically more pleasing as it is a more natural representation (the original integrity of the maps is maintained), and is more economical in data storage. However, it has two shortcomings, firstly when we look at the real world one sees many phenomena which have no sharp boundaries. When we impose lines (vectors) on the image to bound such phenomena we introduce "a highly precise interpretative element into the data which is misleading" (Maffini 1987). Also the cell structure of the raster systems makes data manipulation much easier, e.g. the intersection of themes (levels) is much quicker. The advent of remote sensed data as an input to GIS has resulted in a swing towards raster-based systems, because raw satellite data is in the grid cell format. On the other hand, the Dale County Lands Record Project brought together local, federal and state agencies, and the University of Wisconsin, to demonstrate that the automation of land records is not only feasible but advantageous. Their experience indicated that a vector-based data structure with topological information provided for the broadest range of applications (Ventura et al. 1988).

However it has been agreed that it is essential to have an information system design that can accommodate both cell and polygon inputs. According to Brooner "neither alone is sufficient and we are presented with the clear need to evolve a system that can bridge between the two traditional concepts" (Brooner 1981).

1.7.1 DATABASE STRUCTURE

Another factor that influences the speed with which a query of the non-graphic data can be answered, is the organisation of the database. In general the structure of the database can be of a hierachical, network or relational nature. Hierachical or tree structure is the simpleist (only allowing for one-to-one or one-to-many relationships) but can result in data redundancy and long search times. The network structure avoids the redundancy and allows for many-to-many relationships and the relational structure where data are placed in two-dimensional tables is the most flexible of all. The structure used by the SIEMENS database SICAD is relational.

1.8 DATA QUALITY / ERRORS

Apart from wrong data caused by faulty surveys in the field or mistakes made during input into the system, statistical error exists in geographical data and can be compounded during the overlay process (see Table 1).

Table 1. Sources of possible error in GIS (Burroughs 1986).

I. *Obvious sources of error*
1. Age of data
2. Areal coverage – partial or complete
3. Map scale
4. Density of observations
5. Relevance
6. Format
7. Accessibility
8. Cost

II. *Errors resulting from natural variations or from original measurements*
9. Positional accuracy
10. Accuracy of content – qualitative and quantitative
11. Sources of variation in data:
    data entry or output faults
    observer bias
    natural variation

III. *Errors arising through processing*
12. Numerical errors in the computer:
    the limitations of computer representations of numbers
13. Faults arising through topological analyses:
    misuse of logic
    problems associated with map overlay
14. Classification and generalization problems;
    methodology
    class interval definition
    interpolation

1.8.1 ERRORS IN THE DATA

Boundaries drawn on thematic maps eg roads, should not be regarded as absolute, but as having an associated error or confidence interval (Burroughs 1986).

Natural factors vary along a continuum, and when we impose lines to represent boundaries between classes in this continuum we introduce misleading information. These maps are drawn to meet two kinds of accuracy standards (Bailey 1988). One, the allowable error in positioning boundary lines (horizontal accuracy) and two, the degree of uniformity or purity of the map. This should be stated with the source map, so that a measure of their reliability can be incorporated into the GIS.

In this study maps were hand digitized by an operator into SICAD and thus their accuracy also relies on the diligence with which the operator traced the boundaries.

1.8.2 ERRORS INDUCED BY OVERLAYING MAPS

Inaccuracies inherent in this procedure are significant and have received little attention according to Bailey (1988). Although the use of a computer system can minimize the error produced by overlaying maps with different projections, by transforming them all to a common projection, errors inherent in the source maps may become compounded. Another major component of this error is the enlargement or reduction of maps so that they are all at the same scale. It is important to bear in mind the scale of the original map as "unfortunately there is a tendency to see spatial data handling as scale free; despite the ease with which products can be generated at any scale from the same database, scale of the input document is a major determinant of the accuracy of those products" (Goodchild 1988).

The assembly of maps by manual means into an overlay tends to reduce horizontal errors. The compiler can represent parallel lines separated by a few millimetres by a single line, using his knowledge of correlation among the particular factors in question, factor map reliability and so on. In this manner "sliver" error is reduced. Because this subjective skill is not replicated by the computer system the intersection of two themes can produce numerous small polygons of dubious significance.

Errors inherent in this procedure must be realized and the compiler of overlay maps should attempt to estimate their accuracy and present this in the legend or accompanying text. Possibly source maps could be ranked according to their relative accuracy and the the lower ranking maps could be "force fitted" to those with a higher ranking. An example of the intersection of areas using data from the Cape Peninsula GIS and the associated errors is presented in Chapter 4 p78 and Figure 15.

1.9 APPLICATION OF GIS FOR LAND RESOURCE MANAGEMENT

The demand for GIS technology as a tool for land resource management is increasing. Because of their complexity, analyses concerned with resource use often require vast amount of data, much of it geographic in nature. These data must be analyzed, inter-relationships must be understood, and processes both temporal and spatial must be examined. Effective resource management implies a capability for evaluating alternative suggestions, plans and strategies for the use of resources. GIS can be a tool toward this end (Bacon 1984).

"Industries which rely on natural resources (such as forestry, fisheries, wild flower protection for tourists etc.) will be able to analyze and understand the geographical distribution of resources in more depth by correlating it with other land attributes; for example, wild flower distribution combined with soil type, climate, various types of pollution and the use of fertilizers etc." (Groom 1988).

One indication of the commitment of conservation bodies to GIS is that the Nature Conservancy Council in the United Kingdom has recently committed half a million pounds for the purchase of a GIS, to assist it in its work (Dixon 1989). Here in South Africa, the Natal Parks Board has been involved with GIS since 1985 (Colvin 1990). Thus it is appropriate that here on the Cape Peninsula, where the management of the city of Cape Town and its surrounding natural resources is critical, that an experimental GIS be established.

CHAPTER 2

REMOTE SENSING AS AN INPUT TO GEOGRAPHIC INFORMATION SYSTEMS

2.1 WHY IS THERE THE NEED?

"Remote sensing on its own is not the answer to many resource management problems" (Johannsen and Barney 1981). In the early days of environmental remote sensing there was a tendency to use satellite imagery in isolation from other sources of data. During the late 1970s, map data was increasingly used for the selection of ground control points, geographical determination of training sites (areas selected as typical of a landcover class) and the detection of landcover change. Slowly other map information has come to be used for the purposes of image segmentation (dividing the image into sections prior to processing), and to assist in image classification. This trend, together with the fact that remote sensing systems produce large volumes of spatial data, has led to the need for an efficient geographical data handling and processing system that will transform these data into useable information for resource managers. Such a tool for handling spatial data is the GIS (Simonett 1983).

According to Brooner and Nichols, by 1972 remote sensing was already technically advanced to the point of being useful for obtaining environmental resource data. Bryant (1981) goes a step further stating that "combining the monitoring potential of satellite systems with the automated geo-referencing capabilities of GIS has become not only technically feasible but promises soon to be economically viable". A system is needed to integrate data derived through remote sensing techniques with multiple sources of related data, and to manipulate, store, retrieve, display and update these data. The potential for the integration of remotely sensed data into a GIS was first pointed out by Garrison et al. (1965), but little of the predicted interaction developed. More recently articles by Brooner (1981), Foody and Wood (1987) and Young and Green (1987) have further explored the concept. cartography, remote sensing and GIS are seen as three separate yet interdependent disciplines, see Figure 7.

2.2 ADVANTAGES OF INTEGRATION (modified from Likens 1981)

Advantages of integrating remotely sensed data with other data sets in the context of a GIS, can include:

1) The potential improvements in the spatial resolution of the database.

2) The identification of land cover features that are not included in other layers.

3) The use of remote sensing imagery on a periodic basis to provide updates, i.e. monitoring temporal change. Often remote sensing is the most cost-effective source to update a GIS (Goodenough 1988).

4) The potential for geographic area expansion of the data base using signature extension techniques, to cover areas not previously mapped via conventional means.

5) The use of data from the GIS to guide the selection of training areas for image processing.

"The synergism between 1) remote sensing data for updating GIS information and 2) the use of GIS for improving the information extraction potential of multisensor data; is a major advantage of merging these two powerful technologies" (Estes 1985a).

2.3 LINKING REMOTE SENSING SYSTEMS AND GIS

GIS has been demonstrated to be a powerful tool for the management and analysis of spatial data, likewise with remote sensing systems for the collection and classification of such data. However, nearly all GISs use maps as their primary source of spatial data. Maps are usually digitized and then entered into the master spatial database of the GIS. Although many maps are derived from air photography or other remote sensing devices, until recently little use has been made of digital remotely sensed data.

2.3.1 REMOTE SENSING AS AN INPUT INTO GIS

The question of appropriate spatial scale and resolution has been debated for years. The GIS operator considers the accurate digitally represented, polygon, point or network database (i.e. vector format) to be the raw data which forms the starting point for subsequent work. To the remote sensing specialist on the other hand, the raster format, digital tape represents the raw data, and the classified polygonal output is considered to be the highly refined product.

From the GIS standpoint two major problems exist concerning the data from many remote sensing systems (Knapp and Rider 1979):

1) the accuracy of the classification scheme and the

appropriateness of the categories of classified data.

2) the positional accuracy i.e. geometric correctness, image quality and resolution.

In many cases the combination of these errors has led to the rejection of the remotely sensed data for operational use in GIS. Robinson Baker (1988) in his paper "Remote sensing: the unheralded component of GIS" concludes that the launch of the SPOT satellite with its resolution of 20m in the multispectral mode which allows the identification of cultural and physical features at a level for which many GISs are designed, should herald the re-introduction of digital imagery not as remote sensing but as the spatially orientated digital databases. The challenge according to Logan and Bryant (1987) is "to make GIS equally compatible with vector and raster technologies because the present and future information requirements demand the integration of all data regardless of format".

2.3.2 GIS INPUT INTO REMOTE SENSING SYSTEMS

According to Simonett (1983), this is seen as one of the greatest oversights by those attempting to promote remote sensing input into GIS. The flow of data need not be uni-directional, and in fact the flow of data from GIS to remote sensing systems is highly desirable. At present many remote sensing systems do not give real attention to "ancillary data" e.g. geology, aspect etc. in the development of their classification schemes. McLeod and Logan (1980) point out that "substantial improvements can be made in classification accuracy if ancillary data (terrain, soils, previously determined land cover, etc.) are used in the classification process". Hutchinson (1982) describes three approaches to the use of ancillary data for remote sensing by incorporating those data either before, during or after the classification.

Using this flow of data from GIS to a remote sensing system will in turn increase the likelihood of the remotely sensed classified data being more acceptable to the GIS.

To this end Jackson and Mason (1986) added the prefix "Integrated" to GIS to emphasize the mixing of point, line and polygon data (vector) with raster spatial data (from a remote sensor), and the incorporation of them within one computational environment. According to Curran (1984) this is no easy task and perhaps the best known method is the visual subdivision of the remotely sensed image.

Remote sensing data is being interfaced (experimentally and operationally) with existing GISs. Where automated image processing is not available, the image is photo-interpreted, land cover information derived, classified, encoded and entered into the GIS. Where automation is feasible, the digital tapes are interfaced directly with the GIS.

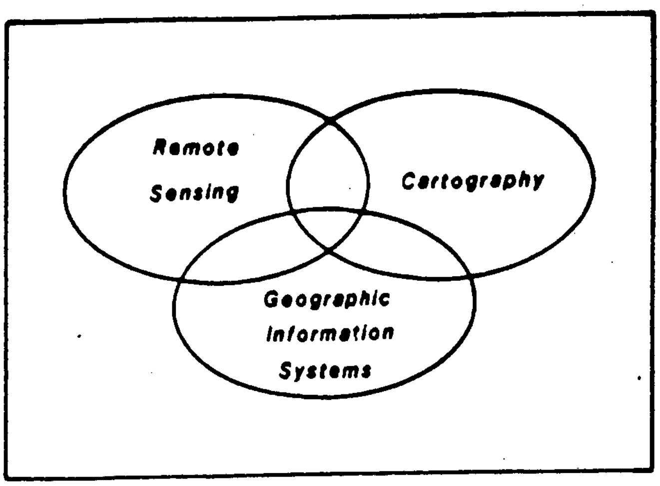

FIGURE 7. Relationship between GIS, Remote Sensing and Cartography (Fisher and Lindenberg 1989).

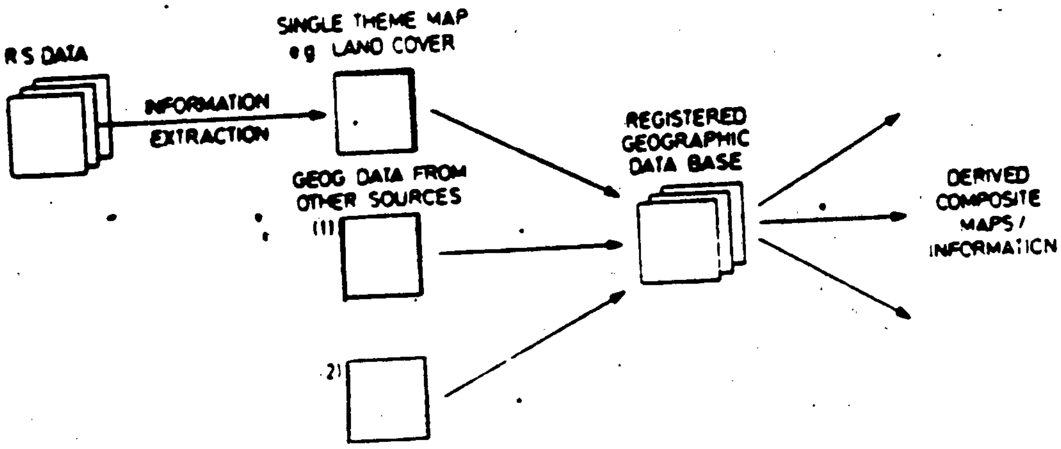

FIGURE 8. Inter-relationship between GIS and remote sensing in this project (after Townshend and Justice 1981).

2.4 EXAMPLES OF INTEGRATING REMOTELY SENSED DATA INTO A GIS

1) Sturdevant (1981) incorporated soil and slope as ancilliary data, in determining land use from remote sensing.

2) Wilson (1986) describes the large GIS for San Francisco Bay area, called BASIS, which necessitated a massive data collection task, warranting the use of remote sensing.

3) Graetz <u>et al.</u> (1986) describes LIBRIS, a GIS developed to integrate LANDSAT spectral data with other relevant spatial data sets (tenure, rangeland type, elevation and slope) for rangeland assessment and monitoring in Australia. LIBRIS stores LANDSAT data from different years enabling detection of change.

4) Smith and Blackwell (1980) integrated conventional maps, LANDSAT imagery and tabular data in their own information system (IBRIS). The user being able to manipulate data from several sources as all data is referenced to a common geographic base.

5) Cibula and Nyquist (1987) in attempting to refine the classification of LANDSAT data for vegetation / landcover used a GIS approach, incorporating topography and watershed boundaries (inferring precipitation and temperature).

In conclusion, "remote sensing forms a natural part of any GIS used as a tool for natural resource assessment" (Hogg and Stuart 1987). However, it only provides part of the dataset with the major portion being derived from data accumulated over years of scientific research and stored in a conventional format.

2.5 INTEGRATION OF REMOTE SENSING INTO THE CAPE PENINSULA GIS

In a study by Computer Sciences Corporation, Shelton and Estes (1981), identified four techniques of progressive refinement for interfacing remote sensing with GIS:

1) Photo-interpretation of the remote sensing image and manual entry of the resulting categorized data into a GIS;

2) Land cover digital classification, geometric correction and production of hardcopy thematic maps; manual entry of resulting categorized data into a GIS or digitization of thematic maps;

3) Land cover digital classification and production of digital categorized images, geometric correction, registration and automatic entry into an automated GIS;

4) Geometric correction, registration of raw remotely sensed data, automatic entry into an automated GIS.

Because the Cape Peninsula GIS system is only capable of handling vector data at present, the SPOT imagery was first analyzed and reflectance tone boundaries drawn. These tones represent differing landcover types (see ch 3 p47). These are grouped into classes and a thematic map created, which is then digitized into the database. This puts it into category 2 of the above, and is illustrated in diagrammatic form in Figure 8.

CHAPTER 3

REMOTE SENSING OF VEGETATION

3.1 VEGETATION MAPPING

In vegetation work the aim of mapping is to simplify the detailed community information on the ground into manageable categories, or to classify ground cover types on certain selected criteria. The primary objective of image interpretation is the reduction of a large number of observations (or data) to a few useful conclusions or features (Piper 1989). In vegetation surveys the view taken by Jarman et al. (1983), is that the properties of the vegetation should be the primary criteria for its classification (i.e. physiognomy, structure and dominance, floristic composition and successional relationship). It is also necessary that nationally acceptable and applicable classification systems should be adopted for describing extant vegetation or land cover types e.g. the structural characterization of the vegetation in the Fynbos Biome (Campbell et al. 1981). Also Bossi (1983) found during the mapping of the vegetation of the Fynbos Biome that Acocks's Veld Types did not satisfactorily represent the range of vegetation. The whole of the Cape Peninsula was simply classified as Machia (or fynbos) and no attempt was made to delimit the extent of the natural vegetation remaining.

3.2 THE IMPORTANCE OF MONITORING VEGETATION

"Current awareness by planners and land managers of the important role that vegetation plays in monitoring a stable environment has created a demand for vegetation mapping and monitoring at various scales" (Jarman <u>et al.</u> 1983). "Natural vegetation not only represents an important resource but also plays a vital role in maintenance of existing ecosystems. It acts as a protective cover regulating change in hydrologic, climatic and soil conditions" (Curtis 1978).

3.3 REMOTE SENSING IN ENVIRONMENTAL STUDIES

The analysis of remotely sensed imagery is applicable to environmental studies for four basic reasons (modified from Simonett 1983).

1) It presents large volumes of the earth's surface from a perspective, and in a format, that facilitates the study of objects and relationships. The whole of the Cape Peninsula was presented at 1:100 000 scale, free from distortion, by SPOT imagery.

2) Certain types of imagery, including SPOT, can provide a three-dimensional view of the terrain i.e. stereoscopic pairs of images.

3) Characteristics of the landcover not visible to the human eye can be transformed into image format e.g. infrared reflectance.

4) Remotely sensed imagery provides the observer with a permanent representation of objects, phenomena and relationships as they exist at a given time, thereby facilitating monitoring. This is particularly important today because of global issues such as the greenhouse effect etc. For an example of the monitoring capability of SPOT imagery see ch3 p55.

3.4 FUNDAMENTALS OF REMOTE SENSING FOR VEGETATION IDENTIFICATION

"All bodies at the earth's surface with a temperature above absolute zero generate and emit energy in radiant form. Each type of surface emits a characteristic array of radiation waves identifiable in terms of their wavelengths and intensities. Thus a characteristic curve or spectral signature may be obtained by plotting the intensities of the emitted radiation against the appropriate wavelength in the electromagnetic spectrum" (Curtis 1978).

In remote sensing the electromagnetic energy emanating from an object is measured. This spectral signature or unique amount of energy is used to identify that object, see Figure 9.

These digital data are not in the familiar format of points, lines and areas (vector format) of our conventional maps, but are coded in pixel-cells in a two-dimensional matrix (raster format) that merely contains a number indicating the strength of reflected electromagnetic radiation in a given band. These digital images only have real value if they can be linked to "ground truthing". In order to do this the image has to be located accurately with respect to a recognized geodetic grid. Therefore the need for a linkage between remote sensing, earthbound survey and cartography arose, and this has been made possible through GIS (Burrough 1986). In vegetation studies information is conveyed to the remote sensor by the degree of absorption, reflection and transmission of light (energy) by the vegetation cover which is primarily a consequence of the physiology and pigment chemistry of the leaves (Curran 1980). However, density, height and vigour of the vegetation, the percentage composition of the species, the soil type, solar angle, climatic and environmental conditions also have an effect on the amount of reflected energy reaching the sensor.

3.4.1 RELATIONSHIP BETWEEN VEGETATION AND REFLECTANCE

Lane (1980) found canopy cover to be the single most important factor in relating spectral reflectance to vegetation factors. However, Jarman et al. (1981) showed that the height of the dominant strata as well as canopy cover were important in distinguishing plant communities at a scale of 1:50 000 in the Langebaan area. Vegetation communities are usually identified by dominant species. Thus stands of dense mixed Fynbos and open shrubs are floristically distinct, but because of their similar reflectance characteristic were not separable (Ripp 1978).

However, a vegetation classification system such as Taylor's 1969 for the Cape of Good Hope Nature Reserve, which is related to leaf surface, and percentage canopy cover, correlates well with spectral data. Thus "effective use of remote sensing techniques for vegetation mapping and monitoring is a function of scale, resolution, season of imagery, kind of vegetation, sensor and spectral sensitivity, processing of the remote sensing product, and speed and precision of the transfer of information to a map product" (Jarman et al. 1983).

