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**GIS AS AN ENABLING TECHNOLOGY:
A NATURAL RESOURCE EXAMPLE**

by

Ruth Evelyn Harrison, B.E.S.

**A thesis submitted to
the Faculty of Graduate Studies and Research
in partial fulfillment of
the requirements for the degree of
Master of Arts
Department of Geography**

Carleton University

Ottawa, Ontario

April 15, 1994

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**GIS AS AN ENABLING TECHNOLOGY:
A NATURAL RESOURCE EXAMPLE**

**submitted by Ruth Evelyn Harrison, B.E.S.
in partial fulfillment of the requirements for
the degree of Master of Arts**

R. Harrison

Thesis Supervisor

James Wallace

Chair, Department of Geography

**Carleton University
April 15, 1994**

ABSTRACT

The purpose of this thesis is to investigate the application of a geographic information system as an enabling technology to an integrated land allocation problem for a 3000 square km study area around Kootenay Lake, British Columbia.

Five provincial ministries capitalized on their existing land based information and utilized a GIS to integrate their data. The overlay analysis technique of indexing was used to determine the areas of potential for the land uses of: outdoor recreation potential, merchantable timber potential and long-term opportunities for mineral exploration and mine development. A second phase of analysis provided an insight into areas of potential competition between the land uses.

It was concluded that GIS technology continues to be of significant value in integrating data sets and is a useful analytical tool in undertaking integrated resource planning.

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REH, 1994

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Chapter 1: Introduction

Degradation of the environment resulting from competing resource demands is a current topic of, often intense, public discussion. This is particularly true in British Columbia where many activities make considerable demands on the natural resources of that province and where the general public has a strong interest in the environment and the wilderness. The pressures on these land resources have led to a need for effective resource management (Laacke, et al., 1992).

There have been increasing calls for integrated resource planning. Recent work on tourism resource management issues by the Centre for Tourism Policy and Research, Simon Fraser University, points to a need for a "solid legal foundation" for activities linked to natural resource allocation and environmental concerns (Williams, 1990). The report of the Forest Resources Commission, in calling for substantial changes to forest planning and management in B.C., also included recommendations on the incorporation

of forest-dependent tourism values in land use planning and "... the establishment of area based tenures for other forest values such as tourism" (B.C. Fishing Resorts and Outfitters Association, 1991).

Effective management of natural resources and the environment requires interdisciplinary skills as well as expertise in the appropriate specialties. Problems in the management of resources such as forests, fisheries, wildlife, minerals, water, tourism and agricultural lands are intensifying as competing demands increase. Expertise in traditional resource disciplines is currently needed and will continue to be in demand, but such experts are more effective managers if their experience and background include an exposure to several disciplines involved in solving resource problems (Keating, 1989).

There is widespread recognition that integrated resource management techniques must be applied by all agencies in order that each can effectively discharge its mandate (Manning, 1990). In the past, resource management has been focused to maximize benefits (economic as well as public) and to minimize conflicts (DeGroot, 1989). In recent decades, geographers, through their interdisciplinary approach, have begun to share in the development of more rigorous analytical approaches and have contributed to the development and application of sophisticated new analytical techniques for the management of natural resources. But the essence of the discipline of geography remains rooted in the tradition of exploration — a multifaceted exploration involving real problems in real places (Borchert, 1987). Managers of resources are attempting to achieve a balance for the overall "public good" in applying management techniques to their

functional areas. The difficulties they face, however, increase as demand for use of limited resources increases and as the public's perception of resource values shifts.

The motivation for this thesis was based on discussions with the Ministry of Tourism in British Columbia and the ARA Consulting Group in the fall of 1989. At that time the tourism industry strongly expressed the need for sound management and protection of tourism resources (Gale and Russell, 1989). These discussions led to the initiative to explore the process of developing an application specific integrated geographic information system (GIS) procedure as a tool to support decision-makers and policy analysts in the task of dealing with the varied factors of determining optimal land uses for the natural resources in question.

The purpose of this thesis is to explore the application of utilizing a GIS, to determine the areas of potential land use for three specific natural resource sectors within a mountainous, wilderness environment. Specifically, a 3000 square kilometre area in the vicinity of Kootenay Lake, British Columbia will be studied. Several variables, such as land use, vegetation, mineral occurrence, wildlife sightings, etc., will be mapped for the entire study area. The analysis of these data will determine the potential suitability of the area for outdoor recreation activities, forest extraction capability and long-term mineral resource opportunities.

1.1 *What is the Challenge to Geographers?*

The challenge to comprehend the problem of integrated resource management fully, and to identify the causes of, and to produce practical solutions in time to avert, further irreparable damage to natural and human systems is one that can be addressed today by geographers with the new technologies available to them. This will, however, require a renewed focus of exploration — an exploration focused on the interface between human and ecological systems and on a means of managing this relationship (Dangermond, 1983).

In his 1984 work, Nelson contended that, with the increasing complexity of human systems, it was becoming necessary to expand the understanding of problems and the horizons of decision making in three dimensions:

1. Cross-sectorally, to include concerns deriving from and impacts affecting other sectors;
2. Horizontally, to extend the planning horizons farther towards the future; and
3. Vertically, to consider more complex causal chains for the problems encountered.

These needs reflect the fact that the nature of the human system and its use of and impact on the biosphere have become more complex (Clark, 1987; Tolba, 1987). Our

comprehension of these relationships and means to address the problems must also expand in all three dimensions to allow us to produce effective solutions.

All of these "dimensions" recognize the increased complexity of relationships and the need to expand our perceptions and analytical approaches to accommodate them. No one discipline will be able to provide a panacea for the increasing complexity of global changes. The need will be integration, cross-disciplinary cooperation and comprehension of the information, and an abandonment of the confines of the traditional disciplinary 'little boxes' which are at least in part responsible for the problem we now encounter (Kessell, 1990). A central role can be defined for geography, tied most closely to the spatial dimension, but built upon the regional and integrative traditions of the discipline. The central challenge is to alter the current reductionism and fragmentation of our institutions (including academic, governmental, and business institutions). What we must seek are broad, yet practical, approaches and sound, but understandable, solutions to these complex problems (Kessell, 1990). How can we be both holistic and comprehensible to those who must act on our recommendation? What must be done to provide decision makers with integrated and practical responses to problems which often exceed their managerial scope of scale of responsibility? This is a significant challenge to all disciplines, not just to geography (Nelson, 1984).

Better data alone will not be adequate to alter the decision process of individuals, governments, and business towards a more holistic approach. Improved tools and methods will be central to our ability to translate information into advice or to provide better understanding of the implications of decisions. Such understanding, whilst ideal

for performing spatial searches based on nominally mapped criteria, are of limited use when multiple and conflicting criteria and objectives are concerned (Carver, 1991). The integration of analytical techniques, designed to cope with multi-criteria problems in GIS, can provide the user with a valuable addition to the functionality of the GIS tool-box (Carver, 1991). Integration of information from different sectors, analysis of inter-relationships and development of better means to model and extrapolate them will all be important if we are to be effective in influencing decisions (National Task Force, 1987; DeGroot, 1989; Roots, 1989).

An area of essential effort is in the development, on different scales, of models of sustainable development; these are needed to help show the nature of the relationships between humans and the biosphere and to identify where it is reasonable to intervene to rectify present and emerging problems. This can occur at many different levels, from the global to the local (Boulding, 1988; Cocklin, 1989).

As Nelson (1984) contended, both the problems and the solutions will require new perspectives and broader approaches, and these will inevitably involve partnerships between non-traditional collaborators, between nations, across disciplines, and between economic sectors. Here, the regional and spatial perspectives will be central to our ability to fashion solutions. The development and evaluation of improved integrated site selection criteria for prioritizing application specific resource utilization and review methods for projects for use at regional and site-specific levels is critical.

Geographers can play a significant role in identifying and implementing solutions to the need for improved decision making abilities. A specific opportunity may include the use of mapped information and rapid GIS output capabilities to provide targeted information expeditiously to decision makers who often operate within tight time frames. Unfortunately, today's decisions are often made without current and accurate information. Geographers can anticipate many of their needs and enhance the communication process to decision makers. The observations by Harvey (1967, p.71) are as relevant as they were twenty five years ago:

"A traditional aim of geographical research is to describe the spatial pattern of objects or events, and to explain that pattern by way of the causal mechanisms which have generated it. This aim implies some way of deducing spatial patterns from a knowledge of temporal processes, a deductive procedure which will be termed a 'time-space transformation for short'. Such time-space transformations have proved extraordinarily difficult to handle given traditional methods of representing spatial forms and temporal processes. In most cases, all that can be done is to discuss some temporal process, for instance diffusion, and simply map its progress over space. The connection between temporal and spatial in such analysis usually remains undefined ..."

Geographers have long been known to be synthesizers of data and brokers of information (McBoyle, pers. com., 1993). With the training geographers receive their background is appropriate to aid decision makers by utilizing the appropriate technologies and the supporting data. By finding effective ways to integrate data and ultimately produce information, geographers can play a vital, supportive role in resource management operations.

1.2 Background

Utilizing GIS as an enabling technology to combine the efforts of resource management techniques is the primary focus of this thesis. The interdisciplinary techniques of GIS allow for more effective management of the natural resources and the environment. The following sections will outline the background of resource management and geographic information systems in order to understand the problems at hand.

1.2.1 Resource Management

Historically, resource management or regulatory systems have been developed around resource sectors such as forestry, agriculture, mining, and fisheries (ARA, 1990). For example, issues concerning the use of land and resources have been a high profile for a long time, particularly in British Columbia where reliance on resource-based industries is strong. These issues are usually addressed at the local, regional or provincial level and revolve around such concerns as depletion of forest reserves, location of landfill sites, land use in wilderness reserves and park areas, and competition for the fishery resource. Faced with shifts in the public's perception of resource values in the 1990s, the challenge these managers face is not just in applying management principles to their respective industry sectors, but employing integrated resource management approaches to land issues (Province of British Columbia, 1990). Increasingly, this means exploring integrated environmental management principles as a solution to balance land use demands in a manner which accommodates existing resource users and ensures that use of the natural resources is available for future generations.

A broader scope for decision making is being established by an integrated resource management approach, especially when it concerns public lands and natural resources. By considering several viewpoints, the potential to make more informed decisions results when accurate, sound data are available and the resource data are "spatial". That is, spatial in context of location and proximity to other resources in question. In general, there is often a lack of understanding between "cause" and "effect" of an event on a particular land resource. The use of maps allows one to illustrate where something has occurred, and where it has affected a land resource. Opportunities can be identified and conflicts may be resolved if people are willing to compromise, based on their increased knowledge from the presentation of the data.

Planning is concerned with the future implications of current decisions. It provides the frame of reference for making choices and a focus for the development of facilities and capabilities. Any attempt at planning and development would be incomplete if the implications of change for the environments involved were not considered (Hawkins, et al., 1979).