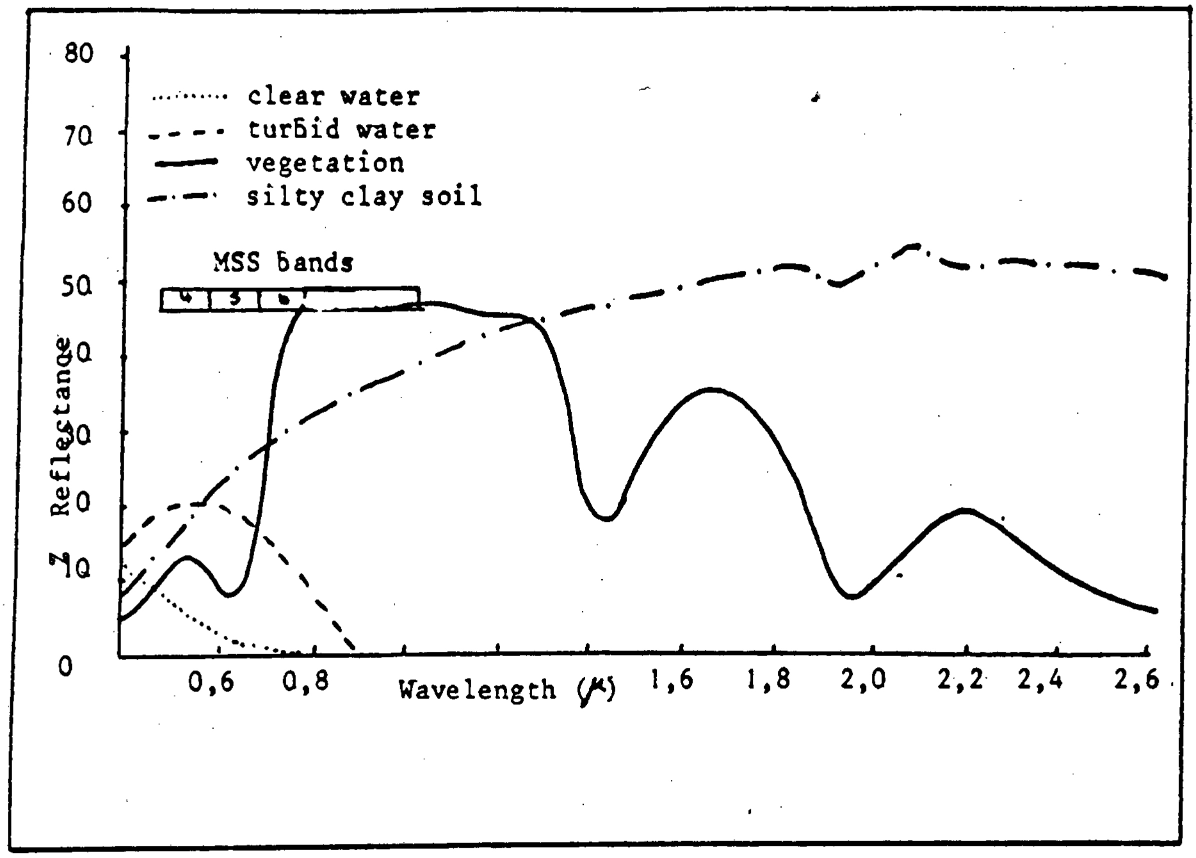

FIGURE 9. GENERALIZED REFLECTANCE CURVES (Jarman 1981)

3.5 SCALE OF STUDY

Vegetation surveys have been grouped into five major classes according to scale by Jarman et al. (1983), the appropriate scale of imagery is given in brackets.

1. General and general reconnaissance (1:500 000 - 1:1 000 000)
2. Reconnaissance (1:40 000 - 1:500 000)
3. Semi-detailed (1:5000 - 1:20 000)
4. Detailed (1:5000 or larger)
5. Ultra-detailed (1:500 or larger)

There is a relationship between the scale of the phenomena to be classified and the spatial resolution of the imagery - classification accuracy does not necessarily improve with spatial resolution (e.g. at low resolution individual trees are not distinguishable, so general reflectance of the canopy, undergrowth and soil is obtained. At greater resolution these elements separate out and what was homogenous now becomes heterogeneous (Mather 1989). Because the SPOT image prints are generally available at a scale of 1:100 000, and the pixel resolution is 20m for the false colour image, and because the standard topographical maps available from the Department of Surveys and Mapping are at 1:50 000, the scale class of this project is essentially "reconnaisance".

3.6 SEASON AND TIME OF IMAGERY

According to Curran (1980), as vegetation senesces the infrared reflectance remains constant but the breakdown in plant pigment causes a rise in the blue and red reflectance. Remote sensing products should usually be made at the time of maximum vegetal contrast. This time of contrast varies depending on the climate and structure of the vegetation. In the northern Cape Gubb (1989) found that summer imagery was superior in most respects, giving maximum contrast between and within classes. Bossi (1983) chose the summer image when working in the Southwestern Cape to allow for maximum discrimination between fynbos vegetation and agricultural land. Ripp (1978) also used a summer image but speculated that better results could be obtained by using October-November or March-May imagery. Zietsman's (1982) reasons for using summer imagery were there was less shadow as a result of higher sun angle and greater contrast in the imagery. Images used in this study are dated 12 December 1987 and 27 September 1989. Both images were taken at similar times of day, 8.44 and 8.48am respectively. The 1989 imagery, because it was taken in spring, exhibits considerably more topographically induced shadow than the 1987 summer image.

3.7 ADVANTAGES OF SATELLITE IMAGERY OVER AERIAL PHOTOGRAPHY (modified from Szekielda 1986)

1) The imagery can be rendered virtually distortion free unlike aerial photography and it covers a greater area on a single image.
2) A constant angle of illumination provides uniform presentation of features.
3) Repetitive imaging allows seasonal contrast and thus monitoring can be carried out.

3.7.1 ADVANTAGES OF SPOT IMAGERY OVER ITS PREDECESSORS

(see Appendix 5 for SPOT specifications)

1) Higher resolution than Landsat: For example landcover classes could be better delineated on the SPOT imagery by visual interpretation.

2) High geometric accuracy: Rough calculations on different parts of the image were within 50m of the digitized lines on the landuse map. This corresponds to 1mm on 1 : 50 000 map (Polton & Brown 1989).

3) Temporal studies are enhanced because the satellite cycle is 21 days, and if necessary the steerable mirrors on the satellite can be tilted to produce off-nadir views of the same area on subsequent paths, thus reducing the cycle.

According to Szekielda (1986) this latter capability of revisit flexibility allows for:

- Monitoring phenomena which vary rapidly over time.
- Improving the possibility of obtaining data timeously.
- Improving the rate of coverage by minimizing the effects of the weather.

Remote sensing and aerial photography should be seen as complementary, not competing sources of data, and always should be conducted with "ground truth" programmes.

3.8 REGISTRATION OF THE IMAGERY

Using the SIEMENS System, an affine transformation was carried out on the print. The errors incurred are within the order of 60 metres. This was considered acceptable in the light of the 20m pixel size of the imagery and the accepted error of up to 20m within the database itself.

The EASI-PACE image processing system at the Division of Earth, Marine and Atmospheric Science and Technology (EMA), Stellenbosch, uses a fifth polynomial to calculate and compensates for distortion in the digital data. Figures of the order of four pixels distortion across the image were obtained using 16 ground control points from the 1: 50 000 topographical map. A comparison of this result with those from the Siemens system both fell within an acceptable limit for this study. When digitizing control points from a map, it is impossible to get 100% accuracy due to paper stretch, parallax error, human error, etc.

3.9 VISUAL INTERPRETATION OF THE IMAGE

3.9.1 WHY ONLY VISUAL?

Van der Westhuizen (1985) found that in mapping the Fynbos Biome, visual interpretation techniques proved to be more successful than the use of computer digital image processing. Gubb's (1989) study supported these findings. Bossi's (1983) computer generated maps were also not as useful as originally hoped. This was because the computer generated categories did not always agree with vegetation classes as defined by botanists. The computer produces categories by classifying only the spectral reflectances of the earth's surface, whereas the vegetation categories obtained through manual interpretation are derived from a combination of information such as geology, topography and field experience of the plant community distribution, in addition to the spectral reflectance.

Westfall (1986) identified the following digital image processing problems for the identification and mapping of natural vegetation - rugged topography, heterogeneity of vegetation stands with subsequent problems of selecting typical training sites of sufficient size for the extraction of spectral signatures, and the interference of soil reflectance caused by incomplete canopy cover.

It was thus decided that although enhancement techniques would be utilized, all classification of the image would be done manually.

3.9.2 WHAT IS IT?

Visual interpretation is the combination of mental acuity and visual perception using the prominent features of scale, size, shadow, tone, texture, topographic location and changes to previous imagery (Bullard and Lakin 1981). The human eye is an extremely sophisticated remote sensing system. A general rule of thumb, taken from the Manual of Remote Sensing (Simonett 1983), is that it takes three resolution cells along the side of an object to detect it and five to identify it. This sets a lower limit of a hectare on the identification of features from SPOT.

3.9.3 METHODS AND RESULTS

Interpretation of the imagery (see Figure 10) based on colour alone reveals four major colour tones (blue, red, white and black), with a range of hues. Table 2 indicates this first level of classification.

Table 2: Interpretation of major SPOT colour tones

COLOUR TONE	CLASS	FEATURE
Black	water shadow	dams seepage
White	sand bare ground cloud	beach/dune
Blue	urban vegetation (low density)	industrial residential fynbos types
Red	vegetation (high density)	cultivated land plantations parkland indigenous alien

Land cover classes have been recognized and these boundaries digitized for incorporation into the GIS as a thematic layer (see Figure 11). Twenty such classes have been delimited (see Tables 3 and 4), using not only the colour but also the features described in paragraph 3.9.2. Some of the classes comprise combinations of reflectance tones e.g. the suburban class is a combination of blue (urban) and pink (parkland). This subjective type of interpretation is virtually impossible to do by image processing.

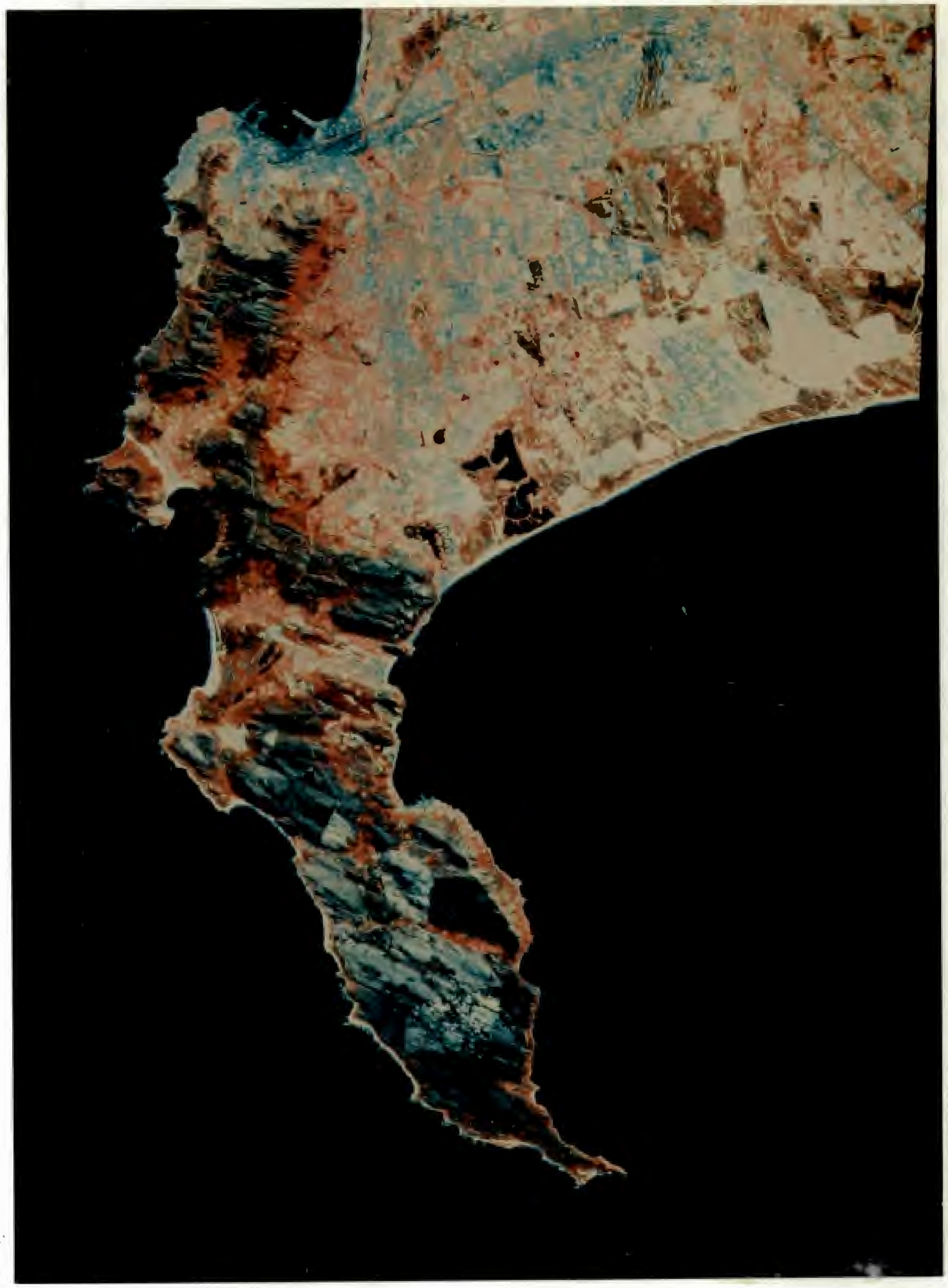

FIGURE 10. SPOT IMAGE OF CAPE PENINSULA

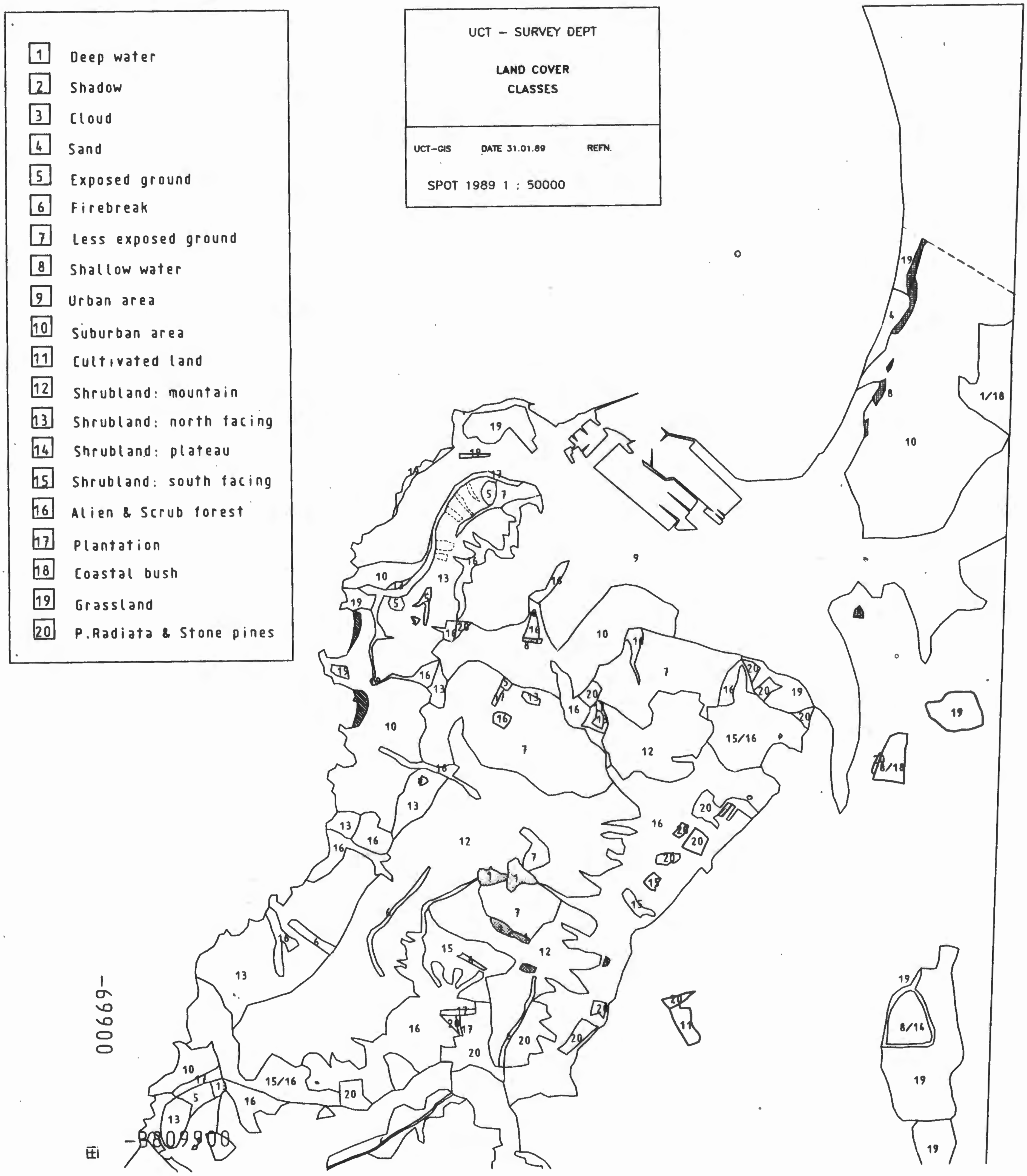

FIGURE 11. LAND COVER BOUNDARIES DERIVED FROM SPOT IMAGERY FOR THE NORTHERN PENINSULA

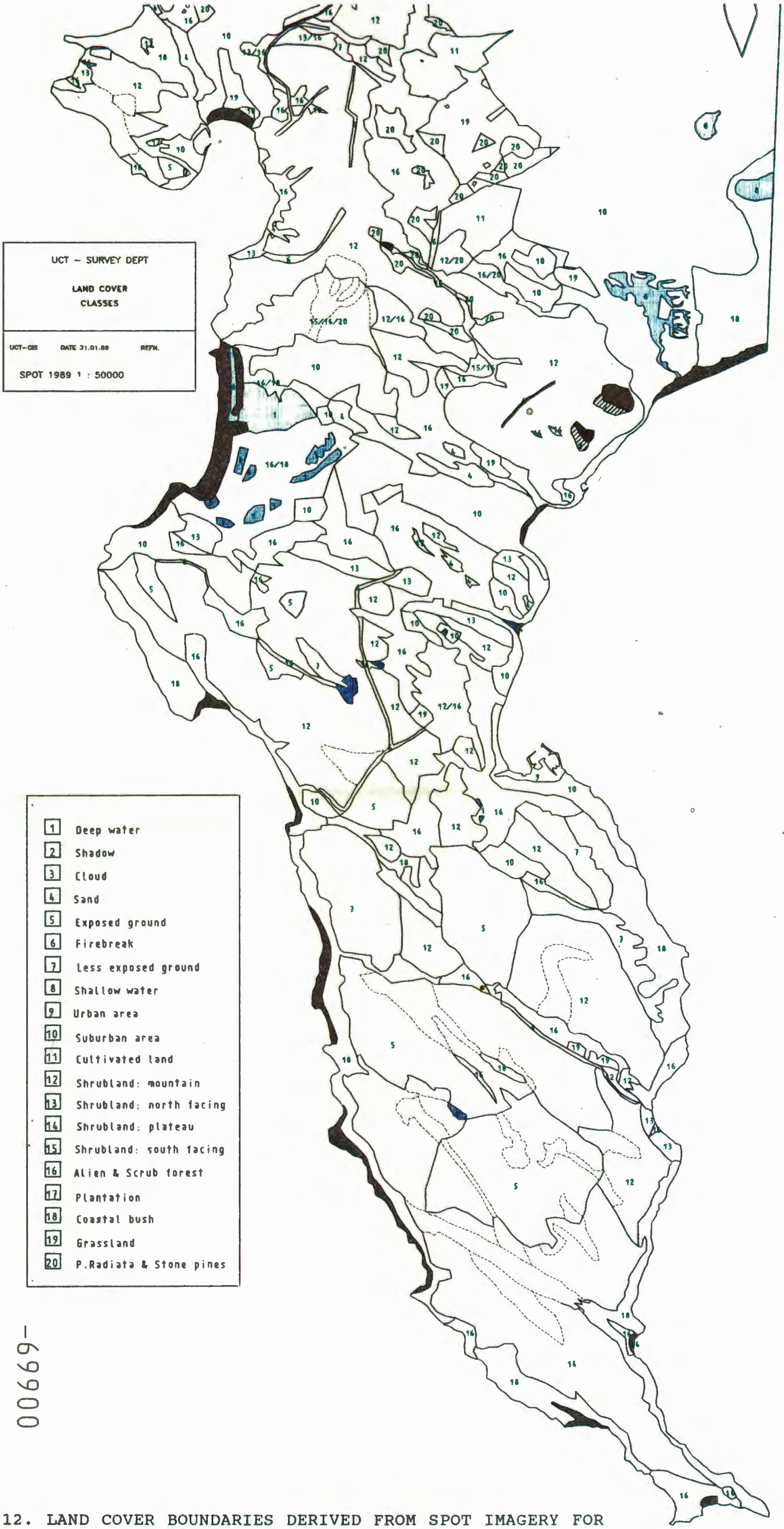

FIGURE 12. LAND COVER BOUNDARIES DERIVED FROM SPOT IMAGERY FOR THE SOUTHERN PENINSULA

TABLE 3. SPOT LAND COVER CLASSES

COLOUR MAJOR	COLOUR BLEND	LAND COVER TYPE	ASSOCIATED FEATURES SHAPE	ASSOCIATED FEATURES TEXTURE	ASSOCIATED FEATURES CONTEXT	VEGETATION HEIGHT (cms)	VEGETATION %COVER	CLASS
Black		Deep water (ocean,dam)	smooth irregular defined	smooth	locality: -sea level -catchment	n/a	n/a	1
		Shadow	ribbon	smooth	association: -clouds -topography	unknown	unknown	2
White		Cloud	irregular	smooth	association: shadow	unknown	unknown	3
		Sand (beach,dune quarry)	defined	smooth	locality: -seashore	nil	nil	4
	Grey/white	Exposed ground (burn,rock)	irregular	mottled	contrast surrounds	0-25	0-5	5
		Firebreak	linear	smooth	management boundary	0-25	0-5	6
	Grey	Less exposed ground	irregular	mottled	locality: -former burn	0-25	5-10	7
Blue		Shallow water (vlei)	smooth irregular defined	homogeneous	locality: -drainage basin	n/a	n/a	8
	Dark blue	Urban area	regular defined	grid pattern	locality: -flat land	varied	0-5	9
	Blue/pink	Suburban	regular defined	grid pattern	metro+open space	varied	5-25	10
	Light Blue/grey	Cultivated Land	defined semi-regular	slightly mottled	locality: -flat/ undulating managed harvested	varied	0-50	11
	Blue/green + minor red	Shrubland: mountain	irregular ill -defined	mottled	association: -topography -high alt -shadow -drainage	25-200	30-60	12
	Blue/green + minor grey	Shrubland: N slopes	irregular ill -defined	mottled	association: -aspect, dry -slope	25-100	25-50	13
	Blue/green + minor black	Shrubland: plateau	irregular ill -defined	mottled	association: -lowland marshes	25-100	50-75	14
	Blue/brown	Shrubland: S slope	irregular ill -defined	mottled	association: -aspect -slope -shadow	100-200	50-75	15

TABLE 4. SPOT LAND COVER CLASSES (continued)

COLOUR		LAND COVER	ASSOCIATED FEATURES			VEGETATION		CLASS
MAJOR	BLEND	TYPE	SHAPE	TEXTURE	CONTEXT	HEIGHT (cms)	%COVER	
Red		Vegetation: alien or scrub forest	irregular defined	homogeneous	locality: -slope -ravine	200-1000	75-100	16
		Vegetation: plantation	regular defined	homogeneous	managed harvested	200-1000	50-100	17
	Orange/red	Coastal bush	irregular ribbon	slightly mottled	locality: -coastal	100-200	50-75	18
	Pink	Parkland (golfcourses sportsfields pastures)	defined	homogeneous	locality: -flat -lowlying	0-25	50-75	19
	Brown	Plantations of -P.Radiata -P.Pinea	smooth regular defined	homogeneous	managed harvested	200-1000	50-100	20

Natural vegetation generally accounted for a small percentage of the spectral reflectance owing to the low projected canopy cover. There were some noticeable correlation between broad sub-divisions on image and soil, geology and terrain morphology in the field e.g. Shrubland: mountain classes are closely related to Table Mountain Sandstone. However, the correlation between geology and vegetation was found to be far from perfect, as according to Campbell(1985) fynbos can occur on many geological formations throughout the biome provided that the rainfall is at least above 600mm and non-fynbos can occur on sandstone provided that the rainfall is at least below 400mm.