Natural resource issues include, as might be expected, broad ranging questions about the conservation and preservation of our natural resources, which have at times been perceived to be in opposition to tourism development. The need to protect our forests for the future and to counteract treelessness in certain areas for greater tourist enjoyment is seen in relation to the potential benefits of careful harvesting that can provide timber, while sustaining a stable ecosystem, in the natural environment. But natural resource issues extend beyond these concerns. The evaluation of alternatives in planning must

begin with such elusive problems as what constitutes beauty. Differences in tastes and preferences and in potential uses of natural resources have to be considered as part of the planning and development process. Natural resource issues touch on social and economic issues when concerns about rural land use, seasonal patterns of usage, local needs and rights of access to recreational resources, and compatibility of various uses of the same space are added to the planning mix (ARA, 1990).

Planning defines the framework, and development, the structure of future tourism; marketing and management make the difference in the effectiveness with which development plans are carried out (Rodriguez, 1979).

A relatively new entrant into the resource management area is the tourism industry. This industry is beginning to respond to the increasing demands for development of outdoor recreation opportunities on a commercial basis. It is the world's fastest growing industry and is expected to exceed three trillion dollars in receipts by the year 2000 (ARA, 1990). Only in recent decades has it attracted the attention of major investors and adopted sophisticated management and marketing techniques to maintain market share. This trend has been accelerated by an increasingly competitive environment and the demands and expectations of more sophisticated consumers. In an era when consumers are opting for specialized vacations, shorter trips, and quality recreation activities, the operators of resorts must maximize productivity to ensure that they meet the needs of customers and market their product effectively.

Over the next decade increased pressure on British Columbia's resource base is expected from a wide range of economic sectors, to the extent that the continued viability of resource-based tourism businesses (e.g. sport fishing, guide outfitters, guest ranches) will increasingly be jeopardized unless more attention is given to planning and managing the resources on which these sectors depend. This situation places tourism in the position of having to embrace resource management and planning techniques which have essentially been the responsibility of earth resource sectors. The integration of conventional mapping, geographic information systems (GIS), resource/land use planning and tourism will be an important and necessary management process for the future.

1.2.2 Geographic Information Systems

Some of the most powerful information tools available to individuals and organizations attempting to reconcile economic and environmental differences are the geographic files being developed through geographic information systems (GIS). Initially, systems were designed to produce maps more efficiently than the manual process. Over the years GIS has become more sophisticated and is now viewed in a very different light than the originally perceived functions of automated cartography and database management. Computer-based geographic information system technology, even though having been available for nearly twenty years, has only recently become practical to use from the aspects of price, functionality and ease of use, with the addition of available data at a reasonable cost.

There are many types of GIS available today. Custodial geographic information systems are both LARGE mainframe and MINI-based SYSTEMS designed to build, manage, and query extensive coverages of geographically referenced data. More and more of our mapping information is being made available in digital format. In addition, there are many work station and PC-based products that are allowing relatively small organizations to acquire access to GIS technology. The focus of these systems is to provide professional users the capabilities to apply GIS technology to their discipline in the decision-making process. The flexibility of these products is quite extensive from very simple desktop mapping to extremely powerful analytical and modelling packages.

A vast selection of data on specific geographic locations, ranging from basic mapping information to socio-economic statistics, is being loaded into geographic information systems. Government and private agencies are consolidating and integrating this information to assist them, among other things, in monitoring and analyzing oil spill impacts, locating mineral deposits, predicting insect infestation for pesticide applications, managing urban growth, and helping retail businesses understand their customers (Parker, 1992). The information needed to solve or research these kinds of issues may be obtained from a wide variety of sources such as paper maps, customer surveys, scientific field surveys, satellite imagery, urban plans, and socio-demographic statistics. GIS are tools which allow one to organize and access the large volumes of mapped data, and most importantly, expedite the analysis of relationships between the data sets.

Extremely reliable data are becoming available to planners for the first time, from a number of government sources (USGS; Environment Canada; Energy, Mines and

Resources; US Census Bureau; etc.) and private agencies (Compusearch, Claritas, etc.) and are being revised and manipulated to create data tailored to the needs of the user. Relationships between features can be inferred based on their physical and spatial attributes, a process which is particularly useful to the analyst. As a result geographic information systems are gaining widespread acceptance in many sectors eliminating time-consuming and expensive field work (Dobbins, 1992).

1.3 Objectives

The essence of the GIS analysis was to incorporate the interests and values of a wide spectrum of users' groups in the study region around Kootenay Lake, British Columbia. Five provincial ministries: BC Ministry of Tourism; BC Ministry of Crown Lands; BC Ministry of Energy, Mines and Petroleum; BC Ministry of Forests; and BC Ministry of Environment were contacted and invited to participate in this case study.

Although several projects have utilized the analysis capabilities of a GIS for land suitability before (Anjomani and Saberi, 1992; Bohard, 1992; Dobbins, 1991; Lauer, et al., 1991) the establishment of a cooperative effort of analysis between the groups competing for the same land resource has not been investigated.

In exploring the potential value of GIS to natural resource management this thesis seeks to:

- determine the information that managers of natural resource based data require to perform their assessment of land based potentials for a given area;
- outline the basic attributes of GIS that may contribute to resource management assessments;
- demonstrate the implementation of a GIS with the appropriate land based and associated data sets for a selected area;
- determine the analytical interests of a spectrum of natural resource users' groups.

It is important to realize that GIS is an enabling technology which can provide us with the capability to see and understand the existing information about our environment and provide the potential to obtain new knowledge from the existing data set. With GIS the interdependence between different aspects of our physical, human and economic system may be explored by organizing information geographically.

By compiling a wide range of data, such as population, soil types, elevation, vegetation cover, transportation routes, etc., into one database it is then possible to analyze the characteristics of one sector in relation to the interests of other sectors on the basis of geographical location. Perhaps the GIS's exploratory tools for spatial analysis offer users the greatest potential benefits. The ability of using a GIS to change perspectives readily

allows the analyst to pose new questions revealing different geographical impacts or solutions which had previously neither been identified nor considered (Dobson, 1993; Dangermond, 1985).

This thesis uses the above capabilities of a GIS. The interaction of humans with the natural environment has been a crucial element in the development of civilization. As the size of the human population expands so does the pressure on the earth's natural resources. The key to achieving a balance is careful management coupled with an understanding of the possible consequences of exploitation of the resources. This management requires a combination of knowledge, data and experience to aid in the decision-making process. Geographical techniques have been used for many years to help visualize information gathered from environmental resource inventories. Monitoring changes or impacts, however, and predicting the consequences of current management strategies have been, inherently, non-geographical; dominated by statistics and descriptive observation. It is, however, exactly these limitations which acted as the catalyst for the development of many of the techniques which lie at the heart of GIS technology.

1.4 Thesis Organization

The first chapter introduces the purpose of the thesis which is to examine a process by which the areas in a pristine, mountainous environment that have the potential for quality outdoor recreation, forest extraction and long-term mineral resource opportunities, that may compete for the same land area.

Chapter 2 examines the utilization of GIS as a decision support tool and database management tool for the users in forest management and mining exploration. The tourism industry is one of Canada's major business sectors (Economist Intelligence Report, 1991) and an increasing demand on the wilderness resource by expanding human demands creates the need for the tourism industry to evaluate their planning process and evaluate the potential role of GIS.

Chapter 3 discusses the selection of the study area around Kootenay Lake in British Columbia. A study undertaken by Tourism Canada on Adventure Tourism in Western Canada (1988) notes that British Columbia accounts for 85% of the western Canada adventure tourism recreation activities and that the Kootenay Region provides the highest quality potential in British Columbia. This particular area was analyzed to determine the most suitable areas for wilderness tourism, forestry logging resources and mineral resource opportunities.

The methodology to assess the potential uses of the land area was a system of weighting individual landscape components. From this input a model was developed and managed using a GIS to readily indicate which areas, based on a predetermined weighting criterion, are most suitable for wilderness tourism, forestry logging potential and mineral resource opportunities. As well, the areas of competition between the most suitable areas for each land use were determined.

Chapter 4 describes the process of utilizing specific criteria determining the areas of land use potential. The development of models to determine those areas of interest and the

results of the land use analysis for the study area are described. The resultant maps produced by the GIS graphically illustrate the spatial patterns of information as they relate to the individual layers of information. From the aggregate maps, sites which exhibit the most suitable areas are shown and areas of land use competition are determined.

Chapter 5 discusses the conclusions and recommendations of this case study.

Chapter 2: Literature Review

The purpose of this chapter is to identify several of the fundamental issues of special concern to the application of GIS to the integrated management of natural resources in British Columbia and to provide an introduction to the relevant literature. This chapter will outline the utilization of geographic information systems (GIS) for land use analysis; changes in the data available and its effect on GIS usage; the Provincial Legislative mandates for the Ministries of Tourism, Forests, and Energy, Mines and Petroleum; and the application of GIS within the sectors of forestry, mining and tourism.

2.1 Recent Trends and Research in Geographic Information Systems

Geographical information systems (GIS) have grown from primitive computer-assisted cartographic programs to very sophisticated analytical systems over the past two decades (Kessell, 1990). Given the different types of data (e.g. locational, topological and attribute) and the resulting potential for organizational complexity, the purpose of this

thesis is to investigate a process that can be employed to construct functionally-integrated spatial databases which support land use assessment and planning, locational analysis and spatial decision making through the use of a GIS.

A GIS is a tool for human use, not a technological end in itself; this fact is being lost too often in the heady rush of technical sophistication (Honea, et al., 1990).

Useful reviews of past developments, recent trends and research needs in the general field of Geographic Information Systems have been presented by Dobson (1993); Masters (1992); Laacke, Skinner and Peuquet (1992); Tomlinson (1984 and 1987); Dangermond (1984 and 1985); Myers (1985); Clark (1986); Onsrud (1987); and Wilkinson and Fisher (1987).

In geography, the idea of using map overlays to study spatial covariance has been around since the availability of transparent media such as vellum and mylar, but the idea of using a multitude of overlays for spatial analysis did not catch on until the 1970s (McHarg, 1969). The map overlay technique was so simple in concept that it was quickly seized upon as an ideal tool to address many environmental problems that demanded immediate national attention. Almost at the same time as the emergence of the McHarg overlay approach, other techniques using line printer maps to create overlays began to appear in use at a number of research institutions through the U.S. and Europe. This technique, now considered primitive, was used largely for environmental assessment purposes, but was also applied to urban land use development and decisions concerning transportation corridors.

In the early 1970s, minicomputers began playing a prominent role in the development of GIS, mostly for specialized tasks such as digitizing. Hardware was limited, however, and software was almost nonexistent. By the mid-1970s, overall GIS development has expanded to stand-alone minicomputer systems and rudimentary workstations. Several commercial systems grew out of these developments, and image processing systems became popular with the advent of satellite data.