Further differentiation of "dense vegetation" (red reflectance) is visually difficult to make by "eye balling" only, however knowledge from "ground truthing" readily provides sub-categories. Thus it was not possible to distinguish between indigenous forest patches and dense alien invasions eg Orange Kloof.

Additional interpretive difficulties are evident:

a) land obscuration due to the presence of cloud covering a large area of Table Mountain and Chapman's Peak in the 1987 imagery, and the severe topography of the northern peninsula.

b) the lower sun angle of the 1989 image produced increased topographical shadow and large areas of vegetation in the Cape of Good Hope Nature Reserve having been recently burnt, thereby giving high reflectance values uncharacteristic of fynbos cover.

3.9.3.1 DETAILED DESCRIPTION OF EACH LAND COVER CLASS

Class 1: Deep Water

This black tone can be either the ocean or a dam, it is an easy class to distinguish by its irregular but definite shape, its position and location at sealevel or in a catchment area and its homogeneous texture. Good examples are the dams on the back of Table Mountain.

Class 2: Shadow

This black class is associated with either clouds (class 3) when they occur adjacent to the southern edge of the cloud, or with topography. In the latter case shadows occur to the south of ridges or cliff faces. Their position results from the study area being in the southern hemisphere and the increased shadow effect on the 1989 image is due to the lower sun angle. An example of topographic shadow is on Karbonkelberg.

Class 3: Cloud

This white class is always associated with shadow (class 2) and thus could be easily distinguished from the other "white or off-white" classes. The 1987 image was particularly affected by cloud over the mountainous areas.

Class 4: Sand

Beaches and dunes are easy to identify by their proximity to the coast, characteristic shape and white colour. Only quarries are more diffficult to identify but they usually contrast their surroundings starkly due to their disturbed nature. Typical examples are the Noordhoek beach, the dunes at Hout Bay and the quarry at Sun Valley.

Class 5: Exposed ground

This grey/white class consists either of rocky terrain, or burnt or cleared areas, both are considered to have a vegetative cover of less than five percent. Burns and cleared areas usually contrast their surroundings on the image and burns often terminate against fire breaks (straight line boundaries). Typical examples occur in the north of the Cape of Good Hope Nature Reserve.

Class 6: Firebreaks

These grey/white features are easily separated from class 5 (exposed ground) by their thin linear form, being an obviously man-made feature. Typical examples are found near Constantiaberg.

Class 7: Less exposed ground

This grey class is part of a continuum starting with newly burnt ground (class 5) and continuing until the ground cover has fully recovered. In order to define this class of post fire regrowth a vegetative cover of between five and ten percent was adopted. This obviously allows for the monitoring of the recovery rate of vegetation after fire or clearing. A typical example occurs on the slopes above Simonstown.

Class 8: Shallow water

This is part of a continuum of water with varying depth, beginning with class 1 (deep water). However when a blue tone was visible it was considered to be a separate class. As before this unit has a definite outline and occurs in lowlying areas. A typical example is the Milnerton lagoon.

Class 9: Urban areas

These dark blue units can be recognised by their grid pattern of roads and plots, little or no vegetation is present e.g. Cape Town city centre.

Class 10: Suburban areas

This class is part of a continuum from class 9 (urban areas), again the grid pattern is present but the vegetative cover has increased to twenty-five percent, causing a mottled blue/pink colouration. This is due to the increase in size and number of open spaces, gardens and parks etc, as in the southern suburbs of Cape Town.

Class 11: Cultivated land

This light blue/grey class is recognizable by its managed nature consisting of defined, semi-regular fields that are harvested and therefore change colour eg Constantia/Tokai area.

Class 12: Shrubland: Mountain

This is generally blue/green with a minor amount of the red class mixed in and can be loosely correlated with mountain fynbos. The units are associated with rugged topography and thus shadows, and because the vegetation has a relatively low vegetative cover (30-50%) and low height (up to 200cms), it is ill-defined (difficilt to draw the boundary line on a map). Minor patches of red representing drainage lines are associated with this class. Examples occur in the Table Mountain and Silvermine reserves.

Class 13: Shrubland: North-facing

These blue/green with minor grey areas are similar to class 12 (shrubland: mountain) except that due to their slope and aspect there are no shadows present. For this reason this class is drier and consequently the percentage vegetative cover is lower e.g. Lions Head.

Class 14: Shrubland: Plateau

This blue/green with minor black fynbos class occurs at lower altitudes than classes 12 and 13, and is confined to the Southern Peninsula in this study area. The dark patches associated with this class are marshy areas. Examples occur in the Cape of Good Hope Nature Reserve.

Class 15: Shrubland: south-facing

This blue brown fynbos class occurs on wetter south-facing slopes and is often associated with shadows. For this reason the vegetation is usually taller and more dense. The best example on the Cape Peninsula is in Orange Kloof.

Class 16: Vegetation: Alien and Scrub Forest

Using visual interpretation techniques it was impossible to differentiate aliens from Scrub Forest, both have a homogeneous red tone (denoting dense, photosynthetically active vegetation). Using local knowledge it can be assumed that the Scrub Forest tends to occur in the kloofs and the aliens to predominate on the slopes. Typical examples of these two vegetation types are the Scrub Forest in the upper reaches of Orange Kloof and the aliens below that.

Class 17: Vegetation: Plantations

Although similar to class 16, these are usually homogenously red, and represent planted stands of exotic trees which can be defined by their regular boundaries. The Tokai Forest and the *Eucalyptus* belts on Signal Hill are typical examples.

Class 18: Coastal Bush

This class is distinguished from class 15, by its orange/red tone and occurs in the form of a strip along the coastal regions, especially in the Cape of Good Hope Nature Reserve.

Class 19: Grasslands

These pink areas are usually well-defined occurring in flat or undulating areas. They comprise golfcourses, sportsfields or pastures, e.g. Mowbray golfcourse.

Class 20: Plantations of _Pinus radiata_ and _P. pinea_
This class is the only brown tone in the image and usually occurs in regularly shaped plantations e.g. near Lions Head.

3.10 NOTICEABLE CHANGE BETWEEN THE 1987 AND 1989 IMAGES: MONITORING POTENTIAL

More detail was discernable on the 1989 image as the photographic product was at a scale of 1: 50 000, as opposed to the 1: 100 000 scale of the 1987 image. However topographical shadow obscures some of the detail on the south-facing slopes in the 1989 image. Below appears a list of some of the changes:

1) There is much less cloud on the 1989 imagery, making for a better assessment of the land cover classes, particularly on the mountainous regions that were under cloud on the 1987 image.
2) The topographical shadow effect is greater on the 1989 imagery due to the lower sun angle.
3) Ephemeral lagoons and vleis are present on the 1989 imagery e.g. near Noordhoek.
4) Urban development: extensions to built-up areas at Sun Valley and Ocean View can be seen on the 1989 image that are not present in 1987.
5) Burns can be monitored. New burns on the 1989 are evident e.g. in the northern part of the Cape of Good Hope Nature Reserve, and the _Eucalyptus_ belt above Llandudno, which is present on the 1987 image, appears as a burnt belt on the image of 1989. Post-fire regrowth can also be monitored.

6) Firebreaks that had been burnt or revegetated between the dates of the imagery were evident.

7) Harvesting: fields near Constantia change from pink to blue/white. Also a grey field near Clovelly golfcourse on the 1987 image is not present in 1989.

CHAPTER 4

CAPE PENINSULA GEOGRAPHICAL INFORMATION SYSTEM

4.1 THE NEED FOR A GIS

Moll et al. (1978), when discussing the Table Mountain National Monument, stated that "the future conservation status of the unique fauna, flora and natural beauty of the mountain is seriously threatened, unless co-ordinated management... is effected". In her book "Table Mountain: a natural wonder", Glen Moll (1987) re-iterated that no management plan for the conservation of the Cape Peninsula existed, a GIS could be a tool for such a management body.

Data, that could be used in the development of a management plan, at present exist at various agencies (including the Cape Town City Council, Regional Services Council, Department of Forestry etc.), at varying scales, are not regularly updated and cannot be analyzed in conjunction with each other. A GIS will fulfil this need and highlight areas and topics where data are missing. By collecting data regularly, temporal change can be monitored.

Thus one of the aims of this project was the establishment of a GIS for environmental planning and monitoring on the Cape Peninsula.

4.2 THE STUDY AREA

The Cape Peninsula GIS conforms approximately to the two adjacent 1:50 000 topographical maps, Cape Town (3318CD) and Cape Peninsula (3418AB & AD), as they cover all the natural areas of the Cape Peninsula including the Cape Peninsula Nature Area (land owned by various local authorities and private individuals; the planning, development and management of which is controlled by an advisory conservation committee). This is an area of approximately 47 000 hectares (Figure 12).

4.2.1 PHYSICAL FEATURES OF THE STUDY AREA

1) The topography is rugged with elevation varying from sea level to over 1000m at Maclear's Beacon on Table Mountain, resulting in a wide range of habitats from geologically young coastal plains to older peaks (Moll 1987).

2) Climate: Mediterranean (warm dry summers and cold wet winters), mean annual rainfall varies from 1 900mm at Maclear's Beacon to 305mm at Cape Point.

3) Geology and Soil: The mountains are composed of quartzitic sandstone (Table Mountain Group Quartzites) which form sandy soils that are nutrient poor (Sprecht and Moll 1983). Underlying the sandstone are Malmesbury shales which decompose to relatively fertile loamy soils. These sedimentary rocks are intruded by granite which weathers to soils with a fairly high clay content. Because the soils are acidic peaty marshes have developed in localised rock basins.

4) Vegetation (fynbos, indigenous forest, plantations and alien infestations). The Fynbos Biome, roughly equivalent to the Cape Floral Kingdom, represents the remnant of the smallest of the world's six floristic kingdoms (Taylor 1978). The other five are the Boreal kingdom (including coniferous forests of the northern hemisphere), the Neotropical kingdom (including the South

American prairies), the Palaeotropical kingdom (including the tropical forests of Africa), the Australian and the Antarctic kingdoms.

Fynbos is typified by tiny-leafed ericas or heaths, spikey sedges or restios and broad-leafed proteas in the overstorey (Taylor 1978). It exhibits unparalleled species diversity (8550 species, Jarman 1982) and more than 70% of the plant species are endemic. The Cape Peninsula alone contains over 2 600 species of flowering plants. Why should the Cape be so rich in species? The answer lies in a combination of factors according to Moll (1987), habitat (topography), climate and soil as described above and the age of the flora (the plants have had over 110 million years to evolve in situ).

Forest communities occur in the deeper, locally mesic ravines on all sides of Table Mountain, and spread out on to the lower slopes on the wetter eastern- and southern-facing slopes (Campbell and Moll 1977). There are approximately 30 indigenous forest tree species on the Peninsula. These forests have been drastically reduced in size as a result of man's interference by felling, fire and alien plant encroachment, thus damaged they are slow to recover.

Plantations of Oak trees (Quercus robur) were planted in 1689, and both European pines (P.pinaster) and Australian acacias (A.saligna & cyclops) in the 1800s (Shaunghnessy 1980). The pines

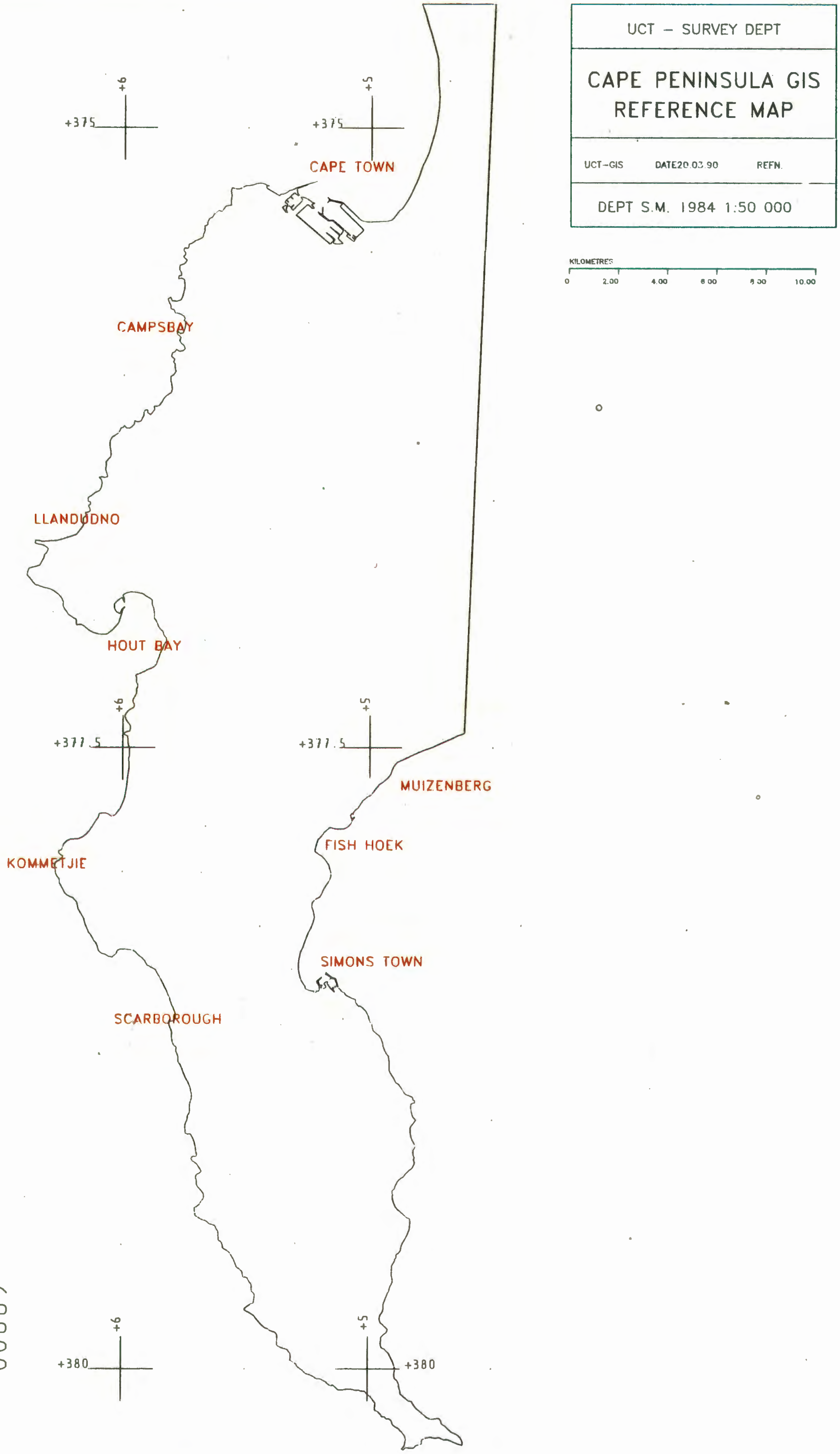

Figure 12. Reference map of the Cape Peninsula GIS study area.

on the back table have subsequently been removed to allow the natural vegetation to recover.

Alien infestations threaten to smother the fynbos, the worst offenders are Rooikrans (Acacia cyclops), Port Jackson willow (Acacia saligna) and Hakeas (various species). In the mid 1970s it was estimated that 25% of Table Mountain was covered in aliens and it requires a concerted eradication programme to control these pests (Campbell and Moll 1976).

4.3 COMPUTER SYSTEM

4.3.1 HARDWARE AND SOFTWARE

In this project the GIS has been created on a Siemens mainframe computer (7536) using SICAD software housed at the Department of Surveying, UCT. The facility consists of a graphics workstation (9731) which includes a digitizing table (See Figure 13), non-graphic terminals (9750), a black and white printer and an eight pen A1 colour plotter (Calcomp 1023).

4.3.2 THE SICAD PHILOSOPHY

4.3.2.1 GRAPHIC DATA

It is a vector based geographical database (GDB) storing information in the form of points, lines and polygons, with different themes on separate layers (see Appendix 3 no 1.10). The system refers to the relationship of points to lines, and lines to areas, as a detail-master relationship. It is not possible to create a master without creating all the necessary detail, likewise a detail cannot be destroyed if it is an integral part of a master.

Figure 14. Photo of SIEMENS workstation.

The block marked in bold (black) indicates the first quartering and would be named "DATABASE NAME .1". This sub-division has been done twice more resulting in files such as "DATABASE NAME .111 (red block).

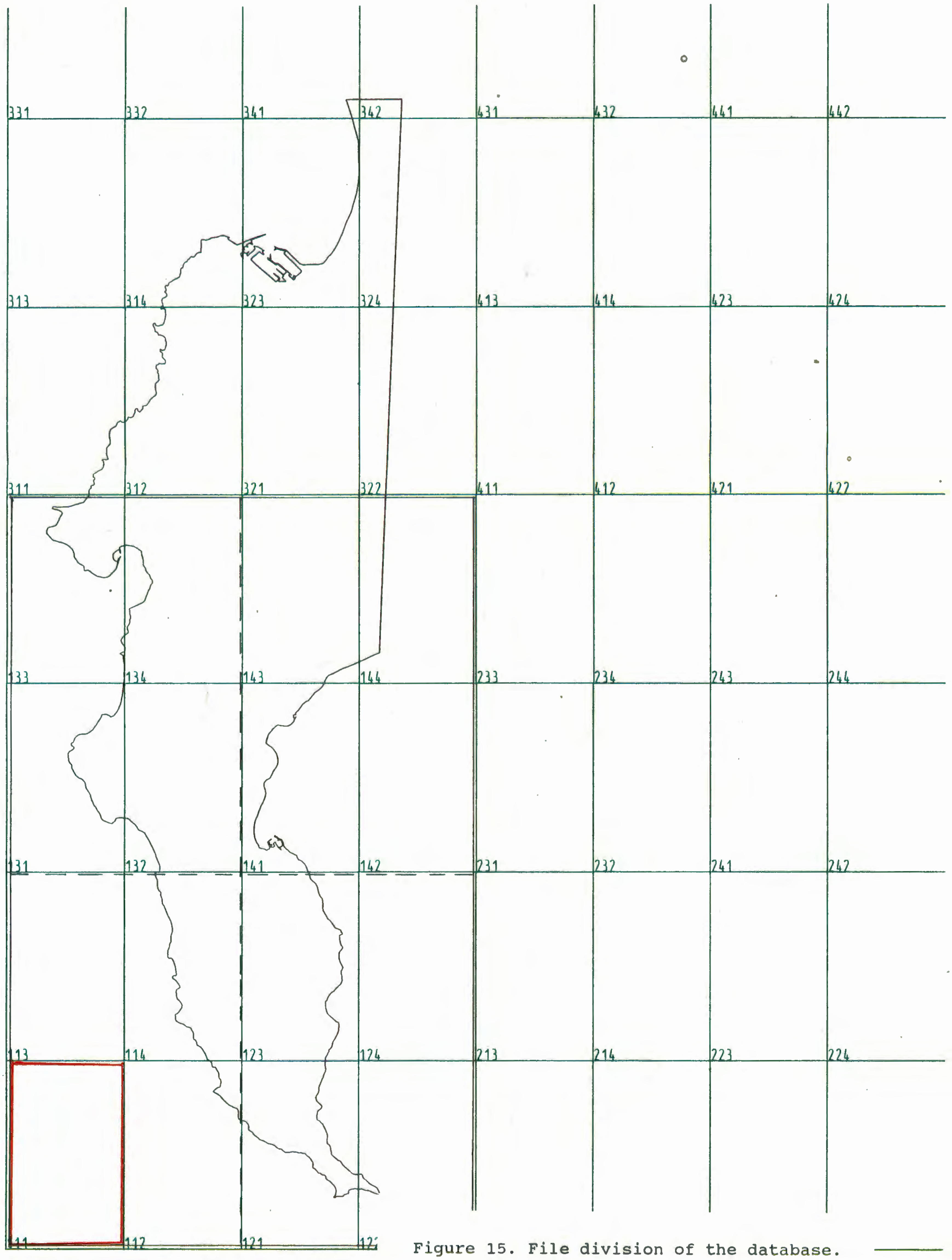

Figure 15. File division of the database.

Using these relationships it is possible to ascertain adjacency, for example what line segments make up a particular polygon, and then in turn to enquire what other polygons those lines are attached to. A practical example of this would be to ask the question, what land-use types abut a lake? (see Appendix 3 no 1.11). This demonstrates the topological structure of the graphic data in the SICAD system.

The graphic data is held in the form of a continuous map i.e. there are no map edges. A rectangular planning area has to be pre-defined at the commencement of data capture and is difficult to enlarge afterwards (see Appendix 3 no 1.1 and no 1.16). Co-ordinates form the key criteria of the database, in this case the national co-ordinate system based on the two-degree belts of the Gauss Conform projection using the Clarke 1880 (modified) ellipsoid, but any cartesian co-ordinate system can be chosen. The system used over the Cape Peninsula is LO19, the x ordinate being measured in metres south from the equator and the y ordinate west from longitude 19^{O}E. Because of the large numbers involved a constant (called a "Rahmen" or frame in SICAD) is applied to the co-ordinates in order to reduce the number of digits involved in calculations.

For data access purposes and efficiency the data base is quartered or broken down into files explicitly (in this study explicit quartering down to the third level was undertaken, see Figure 14). This task is achieved more quickly with an empty GDB (see Appendix 3 no 1.3). The system implements dynamic quartering of the files into cells as the density of data in a particular region of the database demands it. A maximum of eight levels of file division and 14 levels of cell division within any file is possible. Where non-graphic records relate to a particular geographic locality, i.e. where they are linked to the graphics, they are stored in the appropriate cell. The division of the database into files allows for the possibility of multiple access to the database but prevents the same data being updated by two users at the same time.

The resolution of the specific database is determined by the "tolerance". The tolerance is a circle of resolution about a specific position and determines how close points can be placed before they are considered to be one and the same point i.e. they "snap" together. A tolerance of 20m on the ground for the thematic maps in this database has been chosen. Most of the work being at a scale of 1:50 000, this represents 0.4mm on the map. The system is capable, however, of working to a precision of millimetres on the ground (if the Rahmen is so chosen).

4.3.2.2 GRAPHIC DATA INPUT PROCEDURES

Maps at different scales and projections can be utilized but a transformation is necessary to make them compatible with the GDB's co-ordinate system. This entails a transformation to the LO19 co-ordinate system using the inbuilt least squares affine solution, which requires at least three common points on the map and in the database. A mean square error of less than 15m was chosen as a standard accuracy requirement for input into the system when digitizing from maps at scales 1:50 000 or smaller. When inputting 1:10 000 maps it was possible to reduce this to 5m.

Graphic data can be entered via the keyboard if the geographical co-ordinates (latitude and longitude) or national grid co-ordinates of the feature are known, or via the digitizing table if the data are in map form. Procedures to simplify the capture of graphic data were developed by the Natal Parks Board and modified for this project, as direct interface with the system via the command language, is complex and time consuming. These procedures will be referred to in future as the "user interface". Using this user interface it took 36 hours to digitize a set of three soil maps covering the study area, 360 polygons being formed from 1100 line segments.

4.3.2.3 NON-GRAPHIC DATA

Non-graphic records in SICAD consist of simple sequences of attributes, grouped together in two-dimensional tables called relations, stored in the GDB. These non-graphic records consist of attributes of a particular record type, e.g. rare plants (coded as PL) is a record type, and attributes associated with it include the plant's genus, species, protection status etc. (see Table 5). For a list of the non-graphic data in the system and an explanation of the codes used see paragraph 4.4.2). Those attributes which uniquely define the record are known as the

TABLE 5: EXAMPLE OF A NON-GRAPHIC RECORD

RECORD TYPE	PL	(individual plant records)
MAP	3418AB	(1:50 000 map)
CODE	3	
GENUS	ERICA	
SPECIES	CAPITATA	
OWNER	SMINE	FOREIGN KEY (relates this record to relevant ownership record)
REGION	NR	

RECORD TYPE, MAP, CODE, GENUS, SPECIES: KEY ATTRIBUTES (unique attributes needed to define this record) "keys". Each record must contain a key in order to exist. Certain attributes can be used as pointers to other records, these are known as "foreign keys" e.g. the attribute called "owner" in the rare plant record type points to the record type ownership (coded as CN), which in turn records the owner of the land where that particular plant is located (see Appendix 3 no 2.1). Once data have been entered it is difficult to modify the definitions (see Appendix 3 no 2.2). Records can also be linked to a graphic element (a point for example) via element descriptors or parameters (see Appendix 3 no 2.4).

Thus the non-graphic data records form part of a relational database and have been attached to the graphics. This allows one to query the non-graphic database, create a selection set (say a list of plant species), and then ask for the corresponding locations of the plants (held in the graphic database) to be shown graphically and vice versa (see Appendix 3 no 2.5, 2.6 and 2.7). The records can be input via SICAD commands or by using the system editor and then spooling them into the database (see Appendix 3 no 2.3).

4.4 DATABASE STRUCTURE

4.4.1 GRAPHIC DATA IN THE SYSTEM

Four geo-referenced graphic databases have been established:

1) Natural resources

2) Infrastructure and management

3) Fire management

4) Moll's Table Mountain Maps

Each of which can accommodate 30 layers of information (see Tables 6 and 7). (For more information regarding the information stored in the above databases see Appendix 1.) The complete coastline, or part thereof, is included on any level where polygons are created that utilize that coastline, this has been done as once an area element has been created using the coastline, it is not possible to snap another line, on a separate level, onto a common stretch of coastline (see the detail-master relationship explained earlier). Source maps of different scale have been utilized with the proviso that points with known co-ordinates are available for the registration of the new map to the database (as described earlier). However, it must be borne in mind that any product of the GIS is only as accurate as the least accurate information queried.

In order to impart the quality of the data to the user the "truth-in-labelling" concept (Ventura et al. 1988) was adopted. To do this, every theme (or layer) within the database has a block in the top left hand corner indicating the title, source (abbreviations are explained in Appendix 1), date and scale of input. Legends to all the themes in the GDB are stored separately in a picture library or image database (IDB) called DIGIT.IDB with appropriate names (e.g. ALIENKEY is the key for the alien distribution map), and can be displayed simultaneously with the appropriate map via the ADD command i.e. ADD ALIENKEY 0 0. Two master keys exist in the image library DIGIT.IDB, (KEYVERT and KEYHORIZ) which can be modified and saved under new names, to

KEYHORIZ) which can be modified and saved under new names, to create keys for new themes. The legends were created at the same scale as the map, so as long as they are manipulated together (e.g. enlarged using the zoom function) they will remain compatible. For a full list of all the images in DIGIT.IDB see Appendix 2.

4.4.2 NON-GRAPHIC DATA IN THE SYSTEM

Non-graphic records are attached to a particular GDB, and a summary is displayed using the GBSTAT GB command (see Appendix 2 no 1.4), or automatically when accessing a GDB using the user interface described above. Information relating to rare plant species, estuaries, checklists for certain areas and information available for each of the Cape Nature Area landowners is available at present. A list of the record types for each GDB is supplied below. For information about individual records see Appendix 4.

<u>CAPE-GDB</u>

PL - Individual Rare Plant Record

SP - Species Record

RA - Rare Species Locator Code Record

CN - Cape Nature Area Ownership Record

ES - Estuaries

<u>INFR-GDB</u>

CN - Cape Nature Area ownership (the information which is available for each owner)

CH - Checklist of plant species

```
2
** NATURAL RESOURCES ************************************************
*                                                                   *
*    1 - TRANSFORMATION POINTS          16 - SPOT LANDCOVER         *
*    2 - COASTLINE                      17 - ENHANCED SPOT          *
*    3 - GEOLOGY                        18 -                        *
*    4 - VEGETATION-1                   19 -                        *
*    5 - PRECIPITATION                  20 - RARE SPECIES           *
*    6 - TEMPERATURE                    21 -                        *
*    7 - SOILS                          22 -                        *
*    8 - TOPOGRAPHY                     23 -                        *
*    9 -                                24 - ALIENS                 *
*   10 - SURFACE WATERBODIES            25 -                        *
*   11 - RIVERS-PERENNIAL               26 - FAUNA                  *
*   12 - RIVERS-NON PERENNIAL           27 -                        *
*   13 - DAM/VLEI NAMES                 28 -                        *
*   14 - SUBTERRANEAN WATERBODIES       29 - TRIG BEACONS           *
*   15 - HABITAT TYPES                  30 - SPOT TRANS             *
*                                                                   *
************************************************** 99 EXIT ****
* ------ ENTER THE TOPIC NUMBERS FOR RECALL    (0=ALL)      --- *
2
** INFRASTRUCTURE ***************************************************
*                                                                   *
*    1 - TRANSFORMATION POINTS          16 - LANDUSE                *
*    2 - COASTLINE                      17 -                        *
*    3 - CAPE NATURE AREA               18 - RECREATION             *
*    4 - ADMIN BOUNDARIES               19 -                        *
*    5 -                                20 -                        *
*    6 - LEGISLATION                    21 - PROCEDURES             *
*    7 -                                22 -                        *
*    8 -                                23 - IMPACT AREAS           *
*    9 - AIRPORTS/FIELDS                24 -                        *
*   10 - ROADS-I                        25 - CHECK LISTS            *
*   11 - ROADS-II                       26 -                        *
*   12 - RAILLINES                      27 - PLACE NAMES            *
*   13 - PIPELINES                      28 - TOWN NAMES             *
*   14 - TRANSMISSION LINES             29 - TRIG BEACONS           *
*   15 -                                30 -                        *
*                                                                   *
************************************************** 99 EXIT ****
* ------ ENTER THE TOPIC NUMBERS FOR RECALL    (0=ALL)      --- *
?T
```

Table 6. Menu to show existing and potential themes occurring on levels for CAPE-GDB and INFR-GDB

```
** MANAGEMENT: FIRE **********************************************
*                                                                *
*    1 -                              16 - 1976                  *
*    2 - COASTLINE                    17 - 1977                  *
*    3 - 1962                         18 - 1978                  *
*    4 - 1964                         19 - 1979                  *
*    5 - 1965                         20 - 1980                  *
*    6 - 1966                         21 - 1981                  *
*    7 - 1967                         22 - 1982                  *
*    8 - 1968                         23 - 1983                  *
*    9 - 1969                         24 - 1984                  *
*   10 - 1970                         25 - 1985                  *
*   11 - 1971                         26 - 1986                  *
*   12 - 1972                         27 - 1987                  *
*   13 - 1973                         28 - 1988                  *
*   14 - 1974                         29 - TRIG BEACONS          *
*   15 - 1975                         30 -                       *
*                                                                *
*************************************************** 99 EXIT ****
* ------ ENTER THE TOPIC NUMBERS FOR RECALL    (0=ALL)      --- *
2
** MOLLS TABLE MOUNTAIN MAPS *************************************
*                                                                *
*    1 - TRANSFORMATION POINTS        16 - EUCALYPTUS            *
*    2 - COASTLINE                    17 -                       *
*    3 -                              18 -                       *
*    4 -                              19 - FOREST/FYNBOS         *
*    5 -                              20 - FOREST 1600AD         *
*    6 -                              21 - ERODED AREAS          *
*    7 -                              22 - IMPACT AREAS          *
*    8 -                              23 -                       *
*    9 - GRASSLANDS                   24 -                       *
*   10 -                              25 -                       *
*   11 -                              26 -                       *
*   12 - ACACIA SALIGNA               27 -                       *
*   13 - ACACIA MELANOXYLON           28 -                       *
*   14 - ACACIA MEARNSII              29 - TRIG BEACONS          *
*   15 - ALBIZIA LOPHANTHA            30 - SPOT TRANS            *
*                                                                *
*************************************************** 99 EXIT ****
* ------ ENTER THE TOPIC NUMBERS FOR RECALL    (0=ALL)      --- *
?T
```

Table 7. Menu to show existing and potential themes occurring on levels for MANT-GDB and TMTN-GDB

4.5 DATA MANIPULATION

4.5.1 MANIPULATION OF GRAPHIC DATA

The whole database can be queried or any geographical subdivision or window can be requested. Likewise any combination of levels can be set for inquiry. The co-ordinates of an often requested subdivision can be stored as a non-graphic record, and for future use only the code referring to that particular area need be typed in (see Appendix 3 no 1.5). Inherent in the system is the ability to temporarily overlay themes from different layers and/or data sets (Figure 16). It is also possible to add images together permanently, thereby creating a new map. A particular vegetation type (a series of area elements) can be selected and extracted together with its boundaries (associated line elements) and placed on a separate layer (see Figure 17 where upland mixed fynbos has been extracted from the vegetation layer). For more details concerning the SICAD commands for this procedure see Appendix 3 no 1.11.

4.5.2 SPATIAL ANALYSIS

It is possible to intersect particular areas from different themes, using the Boolean logic options described in Chapter 1.6.4, e.g. soil and vegetation. Taking the upland mixed fynbos category extracted in paragragh 4.5.1 and intersecting it with the rock/shallow soil category from the soil layer, the degree of spatial correlation between these two can be determined (see Figure 18). For the relevant SICAD commands to achieve this see Appendix 3 no 1.14.

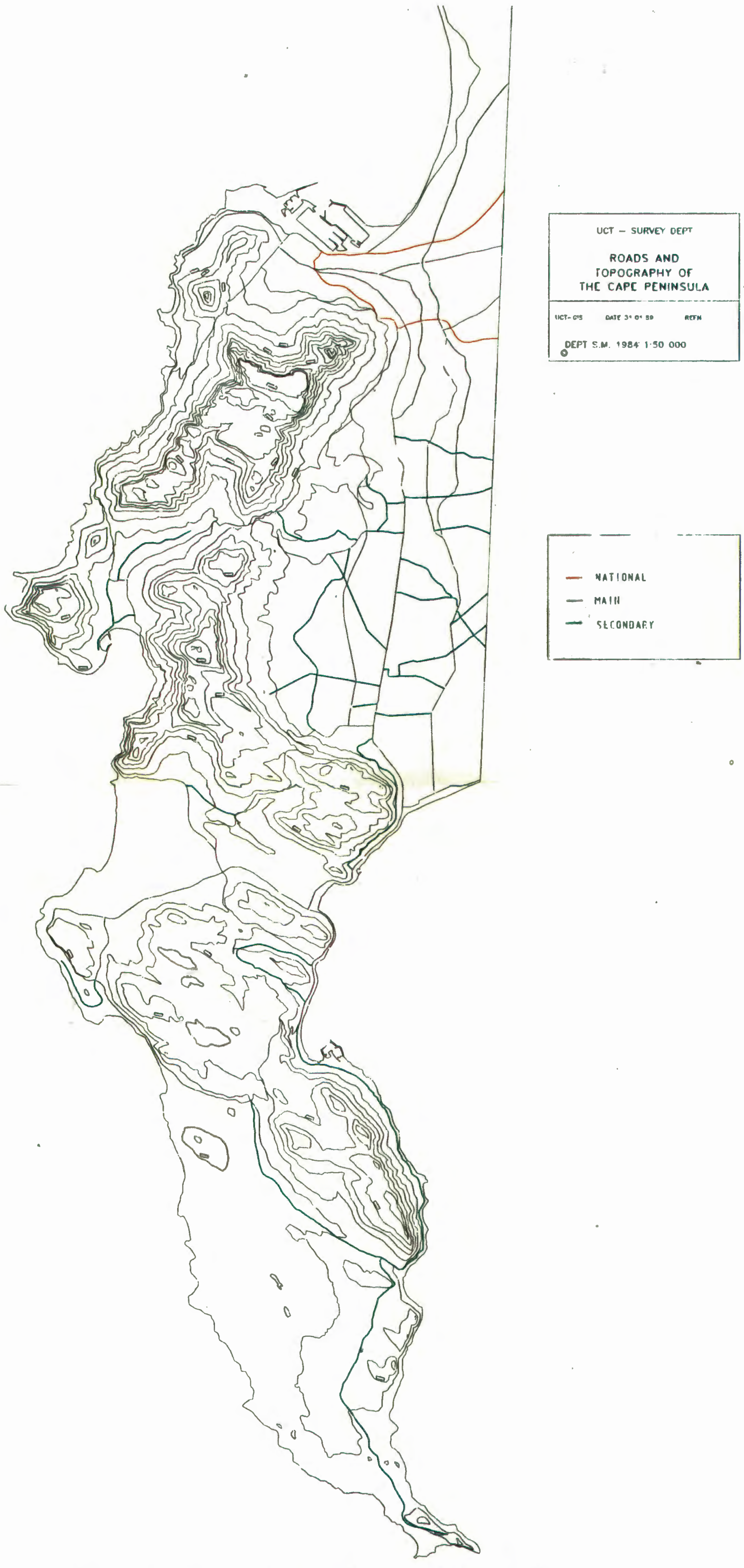

Figure 16. The overlay of data from different databases, contours from natural resources and roads from infrastructure.

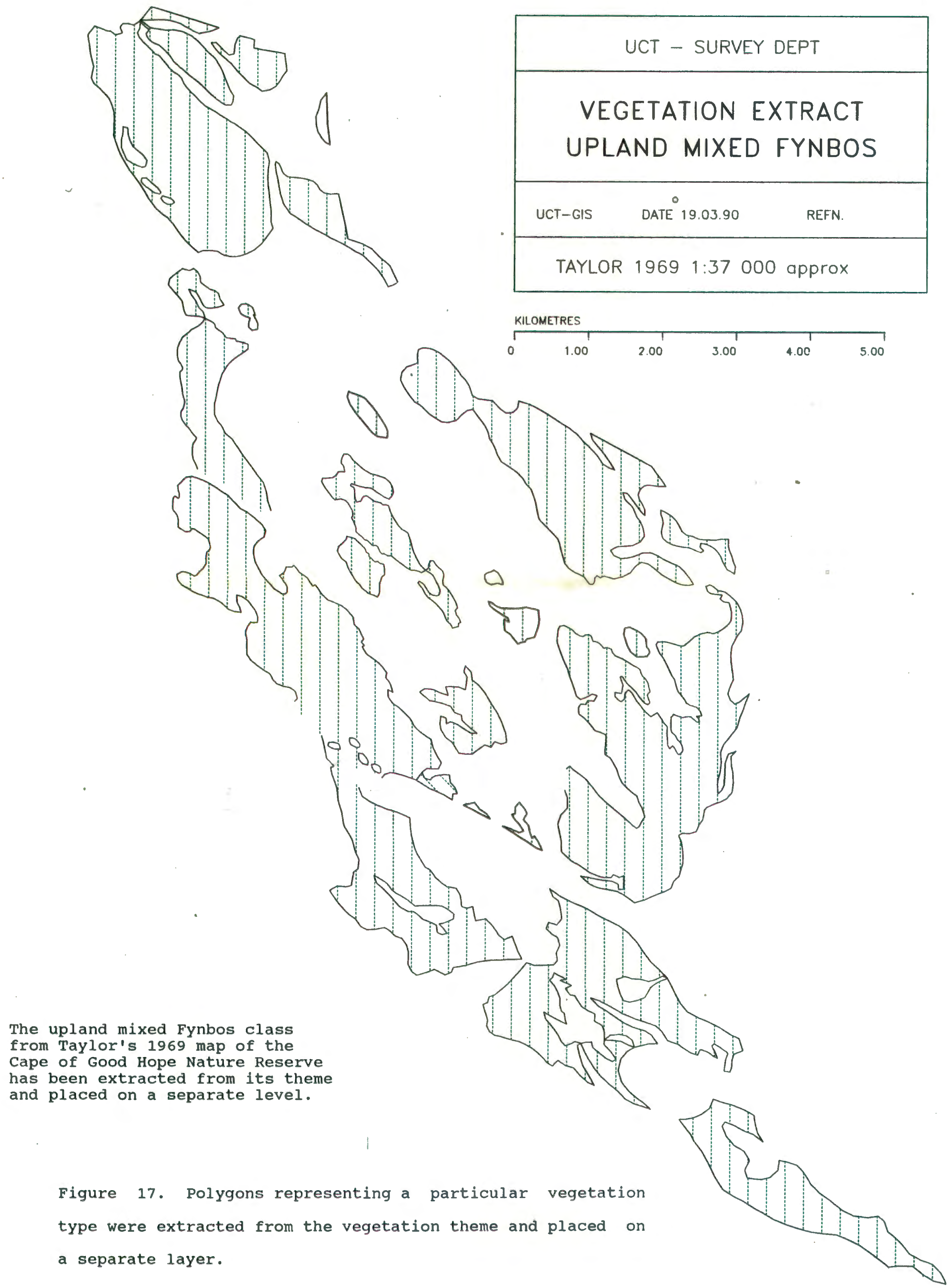

Figure 17. Polygons representing a particular vegetation type were extracted from the vegetation theme and placed on a separate layer.

The vegetation class extracted in Fig 17 was intersected with shallow soil class from SIRI's 1976 soil map of the Cape Peninsula

Figure 18. Intersection between two themes, soil and vegetation.

Both these themes do not have distinct boundaries in the field as they are depicted on the map. With reference to vegetation boundaries, any attempt to demarcate them "must be a crude simplification which ignores the transitional changes determined by micro-climate and topography within a border zone" (Seddon 1971 in MacDougall 1975). Also because vegetation is dependent in part on the soil type, the co-incidence of certain boundaries is expected (botanists may use soil boundaries in mapping vegetation and vice versa). In Figure 19 a "sliver" or spurious polygon error occurs where the complex soil and vegetation boundaries parallel one another when overlain, whereas most probably they should co-incide. This can result in many new small polygons being created that do not represent true spatial variations.

4.5.3 MANIPULATION OF NON-GRAPHIC DATA

For an example of a typical search of the non-graphic data records see Appendix 3 no.2.5. In the following example the rare plant records (code PL) were selected to produce a subset of plants occurring within the Cape of Good Hope Nature Reserve (see table 7), then the corresponding positions of these plants were found (see Figure 20).

4.6 DATA OUTPUT and DISPLAY

Graphical output in the form of printer graphics (screen dump) and colour plotter (high quality maps at any scale up to A1 size) are available. By specifying the particular limiting co-ordinates, maps at a standard scale, e.g. 1:50 000, can be

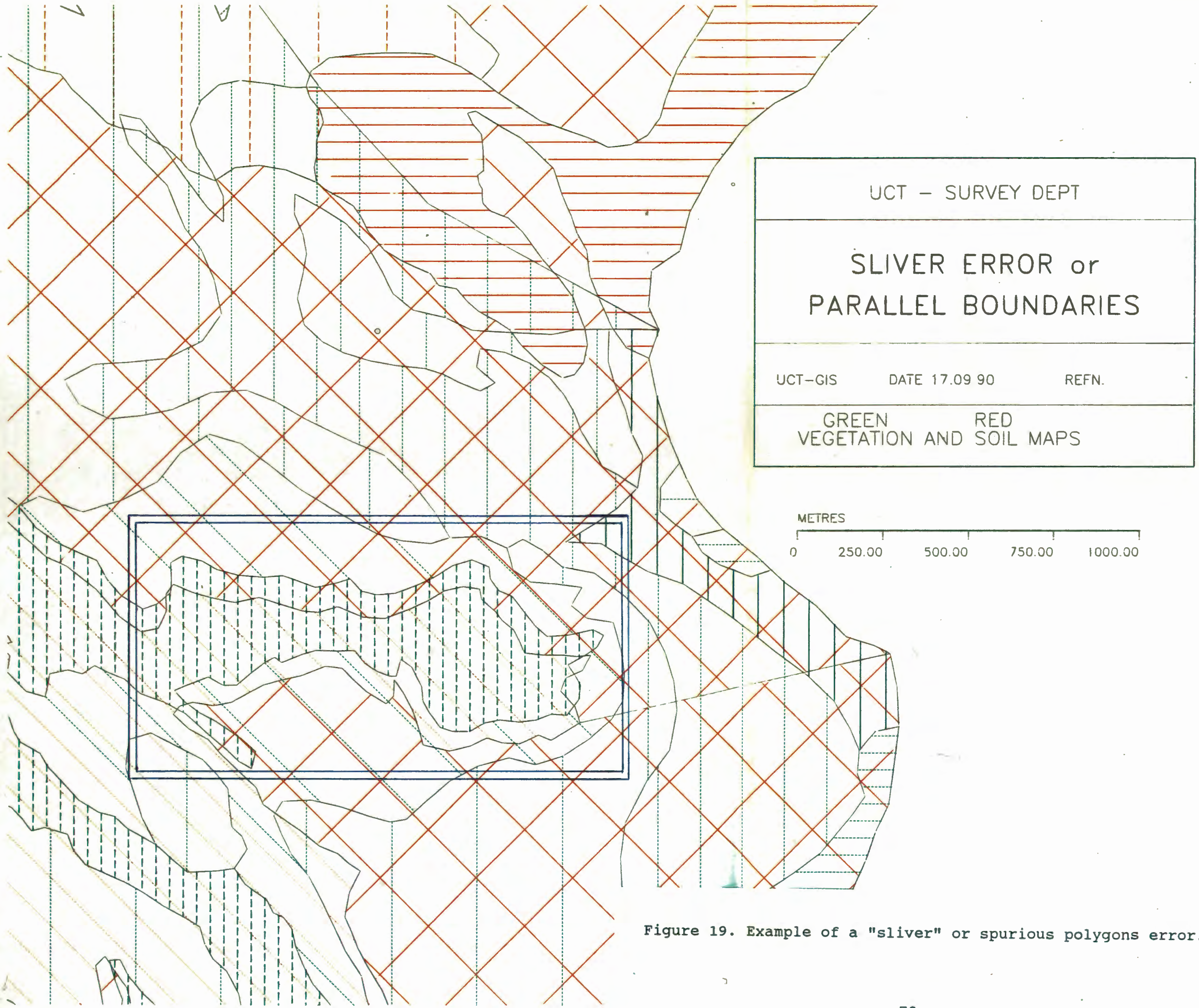

Figure 19. Example of a "sliver" or spurious polygons error.

produced (see list in Appendix 3 no 1.13); otherwise the window chosen for plotting will simply fill the paper. Non-graphic data can be outputted in the form of lists or tables via a printer.