Today, the individual decision maker can command much of the power of the older mainframes through a desktop microcomputer workstation. As workstations gain more storage capacity and faster operating speed, an increasing number of decision support systems and GIS problems can be addressed directly at the user's desk. A recent review of GIS system identified more than 50 vendors that now claim to have PC capabilities (Dobson and Parker, 1990). These developments present us with entirely new sets of opportunities and problems.

The ability of a GIS to provide required information depends, in part, on two interrelated factors:

1. The information must exist in some form in the GIS data base; and
2. The GIS has the processing and analytical capabilities to extract the information from the data.

However, the problem of arriving at the final decision in the face of multiple and conflicting criteria remains. This thesis will describe the process and explore the utilization of a GIS to integrate the spatial data sets required to determine the areas, in a specific study area in British Columbia, that are most suitable for the tourism potential of outdoor recreation, merchantable timber extraction, and mining development as well as identify the possible overlap of the selected land areas with each other.

2.2 Why Utilize Geographic Information Systems?

Sadler and Hull (1990) reported that resource industries represent the engine of change with respect to sustainable development. There is a pressure on most industry sectors to find more resource-efficient and environmentally sound modes of production while continuing to maintain profitability (Friedl, et al., 1988). However, some industries are responding better than others. New systems and processes for decision making must be introduced if sustainable development is to become a reality (Schmoldt, 1992).

The issues facing GIS developers today are not primarily technological but center around establishing guidelines or standards, promoting industry and interagency cooperation, and providing appropriate information management.

In general, decision support systems heavily rely on a computation model which often requires a spatial setting or has a strong spatial component. If a decision support system or a GIS is not designed with the 'human factor' as the primary concern, then the humans who make decisions will look elsewhere for support.

Research and development activities in the last decade have demonstrated that we are on the threshold of applying new techniques to the increasingly complex job of managing our tourism resources (Chen, 1992). This new activity is particularly appropriate given Canada's leadership in the land-related information field, starting with the pioneering work embodied in the Canada Geographic Information System (Tomlinson, et al., 1976) and continuing today with the success of Canada's private sector in commercializing micro-computer based GIS products (Forrest, 1992). The rapid pace of technological change, where our equipment faces obsolescence every year, tends to focus our attention on ways of adapting the new technology to existing systems rather than on ways of using it to facilitate better decision making (Machrone, 1989).

The technology and associated software systems, such as graphical user interfaces and printer support, have reached the state where their use in the tourism sector is being evaluated as a possible research and analysis tool by the Ministry of Tourism in British Columbia and Tourism Canada (Gale, pers. com., 1992). Moreover, Canada's strength in data capture from satellite technology is already proven and can be used to good effect in resource-based tourism product/market matching (Maffini and Simmons, 1986). Together with these technology ingredients, our institutional structure and environment is supportive of an approach where industry and the public sector can, in parallel, develop new tools not only for our own domestic purposes but also for export (Province of British Columbia, 1990).

All of these advances must have a single primary goal: to help human decision-makers make better decisions. If this is not the focus of future system design, then all of our

amazing technological developments will be largely irrelevant, because they will not be used. The present level of enthusiasm among developers about the effectiveness of GIS is understandable; however, we should not let their enthusiasm lead us into grandiose advertisements of the GIS as a panacea for decision-makers. A GIS can be an extremely valuable component of many, but not all, decision support systems. It is a disservice to the GIS concept, and to decision-makers, to claim anything beyond this useful and important function.

2.3 Changes to Spatial Data and Their Sources

Geographic information systems are a powerful resource for analyzing the inter-related systems involved in the types of problems outlined previously. They provide flexible methods for exploring relationships among geographic data and assisting experts from diverse fields in pooling their knowledge to solve complex problems (Dobson, 1993). Using GIS technology, geographic information can be assembled and applied in new ways. The GIS offers a practical means to manage large and diverse spatial data bases and provides effective tools to understand the relationships among diverse phenomena (Smith, et al., 1992). An increasing number of decision-makers and managers have recognized that GIS technology will be essential if they are to address the expanded mandates and complex decisions they now face (Aronoff, 1989).

In the past, the development of GIS software functions has concentrated on replicating manual mapping and analysis procedures. More complex analysis functions have been limited largely by the incompatibility of data formats. Recent GIS software developments

have allowed users to access both raster and vector data at the same time. This began a trend toward true data merging. Now users can visualize geographic data rather than computer files, and much more easily realize solutions to complex spatial problems (Jordan, et al., 1992).

GIS were originally designed as a tool to support decision making for land-use planning. The dramatic growth of the GIS industry has generally been spurred by demands for information management capabilities rather than spatial analysis and modelling functions (Goodchild, 1991). The major success of GIS technology is because of its capability for mapping the Earth's surface and for supporting simple queries of geographic data. Commercial development of GIS software and hardware must, because of financial necessity, support the demands of its majority of uses (Dangermond, 1993).

Before GIS can be used for geographic visualization, the concept of the traditional GIS must be broadened to include all data types: raster vector attribute, spreadsheet, and ancillary data. Most users now recognize the value of integrating raster and vector data into a GIS. The timeliness and accuracy of satellite imagery and aerial photographs make data base updates easier and more cost-effective than creating new vector data from ground truth information. The image processing functions available with raster data provide a new level of analysis that adds depth to a GIS. Images can be classified to show wildlife habitats, soils information, vegetative health and numerous other categories that add to the completeness of a GIS (Jordan, et al., 1992).

The technology already exists for true geographic visualization. However, technology is not enough. Users must be able to access this technology in real-world situations and must be able to access hardware and software that is easy to use and that provides solutions to the problems they face. They must be able to interact with the system and to update their information as time, conditions and parameters change. GIS has the potential to help solve some extremely crucial and earth-threatening problems: global warming, deforestation, erosion, and housing shortages (Dangermond, 1993). The evolution of remote sensing and GIS bears a striking resemblance to the evolution of an earlier geographic movement toward understanding landscapes, a focus of geography (Hartshore, 1939), landscape architecture (Newton, 1971) and landscape ecology (Forman and Godron, 1986). The changes in spatial data, from hard copy paper sources to digital sources, will allow users to access the power of GIS and communicate new information (Jordan, et al., 1992).

2.4 Government Initiatives and the Legislative Environment

The focus of this thesis is to investigate an application of GIS to integrated land management around Kootenay Lake in British Columbia. Five ministries were invited to participate in the analysis and provide expert input based on their own land use management practices. The management of these resources is carried out under a diverse set of legislative mandates.

The Province of British Columbia has a wide range of resource management legislation covering such areas as forestry, mining and the protection of important natural resources

(e.g., ecological areas, wildlife habitat, etc.). Given that there is no specific tourism resource management legislation, the question is whether existing legislation accounts for tourism resource management requirements. The Ministry of Tourism does not have the legislative authority to ensure that tourism resources are accounted for in land use and management decisions. In addition to the fact that there is no legislation which addresses the tourism sectors resource needs, the Ministry is placed in a position of representing tourism's resource interests in an advisory capacity without any formal authority or requirement to recognize its point of view.

The legislation for the Ministry of Forests states that the mandate of this ministry is to explore and maintain areas of highest merchantable timber stands. The Forest Act (B.C. Ministry of Forests, 1993) provides the Ministry of Forests with the responsibility to manage wildlife habitat and scenic resources within most of the province. Although there is a provision in the Act for recreational use of the forests, the main focus of the Act is for the use and management of the forests for harvesting.

The Mining Act (B.C. MEMPR, 1993) for the Ministry of Energy, Mines and Petroleum Resources establishes the framework for resource management decision making and land tenure. The legislation mandates this ministry to maintain maximum long-term opportunities for mineral resource exploration and mine development.

Traditional resource management practices have recently been complicated by the emergence of economic sectors such as tourism competing for the resource base, and public opinion concerning the need to encourage sustainability of natural areas for future

generations. The emphasis on resource usage appears to be shifting from a focus on extraction and resource harvesting to one in which other resource interests will be accommodated. By initiating such processes, the Province has acknowledged that the definition of the "public interest" as it relates to resource management on Crown Lands must take into account the aspirations of many more resource users than simply forestry and mining.

The Ministry of Tourism has placed a priority on sustainable management of the Province's resources from a tourism perspective. In the absence of a legislative mandate, the Ministry has focused on the development of tools (e.g., the Tourism Resource inventory) to identify and promote tourism resource interest in policy and planning processes designed to establish balanced resource regimes in the Province.

2.5 Application of Computerized Technology

Many issues often arise related to resource management planning from a number of perspectives, for example: competing resource uses; competing land uses; impacts on the environment; and impacts on the economy. In British Columbia, the responsibility for management of resources is carried out by many different ministries of the provincial government, such as Ministry of Crown Lands, Ministry of Parks and Ministry of the Environment. The management of these resources has developed around a number of functional areas including forestry, agriculture, mining, wildlife, and fisheries. The Ministry of Tourism in British Columbia has focused on the promotion and marketing of the province as a tourist destination.

The land related information systems market is estimated to be approximately \$25 billion over the next decade (ARA, 1990). This market has emerged largely as a result of significantly enhanced hardware capability and graphical database management techniques. Led by the demands of North America's utility companies and agencies seeking to automate their network and facilities' records, this market generally embraces automated mapping, facilities management, and geographic information systems. Along with improved computer technology, there have been tremendous advances in data capture, not the least of which is from satellite imagery. We are now at the stage where the use and manipulation of land related information in a computer environment is both technically reasonable and cost effective (Higgins, 1992).

2.5.1 GIS Applications in the Forestry Sector

In Canada, every provincial forestry agency has either implemented a GIS to manage its forest data base or is in the process of automating its forestry maps. The British Columbia Ministry of Forests and Lands has been one of the leaders in developing operational GIS and remote sensing applications for forestry (Goodenough, 1986). Under the GIS implementation program, more than half of the forest cover maps have now been digitized and entered in to the forestry GIS (Aronoff, 1989). In addition to providing data storage and retrieval functions, the B.C. Forest GIS generates a wide range of information used in forest harvest planning, regeneration surveys and monitoring, environmental sensitivity assessment, recreation planning, and watershed management (Hegyi and Sallaway, 1986).

Over the past ten years GIS technology has been widely accepted by public forestry agencies and private forestry companies alike (Aronoff, 1989). The managers of the forest have realized the benefits of current, accurate data about the forest inventory (Sommers, 1992).

Forestry management encompasses the management of a wide range of natural resources that occur in forest areas. In addition to timber, forest provide such resources as grazing land for livestock, recreation areas, wildlife habitat, and water supply resources. As a result, the public agencies responsible for forestry management typically have broad mandates (Peters, et al., 1992). GIS has been used for such analysis as timber harvest planning, critical wildlife habitat protection, and planning the route location for scenic roadways (Hart, et al., 1985). To satisfy these diverse responsibilities, competing resource conservation and resource use activities must be accommodated (Nicholson and Bower, 1992). Assessing the compatibility of multiple uses and trading-off competing values are difficult planning processes that are greatly aided by using GIS techniques (Aronoff, 1989). Combining classification and GIS data provides a wealth of information that can be used for complex management decisions (Evans, et al., 1992).

2.5.2 GIS Applications in the Mining Sector

Analysis of the geology of a region, whether for mineral exploration, petroleum exploration, or reconnaissance level mapping, is fundamentally a data integration procedure (A.J. Robinson, 1993). By providing the capability to display and analyze diverse data sets together, a GIS enables the geologist to work with the data more

quickly, more accurately, and in ways that would not be practical using manual methods (Bonham-Carter, et al., 1988; Mihalasky, et al., 1993).

Geologists in the private, government, and academic communities have been using GIS for such things as: updating geology maps from remotely sensed data; integrating and overlaying diverse data sets for exploration; assessing coal and petroleum reserves; predicting mineral and petroleum potential; and mine and environmental planning (Webster, 1989). The GIS allows one to perform overlay techniques quickly with a variety of data and analyze the relationships in greater detail (Webster, 1989). There has also been extensive work conducted by the Geological Survey of Canada on the modelling and analytical functions within a GIS, specifically a technique known as "Weights of Evidence Modelling" (Bonham-Carter, et al., 1988).

The geological community makes use of GIS technology to continue its research and analysis not simply to detect patterns in the data and differentiate between them, but also to organize data in a manner which as nearly as possible reflects the physical and causal structures of the world (Holder, 1988). The application of GIS to the earth sciences facilitates data compilation and synthesis, permits exploratory data analysis and modelling, and may reveal insights not readily obtained by more traditional methods of data analysis and display (Mihalasky, 1993).

2.5.3 GIS Applications in the Tourism Sector

The Economist Intelligence Unit (1992) reported that tourism is the world's fastest growing industry, expected to exceed \$3 trillion in expenditures by the year 2000. In 1988, Canada's tourism expenditures exceeded \$17 billion, of which an estimated \$3 billion occurred in British Columbia (Economist Intelligence Unit, 1991).

Competition in the tourism sector is increasing dramatically as destinations seek to maintain and enhance their capture rates in the world's largest and fastest growing industry (ARA, 1990). With intense competition comes the need to apply new approaches to decision making. Because of the complexity of the issues traditional methods are no longer valid. GIS offers the potential to assist tourism planners and industry in responding to this complex task.

The tourism industry has been one of the last spatially based industries to even consider GIS as a tool in its effort to enhance product development and improve marketing. The industry is only now maturing and governments have historically been preoccupied with marketing areas as a tourist attraction while offering some limited development support (usually in the form of financial programs) to the industry. Thus, while GIS is ideally suited to many of the product and market analysis tasks encountered in the tourism sector, there has to date been no integrated GIS-based tourism analysis system developed. To help fill this gap, the focus of this thesis is to illustrate and analyze the process of preparing a spatially integrated database, and the process by which it can be used to analyze land use potential for various land uses.

In the final report (ARA, 1993), "Tourism Industry's Resource Management Needs", the ARA Consulting Group reported:

"Tourism consumers purchase "experiences". The tourism product is not simply an accommodation facility, a museum, or a hiking trail. It is the total experience from the time the consumer enters the destination area until they leave. Thus a viable product is one which can deliver on all aspects of the experience of the tourism consumer ranging from accommodation and transportation to enjoyment of the natural/historical/cultural resources of an area.

British Columbia's tourism industry is solidly based on its resources. It is known as a destination with diverse scenic areas, remote wilderness and abundant fish and wildlife resources. The viability of this industry is then dependent on how well the resources which are important to tourism are managed."

Tourism departments and natural resource ministries in Canada's public sector face increasing demands for:

- identification and protection of key natural resources;
- support for the private sector to effectively match product potential with market needs and expectation;
- advocacy for development in the face of competing land uses;
- strategic frameworks which guide destination area planning; and
- more effective market analysis (ARA, 1990).

The evolution of the tourism industry, in fact, displays a mixed track record; in some parts of the world, it has undermined the very natural settings and cultural attractions on which it is based (D'Amore, 1983). This assessment needs to be set in the context of tourism as a "global boom industry" of the 1990s, fuelled by more disposable income and discretionary time in industrial countries and by competition for tourism that brings

foreign exchange earnings and can underpin development in emerging nations (Branch, 1990).

A multiple-use approach is necessary to achieve sustainable tourism because pressures are not only from within but from surrounding land users, private interest groups and other government jurisdictions (Clark, 1990). It focuses on identifying the right landscape "niche" for the industry and ensuring that other land-use activities do not foreclose the options, whether for viewing an area or participating in a wilderness activity (Clark, 1990).

The application of GIS to the tourism development process has not been implemented, to date. However, there are several factors which now make the development of a tourism analysis system possible. These include:

- (a) Hardware and software capabilities which are now available at significantly reduced costs for equivalent performance;
- (b) Proven GIS software capabilities, traditionally the domain of mainframe computers, and now available on microcomputers; and
- (c) The development of useable data sets important for tourism development and marketing considerations.

A major development which has altered the state of GIS is the ease with which the technology can now be used by people who have limited knowledge of computer systems and computer programming experience (Lauer, 1991). The adoption of software

development standards is providing developers of geographic information systems great opportunities for building software that enable "mere mortals" to use this technology (Maffini, 1990).

Employing the latest advances in GIS technology, substantial productivity gains for tourism planning, product development analysis, and market analysis will be provided. Industry benefits from the system will include indirect benefits through an improved investment climate as well as direct access to information and analysis useful for industry in feasibility assessments, refinements to their marketing approaches, and reducing investment risks.

2.6 Summary

Effective management of natural resources and the environment requires interdisciplinary skills as well as expertise in appropriate specialties. Problems in the management of resources such as forests, fisheries, wildlife, minerals, water, tourism and agricultural lands are intensifying as competing demands increase. Expertise in traditional resource disciplines is currently needed and will continue to be in demand.

What this thesis is seeking to investigate is the potential use of a computerized technology to bridge the gap between application potential and available technologies. It recognizes the fact that GIS technology has historically required significant technical expertise and substantial development efforts to create the data to derive benefits.

Both the federal and provincial governments have established initiatives to encourage stronger consideration of sustainable development principles in the management of their resources and activities which affect the environment. This case study is a step in this direction in that it requires:

- the application of integrated resource planning to determine tourism potential;
- consideration of impacts on other competing uses and on the environment generally in selecting locations for tourism product development; and
- consideration of resource-based capability to sustain tourism activity.

Described in the next chapter, the methodologies which will be developed in this thesis using GIS technology are intended to enable policy makers and analysts to address these resource management concerns efficiently, in a variety of contexts.

Chapter 3: Methodology

This chapter describes the development of the database used in this thesis. A database is in support of the evaluation of the potential land use of three resource uses in a wilderness environment. A possible competitive process may arise when there are a range of potential uses for the same land area. The purpose of this thesis is to demonstrate the process of integrating data from multiple sources and utilizing the analytical capabilities of a geographic information system to determine the areas of suitable use for outdoor recreation opportunities for tourism potential, forest logging extraction for potential merchantable timber and long-term mineral exploration opportunities and mine development.

The data and analysis for this thesis were based on a pilot project created for demonstration at the Globe '90 conference held in Vancouver, British Columbia in March,

1990. A project committee was established in December, 1989 and consisted of members of the public and private sectors. Participants were:

Private Sector

The DPA Group Inc. in
association with:

INTERA TYDAC Technologies Inc.

Earth Probe Systems Ltd.

IBM Canada Ltd. - Geographic
Systems Centre

Public Sector

British Columbia
Ministries:

Tourism

Environment

Crown Lands

Forests

Energy Mines and
Petroleum Resources

Regional and Economic
Development

The author's role in the project committee was to act as project manager and the operator of the GIS computer system.

Members of the committee expressed concern that even though we may label the study as a "hypothetical analysis for the purpose of demonstration" exercise, the analysis output may not be used in the intended context. As well, due to the politically sensitive nature of the topic, specific reference to the study area location and the members of the committee will not be given other than in general terms. The focus of the thesis will be on the results related to the process of integrating and analyzing the information in a GIS.

This thesis will examine the process of gathering data and investigating the land resource suitabilities for three sectors: wilderness tourism, logging extraction, and mining development and exploration. Individuals from each sector, who contributed expert knowledge related to the mandates established for each ministry, participated in the analysis process and provided input into weighting factors which would determine those areas of greatest capability or suitability for each land use in question.

3.1 Defining the Study Area

A study area rich in resource issues was required for the case study. The first step in the analysis was to identify a suitable area to study which would satisfy the three areas of interest established for this thesis: 1. outdoor recreation opportunities for tourism potential; 2. merchantable timber extraction; and 3. mineral resource exploration opportunities.

The Kootenay region of British Columbia has long been the focus of a wide range of outdoor recreation activities. In recent years there has been increased interest in the provision of such outdoor recreation opportunities on a commercial basis (Careless and Jamieson, 1989). This trend is in keeping with the rapid world-wide development of the tourism industry into a segment known as "adventure travel". Adventure travel is the term used to describe a wide grouping of commercial outdoor recreation activities, ranging from heli-skiing to whale-watching (Careless and Jamieson, 1989). It is experiencing very rapid growth since it is a type of tourism favored by the affluent, activity-conscious "Baby Boom" generation. In British Columbia, adventure travel is

expanding at a rate of between 15 and 20% per year (Careless and Jamieson, 1989). By the year 2000 it is forecast to generate over a half billion dollars in direct revenues (WTC,1988).

A study undertaken by Tourism Canada on Adventure Tourism in Western Canada (1988) notes that British Columbia currently accounts for 85% of the western Canadian adventure tourism revenues. The same study also identified the geographical criteria necessary for the successful operation of various adventure tourism activities, and revealed that for mountain-related activities (skiing, hiking, etc.), the Kootenay region provides the highest quality location in British Columbia. The growing demand for commercial recreation on Crown lands has created a variety of challenges with respect to land management. In addition to the traditional competition between forest management, wildlife management and public recreation for the use of Crown lands the proliferation of adventure travel operations spawned new issues related to the impact of the tourists on the land.

A 3000 square kilometre study area near Kootenay Lake in the British Columbia interior (covered by one 1:250,000 NTS map sheet, 82F) was selected (Figure 3.1). In British Columbia, 93% of the land base is Crown Land, making it appear that there is ample room for wilderness recreation (Province of British Columbia, 1990). However, the majority of the land is designated, or the resources on the land are legally committed, for a wide range of uses including forestry and mineral uses. The area around Nelson, BC is relatively undeveloped in terms of resource development and appears to be an ideal site for analysis (i.e., no preconceived development plans).

Figure 3.1: The Study Area

3.2 Determining the Users' Groups

Five provincial ministries: BC Ministry of Tourism; BC Ministry of Crown Lands; BC Ministry of Energy, Mines and Petroleum; BC Ministry of Forests; and BC Ministry of Environment were contacted by the author, as project manager, and invited to participate in the case study.