4.7 OVERLAYING SPOT LANDCOVER BOUNDARIES ON ANCILLARY DATA

It was envisaged that the visual classification of the satellite image into vegetation classes would be aided by the ability to overlay the "ancillary data" already stored in the GIS and that once classified, the land cover class boundaries would be digitized into the system to augment the GIS. To this end the areas comprising Table Mountain Sandstone were overlain on the SPOT interpretation to access the correlation between that rock type and the mountain fynbos category.

4.8 MONITORING ENVIRONMENTAL CHANGE

The GIS is seen as an experimental monitoring tool for long term planning of the Cape Peninsula. A GIS is an ideal tool for this purpose as temporal data can be stored on different layers e.g. changing landuse patterns over time. In order to do this the database has to be updated regularly and satellite imagery is an ideal way to achieve this efficiently. From the SPOT imagery analyzed in this study changes such as new burns, extensions to built-up areas etc. were clearly visible and easy to map.

Table 8. Non-graphic selection set of seven plants

map showing location of selection set.

```
SATZTYP      PL
MAP          3418AB
CODE         3
GENUS        ERICA
SPECIES      CAPITATA
LOCALITY     SC
STATUS       A
OWNER        COGHNR
REGION       NR
*************************************************************
SATZTYP      PL
MAP          3418AB
CODE         4
GENUS        RESTIO
SPECIES      DODII
LOCALITY     SC
STATUS       A
OWNER        COGHNR
REGION       NR
*************************************************************
SATZTYP      PL
MAP          3418AB
CODE         4
GENUS        MIMETES
SPECIES      HIRTUS
LOCALITY     SC
STATUS       A
OWNER        COGHNR
REGION       NR
*************************************************************
SATZTYP      PL
MAP          3418AB
CODE         6
GENUS        AUDOUINIA
SPECIES      CAPITATA
LOCALITY     SC
STATUS       A
OWNER        COGHNR
REGION       NR
*************************************************************
SATZTYP      PL
MAP          3418AB
CODE         6
GENUS        ERICA
SPECIES      CAPENSIS
LOCALITY     SC
STATUS       A
OWNER        COGHNR
REGION       NR
*************************************************************
SATZTYP      PL
MAP          3418AB
CODE         7
GENUS        MIMETES
SPECIES      HIRTUS
LOCALITY     SC
STATUS       A
OWNER        COGHNR
REGION       NR
*************************************************************
SATZTYP      PL
MAP          3418AB
CODE         8
GENUS        ERICA
SPECIES      FONTANA
LOCALITY     SC
STATUS       A
OWNER        COGHNR
REGION       NR
```

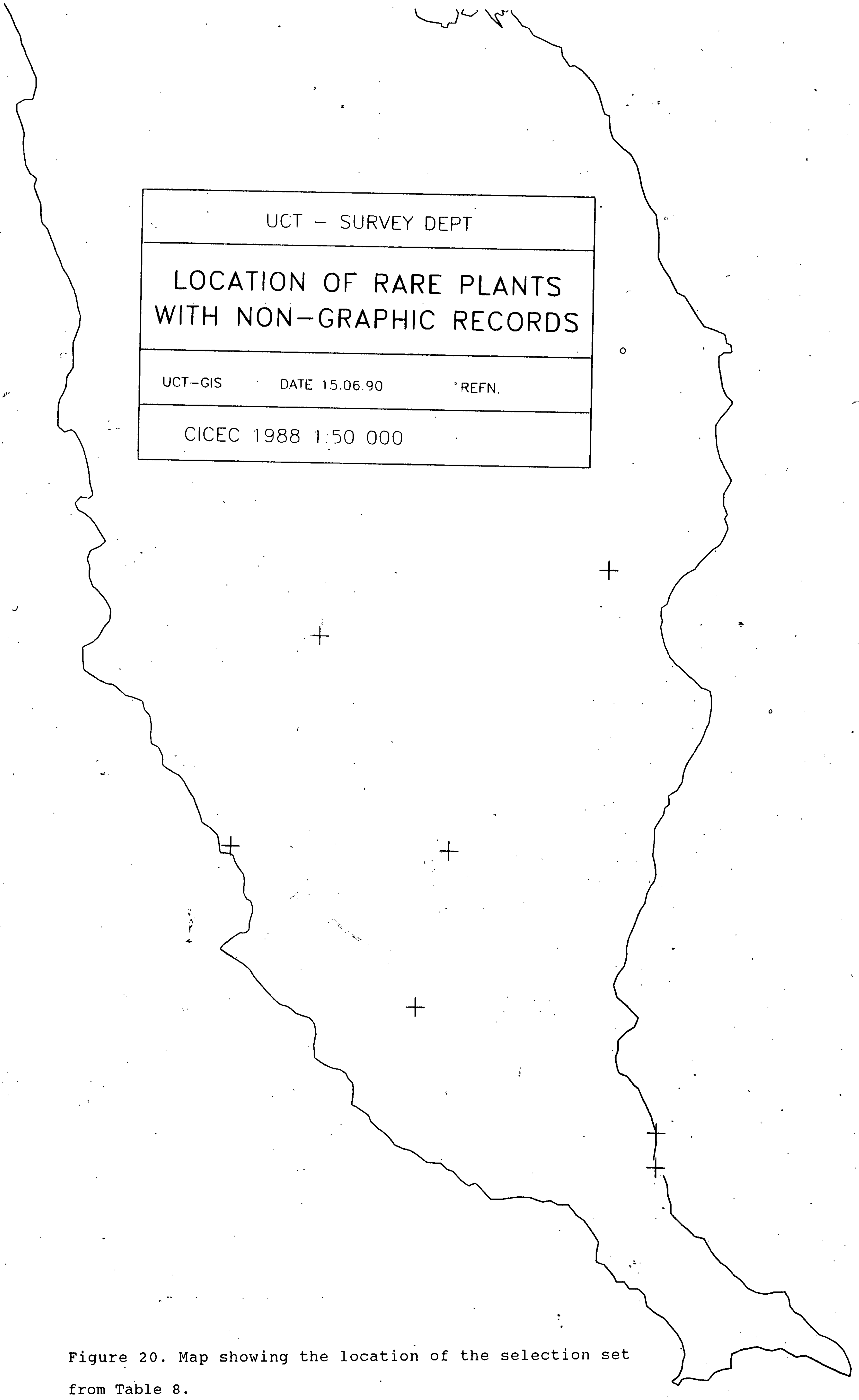

Figure 20. Map showing the location of the selection set from Table 8.

CONCLUSION

A: Remote sensing

The SPOT imagery was found to be a useful tool for determining land use classes and accurately mapping them, due to the high resolution and spatial accuracy. However, in attempting to classify the vegetation the following restrictions were noted:

1) SPOT has only three spectral bands, restricting a detailed breakdown of vegetation classes;

2) The extreme relief of the study area results in steep slopes and large shadows, thereby obscuring parts of the image from interpretation;

3) The percentage vegetative cover in the fynbos is relatively low resulting in a large amount of interference from the substrata.

More accurate classification of land cover types can be achieved if the classification procedure incorporates topographic and attribute information for the area (Mather 1989). Thus by incorporating the land cover boundaries derived from the SPOT imagery into the Cape Peninsula GIS, one will be able to analyze them together.

The value of remotely sensed data to the user of an environmental GIS is that large area data coverage is provided in a timely and cost-effective way (Mather 1989).

B: GIS

The acquisition of a GIS is no instant solution to all spatial data handling tasks because true to all major innovations, GIS creates problems of its own. Highly specialized personnel are needed to address these problems satisfactorily (Zietsman 1989).

"A successful GIS must evolve from an inventory tool (a simple databank) to an analysis tool (incorporating complex retrieval and statistical processing), and then ultimately to a management tool (a system capable of modelling and with complex decision support capabilities)" (Crain and Macdonald 1983).

One of the shortcomings of the GIS as it stands at present is the lack of a detailed vegetation map of the area. This is an essential factor in monitoring the ecological wellbeing of the region. "Plants are a measure of the conditions under which they grow and act as an index for soil and climate. The fact that changes in vegetation occur is visible proof of the dynamic nature of the environment. It is necessary to be able to record and follow vegetation changes in order to predict and determine and control any changes which could severely upset the desired balance" (Jarman et al. 1983). A GIS is the ideal tool to undertake such a monitoring task.

A GIS makes it "possible for planners and decision-makers to explore a range of possible scenarios and to obtain an idea of the consequences of a course of action before the mistakes have been irrevocably made in the landscape itself" (Burroughs 1986).

A GIS is in effective use when the complete system is operational, sufficient base data has been captured, and the user is confident and skilled enough to manipulate the data in such a manner as to aid in management decision making and planning. (Zietsman 1989). Thus the challenge now that a large (although not comprehensive) dataset has been established, is the task of developing a process or model for selecting and integrating the tremendous amount of data and large number of overlays into a single output to aid decision making.

REFERENCES (asterisked) AND ADDITIONAL BIBLIOGRAPHIC MATERIAL

This list contains all references quoted in the text and other sources consulted

Abiodun, A.A., 1978. The economic implications of remote sensing from space for the developing countries, **In:** Proceedings of International Conference on Earth Observation from Space and Management of Planetary Resources, Toulouse.

* Allam, M.M., 1989. An overview of GIS activities in the provincial and municipal government of Canada, CISM Journal ACSGC **45**(3) p253-257.

Anon, , 1983. Brief recall of the SPOT satellite, PECORA 8 symposium.

Anon, , 1986. SPOT Newsletter July 1986, SPOT Image, Toulouse, France.

Anon, , 1988. SPOT Newsletter July 1988, SPOT Image, Toulouse, France.

* Anon, ,1989-1987 SICAD usres guides, Siemens, Munich, Germany.

* Bacon, C.J., 1984. Geographic information systems in resource management, Proceedings of the International Conference on Operations Research and Requirements in Southern Africa, CSIR Pretoria.

Bacon, C.J. and Kanowitz, R.L., 1986. Towards a geographic information system for the Siyaya catchment project, S.Afr.J. of Photogrammetry, Remote Sensing and Cartography **14**(5) p299-311.

* Bailey, R.G., 1988. Problems with using overlay mapping for planning and their implications for geographic information systems, Environmental Management **12**(1) p11-17.

Barnes, G., 1989. Land information management as a user of GIS products and technologies, Proceedings First International Conference on Geographical Information Systems in Southern Africa, University of Natal, Pietermaritzburg.

Berry, J.K., 1986. Geographic information systems report part 3: GIS learning computer-assisted map analysis, Journal of Forestry **84** p39-43.

Berry, J.K., 1987. Computer-assisted map analysis: potential and pitfalls, Photogrammetric Engineering and Remote Sensing **53**(10) p1405-1410.

Blais (ed), J.A.R., 1987. Lecture notes in digital mapping and land information, Dept of Surveying Engineering, University of Calgary, Calgary, Alberta.

Bossi, L., 1979. Computer classification of land features from portion of LANDSAT-1, scene E 1055 - 08064 in the Ysterfontein area, Unpublished Honours Project, Computer Science Department, UCT.

* Bossi, L., 1983. Mapping the vegetation of the Fynbos biome with the aid of LANDSAT imagery, Unpublished M.Sc. Dissertation, Department of Botany, UCT.

* Brooner, W.G., 1981. An overview of remote sensing input to geographic information systems, Proceedings of the PECORA 7 Symposium, Remote Sensing: An Input to Geographic Information Systems in the 1980's, American Society of Photogrammetry, Sioux Falls, South Dakota, p318-329.

* Brooner, W.G. and Nichols, D.A., 1972. Considerations and techniques for incorporating remotely sensed imagery into the land resource monitoring process, Remote Sensing of Earth Resources, **1**, p1-24, University of Tennessee, Tullahoma, TN.

* Bryant, n., 1981. Some technical considerations on the evolution of the IBIS system, Proceedings of PECORA 7, Sioux Falls, South Dakota.

* Bullard, R.K. and Lakin, P.J., 1981. First steps in remote sensing, North east London polytechnic.

* Burrough, P.A., 1986. Principles of GIS for land resource assessment, Clarendon Press, Oxford.

* Campbell, B.M., 1985. A classification of mountain vegetation of the fynbos biome. Memoirs of the Botanical Survey of South Africa No50.

* Campbell, B.M., and Moll, E.J., 1977. The forest communities of Table Mountain, South Africa, Vegetatio **34** p105-15.

* Campbell, B.M., Cowling, R.M., Bond, W. and Kruger, F.J., 1981. Structural characterization of vegetation in the Fynbos Biome, South African National Scientific Programme Report No.52, Pretoria CSIR.

Campbell, W.G. and Mortenson, D.C., 1989. Ensuring the quality of geographic information system data: a practical application of quality control, Photogrammetric Engineering and Remote Sensing **55**(11) p1613-1618.

* Carter, J.R., 1988. A typology of geographic information systems, Advances in Digital Image Processing. Proceedings of annual conference of Remote Sensing Society, Nottingham.

* Chevrel, M., Courtois, M. and Weill, G., 1981. The SPOT satellite remote sensing mission, Photogrammetric Engineering and Remote Sensing **47**(8) p1163-1171.

* Chorley, R., 1988. Some reflections on the handling of geographical information, Int.J.Geographical Information Systems **2**(1) p3-9.

Chrisman, N.R., 1987. The accuracy of map overlays: a reassessment, Landscape and Urban Planning **14** p427-439.

* Cibula, W.G. and Nyquist, M.O., 1987. Use of topographic and climatological models in a geographical data base to improve LANDSAT MSS classification for Olympic National Park, Photogrammetric Engineering and Remote Sensing **53**(1) p67-75.

* Colvin, I., 1990. A short history of the Natal Parks Board GIS, NAGIS News **2** p3-4.

* Colvin, I., 1989. The SIEMENS NPGIS manual, Natal Parks Board, Pietermaritzburg.

Colvocoresses, A.P., 1981. Digital elevation data as an aid to land use and land cover classification, Proceedings of the PECORA 7 Symposium, Amercan Society of Photogrammetry, Sioux Falls, South Dakota.

* Cowen, D.J., 1988. GIS versus CAD versus DBMS: what are the differences? Photogrammetric Engineering and Remote Sensing **54**(11) p1551-1555.

* Crain, I.K. and MacDonald, C.L., 1983. From land inventory to land management: the evolution of an operational GIS, Proceedings of AUTOCARTO 6 p41-49.

* Curran, P., 1980. Multispectral remote sensing of vegetation amount, Progress in Physical Geography **4**(3) p315-341.

Curran, P.J., 1982. Multispectral photographic remote sensing of green vegetation biomass and productivity, Photogrammetric Engineering and Remote Sensing **48**(2) p243-250.

* Curran, P.J., 1984. Geographic information systems, Area **16** p153-8.

Curran, P.J., Danson, F.M. and Leafe, R.N., 1988. SPOT-1 HRV data and vegetation amount, Conference proceedings SPOT-1 Image utilization, assessment, results Toulouse France.

Curran, P.J. and Milton, E.J., 1983. The relationship between the chlorophyll concentration, LAI and reflectance of a simple vegetation canopy, Int.J.Remote Sensing **4**(2) p247-255.

* Curtis, L.F., 1978. Remote sensing systems for monitoring crops and vegetation, Progress in Physical Geography **2**(1) p55-79.

* Dangermond, J., 1983. A classification of software components commonly used in GIS, Proceedings US/Australia Workshop on Design and Implementation of Computer-based GIS, Amherst, New York.

* Dangermond, J., 1990. CAD versus GIS: which is better for automated mapping? Computer Graphics **1**(4) p13-18.

Davis, F.W., Stoms, D.M., Estes, J.E., Scepan, J. and Scott, J.M., 1990. An information systems approach to the preservation of biological diversity, Int.J.Geographical Information Systems **4**(1) p55-78.

* Depart of Environ, , 1987. Report of the Committee of Enquiry into the Handling of Geographic Information chaired by Lord Chorley, Her Majesty's Stationery Office, London.

* Devine, H.A. and Field, R.C., 1986a. Geographic information systems report part 1: The gist of GIS, Journal of Forestry **83** p17-22.

Devine, H.A. and Field, R.C., 1986. Geographic information systems report part 2: GIS applications, Journal of Forestry **84** p35-41.

Dick, P.I. and Loberg, E., 1988. Use of SPOT imagery for vegetation/biomass mapping, geotechnical mapping, catchment area determination and settlement location in the Turkana district, northern Kenya, Conference proceedings SPOT-1 Image utilization, assessment, results Toulouse France.

* Dixon, D., 1989. 'A country practice', Mapping Awareness **3**(4) p6-8.

* Dueker, K.J., 1979. Land resource information systems: a review of fifteen years experience, Geo-Processing **1** p105-128.

Ehlers, M., Edwards, G. and Bedard, Y., 1989. Integration of remote sensing with geographic information systems: a necessary evolution, Photogrammetric Engineering and Remote Sensing **55**(11) p1619-1627.

Estes, J.E., 1981. Remote sensing and geographic information systems coming of age in the eighties, Proceedings of the PECORA 7 Symposium Remote Sensing: An input to Geographic Information Systems in the 1980's, American Society of Photogrammetry, Sious Falls, South Dakota, p23-37.

* Estes, J.E., 1985a. The need for improved information systems, Canadian Journal of Remote Sensing **11**(2) p124-131.

Estes, J.E., 1985. Geographic applications of remotely sensed data, Proceedings of the IEEE **73**(6) p1097-1107.

* Faust, N.L., 1987. Automated data capture for geographic information systems: a commentary, Photogrammetric Engineering and Remote Sensing **53**(10) p1389-1390.

* Fisher, P.F. and Lindenberg, R.E., 1989. On distinctions among cartography, remote sensing and geographic information systems, Photogrammetric Engineering and Remote Sensing **55**(10) p1431-1434.

* Foody, G.M. and Wood, T.F., 1980. The use of LANDSAT TM data in a GIS for environmental monitoring, Advances in Digital Image Processing, Proceedings of Annual Conference of Remote Sensing Society, Nottingham.

* Garrison, W.L., Alexander, R., Bailey, W., Dacey, M.F. and Marble, D.F., 1965. Data system requirements for geographic research, Scientific experiments for manned orbital flight: Proceedings of the American Astronautical Society's third Goddard Memorial Symposium.

* Gelinas, R., 1985. Land use monitoring methodology using the Canada land data system, **In**: the decision maker and LIS, Proceedings FIG Int. Symposium, Edmonton, Alberta, Canada.

* Goodchild, M.F., 1988. The isssue of accuracy in global databases, **In** Mounsey H.(ed), Building Databases for Global Science, Taylor and Francis, p31-48.

Goodchild, M.F. and Kemp, K.K., 1990. NCGIA Core Curriculum, University of California, Santa Barbara.

* Goodenough, D.G., 1988. Thematic mapper and SPOT integration with a geographic information system, Photogrammetric Engineering and Reomte Sensing **54**(2) p167-176.

* Graetz, R.D., Pech, R.P., Gentle, M.R. and O.Callaghan, J.F., 1986. The application of LANDSAT image data to rangeland assessment and monitoring: the development and demonstration of a land image-based resource information system (LIBRIS), Jnl of Arid Environments **10** p53-80.

* Groom, G.G.D., 1988. The land information revolution, The Australian Surveyor **34**(2) p153-169.

* Gubb, A., 1989. An evaluation of LANDSAT MSS data for ecological land classification and mapping in the northern Cape, Unpublished thesis, Botany dept UCT.

* Guptill, S.C., 1989. Evaluating geographic information systems technology, Photogrammetric Engineering and Remote Sensing **55**(11) p1583-1587.

* Hackman, G.A., Willatts, E.C. and Worth, J., 1972. Instant maps, The Geographical Magazine **44**(1) p775-781.

* Hamilton, A.C. and Williamson, I.P., 1985. A critique of the FIG definition of "Land Information System", **In**: The decision maker and Land Information Systems, Proceedings FIG Int. Symposium, Edmonton, Alberta, Canada.

Harms, D.J., Smidt, D.E., Uiterwijk, U. and Van de Waal, E.H., 1988. Changes in species composition of heathland, monitored by means of remote sensing and field mapping: the results of the Heispot project, Conference proceedings SPOT-1 Image utilization, assessment, results, Toulouse France.

Harris, R., 1987. Satellite Remote Sensing: An Introduction, Routledge and Kegal Paul, London.

* Hill, J.M., Harlow, C.A. and Zimmerman, P., 1983. GIS as applied to the manipulation of environmental data, The Environmentalist **13**(1), p33-38.

* Hogg, J. and Stuart, N., 1987. Resource analysis using remote sensing and an object-oriented geographical information system, Advances in digital image processing: Proceedings of annual conference of remote sensing society, Nottingham.

* Hutchinson, C.F., 1982. Techniques for combining LANDSAT and ancillary data for digital classification improvement, Photogrammetric Engineering and Remote Sensing **48**(1) p123-130.

* Jackson, M.J. and Mason, D.C., 1986. The development of integrated geo-information systems, Int.J.Remote Sensing **7**(6) p723-740.

* Jarman, M.L., 1982. A look at the littlest floral kingdom, Scientiae **23**(3) p9-19.

Jarman, M.L., 1979. An investigation into the usefulness of various remote sensing products for studying and mapping the Fynbos biome, Progress Report, CSP, CSIR, Pretoria.

* Jarman, M.L., 1981. Remote sensing applications in vegetation mapping with special reference to the Langebaan area, South Africa, Unpublished M.Sc. Dissertation, Department of Botany, UCT.

* Jarman, M.L., Bossi, L. and Moll, E.J., 1981. Remote sensing products for studying and mapping the Fynbos biome, Eco-lab Publication, Department of Botany, UCT.

Jarman, M.L., Bossi, L. and Moll, E.J., 1983. The role of digital processing in mapping the major vegetation units in the Fynbos biome, in Martin, CGC (ed): Proceedings, EDIS 83 Symposium, 19-20 September 1983, Pretoria. South African Society for Photogrammetry, Remote Sensing & Cartography, Cape Town.

Jarman, M.L. and Jackson, A.A., 1981. Use of LANDSAT data in mapping vegetation at a semi-detailed scale in the Langebaan area, South Africa, S.A. J. of Photogrammetry, Remote Sensing & Cartography **13**(1) p25-37.

* Jarman, M.L., Jarman, N.G. and Edwards, D., 1983. Remote sensing and vegetation mapping in South Africa, Bothalia **14**(2) p271-282.

Jensen, J.R., 1983. Educational image processing: an overview, Photogrammetric Engineering and Remote Sensing **49**(10) p1151-1157.

Jewell, N., 1988. An evaluation of multidate SPOT data for agriculture and land use mapping in the United Kingdom, Conference proceedings SPOT-1 Image utilization, assessment, results, Toulouse France.

* Johannsen, C.J. and Barney, T.W., 1981. Remote sensing applications for resource management, J.Soil and Water Conservation **36** p128-134.

Johannsen, C.J. and Sanders, J.L., 1982. Remote Sensing for Resource Management, Soil Conservation Society of America, Ankeray, Iowa.

Johnston, K.M., 1987. Natural resource modelling in the geographic information system environment, Photogrammetric Engineering and Remote Sensing **53**(10) p1411-1415.

Jones, A.R., Settle, J.J. and Wyatt, B.K., 1988. Use of digital terrain data in the interpretation of SPOT-1 HRV multispectral imagery, Int.J.Remote Sensing **9**(4) p669-682.

Justice, C.O., Wharton, S.W. and Holben, B.N., 1981. Application of digital terrain data to quantify and reduce the topographic effect on LANDSAT data, Int.J.Remote Sensing **2**(3) p213-230.

Justice, J.R.G. and Justice, C.O., 1980. Unsupervised classification of MSS LANDSAT data for mapping spatially complex vegetation, Int.J.Remote Sensing **1**(2) p105-120.

* Knapp, E.M. and Rider, D., 1979. Automated geographic information systems and LANDSAT data: a survey, Computer Mapping in Natural Resources and the Environment, Harvard Library of Computer Graphics 4 p57-68.

* Lane, S.B., 1980. Interpretation of digital LANDSAT-1 imagery from Verlorenvlei, South Western Cape, Unpubl M.Sc. School of Environmental Studies, UCT.

* Likens, W., 1981. Hierarchical modeling for image classification, Proceedings of PECORA 7 Symposium, American Society of Photogrammetry, Sioux Falls, South Dakota.

Lodwick, G.D. and Feuchtwanger, M., 1987. Land-related Information Systems, Dept of Surveying Engineering, University of Calgary, Calgary, Alberta.

* Logan, T.L. and Bryant, N.A., 1987. Spatial data software integration: meeting CAD/CAM/mapping with GIS and image processing, Photogrammetic Engineering and Remote Sensing **53**(10) p1391-1395.

* MacDougall, E.B., 1975. The accuracy of map overlays, Landscape Planning **2** p23-30.

* Maffini, G., 1987. Raster versus vector data encoding and handling: a commentary, Photogrammetric Engineering and Remote Sensing **53**(10) p1397-1398.

Malan, O.G. and Turner, B., 1983. The Heilbron crop mapping project:the identification of agricultural crops in the Heilbron area by the use of satellite imagery parts 1,2 and 3, NPRL, CSIR special report.

Malan, O.G. and Turner, B., 1984. Mapping of winter crops on the South African highveld, Proceedings COSPAR conference, Graz, Austria.

Malan, O.G. and Westfall, R.H., 1986. A new strategy for vegetation mapping with the aid of LANDSAT MSS data, Proceedings 26th COSPAR conference: Advances in space research, July 1986, Toulouse, France.

* Marble, D.F., 1985. Geographic information systems and land information systems: differences and similarities, In: The decision maker and LIS, Proceedings FIG Int. Symposium, Edmonton, Alberta, Canada.

Marble, D.F. and Peuquet, D., 1983. Geographic information systems and remote sensing, **In** Colwell, R.N.(ed), Manual of Remote Sensing. American Society of Photogrammetry, Falls Church, Virgina p923-958.

* Martin, C.G.C. and Tregidga, A., 1988. Grids and co-ordinates systems, Department of Surveying, UCT.

* Mather, P.M., 1989. Remote sensing: an input to geographical information systems, Proceedings of First International Conference on Geographical Information Systems (SAGIS), University of Natal, Pietermaritzburg.

* McLaughlin, J., 1985. Land information management: a Canadian perspective, J. of Suveying Engineering **111**(2) p93-104.

* Mcloed, R.G. and Logan, T.L., 1980. The use of LANDSAT, digital terrain, and ground sample data as inductively derived information input to a multispectral classifier for wildlands mapping and inventory, **In:** Manual of Remote Sensing 1 (1983).

* Moll, E.J. and Campbell, B.M., 1976. The ecological status of Table Mountain, Department of Botany, University of Cape Town.

* Moll, E.J., McKenzie, B., McLachlan, D. and Campbell, B.M., 1978. A Mountain in a city - the need to plan the human usage of the Table Mountain National Monument, South Africa, Biol. Conserv. **13** p117-131.

* Moll, G., 1987. Table Mountain: a natural wonder, Wildlife Society, Cape Town.

Newby, T.S., 1984. The use of digitally interpreted satellite imagery, with special reference to topographical shadow effects, as an aid to vegetation mapping in the Hottentots Holland mountain catchment area of the Western Cape Province, Unpublished M.Sc. Thesis, School of Environmental Studies, UCT.

* Newell, R.G. and Theriault, D.G., 1990. Is GIS just a combination of CAD and DBMS? Mapping Awareness **4**(3) p42-45.

Palmer, A.R., (in Prep). Using LANDSAT MSS data to detect and map vegetation units in the semi-arid Karoo region, South Africa: an assessment, Unpublished report, Botanical Research Unit, Grahamstown.

* Parker, H.D., 1988. The unique qualities of a geographic information system: a commentary, Photogrammetric Engineering and Remote Sensing **54**(11) p1547-1549.

Philipson, W.R., 1984. Problem solving with remote sensing, Photogrammetric Engineering and Remote Sensing **50**(12) p1753-1756.

Philipson, W.R., 1986. Problem-solving with remote sensing: an update, Photogrammetric Engineering and Remote Sensing **52**(1) p109-110.

Piper, S., Fincham, R. and Hine, S., 1990. Decision support systems for GIS, S.A.Jnl.of Surveying and Mapping **20**(6) p253-258.

* Piper, S.E., 1989. Feature extraction, Proceedings of workshop on integrated remote sensing and geographic information systems, Dept of Water Affairs, Pretoria.

* Polton, I. and Brown, B., 1989. An integrated remote sensing and GIS approach to the study of catchments, Proceedings of First International Conference on Geographical Information Systems in Southern Africa (SAGIS), University of Natal, Pietermaritzburg.

Poolman, J., 1989. Making GIS operational in Southern Africa, **In:** Macdevette D.R. (ed) Managers / decision-makers Forum. Proceedings of a workshop at SAGIS '89 Conference, University of Natal, Pietermaritzburg.

Randall, L., 1988. Mapping land cover from satellite data, Proceedings of a colloquium held at the Hydrological Research Institute, Pretoria on 8th November 1988 entitled Remote sensing can contribute to integrated catchment management.

* Reed, B.C., 1988. Using textual measures to distinguish spectrally similar vegetation, Annual convention of ACSM/ASPRS 4, Baltimore, Maryland.

* Rhind, D., 1989. Geographical and land information systems: their relationship, shortcomings and future prospects, Proceedings of the Conference of Southern African Surveyors (CONSAS 89).

Richardson, A.J., 1977. Distinguishing vegetation from soil background information, Photogrammetric Engineering and Remote Sensing **43**(12) p1541-1552.

* Ripp, M.R., 1978. The use of digital analysis of LANDSAT-1 imagery in mapping vegetation of the southern Cape Peninsula, South Africa, Unpublished Hons. Thesis, Department of Geography, UCT.

* Robinson Baker, G., 1988. Remote sensing: the unheralded component of geographic information systems, Photogrammetric Engineering and Remote Sensing **54**(2) p195-199.

Sabins, F.F., 1978. Remote Sensing Principles and Interpretation, Freedman and Co, San Fransisco.

Scheepers, J.C., 1978. Investigation into the coordination of vegetation classification, Unpubl. Report, Department of Agriculture Technical Services, Pretoria.

Scogings, D.A. and Piper, S.E., 1984. A pilot study to evaluate the feasibility of constructing half yearly medium scale landcover maps of selected non-urban areas of Natal using remote sensing data. Department of Surveying, University of Natal.

* Shaunghnessy, G.L., 1980. Historical ecology of alien woody plants in the vicinity of Cape Town, South Africa, Unpublished Ph.D. thesis, School of Environmental Studies, UCT.

* Shelton, R.L. and Estes, J.E., 1981. Remote sensing and geographic information systems: an unrealized potential, Geo-processing **1** p395-420.

* Simonett, D.S., 1983. Development and principles of remote sensing, **In**: Colwell, R.N. (ed), Manual of Remote Sensing. American Society of Photogrammetry, Falls Church, Virginia, p1-35.

* Smith, A.Y. and Blackwell, R.J., 1980. Development of an information data base for watershed monitoring, Photogrammetric Engineering and Remote Sensing **46**(8) p1027-1038.

* Smith, R.S., Sudhakar, M., Star, J.L. and Estes, J.E., 1987. Requirements and principles for the implementation and construction of large-scale geographic information systems, Int.J.Geographical Information Systems **1**(1) p13-31.

* Specht, R.L. and Moll, E.J., 1983 Mediterranean-type heathlands and Sclerophyllous shrublands of the world: an overview, **In**: Kruger, F.J., Mitchell, D.T. and Jarvis, J.U.M. (eds) Mediterranean-type ecosystems, Springer-verlag, Berlin, Germany.

* Sturdevant, J.A., 1981. The development and application of a county-level geographic data base, Proceedings of PECORA 7 Symposium, American Society of Photogrammetry, Sioux Falls, South Dakota.

* Szekielda, K., 1986. Satellite Remote Sensing for Resources Development, Graham and Trotman Limited, London.

Tateishi, R. and Mukouyama, Y., 1987. Land cover classification using SPOT data, Geocarto International **2** p17-29.

* Taylor, H.C., 1969. A vegetation survey of the Cape of Good Hope Nature Reserve. M.Sc Thesis, Botany Dept, UCT.

* Taylor, H.C., 1978. Capensis **In**: Werger M.J. (ed) Biogeography and ecology of Southern Africa, The Hague, Netherlands.

Thirwall, S.L., 1989. Information content of SPOT data for topographic mapping of the Sherbrooke, Quebec test area, CISM Journal ACSGC **43**(2) p133-143.

Tomlinson, R.F. and Boyle, R.A., 1981. The state of development of systems for handling natural resource inventory data, Cartographica **18**(4) p65-95.

* Townshend, J. and Justice, C., 1981. Information extraction from remotely sensed data: A user view, Int.J.Remote Sensing **2**(4) p313-329.

Tucker, C.J., 1978. A comparison of satellite sensor bands for vegetation monitoring, Photogrammetric Engineering and Remote Sensing **44**(11) p1369-1380.

Turner, B., 1984. Review: combinations of satellite spectral bands for monitoring vegetation with examples of the vegetation indices from LANDSAT MSS for wheat on the Highveld for the 1981,1982,1983 seasons, Internal report NPRL, CSIR Pretoria.

* van der Westhuizen, P.J., 1984. National programme for remote sensing, FRD/CSIR Report.

Veenstra, C. and McMaster, C., 1988. Assessment of SPOT imagery for topographic revision and vegetation mapping, Conference proceedings SPOT-1 Image utilization, assessment, results, Toulouse France.

* Ventura, S.J., Niemann, B.J. and Moyer, D.D., 1988. A multipurpose land information system for rural resource planning, J.Soil and Water Conservation **43** p226-229.

* Venugopal, G., 1988. Area sensitivity and feature sensitivity of SPOT 1 data: a statistical analysis, Annual convention of ACSM/ASPRS4, Baltimore, Maryland.

* Walsh, S.J., 1988. GIS: An instruction tool for earth science educators, Jnl of Geography **12** p17-25.

* Walsh, S.J., Lightfoot, D.R. and Butler, D.R., 1987. Recognition and assessment of error in geographic information systems, Photogrammetric Engineering and Remote Sensing **53**(10) p1423-30.

* Westfall, R.H. and Malan, O.G., 1986. A method for vegetation stratification using scale-related, vegetation enhanced satellite imagery, Bothalia **16**(2) p263-268.

* Wilmersdorf, E., 1986. A land information system (LIS) for an urban region, Proceedings Auto Carto, London.

* Wilson, P.M., 1986. Using LANDSAT data with a geographic information system, Mapping and Modern Imagery, Proceedings of Int. Soc. Photogrammetry and Remote Sensing.

* Young, J.A.T. and Green, D.R., 1987. Is there really a role for remote sensing in geographic information systems? Proceedings of the Annual Conference of the Remote Sensing Society, Nottingham, p309-317.

* Zietsman, H.L., 1982. Grondgebruikkartering van suid-wes Kaapland met behulp van LANDSAT-gegewens, Instituut van Kartografiese Analise, Universiteit van Stellenbosch.

* Zietsman, H.L., 1989. Potential uses of GIS in Southern Africa: a third world perspective, **In**: MacDevette D.R. (ed) Managers / Decision Makers Forum. Proceedings of a workshop at SAGIS '89 Conference, University of Natal, Pietermaritzburg.

APPENDIX 1: DATA STORED IN THE CAPE PENINSULA GIS

This appendix lists all the data level by level that is stored in each of the four databases (GDBs). Abbreviations of the source of the maps, given in brackets is that found stored with each map in the database. The name of the relevant key, which can be found in the IDB (DIGIT.IDB), is given for each theme. Not all levels were utilized as more data has yet to be collected, and the data density in certain cells (along the coastline) reached a maximum.

Pen number (SICAD parameter ST) relates to line colour which is dependent on the pen position in the plotter, the numbers below were chosen as other numbers (colours) do not show up on the monochrome screen.

1 = green
4 = black
5 = blue
7 = red

Line type (SICAD parameter SM)

1 = solid
2 = dashes
3 = dots
4 = dash/dot

1. Natural Resources CAPE-GDB

Level 1 Transformation points

These consist of a 5 kilometre grid over the entire study area, used for registering the standard topographical maps to the geographical database.

Level 2 Coastline

Source: Survey and Mapping Dept (Dept S.M.)
Scale: 1:50 000
Date: 1984
Extent: complete

Level 3 Geology

key:GEOLKEY

Source: Geological Survey (Geol Survey)
Scale: 1:50 000
Date: 1984
Extent: complete

Abbreviations in description e.g. Qsr refer to source maps

Name	Description	Colour	Line Type	Density	Hatching Angle
A	White sand/shell Qsr	4	1	200	45
B	Limestone/calcrete Qc	4	1	100	0
C	Light grey/pale red sandy soil Qg	4	1	100	45
D	Scree/gritty sand Qt	4	1	50	90
E	Qc but crossbedded	4	1	200	90
G	Ferricrete Qf	4	1	50	45
K	Fill Qd	4	1	200	0
M	Brackish calcareous soils Qb	4	1	50	0
F	Thinly bedded sst/silt /mud Og	5	2	100	135
I	Qtz sandstone Op	5	2	200	-45
H	Granite Ec	1	3	150	30
J	Phyllite/greywache	7	4	100	-90
L	Alluvium	0	0	-	-

Level 4 Vegetation

Key: VEGTXT

Source: Taylor H.C. M.Sc.Thesis, Botany Dept, UCT
Scale: 1:37 000 approx
Date: 1969
Extent: Cape of Good Hope Nature Reserve

Name	Description	Line Colour	Type	Hatching Density	Angle
A	Eriocephalus coast shelf & dune fynbos	1	3	200	45
B	Coleonema fynbos	1	3	100	45
C	Helichrysium scirpus marsh	5	2	20	45
D	Upland mixed fynbos	1	3	250	90
E	Tall fynbos	1	3	125	90
F	Pseudo savannah	7	1	75	90
G	Plateau fynbos	1	3	175	135
H	Tussock marsh	5	2	40	90
I	Seepage scrub	5	2	75	135
J	Sideroxylon scrub	1	3	50	0

K	Tall scrub	1	3	150	0
L	Pine/Acacia thicket	7	1	10	0
X	Vleis	5	2	50	-45

Level 5 Mean Annual Precipitation

Key: RAINKEY

Source: Computer Centre for Water Research (CCWR), University of Natal, Pietermaritzburg (UNP).
Scale: 1:50 000
Date: July 1989
Extent: complete

Name	Description	Line Colour	Line Type	Hatching Density	Hatching Angle
A	< 40mm	7	1	200	90
B	40 - 50	7	1	150	90
C	50 - 60	7	1	100	90
D	60 - 70	7	1	50	90
E	70 - 80	4	4	150	0
F	80 - 90	4	4	100	0
G	90 - 100	4	4	50	0
H	100 - 110	1	3	150	45
I	110 - 120	1	3	100	45
J	120 - 130	1	3	50	45
K	130 - 140	5	2	200	-45
L	140 - 150	5	2	150	-45
M	150 - 160	5	2	100	-45
N	>160	5	2	50	-45

Level 7 Soils

Key: SOILKEY

Source: Soil and Irrigation Research Institute (SIRI)
Scale: 1:20 000
Date: 1976
Extent: complete but excluding urban areas

Name	Soil type	Line Colour	Line Type	Hatching Density	Hatching Angle
A	Red/yellow apedal soil <15% clay	7	1	50	0
B	Red/yellow apedal soil >15% clay	7	1	100	0
C	Shallow-mod.deep grey sandy soil	5	2	200	90
D	Deep non-hydromorphic grey soil	4	4	150	30
E	Deep hydromorphic grey soil	4	4	75	30
F	Shallow/deep podzols	1	3	100	135
G	Shallow non-hydromorphic soil	4	4	100	90
H	Shallow/mod.deep hydro sandy with clay soil	4	4	50	90

I	Alluvial deposits	1	3	50	45
J	Rock and shallow soil	4	1	200	-45

Level 8 Topography

Source: Survey and Mapping Department (Dept S.M.)
Scale: 1:50 000
Date: 1984
Extent: Complete, hundred metre contour interval

Level 10 Surface Waterbodies

Key: WATERKEY

Source: Survey and Mapping Department (Dept S.M.)
Scale: 1:50 000
Date: 1984
Extent: complete

Name	Description	Colour	Line Type	Hatching Density	Hatching Angle
A	Dam	5	1	25	0
B	Vlei	5	1	25	90
C	Wetland	5	1	50	45
D	Lagoon	5	1	50	135

Level 11 Rivers - perennial *

Key: RIVERKEY

Source: Survey and Mapping Department (Dept S.M.)
Scale: 1:50 000
Date: 1984
Extent: complete

Line colour 5 Line type 1

Level 12 Rivers - non-perennial *

Key: RIVERKEY

Source: Survey and Mapping Department (Dept S.M.)
Scale 1:50 000
Date: 1984
Extent: complete

Line colour 5 Line type 2

* Attached to rivers on level 11 and level 12 are non-graphic records concerning estuaries

Source: An assessment of the state of the estuaries of the Cape and Natal in 1985/86 (NSP130)
Date: August 1986

Record name	Description
ES	Estuaries

Level 13 Dams/vlei names

Source: Surveying and Mapping Department (Dept S.M.)

Text height=100, colour=5(blue), font=DR

Alexandra reservoir
Devilliers dam
Hely Hutchinson reservoir
Jackson reservoir
Kleinplaas dam
Lewis Gay dam
Princess vlei
Rawson reservoir
Rondevlei
Silvermine dam
Sandvlei
Sirkelsvlei
Soutpan
Victoria reservoir
Wildevoel vlei
Woodhead reservoir

Level 14 Wetlands surveyed by Freshwater Research Unit (FRU)

Source: Zoology Dept, UCT
Scale: n/a
Date: 1989
Extent: incomplete survey

Position of wetland stored as a point with point symbol code=C (small cross). Latitude and longitude taken from FRU, only approximate.

		S	E
01	Kleinplaats West	34 10 20	18 23 10
02	Kleinplaats East	34 09 40	18 23 35
03	Glencairn Vlei	34 09 40	18 25 50
04	Groot Rondevlei	34 14 25	18 23 00
05	Klaasjaggers Estuary	34 13 55	18 22 50
06	Blaawberg Vlei	34 17 05	18 23 40
07	Little Princes Vlei	34 02 50	18 28 35
08	Langevlei	34 03 30	18 28 00
09	Princess Vlei	34 02 50	18 29 50
10	Maclears Beacon	33 58 00	18 25 35
11	Window sponge	33 58 29	18 25 20
12	Noodhoek Soutpan	34 07 12	18 22 41
13	Kenilworth Race Course	33 59 45	18 29 15
14	Wildevoelvlei	34 08 06	18 21 46
15	Chemony Vlei	34 07 07	18 23 49
16	Rompe Vlei	33 59 40	18 29 52
17	Silvermine source	34 04 02	18 23 16
18	Silvermine Dam Inflow	34 04 25	18 23 45
19	Silvermine river floodplain	34 07 35	18 25 43
20	Pinelands- the crossing	33 56 07	18 29 27

Level 16 SPOT 1987 : visual interpretation

Source: Satellite Application Centre (SAC), Haartebeesthoek
Scale: 1:100 000
Date: 12 Dec 1987
Extent: Signal Hill to Scarborough

Code	Description
1	deep water
2	shadow
3	cloud
4	sand
5	exposed ground
6	firebreak
7	less exposed ground
8	shallow water
9	urban area
10	suburban area
11	cultivated land
12	shrubland: mountain
13	shrubland: north facing
14	shrubland: plateau
15	shrubland: south facing
16	alien &/or scrub forest
17	plantations
18	coastal bush
19	grassland
20	Pinus radiata &/or P. pinea

Level 17 Enhanced SPOT Imagery - Visual interpretation

Source: EMA, Stellenbosch
Scale: 1:50 000
Date: 12 Dec 1987
Extent: Signal Hill to Scarborough

Line type=dashed (SM=2)

Level 18 SPOT 1989 : visual interpretation

Source: SAC
Scale: 1:50 000
Date: 27 September 1989
Extent: complete

Line type =dashed (SM=2), line colour = green (ST=1)

Level 20 Location of rare plants

Source: Cape Inventory of Critical Environmental Components (CICEC), Cape Department of Nature and Environmental Conservation
Scale: 1:50 000
Date: 1988
Extent: incomplete

The position of the plant is marked by a point, (PKZ=T, small circle) to which non-graphic data is attached.