With cooperation from the participating Ministries in assembling data required for the project, a list of the components of the data base was faxed to each participant. The structure and contents were refined through discussions as the data were received and converted into GIS format. Details of the rationale for decisions made are not available because this project was to be considered as demonstration only and not to be regarded as analysis leading to policy decision. As such, participants adopted a hypothetical case study approach.

Each of the participating government ministries then selected a representative who assumed the role of expert user for the range of resource interests encompassed by their individual mandates. As the project manager, the author capitalized on the expertise within each ministry and allowed the expert users to define their own decision making rules. The role of the project manager was then to integrate the information into the GIS and to analyze the data.

The mandates for the selected ministries are as follows:

Ministry of Tourism: To encourage growth and development of the tourism sector in the province and fulfilling an advocacy role in assisting industry to achieve developments which are not only viable from a private sector perspective but also reflect the public interest (B.C. Ministry of Tourism, 1993).

Ministry of Energy, Mines and Petroleum: To maintain maximum long-term opportunities for mineral resource exploration and mine development (B.C. MEMPR, 1993).

Ministry of Forests: To determine and maintain areas of high merchantable timber harvesting (B.C. Ministry of Forests, 1993).

Each of the representatives, from the five ministries, was asked to define a single goal, based on their individual ministerial mandates, for land use in the study region.

Objectives established by the three groups were:

- **Tourism:** To identify areas best suited for outdoor recreation sites.
- **Forestry:** To identify merchantable timber areas.
- **Mining:** To maintain maximum long-term opportunities for mineral resource exploration and mine development.

3.3 Identification of Data Sources

The five provincial ministries participating provided over 35 layers of data in addition to data provided from the Federal government departments of Environment Canada and Energy, Mines and Resources. Much of the data required already existed in digital form from the various agencies. This data did not require pre-processing, only a translation of format for the GIS. The translator available with the SPANS GIS provided a selection of over 20 different raster and vector formats that could be translated into the SPANS format. This translation software and procedure is a standard among most commercial GIS systems available today. Some of the information was only available in paper format and was digitized. The satellite image was classified for forest cover type using the Earth Probe image analysis system. Unfortunately, some data that were only available for two sub-areas of the study area. For the purpose of demonstrating the process of the analysis for this thesis the overlay analysis was conducted for the sub-set areas separately. This presented a limiting factor in the analysis.

- Energy, Mines and Resources (EMR) topographic data

The 1:250,000 topographic data for the NTS map sheet 82F were received from EMR in Standard Interchange Format (SIF) on 9 track tape. These data (roads, rivers, railways, contours, etc.) were separated into eleven layers allowing the road network layer to be utilized for analysis. None of the other layers were required for the analysis.

- **Environment Canada - Canada Land Inventory (CLI) data**

Data for five CLI layers: agriculture, ungulates, waterfowl, forestry, and outdoor recreation, were received in Canada Land Data System ASCII Raster File format. This information also provided the base map of the study area.

- **British Columbia Ministry of the Environment**

Various paper maps were provided for this thesis, including data for hiking trails, cabin locations, rest stop and wildlife viewing sites, and heritage areas. These paper maps were converted into digital information using the digitizing module of the GIS by a consulting firm specializing in data conversion.

- **Kootenay Commercial Winter Recreation Opportunities Study**

This study had been sponsored by the British Columbia Ministry of Crown Lands. Data for the study provided mapped information on vegetation, "recreation usage", and related attractions. These were converted into digital format using the digitizing module of the GIS by a consulting firm specializing in data conversion.

- **British Columbia Energy, Mines and Petroleum Resources (EMPR)**

British Columbia EMPR supplied the provincial digital MINFILE for the study area. This is a point file mineral inventory data base of provincially controlled land, showing

mineral occurrence, location, commodity information, geological information and reference information.

EMPR also supplied a geochemistry file containing some 20 elements for each point location. The data for copper, zinc, and lead were used to create maps of geochemical concentration.

- Earth Probe Corporation

Earth Probe provided a geometrically corrected and classified satellite image that covered the northeast portion of the study area. The image provided vegetation/forest cover data for a fall scene taken in late September, 1989. An image for the entire study area was available by special request only and would have to be purchased. The provision for purchasing data was not made, as all other data had been donated to the project on a demonstration basis.

- EMR Geological Survey

A portion of the CANMINDEX file containing point information on known mineral deposits on Federal land was obtained on diskette in ASCII format.

3.4 Determining the Geographic Information System

Several factors must be considered when choosing a suitable geographic information system for this analysis from the many that are commercially available today. The author determined that five major characteristics had to be met in order to be able to carry out the analysis objectives that the various users' groups had determined. The five criteria are: transportability from one location to another, ease of use, the ability and flexibility to integrate various data sources and types, statistical analysis functions to determine area, and advanced modelling functions to determine the areas of interest for the users' groups.

In addition, the users' groups determined that the strength of utilizing a geographic information system must enable the analyst to manage the decision criteria and appropriate to meet the objectives for the analysis system, namely:

- ease of use through packaged applications based on graphical user interfaces;
- layers of resource and infrastructure data can be selected quickly;
- overlay and modelling techniques can be quickly and easily applied in order to interpret and interrelate the selected layers;
- results can be reviewed and adjusted in real time, so that alternative scenarios and options can be compared for optimum results (particularly useful in conflict resolution situations);
- data manipulation of market profiles can be quickly and efficiently adjusted for specific product perspectives; and
- maps and reports can be annotated and produced in order to facilitate the communication of issues and possible resolutions.

TYDAC Technologies SPANS™ geographic information system meets the above criteria and was used for the task. SPANS operates on a personal computer and provided the author with the ability to move the GIS from one location to another while carrying out the analysis procedures with the various groups. The GIS is menu driven which allowed the author the capability to navigate through complex tasks. SPANS provided a module for digitizing the paper maps into digital format, and also provided interfaces to the various digital formats provided from the provincial and federal ministries allowing that digital data to be imported into the GIS.

SPANS also showed several characteristics that made it suitable for this application of determining the potential of an area for a particular resource use. One of those characteristics is the implementation of the quadtree data structure. This hierarchical type of grid data structure provides a method of organizing and indexing spatial data. SPANS uses quadtrees to store and manipulate area and surface data quickly and efficiently. This feature was important in the analysis and modelling portion of this project because it allowed for fast manipulations of the data thus producing the results needed with the additional capability of allowing the users to refine their criteria and evaluate the model a second or third time.

SPANS provided all of the capabilities needed by the author to complete the analysis needed for the objectives of thesis without any external programming or computer skills. As part of the original project team for the demonstration data base at Globe '90, the SPANS GIS was provided by INTERA TYDAC and was operated by the author.

3.5 Analysis Issues

The analysis will focus on issues related to development potential for resource activities. Three different tourism attraction potentials that also embody, or have an impact on, the mandates of the forest industry and mineral industry were identified as separate analysis issues. Although "adventure travel" can be generalized, the tourism potential of an area is dependent on the length of time a tourist stays in an area and the distance travelled into an area. The outdoor recreation activities chosen were:

- front country tourism potential,
- mid-country tourism potential, and
- back country tourism potential.

Commercial back country recreation was defined to include recreational activities that are carried out in relatively undisturbed natural environments at distances greater than 10 km from a major road network (Province of British Columbia, 1990). Such activities generally consist of packaged back country experiences that are planned and structured to maximize the satisfaction of the participants (Province of British Columbia, 1990). Mid-country recreation is defined to take place in areas that are a distance of 5 to 10 km from a road network and are suitable for day hiking and/or overnight camping. The areas of mid-country and back country are not mutually exclusive due to the human nature of the participants. In general, because the participants are travelling on foot or horseback they may encounter activities that take place in the overlap area between 5 to 10 km. This overlap was accounted for in the analysis by the users specifying a lower weighting factor to the area of 5 to 10 km distance from the road when determining the

most suitable areas for back country recreation. Front country recreation takes place in those areas less than 5 km from a road network and may include day activities with no overnight stay.

In addition, the outdoor recreation users' group determined that the areas for most suitable front country recreation activities would also include: the vegetation areas of Engelmann Spruce and Sub-alpine Fir and Douglas Fir/Ponderosa Pine; an area of high capability for ungulates and waterfowl based on the Canada Land Inventory maps; and be located less than 0.5 km from a rest stop or known wildlife viewing site.

The outdoor recreation users' group determined the areas for most suitable mid-country recreation potential should include: the areas classified with land status of provincial, parks or protected areas; a high capability for waterfowl and ungulates according to the CLI maps; areas of Douglas Fir/Ponderosa Pine — although all vegetation areas were considered to some degree — being located less than 0.5 km from a known cabin location; and being located less than 0.5 km from a hiking trail.

The outdoor recreation users' group determined the areas for most suitable back country recreation potential should include: the areas classified with land status of provincial, parks or protected areas, with the possibility of also utilizing Indian Reserve land; a high capability for waterfowl and ungulates according to the CLI maps; areas of Alpine vegetation — although all vegetation areas were considered to some degree — with Glacier and Douglas Fir/Ponderosa Pine being the next most suitable; being located less than 0.5 km from a known cabin location; being located less than 0.5 km from a hiking

trail; and located in an area of known Back Country Hiking as determined by the Ministry of Tourism.

The forest logging extraction experts established their requirements based on the only suitable data available at the time of analysis: CLI Soil Capability for Forestry and a classified satellite image of forest cover. However, only a portion of the entire study area was covered by these data layers. In the course of the analysis a special sub-area will be created to demonstrate the use of these data as part of the overall analysis for this thesis. For the analysis, those areas with a high index for the land capability for forestry and areas classified as coniferous forest were selected.

The mineral resources users determined that in order to satisfy their objectives the areas most suitable for long-term opportunities for mineral resource exploration and mine development would include: areas of known mines; areas of large deposits (known or probable); high concentrations of copper, lead and zinc; less than 10 km from a road; provincial land status or private land status; areas of high capability for agriculture; the exclusion of areas around heritage sites; and low capability for ungulates, waterfowl and recreation according to the CLI data layers.

3.6 Method of Analysis

The analytical method chosen by the users' groups was a type of arithmetic overlay called the index overlay method. This method was chosen because it was the simplest to use and each expert was able to specify the importance of each thematic layer relative

to all others, and within each layer, rank the attributes according to the objectives specified. Arithmetic and logical overlay operations are part of all GIS software packages (Aronoff, 1989). The index overlay of the SPANS GIS is a method of creating a new map layer by performing arithmetic operations (addition, subtraction, division and multiplication) on the attribute values associated with the entities on one or more other maps. In the index overlay method, entities are weighted according to their importance or worth and the attribute values are scored according to their ability to reflect certain conditions imposed by the criteria of the application.

Aronoff (1989) describes the overlay process. The flexibility provided to the operator and the level of performance of overlay operations vary widely among the many GIS available. One of the major factors affecting the performance of these functions is the data model being used. Raster and vector models differ significantly in the way arithmetic and logical operations are implemented. Overlay operations are usually performed more efficiently in raster-based, or cell-based, systems. The arithmetic operation is performed on every cell of the input data layer and the result is written to the corresponding cells of the output data layer. In the vector domain each polygon can differ in size and shape and so the boundaries of the polygons in one data layer usually will not coincide with the boundaries of polygons in the other data layer. In order to perform any arithmetic operation on two or more vector layers a new layer must first be created to account for the "new" polygons that will be created where the polygons overlap. When a large number of irregularly shaped polygons are involved, the vector overlay procedure generally requires significantly more processing time than raster overlay.

The SPANS GIS performs its overlay analysis in the raster domain. There is no need to calculate intersections of boundaries or make any modifications to the feature boundaries because each spatial element is a single cell of standard size.

The first assignment of the users' group was to define their land use requirements as they pertain to the needs and desires of their resource group. Rather than one limiting definition, each group developed a series of definitions which described the land use. To determine the capability and suitability of the potential resource uses an interactive approach between the users' groups and the author to derive capability and suitability findings for each stakeholder perspective used in the research.

After the user groups had determined the map layers for input into their analysis (see section 3.5 Analysis Issues) they were required to rank each of these maps as to their importance in the analysis. SPANS GIS prepares a template for the user and ranks each input map equally. At this time, the user may choose to use the GIS rankings or may changes the input values. After the maps have been ranked, the next task of the users is to chose a scale (for example, the users chose the simple scale from 1 through 10) on which they based the desirability of the individual layers or classes within each map. A numeric value of 10 indicated a qualitative value of "excellent" suitability or desirability. As the scale decreased the suitability changed within a range from high to poor suitability. In practice, it required the users to make decisions on weights and rankings of attributes and attribute criteria respectively for each stakeholder area. This is a qualitative approach based upon the expert knowledge of the individuals involved.

The information on each map layer must first be assigned to some common scale by scoring the suitability (score_i) of each map to the analysis result in question. The score that each location on the map (weight_i) receives on this common scale can then be weighted according to the importance (score_i) of the map layer on which it is found. The total, calculated from all the various map layers, will represent a measure of suitability. The measure of suitability assigned to each location is called an index and is calculated through a computation algorithm which calculates the average score in the SPANS GIS.

The average score is calculated as follows (INTERA TYDAC, 1993, Reference Manual, p. 8-32):

1. All negative scores are rounded to the nearest integer.
2. For areas where there is a negative score the average score equals the minimum of the negative scores.
3. For areas where all scores are non-negative, the average score equals:
$$\text{SUM}_i = \sum_{i=1}^n (\text{score}_i * \text{weight}_i) / \sum_{i=1}^n (\text{weight}_i)$$

where, n is the number of input maps.
4. The average scores are rounded to the nearest integer.
5. The maximum individual score is assigned class 1. All average scores are assigned classes relative to this class.

The suitability results were expressed in the form of maps. These suitability results were created using the GIS technology and were produced in both digital and hard copy form. The intermediate results were then further analyzed through map overlay techniques to

identify areas of potential competition measured on a ten-point scale. It was decided by the user groups that those areas with the highest suitability for the selected tourism product under study and the highest suitability for both forest logging extraction potential and long-term mineral resource opportunities would be assigned to the category of greatest competition. The final scale of gradation expressed the results as categories from "excellent" suitability or "extreme" competition through to "poor" suitability or "no" competition. Areas of exclusion area also indicated on the maps.

The use of the SPANS GIS enabled participants in the project to apply their judgement at all analysis steps. To assess the many and varied factors in open space acquisition can become a complex and unmanageable task without the tools afforded by GIS (Bohard, 1992). By allowing the users to indicate their preferences presented a situation by which a different group of participants would produce a different set of results. Therefore, one must assume that the overlay process will produce results each time based on the input into the index overlay templates. However, the results would not be repeatable based on the qualitative input from the experts. These judgements can be reflected in the form of ratings to describe the relative significance of each element of each land use component. This weighting process establishes the "rules" for the overlay analysis to derive locations of high capability and high suitability for each stakeholder's respective interest. The specific index overlay templates used for the analysis in this thesis can be found in Appendix A. An illustration of the data weighting process, from an example used in the case study in the SPANS GIS is provided in Figure 3.2.

Figure 3.2: An Illustration of the Weighting Process

Chapter 4: Analysis and Results

The resource planning procedure is often a complicated and interrelated process, where issues arise from a number of perspectives: competing resource and land uses, as well as impacts on the environment and the economy (ARA, 1990). In large geographic areas, the process is even further complicated in regards to keeping track of the range, location and diversity of interest areas (Burrough, 1986).

This chapter will explain and illustrate the final stages of the database development and analysis. The suitability for three land uses, and the potential competition between them, will be described in this chapter to achieve the objectives of this thesis set out in Chapter 1.

1. Tourism potential for the areas defined as by "front country", "mid-country" and "back country."

2. Mineral resource exploration potential.
3. Forest logging extraction potential.
4. Competing land use between front-country tourism potential, logging potential and long-term mineral resource opportunities.
5. Competing land use between mid-country tourism potential, logging potential and long-term mineral resource opportunities.
6. Competing land use between back-country tourism potential, logging potential and long-term mineral resource opportunities.

4.1 Land Use Analyses

4.1.1 Tourism Potential

Front country tourism potential was determined through a series of three index overlays. The first overlay produced a map to determine the areas of front country wildlife viewing potential. The second overlay produced a map with results for the potential for front country summer recreation. These base layer maps are found in Appendix B and the overlay templates are found in Appendix A. The final output map showing Front Country Tourism Potential was based on the recreation potential determined by the first two overlay analyses described above and is illustrated in Figure 4.1.

An area analysis of the final map was performed in the GIS. The results show that there was no area which satisfied the highest scoring (that of Index 10) for all of the input data. The second highest score (Index 9) covered only 0.01% of the entire area. Areas

Figure 4.1

Front Country Tourism Potential

represented by the score Index 8 and Index 7 (high potential suitability) represented 0.95% and 0.40% of the total area respectively. However, the area represented by the area classified as Excluded, covered 82.88% of the total area. This last area was deemed excluded for front country tourism on the basis of stakeholder input which required front country tourism areas to be within 5 km of the road access.

Table 4.1: Area Analysis for Front Country Tourism Potential¹

Class	Score	Description	Area %	Cum %	Area (km ²)
1	Index 10	Excellent	0.00	0.00	0.00
2	Index 9	Very High	0.01	0.01	0.37
3	Index 8		0.95	0.97	25.86
4	Index 7	High	0.40	1.37	10.89
5	Index 6		13.10	14.47	355.09
6	Index 5	Moderate	1.36	15.83	36.83
7	Index 4		0.91	16.74	24.71
8	Index 3	Poor	0.38	17.12	10.21
9	Index 2		0.00	17.12	0.0
10	Index 1	Very Poor	0.00	17.12	0.0
11	Index 0	No Potential	0.00	17.12	0.0
12	Index -1	Excluded	82.88	100.00	2246.12
Total of 12 classes			100.00		2710.08

The tourism potential map for the mid-country area (Figure 4.2) was determined through an overlay process similar to that for front country tourism potential. First, the potential areas for wildlife viewing were calculated, followed by the calculation of the potential for mid-country summer recreation. The final overlay of the combination of those two maps produced the map illustrating the mid-country tourism potential.

¹Information in the table and the corresponding map is matched sequentially by SPANS GIS.

Figure 4.2

Mid-Country Tourism Potential

- Potential
- Water
 - Excellent
 - Very High
 - High
 - Moderate
 - Poor
 - Very Poor
 - No Potential
 - Excluded

0 8 km

-116 50

49

-118

The area analysis results for this map indicate that those areas scoring the highest potential were classified as Index 7, with an area of 0.07% of the total area (Table 4.2). Approximately 11% of the area fell in the middle range of Index 4 and Index 5 which were considered, by the experts, to be of potential moderate suitability.

Table 4.2: Area Analysis for Mid-Country Tourism Potential

Class	Score	Description	Area %	Cum %	Area (km ²)
1	Index 10	Excellent	0.00	0.00	0.00
2	Index 9	Very High	0.00	0.00	0.00
3	Index 8		0.00	0.00	0.00
4	Index 7	High	0.07	0.07	1.82
5	Index 6		0.15	0.22	4.13
6	Index 5	Moderate	10.74	10.96	291.02
7	Index 4		20.57	31.53	557.57
8	Index 3	Poor	14.12	45.65	382.62
9	Index 2		17.19	62.84	465.83
10	Index 1	Very Poor	4.22	67.06	114.41
11	Index 0	No Potential	0.03	67.09	0.81
12	Index -1	Excluded	32.91	100.00	891.87
Total of 12 classes			100.00		2710.08

The tourism potential map for the back country area (Figure 4.3) was also determined by the same series of overlay procedures as front country and mid-country tourism potential. Back country wildlife viewing potential and back country summer recreation potential were calculated and then overlain to produce the back country tourism potential map.

The results for the potential areas most suitable for back country tourism (Table 4.3) are similar to those of the mid-country tourism potential. The most suitable areas are scored

Figure 4.3

Back Country Tourism Potential

as Index 7 with only 0.07% of the total area. Index 4 and Index 3 represent approximately 34% of the total area and were determined to be areas of moderate suitability by the users.

Table 4.3: Area Analysis for Back Country Tourism Potential

Class	Score	Description	Area %	Cum %	Area (km ²)
1	Index 10	Excellent	0.00	0.00	0.00
2	Index 9	Very High	0.00	0.00	0.00
3	Index 8		0.00	0.00	0.00
4	Index 7	High	0.07	0.07	1.82
5	Index 6		0.19	0.26	5.12
6	Index 5	Moderate	9.79	10.05	265.45
7	Index 4		23.00	33.05	623.26
8	Index 3	Poor	11.26	44.30	305.04
9	Index 2		29.83	74.14	808.50
10	Index 1	Very Poor	8.68	82.81	235.15
11	Index 0	No Potential	0.07	82.88	1.78
12	Index -1	Excluded	17.12	100.00	463.96
Total of 12 classes			100.00		2710.08

Based on the input criteria from the experts it would appear that this area would be a suitable site, but not exceptional for the development of back country recreation activities as tourism attractions.

4.1.2 Mineral Resource Exploration Potential

The long-term opportunities for mineral resources (Figure 4.4) were determined by overlaying eleven map layers. The area analysis indicates that a large portion of the study area (greater than 85%) can be described as having poor potential for mineral

Figure 4.4

Long Term Opportunities for Mineral Resource Exploration

resource exploration potential. Several areas indicate moderate to high suitability rankings in the eastern half of the study area.