Record name	Description
RA	Rare species locator code record
SP	Species record
PL	Individual plant record
CN	Cape Nature Area ownership record

Level 24 Invasive Plant Distribution

Key: ALIENKEY

Source: Department of Environment Affairs (Dept Environ)
Scale: 1:50 000
Date: 1984
Extent: Cape Peninsula Nature Area

Name	Description	Line		Hatching	
		Colour	Type	Density	Angle
A	Plantations	1	3	100	90
B	Light Infestation	7	1	200	45
C	Medium Infestation	7	1	100	45
D	Dense Infestation	7	1	50	45
E	Vleis and dams	5	2	25	0

Level 29 Trigonometric Beacons

Source: Trigonometric Survey Office, Mowbray (Trig Survey)
Scale: n/a
Date: 1988
Extent: selected

All trig beacons have small triangles as point symbols with the name of the beacon as a text element.
Text height=200,colour=4(black),font=default

Beacons from 3318CD Cape Town

Name	No	Lo19 Y	Lo19 X
Lions Rump	15	55 060.43	3754 315.48
Maclears (Table Mtn)	28	53 028.36	3759 830.62

Wynberg Hill	32	50 931.08	3762 898.83
Lions head	51	56 418.44	3756 332.32
Cecilia	115	54 223.03	3763 109.39
Devils Peak	116	51 786.36	3758 429.85
Fernwood	119	52 888.92	3760 506.79
Slangoile	129	57 151.29	3761 255.18
Ter 2	283	60 334.15	3762 711.98
H.G.New	343	59 522.13	3763 446.59

Beacons from 3318CD Cape Peninsula

		Lo19	
Name	No	Y	X
Buffelsfontein	1	51 619.37	3799 039.59
Constantiaberg	3	56 673.78	3769 540.52
Elsiepiet	6	51 985.12	3780 159.10
Karbonkelberg	10	62 329.45	3768 006.23
Olifantsbosch	14	56 502.36	3792 882.44
Paulsberg	15	49 340.55	3796 074.95
Bonteberg	23	56 686.25	3787 807.02
Chapmans	25	59 038.98	3773 356.84
Glencairn	30	53 334.16	3781 425.95
Grootkop	31	56 093.51	3784 022.31
Kalk Bay	33	51 648.74	3775 963.67
Klaas Jagersberg	34	52 656.06	3787 868.97
Little Lions Head	38	60 580.66	3765 417.93
Noodhoek	41	55 674.70	3773 603.69
Rooihoogte	48	50 479.08	3792 978.96
Rooikrans	49	57 565.15	3779 507.48
Steenbergkoppie	66	53 612.21	3772 725.05
Vlakkenberg	73	55 488.65	3766 582.34
Muizenberg X	90	49 910.89	3775 514.89
Trappies	91	51 573.92	3777 678.68
Welcome	126	55 117.15	3779 959.13
Margate (new)	142	47 423.76	3772 960.59
Peers Cave	154	54 739.56	3776 568.79
Kommetjie N	183	62 000.08	3779 718.00
Dassenberg	188	56 415.14	3775 594.00

Level 30 Spot Transformation Points

These are distinctive points visible on the image, whose co-ordinates were estimated from the 1:50 000 topographical maps, for registering the SPOT image with the geographical database.

Number	Description	Y	X
1	Robben Island N harbour pier	57 500	3741 200
2	Tableview main crossroads	47 450	3744 000
3	N2 crossing Soutvlei	47 400	3757 600
4	Soutvlei entering Tablebay	48 850	3753 250
5	Cape Town harbour W pier	52 250	3752 150
6	Tokai crossroads	50 800	3770 650
7	Glen Avon crossroads	51 150	3767 100
8	Alphen crossroads	50 400	3765 100

9	Houtbay harbour S pier	59 950	3769 300
10	Logies rock (island)	61 500	3764 050
11	Whale rock (island)	57 900	3758 150
12	Die Middelmas (island)	64 100	3766 800
13	Sunnycroft sunvalley Y-junction	55 750	3777 750
14	Oceanview T-junction	59 500	3779 500
15	Witsand crossroads	60 510	3781 850
16	Kleinplaas dam wall S	56 500	3782 800
17	Simonstown harbour W wall	51 900	3784 250
18	Cape Point	46 150	3803 100
19	Strandfontein sewerage works (centre of wheel)	44 900	3772 650

Additional transformation points for use with Molls 1976 Table Mountain maps.

Kloofneck	55 800.00	3756 900.00
Rhodes Memorial turnoff	49 900.00	3759 600.00
Kirstenbosch Junction	52 050.00	3762 650.00
Lekkerwater/sea	59 200.00	3761 500.00
Disa stream junction	56 850.00	3765 150.00

2. Infrastructure INFR-GDB

Level 1 Transformation Points

(as for CAPE-GDB above)

Level 2 Coastline

(as for CAPE-GDB above)

Level 3 Cape Peninsula Nature Area Ownership
Key: CNAKEY

Source: City of Cape Town (CCC), City Engineer
Scale: 1:50 000
Date: 1989
Extent: complete

Name	Description	Line Colour	Line Type	Hatching Density	Hatching Angle
C	Cape Town City Council	4	4	500	-45
D	S.A.Defence Force	7	1	100	90
E	Environment Affairs & Forestry	1	3	200	0
F	Fish Hoek Municipality	4	4	100	45
G	Public Works &	1	3	100	0

	Land Affairs				
K	National Botanic Gardens	1	3	50	0
P	CPA - CDNEC	5	2	100	60
R	Regional Service Council	5	2	200	60
S	Simon,s Town Municipality	4	4	200	45
X	Private Land	5	2	100	30

Level 10 Roads

Key: ROADKEY

Source: Survey and Mapping Department (Dept S.M.)
Scale: 1:50 000
Date: 1984
Extent: complete

Name	Description	Line	
		Colour	Type
A	National	7	1
B	Main	4	1
C	Secondary	1	1

Level 16 Landuse: Guide Plan for the Cape Peninsula

Key: GUIDEKEY

Source: Cape Metro Planning Committee (CMPC)
Scale: 1:100 000
Date: 1989
Extent: complete

Name	Description	Line		Hatching	
		Colour	Type	Density	Angle
A	Urban Development	5	2	100	90
B	Industrial Purposes	5	2	200	0
C	Nature Area	1	3	500	-45
D	Open Space	1	3	300	-30
E	Government Use	4	4	200	45
F	Mineral/Construction Materials	7	1	200	135
G	Dumping Site	7	1	100	135
H	Sewerage Works	7	1	50	135
I	Agriculture	1	3	400	-90

Level 25 Checklists

The Cape Peninsula Nature Area ownership map (level 3) has been modified to indicate roughly the area each checklist covers. The non-graphic record (CH) is attached to the text element within the area.

Record name	Description
CH	Plant Species Checklist

Level 27 Place names

Text height=200, colour=1(green), font=CR2

Cape of Good Hope Nature Reserve
Silvermine Nature Reserve
Table Mountain Nature Reserve

Level 28 Town names

Text height=200,colour=7(red),font=DR

Campsbay
Cape Town
Fish Hoek
Houtbay
Kommetjie
Llandudno
Muizenburg
Scarborough
Simons Town

Level 29 Trigonometric Beacons

(as for CAPE-GDB above)

3. Fire Management MANT-GDB

Key: FIREKEY

Title: Fire Frequency and Extent
Source: City of Cape Town, City Engineer
Scale: 1:10 000
Date: 1984 (Silvermine), 1989 (Table Mountain)
Extent: Table Mountain & Silvermine Nature Reserves only

Level 1 Key

Level 2 Coastline (as for CAPE-GDB above)

Level	Name	Year	Line		Hatching	
			Colour	Type	Density	Angle
3	A	1962	1	3	60	-90
4	B	1964	1	3	100	-90
5	C	1965	1	3	120	-90
6	D	1966	1	3	140	-90
7	E	1967	1	3	160	-90
8	F	1968	1	3	180	-90
9	F1	1969	1	3	200	-90

10	G	1970	5	2	20	45
11	H	1971	5	2	40	45
12	I	1972	5	2	60	45
13	J	1973	5	2	80	45
14	K	1974	5	2	100	45
15	L	1975	5	2	120	45
16	M	1976	5	2	140	45
17	N	1977	5	2	160	45
18	O	1978	5	2	180	45
19	P	1979	5	2	200	45
20	Q	1980	7	1	20	135
21	R	1981	7	1	40	135
22	S	1982	7	1	60	135
23	T	1983	7	1	80	135
24	U	1984	7	1	100	135
25	V	1985	7	1	120	135
26	W	1986	7	1	140	135
27	X	1987	7	1	160	135
28	Y	1988	7	1	180	135
29	TRIGONOMETRIC BEACONS (as for CAPE-GDB above)					
30	Z	1989	7	1	200	135

4. Molls' Table Mountain Maps TMTN-GDB

Level 1 Transformation Points

(as for CAPE-GDB above)

Level 2 Coastline

(as for CAPE-GDB above)

The following details hold true for all the maps listed below

Source: Moll,Botany Dept, UCT
Scale: 1:18 000 approx
Date: 1976
Extent: Table Mountain

The level chosen for each theme in this database corresponds with the Moll source map number from which the theme was taken unless otherwise stated.

Level 9 Distribution of Grasslands

Key: Grasskey

Name	Description	Line Colour	Line Type	Hatching Density	Hatching Angle
A	<25% PCC Non-indigenous	1	1	100	90
B	>25% PCC Non-indigenous	1	1	200	0

* PCC = projected canopy cover
* DA = diameters apart

Level 12 Distribution of <u>Acacia saligna</u>

Key: Saligkey

Name	Description	Colour	Line Type	Hatching Density	Angle
A	> 25% PCC	1	1	40	45
B	10DA - 25% PCC	1	1	80	45
C	40DA - 20DA	1	1	120	45
D	> 50DA	1	1	160	45
outlier					

Level 13 Distribution of <u>Acacia melanoxylon</u>

Key: Melankey

Name	Description	Colour	Line Type	Hatching Density	Angle
A	> 25% PCC	1	1	40	135
B	10DA - 25% PCC	1	1	80	135
C	40DA - 20DA	1	1	120	135
D	> 50DA	1	1	160	135
outlier					

Level 14 Distribution of <u>Acacia mearnsii</u>

Key: Mearnkey

Name	Description	Colour	Line Type	Hatching Density	Angle
A	> 25% PCC	1	1	40	-45
B	10DA - 25% PCC	1	1	80	-45
C	40DA - 20DA	1	1	120	-45
D	> 50DA	1	1	160	-45
outlier					

Level 15 Distribution of <u>Albizia lophantha</u>

Key: Albizkey

Name	Description	Colour	Line Type	Hatching Density	Angle
A	> 25% PCC	1	1	40	-90
B	10DA - 25% PCC	1	1	80	-90
C	40DA - 20DA	1	1	120	-90
D	> 40DA	1	1	160	-90
outlier					

Level 16 Distribution of <u>Eucalyptus spp</u>.

Key: Eucalkey

Name	Description	Colour	Line Type	Hatching Density	Angle
A	> 25% PCC	1	1	40	30
B	10DA - 25% PCC	1	1	80	30
C	40DA - 20DA	1	1	120	30
D	> 50DA	1	1	160	30
E	plantation	1	1	20	-30

Level 19 Forest and Fynbos

Key: Forkey

(combining Moll's maps 19 and 20)

Name	Description	Line Colour	Line Type	Hatching Density	Hatching Angle
A	Undisturbed Forest	1	3	50	-90
B	Disturbed Forest	1	3	100	-45
C	Scrub	1	3	100	45
D	Fynbos	4	4	200	90
E	Disturbed sites	7	1	100	0

Level 20 Forest 1600AD

(adapted from Moll map 6)

Level 21 Erosion

Key: Erokey

Name	Description	Line Colour	Line Type	Hatching Density	Hatching Angle
A	Severe	7	1	30	45
B	Incipient	7	1	60	45

Level 22 Distribution of Impact Areas

Key: Impkey

Name	Description	Line Colour	Line Type	Hatching Density	Hatching Angle
A	High	7	1	40	-90
B	Low	7	1	80	-90
C	Semi wilderness	7	1	120	-90

APPENDIX 2: LIST OF IMAGES STORED IN DIGIT.IDB

This is a list of Images stored in DIGIT.IDB (default image library of user interface). Unless otherwise stated maps cover complete study area.

Name	Description
ALBIZ	Albizia lophantha
ALBIZKEY	Key for ALBIZ
ALIENKEY	Key for alien map
ALIENS	Complete alien map
BUFFER	Road map + 200m buffer zone
COAST	Outline of study area
CNA	Cape Nature Area ownership (boundary only)
EROSION	Erosion map of table mountain
EROKEY	Key to erosion map
EUCAL	Eucalyptus spp.
EUCALKEY	Key for EUCAL
FILEDIV	Shows file division for GDB
FIRE	Fire map TMTN and SMINE
FIRE2	Updated fire map of table mountain
FIREKEY	Key for fire map
FOREST	Forest map of table mountain
FOREST3	" " only forest
FOREST16	" " forest 1600AD
FORKEY	Key to forest map
GEOL	Geology map
GEOLKEY	Key for geology map
GRASS	Grassland map
GRASSKEY	Key for GRASS
GUIDE	Cape Metro Guide Plan
GUIDEKEY	Key for Guide Plan
IMPACT	Impact map
IMPKEY	Key for IMPACT
KEYHORIZ	Master key (horizontal format 4 columns)
KEYVERT	Master key (vertical format 1 column)
MEARN	Acacia mearnsii
MEARNKEY	Key for MEARN
MELAN	Acacia melanoxylon
MELANKEY	Key for MELAN
NAMES	Dams/vleis,trig beacons,reserves
NATURE	Cape Nature Area Ownership
NATURKEY	Key for Nature
RAIN	Mean annual precipitation
RAINKEY	Key for rain
REF	Reference map
RIVER	River map
RIVERKEY	Key for RIVER
ROADS	Road map
ROADSKEY	Key for roads
SALIGNA	Acacia saligna
SALIGKEY	Key for SALIGNA
SAVE	Default save name

SOILALL	Complete soil map
SOILKEY	Key for soil
SPOT (1987)	Landcover boundaries
SPOTPLOT (1987)	Landcover boundaries for Cape Town with numbers
SPOTENHD (1987)	Landcover from enhanced imagery
SPOT89 (1989)	Landcover boundaries
TOWN	Town names
TRIG	Trig beacons
TRANS	Transformation points for SPOT & MOLL maps
VEG	Taylors Vegetation map for Cape Point
VEGTXT	Key for veg
WATER	Complete waterbodies map
WATERKEY	Key for water

INTERSECTION THEMES

VEGSOIL	Rock/Upland mixed fynbos
VEGSOIL2	Podzol/Tussock marsh
VEGSOILP	VEGSOIL2 + key
COLIN	b/w VEGSOIL2 + key
COLIN2	b/w VEGSOIL + key
COLKEY	key for VEGSOIL

APPENDIX 3 NOTES ON SICAD-GDB FOR THE CAPE PENINSULA GIS

The system is running SICAD V4.4 (as of March 1990)

These notes should be read in conjunction with:

- Grids and Co-ordinate Systems, Martin and Tregidga, 1988.
- The SIEMENS NPBGIS Manual (User interface manual), Colvin, 1989.
- SICAD manuals (-KRT1,1989; -KRT2,1987; -GR,1987; -FSCH,1988; -GDB,1988)

These describe and explain the SICAD commands mentioned in this Appendix and are available in the Department of Surveying, UCT.

*** Help facilities are available on the machine ***
Type HELP error code in BS2000 or
HELP 'sicad command' in SICAD

1 GRAPHIC DATA

1.1 GDB SET-UP

The original database was set up with a planning area of GDB coordinates 0, 0 (bottom left-hand corner), and 50 000, 80 000 (top right-hand corner).

GBNEU CAPE-GDB 0 0 50000 80000 (creates a new GDB)
GBNAM CAPE-GDB MW 0 (opens the GDB, MW is the code for the system administrator allowing unrestricted access)
RAHMEN -70 -3810 1000 (reduction constant)
PAS RN NAM=LO19 (establishing the LO19 coordinate system)

It is advisable to make the planning area fit the database as closely as possible for maximum storage capacity. However the planning area should allow for proposed extensions as to increase its size after data has been entered is problematic (see paragraph 1.13 below). The above co-ordinates were chosen to allow for the expansion of the database by the inclusion of the two adjacent 1:50 000 maps, 3318CD (Bellville) and 3418DA (Mitchells Plain).

Subsequent databases were given the same planning area and origin, to facilitate overlaying.

1.2 ADD A GDB TO LIST FOR USE WITH THE USER INTERFACE

To add a new GDB to the list in the interface, edit the procedure P.GDBLIST using the system editor and add in the new GDB (P.NEWNAME-GDB) to the list. Then edit P.CAPE-GDB to create a menu showing what data is on what level and save it as P.NEWNAME-GDB (see paragraph 1.6 below).

1.3 QUARTERING THE GDB

It is advisable to divide the GDB into sub-files, using the GBDVI command, at the outset as it is quicker when the GDB is empty. This file quartering is especially important in areas where the density of data is expected to be high. The file and cell structure of the GDB can be displayed using the GBAU command (see Figure 14 p69). However once done it is impossible to reverse with SICAD version 4.4 and if numerous files are created it may not be possible to extract them all for update (GBLER) simultaneously.

1.4 STATUS OF THE GDB

The present status of the GDB can be ascertained using the GBSTAT commands.

GBSTAT AN will indicate whether or not the GDB is open. GBANRS allows a forced cancel of a task that still remains open i.e. the GBLER command has been used (read and edit) but no GBSAV (write back to the database) followed.
GBSTAT GBD indicates the file breakdown and the amount of data in each file.
GBSTAT ZL indicates which file has the greatest cell-division ie the greatest data density.

1.5 SELECTING DATA FOR EXTRACT FROM THE GDB

To restrict the amount of data called from the GDB and increase the speed of data handling, the following options are available:

1) specific layers can be requested using the GBEBN command or via the user interface.

2) specific subsets or windows of the GDB can be requested by specifying particular limiting co-ordinates with the GBLES(read only) / GBLER(read and write) commands, or with the user interface.

Using the user interface various subsets of the database can be extracted without typing in the co-ordinates. The areas, codes and GDB co-ordinates are given below.

AREA	CODE	APPROX GDB CO-ORDINATES
Study Area	CAPEVEG	5000 5000 25000 70000
Cape of Good Hope Nature Reserve	COGHNR	5000 5000 25000 30000
Silvermine Nature Reserve	SMINE	5000 30000 25000 45000
Table Mountain Nature Reserve	TMTN	5000 45000 25000 60000
Cape Town 1:50 000	3318CD	5000 45000 25000 70000

Cape Peninsula 1:50 000	3418AB	5000	5000	25000	45000
Kommetjie- Fish Hoek Area	KOM-FISH	2000	20000	25000	37000
Simonstown - Houtbay	SIM-HOUT	2000	20000	30000	45000

To add subsets to this list the procedure CORNREC must be used.

1.6 EXTRACT DATA FROM FILE

To extract data from a particular file e.g. CAPE-GDB.32, the co-ordinates must first be found and used for the extraction.

```
GBZPDP DP 0 .32        (finds corner points of file)
POSA                   (displays co-ordinates)
GBLES %P0 %P1          (extract required data)
```

1.7 MODIFY MENUS IN THE INTERFACE

In order to add text to either the list of databases or one of the menus indicating the information on each level, follow the following procedure

PSEL GDBLIST (for database list) FIL=P.GDBLIST
or
PSEL CAPE-GDB (for natural resources) FIL=P.CAPE-GDB
or
PSEL INFR-GDB (for infrastructure) FIL=P.INFR-GDB
or
PSEL MANT-GDB (for fire management) FIL=P.MANT-GDB
or
PSEL TMTN-GDB(for Moll's maps) FIL=P.TMTN-GDB
These SICAD commands place the procedure in a file that can be accessed by the system editor.
Then add the amendments and save them using the editor.
On completion
PADD P.GDBLIST PRO=* (writes the file back to a SICAD procedure)
DOP * (tests the new amendments)
PSAV GDBLIST (saves the procedure)

1.8 SAVING DATA IN THE GDB

When doing the initial save of data into the GDB using the GBSAV XUR=? YUR=?, the two values (which represent the origin of the image) must be set such that the whole image fits into the planning area of the GDB.

It is advisable to save the image in the image library (IDB) first before trying a GBSAV as the screen is cleared with this command even if the procedure is unsuccessful. If the GBSAV is unsuccessful, the GBZPDP command can be used to put the problematic element into the selection set for further analysis.

1.9 GENERATION OF BLOCK GRID

These were regularly spaced points, at 5km intervals over the whole study area, used for transformation of the 1:50 000 map series.
The command sequence was as follows:

```
COIN LO19 70000 3745000   (input LO co-ord)
EPG %P1                   (create point at above co-ord)
SRT PG p1 p2              (select point)
CS*5 %P1 PAL+5000X        (create row by copying selected point)
SEMI; SRT PG p1 p2        (select row of points)
CS*12 %P1 PAL-5000Y       (create grid by copying selected row)
```

(See Martin and Tregidga 1988 p46)

1.10 THEORY OF LEVELS IN THE GDB

It is possible to view different levels of data using the EBD command. To write to a particular level the REB command is used, data on other levels may be selected or snapped onto by specifying them also with the REB command. It is possible to transfer elements from one level to another using the EBS command, even lines pertaining to a polygon may be transferred, leaving the polygon (seen as hatching) behind. However it is not possible to move such a line to another locality as this disrupts the integrity of the polygon. (These commands are all handled with the user interface and a list of what's on each level will appear on the screen as an aid).
The EBA command displays what levels are currently viewed and selected, with the VA=1 option a list of what elements occur on all the layers is provided.

1.11 MASTER-DETAIL SELECTION

Once a selection set of elements has been created, it is possible to find all the "detail" elements that relate to these elements eg all the points and/or lines that make up particular area elements. To do this refer to the SKK and SKKS commands in the -KRT1 manual.

1.12 TO FORCE AN IMAGE INTO THE GDB (i.e. not being an extract)

To replace part of a GDB with an independent image from the IDB, the following procedure was adopted:

```
GBNAM          (open GDB)
GBEBN L ?      (unlock certain levels only for manipulation)
GBLER          (extract from GDB data to be replaced)
DD             (half size of image on the screen)
LR             (erase all elements)
GBSAV          (save back to GDB)
```

```
LAD ?           (call up image from IDB)
GBSTAT GV       (check XUR and YUR values)
GBEBN S ?       (save data only onto specific levels)
GBSICU NEU      (severs link to GDB enabling one to
GBSICU UEB      write back new image as an update)
GBSAV XUR=? YUR=?
```

1.13 PLOTTING OPTIONS FOR FIXED SCALE MAPS

The following co-ordinates were determined to create particular fixed scale maps of a particular GDB extract (area), using the user interface.

AREA	SCALE	PAPER SIZE	GDB CO-ORDINATES
CAPETOWN 3318CD	1:50 000	A2 vert	-1500 -1500 18500 22700
SOUTHERN PENINSULA 3418AB	1:50 000	A1 vert	0 0 20000 40000
CAPEVEG STUDY AREA	1:100 000	A2 vert	500 500 36000 56500
COGHNR	1:50 000	A3 vert	3000 1000 17500 20000
TMTN	1:50 000	A3 horiz	0 41000 20000 54800
SMINE	1:50 000	A3 horiz	6000 25000 26000 38800
CAPEVEG	fill paper	A3 vert	0 0 36000 63000

1.14 INTERSECTION OF DIFFERENT LEVELS

This is achieved using the SICAD-FSCH module, see the VERFLFL command. The polygons created by the intersection are placed on the specified level, a procedure called INTERSECT has been written to facilitate this. Another procedure (AREAEVAL) will calculate the total area with any specified name within the image. It should be noted that the tasks create an area (FL), measure an area (BEFL) and create an intersection of areas (VEFLFL), all have different limits i.e. the maximum size of the areas themselves is variable. The VEFLFL requires smaller areas than the others and may therefore necessitate the sub-division of large areas.

1.15 BUFFER ZONES

It is possible to create buffer zones around lines of type LY only, see BUFFER command in SICAD-FSCH manual.

1.16 CHANGE PLANNING AREA

To change the planning area of a GDB with both graphic and non-graphic data in it, the following procedure is advised.

```
*** FIRST MAKE A COPY OF THE DATABASE ***
GBLEDT filename1 0          (set up file to store definitions)
GBD record typeP DVA=D     (writes definition to file)
Repeat this for all record types, and then edit the file so that
it begins with PROCD and ends with ENDP. It is now a procedure
that can be used to redefine the record in the new database.
GBLEDT filename2 0          (sets up file to store data)
GBSUCH record type 'X'     (search for all non-graphic records)
GBSUCH record typeN 'X'    (adds records to previous selection)
GBD 0 DVA=D                (writes all records to file)
```

The above series of commands allows one to transfer non-graphic records and their definitions from one GDB to another.

```
GBATW element type/record type/shortname     (attaches pointers
                                              to graphic elements)
GBGQEL .A 0 0 0 0 50000 80000 (spool out data, creates file named
                               SQD.filename.001 etc)
```

```
*** ERASE DATABASE ***

DO P.GBNEU                  (creates new GDB with modified planning
                           area, does file division and spools
                           graphic data back into new GDB)
PADD filename1 PRO=*
DOP *                      (recreates record type in new GDB)
GBSPDT filename2 0           spools back in non-graphic data
```

2 NON-GRAPHIC DATA

2.1 CREATION OF NON-GRAPHIC RECORDS

In order to create non-graphic records the relevant GDB must be open. The GBSTAT GB command will display all non-graphic records created and their relationship (pointers). The following three commands create a non-graphic record structure.

Command	Function
GBDFAT	Creates attributes of non-graphic records
GBDFZS	Indicates which of the above attributes are to be "key" attributes i.e. those necessary to define that record type.

GBDFFS Allows pointers from one record type to another to be indicated. These pointers will automatically come into effect as data records are created.

It is possible to recall and display the definition of a non-graphic record using the GBD command. (KT H will print out this as a screen dump, KT G is the command for a screen dump of the graphics screen).

2.2 ALTERING THE DEFINITION

In order to change the definition of non-graphic data records, the data must be spooled out into a file and then the graphic records themselves destroyed. The record structure can then be modified and the data spooled back in. The necessary commands appear below.

```
GBSUCH PL 'X'     (select all the records)
GBLEDT TEMP 0 (create file called 'temp')
GBD PLL DVA=D (for just the blank form written to file)
or
GBD 0 DVA=DL (all data records written to file)
GBSLOE PL 0 (destroys all records)
```

Now the structure of the definition can be modified and then the data spooled back in using GBSPDT TEMP 0

2.3 DATA INPUT

Data can be entered directly in SICAD using the GBATAE command or via the system editor by following the procedure below:

```
GBLEDT "filename" 0           (sets up file)
GBD "record type"L DVA=D      (creates blank record in file)
```

The blank record structure is now available to be copied and filled in using the editor, creating as many records as are required (see paragraph 3.6 SYSTEM EDITOR under general administration tasks of this Appendix). To spool the data back into the database, use the command below.

```
GBSPDT "filename" 0 (spools back in data)
```

2.4 ATTACHING NON-GRAPHIC RECORDS TO GRAPHIC ELEMENTS

Non-graphic records may be attached to elements in the graphics. In order to do so, descriptors or parameters that were used in the definition of the attribute to act as the link (see GBDFAT) must be attached to the graphic element. This can be done with the PAS command e.g.

```
SRT PG p1         (select a particular point)
```

PAS PG CODE='1'   (add the descriptor)

This point(PG) in the graphics can now be linked to the non-graphic record which has an attribute CODE=1. In order to effect the linkage(s), all relevant graphic elements must be selected. Then follows the sequence of commands below.

GBSICPD   (makes available element decriptors and parameters)
GBSBEF PG ES "record type"   (PG=point ES=create)
GBSAV   (the actual linkage only occurs with GBSAV)

2.5 SEARCHING FOR NON-GRAPHIC RECORDS

Non-graphic records contained within a specific GDB can be selected using the following search commands.

command	function
GBSUCHP	search for all non-graphic records attached to a particular graphic element.
GBSUCH	search for all records with a particular value for an attribute e.g. all plant records where species = ?
GBSUCHI	search for a particular record where one must know the key attributes that uniquely define it eg plant record with specific species, genus and locality.
GBSUCH(R) OR (V)	allows further search on previously selected records to related records via forward pointers (V) or back pointers (R) e.g. using the solution set from the GBSUCHI search and finding all the owner records.

Example of a non-graphic data record search:

GBSUCHA PG RA 'X' p1 p2	(find all rare plant records attached to point elements in a rectangle)
GBSUCHR RA PL 'GEN=ERICA'	(from the above search set find the plant records where genus is <u>Erica</u>)
GBD 0	(display search set)

2.6 TO CONVERT FROM GRAPHIC ELEMENTS TO NON-GRAPHIC RECORDS

To search in the graphics for the location of rare plant species (points) and from the search set find attached non-graphic records. Firstly call up correct level from the relevant GDB (GBEBN AND GBLER), then:

```
SRT PG                  (select points in a rectangle)
GBZPDP SMEM X X         (convert from SICAD selection set to GDB)
GBEMFM PG RA        (convert from GDB graphic element set to non-
                     graphic record)
GDB 0                (display result set)
```

2.7 TO CONVERT FROM NON-GRAPHIC RECORDS TO GRAPHIC ELEMENTS

To find graphic elements associated with particular non-graphic records.

```
GBSUCH ?           (select non-graphic records)
GBFMEM RA PG     (convert from record to graphic element)
(GBLES GVA=SE)
GBEMAU             (determine cells in which graphics sit)
GBLES %P0 %P1, DFN    (call up cells from graphics)
GBZPDP EMSM X X       (put search set into selection set)
PDA PG            (see  details of elements)
```

3 GENERAL ADMINISTRATION TASKS

The following tasks are carried at by the systems administator at the CPU (TSOS is the administation package).

3.1 INITIALIZE TAPE

```
Command                     Function

LOGON TSOS,,'PDP11'         (sign on to TSOS)
EXEC INIT                   (load init)
INIT T9P,VSN=TAPE01,UNIT=T0
```

Load correct tape on tape drive, press EIN button on the console, and type in TSN. e.g. 239.

END

3.2 ARCHIVE

3.2A DAILY or FULL ARCHIVE

A complete backup of the system is created by a full archive, this must be done on a regular basis to avoid losing too much data in the event of a system crash. Daily archives only backup modifications made since the last full archive.

```
LOGON TSOS,,'PDP11'         (sign on to TSOS)
EXEC ARCHIVE           (load archive)
Q, POOL            (check which tapes are free)
END
```

```
DO P.ARC.DAILY (FULL)    (run appropriate procedure)
'(BAC001,BAC002,TAPE01....)'  (enter tape versions)
```

3.2B ARCHIVE SPECIFIC FILES

```
LOGON TSOS,,'PDP11'       (sign on to TSOS)
EXEC ARCHIVE          (load archive)
F ,NA=$CAPEVEG.INFR-GDB       (specify file name)
F ,NA=$CAPEVEG.INFR-GDB.      (specifies all file divisions)
F ,NA=.........
S  ,DIR=NONE,LIST=SYSLST,TAPE=TAPE01,TAPE....),DEVICE=T9P,
CHANGED=NO      (save to tape)
END
LOGOFF          (print out of archive will follow)
```

3.2C RESTORE SPECIFIC TAPE OR FILE FROM ARCHIVE

```
LOGON TSOS,,'PDP11'
EXEC ARCHIVE
F ,NA=$CAPEVEG.........,TO=PUBLIC
          for specific tape
R ,DIR=NONE,REP=ALLP,L=SYSOUT,FROM=S.9007003......,DEVICE=T9P
          for specific file
R , DIR=NONE,FROM=(TAPE02),.....
```

3.2D PURGE TAPES

To purge tapes whose retention period is up.

```
LOGON TSOS,,'PDP11'
EXEC ARCHIVE
* PURGE ,SV=OBSOLETE
```

To purge tapes whose retention period is not obsolete (e.g. after a full back-up, to free the now redundant daily back-up tapes)

```
* PURGE ,SV=(S.100589.113500,S.092189.102000,....),FORCE=YES
```

3.2E REMOVAL AND ADDITION OF TAPES TO ARCHIVE POOL

To remove unusable tapes from the pool.

```
* POOL ,REM=BAC002 (tape can then be re-initialized)
```

to add new tape to the pool

```
* POOL ,ADD=BACOO2
```

3.3 WRITE SPECIFIC FILES TO TAPE (non-archive format)

```
LOGON CAPEVEG,BOTANY,'MIKEW'
EXEC TSOSMT
* GEN SAVTAP,VSNOUT=UCT001
* ADD UCT.IDB,GL.INT,AREAEVAL,etc
* END
```

3.4 DATA TRANSFER PROCEDURE

Data was written from SICAD to a SAM (ASCII) file using the SICAD command "GBGQEL".

It was then written to magnetic tape using PERCON (software available on the SIEMENS), procedure name E.WR and read into a PDP11 mini computer.

The file structure was converted from one with Fortran carriage control to one with records of variable length and carriage control at the end of each line using the editor.

KERMIT was used to transfer the data to the hard disk of a PC. The DOS 3.3 back-up command was used to transfer the data to floppy disc.

3.5 RESET USER CPU TIME OR INCREASE PUBLIC SPACE

```
LOGON TSOS,,'PDP11'       (sign on to TSOS)
ACCOUNT RECORD=CAPEVEG    (CAPEVEG is user-id)
JOIN CAPEVEG,ACCNB=BOTANY,TIME=65000    (re-allocate CPU time)
or
JOIN CAPEVEG,PUBSPACE=150000     (increase public space)
```

3.6 SYSTEM EDITOR

This editor can be used to write procedures, view the content of files, and to input non-graphic data records.

```
LOGON (user-id)

EXEC EDT

r 'FILENAME'          (read file)
+ or -                (scan file)
d                     (delete line)
x                     (marks line to edit)
n eg 5                (gives 5 free lines to enter text)
@lisi 1-50 (lines) I       (prints file)
@d                    (clears screen)
halt                  (ends edit)
```

```
c                    (marks lines to copy)
a                    (copies marked lines after this one)
b                    (copies marked lines before this one)
```

3.7 TO COPY A FILE FROM ONE USER-ID TO ANOTHER

```
LOGON (SOURCE USER-ID)    (sign on)
FSTAT FILENAME,ALL        (displays file to copy)
CAT FILENAME,SHARE=YES,STATE=U     (makes file shareable)
LOGOFF BUT                (sign off)
LOGON (RECEIVING USER-ID)      (sign on)
COPY $SOURCE USER-ID.FILENAME,NEW FILENAME,SAME  (effect copy)
```

APPENDIX 4: DEFINITION OF ALL NON-GRAPHIC RECORDS

Below follows a listing of all the non-graphic records in the Cape Peninsula GIS. They occur in the form of a procedure printed out from the Siemens computer. The SICAD command for creating non-graphic records are explained in Appendix 3 p125.

CAPE-GDB

```
PROCD
GBDFAT  PL  GENUS         GEN     TF  -   -       -
GBDFAT  PL  SPECIES       SPE     TF  -   -       -
GBDFAT  PL  CODE          COD     N   -   -       -
GBDFAT  PL  LOCALITY      LOC     K   -   -       -
GBDFAT  PL  STATUS        STA     N   -   -       -
GBDFAT  PL  OWNER         OWN     TF  -   -       -
GBDFZS  PL  L        GEN  SPE  COD  -
GBDFFS  PL  RA   J   COD  -    -    -
GBDFFS  PL  SP   J   GEN  SPE  -    -
GBDFFS  PL  CN   J   OWN  -    -    -
ENDP
***********************************************************
*
GBD SPP
PROCD
GBDFAT  SP  GEUS          GEN     TF  -   -       -
GBDFAT  SP  SPECIES       SPE     TF  -   -       -
GBDFZS  SP  G        GEN  SPE  -   -
ENDP
***********************************************************


GBD RAP
PROCD
GBDFAT  RA  MAP           MAP     TF  DE  MAP     -
GBDFAT  RA  CODE          COD     N   DE  CODE    -
GBDFZS  RA  L        MAP  COD  -   -
ENDP
***********************************************************
*
GBD CNP
PROCD
GBDFAT  CN  OWNER         OWN     TF  DE  OWNER   -
GBDFAT  CN  CODE          COD     N   -   -       -
GBDFZS  CN  L        OWN  -    -   -
ENDP
***********************************************************
*
```

```
*
GBD ESP
PROCD
GBDFAT   ES   NAME        NAM    TF  -   -         -
GBDFAT   ES   INDEX       IND    TF  DE  INDEX     -
GBDFAT   ES   CATEGORY    CAT    I   -   -         -
GBDFAT   ES   ECRU.NO     ECR    I   -   -         -
GBDFZS   ES   L      IND  -    -    -
ENDP
*************************************************************
```

INFR-GDB

```
*
GBD CNP
PROCD
GBDFAT   CN   OWNER       OWN    TF  DE  OWNER     -
GBDFAT   CN   VEG         VEG    TF  -   -         -
GBDFAT   CN   GEOLOGY     GEO    TF  -   -         -
GBDFAT   CN   RAIN        RAI    TF  -   -         -
GBDFAT   CN   SOIL        SOI    TF  -   -         -
GBDFAT   CN   RARES       RAR    TF  -   -         -
GBDFAT   CN   ALIENS      ALI    TF  -   -         -
GBDFAT   CN   TRIG        TRI    TF  -   -         -
GBDFAT   CN   GUIDE       GUI    TF  -   -         -
GBDFAT   CN   FIRE        FIR    TF  -   -         -
GBDFZS   CN   L      OWN  -    -    -
ENDP
*
GBD CHP
PROCD
GBDFAT   CH   NAME        NAM    TF  DE  NAM       -
GBDFAT   CH   NUMBER      NUM    I   -   -         -
GBDFAT   CH   AREA        ARE    R   -   -         -
GBDFAT   CH   REFERENC    REF    TF  -   -         -
GBDFZS   CH   L      NAM  -    -    -
ENDP
*************************************************************
*
```

APPENDIX 5: The SPOT satellite and imagery

A SPOT scene of the earth's surface is composed of a two dimensional array of cells or picture elements (pixels). Associated with each pixel are observations of earth's surface radiance as measured in three relatively narrow bands of the electromagnetic spectrum.

The sensor has the following characteristics:

- swathwidth = 60kms

- in multispectral mode there are three bands with a pixel size of 20m

colour band	wavelength	characteristic
1) green band (LANDSAT band 4 = .50 - .60um)	.50 - .59um	maximum chlorophyll reflectance
2) red band (LANDSAT band 5 = .60 - .70um)	.61 - .68um	condition of vegetation, discrimination of crops and rocks high chlorophyll absorption
3) infra red (LANDSAT band 6 = .70 - .80um) (LANDSAT band 7 = .80 - 1.1um)	.79 - .89um	vigourous vegetation growth. weak response to water.

In panchromatic mode the pixel size is 10m.

Multispectral bands have been selected (Chevrel et al. 1981) to allow:

1) Good discrimination among crop species, different types of vegetation and within different soil types.

2) Consistent relationship between spectral reflectance and vegetation properties.

3) Compatible interpretation of spectral signatures obtained by LANDSAT D and SPOT.

4) Improved radiometric sensitivity and resolution for surface water work.

5) At least one spectral band to provide some water penetration.

They were also chosen according to Venugopal (1988) to minimize the atmospheric effects of the atmosphere upon them i.e.

a) decreased Rayleigh scattering with increase in wavelength,

b) ozone absorption,

c) absorption due to water vapour.

Option available:

- quarter scenes,

- scene centred anywhere along satellite track and/or any length,

- 4 scene mosaic, processed simultaneously,

- instrument can be tilted sideways from 0 - 27 degrees allowing scene centre to be targeted anywhere within a 950km wide strip centred on the satellite track. This allows more frequent multi-temporal analysis,

- scenes obtainable at any scale between 1:50 000 and 1:400 000,

- different levels of image restoration available (as at 1983).

  level 1A - raw level

  level 1B - systematic geometrical and radiometric corrections

  level 2 - precision processed level, geometrical correction using 6 or 8 ground control points per scene

  level S - SPOT scene transformed to register with an other reference scene for multi-temporal analysis.

* special products must acquire on computer compatible tape (CCT).

POSTSCRIPT

TRANSFER OF CAPE PENINSULA GIS FROM SICAD TO ARC-INFO SYSTEM

As was explained in the introduction the Siemens system was phased out at the end of 1990 and replaced with an ARC-INFO system. This necessitated the transfer of all the data to the new system.

All the data from the Siemens was transferred to the ARC-INFO system (excluding symbols) using the following procedure.

1. It was written into ASCII files, level by level (theme by theme) and sent to Geographical Information Management Systems, GIMS (the South African suppliers of ARC-INFO) for conversion into ARC-INFO format. The SICAD commands were as follows:

```
GBNAM      (database name)
GBEBN L x  (each level done separately)
GBGQEL .A 0 0 GVA=T 0 0 50000 80000     (ASCII file creation)
```

2. The converted files were received from GIMS on a cartridge and loaded onto the VAX mainframe by Information Technology Services (ITS) at UCT. From here it was transferred to the HP9000 mini computer, and from there onto the PC in the ARC-INFO GIS laboratory.

3. Next each file had to be "imported" into ARC-INFO using the IMPORT command (an ARC command). Each theme then became a "coverage" in ARC-INFO terminology and is stored as a separate directory.

4. Some themes had been split into a number of files during the transfer and to join them together again the MAPJOIN command (polygon coverages) was used. Other required files to be joined using ARC-EDIT and the GET command (text and line coverages).

5. To compensate for the "Rahmen" (or frame) from SICAD and transform the data back to real Lo coordinates it was necessary to perform a transformation on each coverage (TRANSFORM command). An offset of three million metres on the X-axis was used as the software was only capable of working to single precision on the PC, resulting in an accuracy of 0.1 of a metre.

In order to convert to Lo coordinates, the X and Y axis had to be transposed and both signs made negative (constraints of the ARC-INFO software). Thus the new control points were calculated as follows:

Y (Lo ord) = Y (local ord) - 810000 (X value for Rahmen)
X (Lo ord) = X (local ord) - 70000 (Y value from Rahmen)

All coverages have been stored on disc prior to transformation, because when the workstation arrives whish allows for double precision, it may be advantageous to reperform the transformation. The new coverage (directory) names are as follows:

DIR CAPE

CAPE02	coastline
CAPE03	geology
CAPE04	vegetation
CAPE05	precipitation
CAPE07	soil
CAPE08	contours
CAPE09	waterbodies
CAPE10	rivers (perennial)
CAPE11	rivers (non-per)
CAPE12	dam/vlei names
CAPE13	SPOT 1987
CAPE14	SPOT 1989
CAPE15	alien vegetation
CAPE16	trig beacons
CAPE17	SPOT transform pts

DIR INF

INFR0	landuse
INFR01	Cape Nature Area
INFR02	roads
INF04	place names
INF05	town names

DIR MOLL

MOLL01B	grassland
MOLL02B	A.saligna
MOLL03B	A.melanoxylon
MOLL04B	A.mearnsii
MOLL05B	A.lophanthi
MOLL06B	eucalyptus
MOLL07B	forest/fynbos
MOLL08B	forest 1600AD
MOLL09B	eroded areas
MOLL10B	impact areas

DIR FIRE

FIRE01	key
FIRE02	1962
FIRE03	1964
FIRE04	1965
FIRE05	1966
FIRE06	1967
FIRE07	1968
FIRE08	1969
FIRE09	1970
FIRE10	1971
FIRE11	1972
FIRE12	1973
FIRE13	1974
FIRE14	1975
FIRE15	1976
FIRE16	1977
FIRE17	1978
FIRE18	1979
FIRE19	1980
FIRE20	1981
FIRE21	1982
FIRE22	1983
FIRE23	1984
FIRE24	1985
FIRE25	1986
FIRE26	1987
FIRE27	1988
FIRE28	1989