Table 4.4: Area Analysis for Long-term Opportunities for Mineral Resource Exploration and Mine Development

Class	Score	Description	Area %	Cum %	Area (km ²)
1	Index 10	Excellent	0.00	0.00	0.00
2	Index 9	Very High	0.00	0.00	0.00
3	Index 8		0.00	0.00	0.00
4	Index 7	High	0.06	0.06	1.75
5	Index 6		0.35	0.41	9.44
6	Index 5	Moderate	9.63	10.04	261.01
7	Index 4		32.55	42.59	882.03
8	Index 3	Poor	31.26	73.85	847.20
9	Index 2		25.65	99.50	695.15
10	Index 1	Very Poor	0.46	99.96	12.49
11	Index 0	No Potential	0.00	99.96	0.00
12	Index -1	Excluded	0.04	100.00	1.01
Total of 12 classes			100.00		2710.08

4.1.3 Merchantable Timber Potential

The merchantable timber potential was determined by analyzing the two map layers which included the Canada Land Inventory (CLI) for Forest Potential and the satellite image classified for forest types, as separate sub-areas. This analysis was limited in two ways: 1. the CLI data (Figure 4.5) was available for approximately 50 percent of the study area (the western half), and 2. the satellite image (Figure 4.6) only covered a portion of the north east quadrant of the study area. The representatives of the forest stakeholder group chose to include those areas from the Canada Land Inventory for

Figure 4.5

CLI Soil Capability for Forestry

Source: Landsat TM classified by
Earth Probe Systems

Classified Satellite Image - Forest Cover Type

Figure 4.6

Forestry that fell into Classes 1 through 3 for the western portion of the study area and the areas determined to be classified as coniferous or mixed coniferous from the classified Landsat satellite image, of a scene collected in September 1989, for the northeastern portion of the study area, as those areas with the highest potential for merchantable timber sites.

The CLI Soil Capability for Forestry map covered 1386.50 square kilometres, approximately 50% of the study area. The area analysis results in Table 4.5 show that 43.61% of the area falls into the classes chosen by the users' group.

Table 4.5: Area Analysis for CLI Soil Capability for Forestry

Class	Capability	Area %	Cum %	Area (km ²)
1	Class 1	10.39	10.39	143.99
2	Class 2	9.73	20.11	134.87
3	Class 3	23.49	43.60	325.67
4	Class 4	7.53	51.14	104.47
5	Class 5	20.24	71.37	280.61
6	Class 6	9.00	80.37	124.78
7	Class 7	19.63	100.00	272.12
Total of 7 classes		100.00		1386.50

The area analysis of the satellite image (fall scene), classified for forest cover, indicates that it represents approximately 810 square kilometres (30% of the total area). The forest users' group indicated that the most suitable areas would be classified as coniferous forest in open areas or coniferous forest on shaded hillside (26.5% of the image).

Table 4.6: Area Analysis for Classified Satellite Image - Fall Scene

Class	Cover Type	Area %	Cum %	Area (km ²)
1	Coniferous, Shaded Hillside	12.48	12.48	101.227
2	Coniferous, Open Area	14.02	26.51	113.727
3	Mixed Coniferous and Deciduous	18.59	45.10	150.773
4	Deciduous	16.66	61.76	135.094
5	Deciduous, Open Meadows	1.78	63.54	14.434
6	Clear Cut, with Some Regrowth	15.36	78.90	124.598
7	Bare Rock and Soil	7.21	86.11	58.441
8	Ice and Snow	7.43	93.54	60.270
9	Water	6.46	100.00	52.391
Total of 9 classes		100.00		810.953

In visually analyzing the two base map layers for the forestry group, it appears that the two sub-areas overlap. It will be assumed that there will be discrepancies in the results produced with the input of these map layers in the overlay analysis. One of the maps specifies soil capability for forestry based upon their inherent ability to grow commercial timber. The other map layer represents the actual forest cover present. It must be realized that there will be differences in the results of the analysis, although the forest users' group agreed that the information would be relevant for both analysis results, and should be conducted for both sub-areas. The users were concerned with the process of integration rather than the results of the analysis.

4.1.4 Front Country Land Use Competition

The potential areas of competition in the front country were determined through a three map overlay of front-country tourism potential, mineral resource opportunities, and

forestry logging potential. Two analyses were conducted, one for each of the areas for which forest data were available.

The spatial patterns from the map in Figure 4.7 and statistical analysis in Table 4.7 indicate that there are no areas of direct competition for the area covered by the satellite image. The areas scored as moderate to high suitability only result in approximately 18% of the total area. Areas beyond the 5 km distance from the road cover more than 81% of the total area.

Table 4.7: Area Analysis for Land Use Competition in the Front Country - Satellite Image Coverage

Class	Score	Description	Area %	Cum %	Area (km ²)
1	Index 10	Extreme	0.00	0.00	0.00
2	Index 9	Very High	0.00	0.00	0.00
3	Index 8		0.01	0.01	0.049
4	Index 7	High	3.80	3.80	30.780
5	Index 6		8.04	11.84	65.203
6	Index 5	Moderate	6.49	18.33	52.630
7	Index 4		0.40	18.73	3.217
8	Index 3	Low	0.00	18.73	0.012
9	Index 2		0.00	18.73	0.00
10	Index 1	Very Low	0.00	18.73	0.00
11	Index 0	No Competition	0.00	18.73	0.00
12	Index -1	Excluded	81.27	100.00	659.062
Total of 12 classes			100.00		810.953

Figure 4.8 indicates those areas of land use competition when the CLI Soil Capability for Forestry map was available. Table 4.8 shows that statistically those areas of highest land use competition for this area fall into the category Index 7 and represent 0.7% of the total

Front Country Land Use Competition - Satellite Image Coverage

50
-116

- Competition**
- Water
 - Extreme
 - Very High
 - High
 - Moderate
 - Poor
 - Very Poor
 - No Competition
 - Excluded
 - Missing Data

8 km
-1 0

49

-118

Figure 4.7

Figure 4.8

Front Country Land Use Competition -

Western Portion

area. Over 97% of the total areas falls into the area determined to be more than 5 km from the road.

Table 4.8: Area Analysis for Land Use Competition in the Front Country - Western Portion

Class	Score	Description	Area %	Cum %	Area (km ²)
1	Index 10	Extreme	0.00	0.00	0.00
2	Index	Very High	0.00	0.00	0.00
3	Index 9		0.00	0.00	0.00
4	Index 7	High	0.70	0.70	9.71
5	Index 6		0.62	1.32	8.59
6	Index 5	Moderate	0.23	1.55	3.13
7	Index 4		0.50	2.04	6.88
8	Index 3	Low	0.53	2.57	7.31
9	Index 2		0.25	2.82	3.51
10	Index 1	Very Low	0.00	2.82	0.00
11	Index 0	No Competition	0.00	2.82	0.00
12	Index -1	Excluded	97.18	100.00	1347.38
Total of 12 classes			100.00		1386.50

4.1.5 Mid-Country Land Use Competition

The areas of potential competition in the area of the mid-country were determined by a three map overlay between mid-country tourism potential, forest logging potential, and mineral resource opportunities. Figure 4.9 and Figure 4.10 show the areas where the potential land uses are in possible competition.

For the area covered by the satellite image Table 4.9 indicates approximately one half of the total area of this map has been excluded by the area which would be categorized as front country. A very small portion of the area, approximately 10%, would appear to

Figure 4.9

*Mid-Country Land Use Competition -
Satellite Image Coverage*

Figure 4.10

Mid-Country Land Use Competition -

Western Portion

show the potential of moderate to high competitive resource usage (Index 7 and 6).

Table 4.9: Area Analysis for Land Use Competition in the Mid-Country - Satellite Image Coverage

Class	Score	Description	Area %	Cum %	Area (km ²)
1	Index 10	Extreme	0.00	0.00	0.00
2	Index 9	Very High	0.00	0.00	0.00
3	Index 8		0.00	0.00	0.00
4	Index 7	High	0.30	0.30	2.406
5	Index 6		10.48	10.78	85.010
6	Index 5	Moderate	19.89	30.67	161.338
7	Index 4		11.72	42.40	95.073
8	Index 3	Low	2.32	44.72	18.837
9	Index 2		0.00	44.72	0.008
10	Index 1	Very Low	0.00	44.72	0.00
11	Index 0	No Competition	0.00	44.72	0.00
12	Index -1	Excluded	55.28	100.00	448.281
Total of 12 classes			100.00		810.953

Table 4.10: Area Analysis for Land Use Competition in the Mid-Country - Western Portion

Class	Score	Description	Area %	Cum %	Area (km ²)
1	Index 10	Extreme	0.00	0.00	0.00
2	Index 9	Very High	0.00	0.00	0.00
3	Index 8		0.00	0.00	0.00
4	Index 7	High	0.23	0.23	3.21
5	Index 6		8.22	8.45	113.91
6	Index 5	Moderate	21.85	30.30	302.92
7	Index 4		7.44	37.74	103.20
8	Index 3	Low	11.93	49.67	165.46
9	Index 2		13.85	63.52	192.02
10	Index 1	Very Low	2.54	66.06	35.23
11	Index 0	No Competition	0.00	66.06	0.00
12	Index -1	Excluded	33.94	100.00	470.54
Total of 12 classes			100.00		1386.50

4.1.6 Back Country Land Use Competition

The areas of potential competition in the area of the back country were determined by a three map overlay between back country tourism potential, forest logging potential, and mineral resource opportunities. Figure 4.11 shows the areas where potential land use competition may arise in the area of the satellite image. Figure 4.12 indicates the areas of the back country where potential land use competition may occur for the area of the CLI Soil Capability for Forestry map.

Over 50% of the area covered by the satellite image has been determined to be in an area of exclusion, that is Index -1 (Table 4.11). Approximately 11% of the area is indicated as an Index 7, or an area of high potential land use competition.

Table 4.11: Area Analysis for Land Use Competition in the Back Country - Satellite Image

Class	Score	Description	Area %	Cum %	Area (km ²)
1	Index 10	Extreme	0.00	0.00	0.00
2	Index 9	Very High	0.00	0.00	0.00
3	Index 8		0.00	0.00	0.00
4	Index 7	High	0.66	0.66	5.392
5	Index 6		10.49	11.15	85.054
6	Index 5	Moderate	20.24	31.39	164.125
7	Index 4		12.32	43.72	99.946
8	Index 3	Low	1.00	44.72	8.116
9	Index 2		0.00	44.72	0.039
10	Index 1	Very Low	0.00	44.72	0.00
11	Index 0	No Competition	0.00	44.72	0.00
12	Index -1	Excluded	55.28	100.004	48.281
Total of 12 classes			100.00		810.953

Figure 4.11

Back Country Land Use Competition - Satellite Image Coverage

**Back Country Land Use Competition -
Western Portion**

Figure 4.12

Table 4.12 shows the statistical area analysis for the area covered by the CLI Soil map. Approximately 40% of the total area indicates an areas of potential moderate conflict between the three land uses, that is Index 5 and Index 4. However, the area analysis indicates that there is little potential competition between the land uses with no score associated with Index 10, Index 9 or Index 8.

Table 4.12: Area Analysis for Land Use Competition in the Back Country - Western Portion

Class	Score	Description	Area %	Cum %	Area (km ²)
1	Index 10	Extreme	0.00	0.00	0.00
2	Index 9	Very High	0.00	0.00	0.00
3	Index 8		0.00	0.00	0.00
4	Index 7	High	0.26	0.26	3.62
5	Index 6		7.40	7.66	102.55
6	Index 5	Moderate	32.21	39.86	446.54
7	Index 4		12.02	51.89	166.70
8	Index 3	Low	13.47	65.35	186.70
9	Index 2		24.75	90.10	343.16
10	Index 1	Very Low	7.08	97.18	98.11
11	Index 0	No Competition	0.00	97.18	0.00
12	Index -1	Excluded	2.82	100.00	39.12
Total of 12 classes			100.00		1386.50

Although the area around Kootenay Lake was perceived to be an area of competition by the users' groups when interviewed individually, none of the analysis suggests that there are extensive areas of acute land competition. Most areas were moderately competitive or slightly competitive between users. Therefore, at first glance there would very little problem between the users' groups in developing this area for their respective resource uses.

This analysis provides a very basic "first cut" at determining the most suitable areas for potential resource development. Different proposals related to the land uses desired and analyzed in this chapter should be examined for this area. The results of the analysis will be affected each time a group of expert users is brought together to determine those areas that they deem "best" for their particular land use. However, the basic premise of analysis has been outlined in this theses.

In addition, how they may vary in environmental, social and economic benefits that can be generated for the residents of the province, must also be considered. The analysis of land use competition provides the opportunity to evaluate different proposals and then to select that proposal which would generate the greatest overall economic benefit while balancing the needs of the other resource users and residents, and the capacity of the land base and the natural resources to bear such use. While it may be difficult to assess the "greatest economic benefit", GIS improves the early stages in the planning process and potentially provides an unbiased basis for decision making. At that point the aggregate benefit must be defined.

4.2 Response of the Users' Groups

Having identified the preferences for uses of specific areas within the study area by each group the next step involved a consultative process amongst all of the users. It had been previously decided that there would not be a scientific analysis of the data involved, and that the purpose of the analysis was for demonstration purposes only. However, there were some preliminary conclusions and observations from those users involved.

The users agreed that the act of bringing the Ministries together to explore integrated resource planning increases awareness and understanding and is an important ingredient in pursuing integrated resource planning on an ongoing basis.

As for the analysis process itself, one of the advantages of using GIS technology is that the users' were forced to make explicit their assumptions. This helps not only in improving the quality of the analysis but also in engendering awareness of the perspective of the other users. GIS can also be practical as a tool for the presentation and dissemination of information to other user groups. The capability to assemble such a large amount of data on a micro-computer and perform the overlay analysis in a very short period of time (a few minutes) was impressive for the users to observe.

The users admitted they had a preconceived notion as to the outcome of the results because each individual is very familiar with their specific input information. However, they were surprised when the area did not contain any areas of intense direct competition. They concluded that having the ability of analyzing the data with a GIS allowed them to "see" this information differently. To reiterate an earlier statement, cause and effect is not well understood. However, in a spatial context the individuals' personal interpretations and bias are often removed through the requirement of a GIS to have the input made explicitly.

GIS technology provides the opportunity for interactive testing of integrated resource planning options. There is real potential to extend this approach beyond the confines of governments and experts into more public forums. To do so will require careful

consideration of logistics but it was agreed by those involved that it would be a worthwhile avenue to investigate. GIS continues to be of significant value in integrating the different data sets and is a useful analytical tool in undertaking integrated resource planning.

More accessibility by policy analysts, resource managers and decision-makers to GIS technology will advance our capacity to undertake effective integrated resource planning.

In the province of British Columbia, as in other provinces, there is considerable investment being made into creating digital databases, particularly in forestry, digital terrain mapping and wildlife. Many are designed for inventory and applications specific to individual ministries. This thesis is one example of an analysis oriented project which provides valuable experiences in regards to usage of this type of data.

Chapter 5: Conclusions and Recommendations

This thesis was the result of an exploration of an integrated geographic applications to support decision-makers and policy analysts of five provincial ministries in British Columbia with the task of dealing with the varied factors of determining areas for optimal land use.

5.1 Objectives and Results

In the province of British Columbia, as in other provinces, there is considerable investment being made creating digital databases, particularly in forestry, digital terrain mapping and wildlife. Many are designed for inventory and applications specific to those individual ministries. This thesis focused on four key objectives.

- *To determine the information that managers of natural resource based data require to perform their assessment of land based potentials for a given area.*

In pursuing this objective it was determined that the Province of British Columbia has a wide range of resource management legislation covering the protection of important natural resources. Traditional resource management practices have recently been complicated by the emergence of economic sectors such as tourism competing for the resource base, and public opinion concerning the need to encourage sustainability of natural areas for future generations. By initiating such processes, the Province has acknowledged that the definition of the "public interest" as it relates to resource management on Crown Lands must take into account the aspirations of many more resource users than simply forestry and mining.

In addition, the Provincial ministries in British Columbia have been creating digital databases of their land based information for management purposes. The case study analysis of this thesis allowed these managers to see, not only their data, but data from other provincial ministries in an integrated format.

As a result the users determined that to be more effective managers their background and experience needed to include the exposure to other disciplines involved in the solving the problems of resource management. In addition, to determine the information that they needed to assess their land based needs they needed to look beyond their own discipline and often found that it already existed in a format that could easily be accepted by the GIS.

2 OF/DE 2

PM-1 3½"x4" PHOTOGRAPHIC MICROCOPY TARGET
NBS 1010a ANSI/ISO #2 EQUIVALENT

PRECISIONSM RESOLUTION TARGETS

- Outline the basic attributes of GIS that may contribute to resource management assessments.

Over the past decade GIS technology has been widely accepted by natural resource agencies, especially those of forestry and mining. The managers of these agencies have realized the benefits of current, accurate data about their inventories. Ease of use through a packaged application allowed the expert analysts to select the information to be analyzed in a timely manner. The strength of the overlay analysis allowed for interpretations and adjustments of the results in real time, so that alternative scenarios and options can be compared for optimum results. As well, the ability to compose maps and reports that can be annotated and produced in order to facilitate the communication of the issues and possible resolutions was determined to be a positive characteristic of utilizing a GIS.

- *To demonstrate the implementation of a GIS with the appropriate land based and associated data sets for a selected area.*

The GIS was able to incorporate all of the data sets, 35 layers of base data provided by the participating ministries. Each data layer was translated into the appropriate digital format for the GIS to incorporate. It was agreed by the users' groups participating that they were supplied with all of the data necessary to carry out the analysis for this thesis.

- *Determine the interests and values of a spectrum of natural resource users' groups.*

Through a consultative process the interests of the five provincial ministries were established. The result of the co-operative effort allowed each representative to capitalize on their existing land based information and utilized a GIS to integrate their varied data sets. The results of the analysis illustrated the areas of potential land uses. Areas that would require inter-minister discussions, those areas of competition, were also determined.

The users' groups determined that this case study allowed them to work together in an environment that was non-threatening as to the outcome of the results, largely due to the "demonstration" nature of the project. The experts involved concluded that the GIS allowed them to explore potential conflicts in a neutral setting and presented a new option for land use trade off analysis.

5.2 Limitations

Data were gathered for the study area as defined by the NTS map sheet 82F. However, the forest data layers from the satellite image and the CLI Soil Capability for Forestry did not cover the entire study area. The satellite image, classified for forest type, only covered a portion of the north-eastern area of the study site. There was no capital budget allocated to secure an image for the entire area. It was decided that a sub-set of the study area including this image would be created. In addition the forestry data were

limited because the CLI Soil Capability for Forestry data were only available for the western portion of the study area. The study area was also sub-set for this data set.

The results from the overlay analysis for the two sub-areas showed differences. The Landsat TM data provided information on the actual forest cover of the area, and the forest users group could determine which categories would provide merchantable timber. The CLI data provided information related to the capability of the soil to support the growth of commercial timber.

The scope of the study was limited to an area around Kootenay Lake in British Columbia. This study area was blessed with a significant amount of data already in digital format that was easily accepted by the GIS. Another study area might not provide the analyst with such appropriate data that would require extra pre-processing or the actual creation of digital data.

This case study focused on the process of creating a database and attempting to analyze various land covers for areas of most suitable tourism recreation, merchantable timber and long term opportunities for mineral exploration. The focus was not on the results due to the politically sensitive nature of the area in questions. Currently, there is very strong debate in the field of GIS as to the accuracy and application of many of the results of projects carried out with the aid of GIS. So many external factors: the participants, the data, the GIS system used, the statistical analysis performed, can affect the results. However, the process is repeatable and this process has been used extensively in the area of site selection analysis. This topic could be a complete thesis in itself.

5.3 Benefits from the Case Study

1. The analysis from this thesis provides an avenue for further exploration of co-operative analysis between natural resource managers of the same land area. GIS was the common analysis tool in bringing together five provincial ministries. Each users' group was able to see the degree to which their choices for optimal land use would affect other potential land uses of the area.
2. The results of the analysis from this thesis provide a forum for exploration of the application of GIS to a resource-related decision-making process. By means of the co-operative approach, each of the users' groups was able to explain their choices with the other ministries present. The result was the introduction to the ministries of the potential to work together, and through inter-ministry discussions determine those areas of land use, for each participating ministry, that would provide a response to their individual mandates and to the overall suitability of the land area in question.
3. The results from the analysis indicate advances in the application of GIS as a tool for integrating diverse data sets and providing a useful analytical tool in undertaking integrated resource planning.

Implementation of a geographic information system within the tourism sector will generate substantial benefits related to its capacity to support growth and development of the resource based tourism industry in a sustainable development context. The

availability of a geographic information system, supporting databases, and trained users in the use of GIS will potentially ensure more efficient and focused tourism related decision making.

Just as important will be access to the use of GIS and the readily available databases by the tourism industry. For example, the industry will be able to test product development ideas, assess the feasibility of their tourism projects, analyze their success, and identify new markets to target in their marketing strategies.

Beyond the benefits of this thesis itself, there are a number of spinoffs important from an economic development perspective to both British Columbia and Canada. The results of the analysis from this thesis offer the tourism industry an opportunity to diversify the information technology development efforts of both levels of government.

5.4 Recommendations for Future Analysis

5.4.1 Refining the Analysis

Having identified the preferences for uses of specific areas within the study area by each stakeholder, the next step involved in an integrated analysis is to identify those areas where competing uses are encountered and begin to examine the land use trade-offs. In an integrated planning process, be it for an urban area or for a rural area, as is used in this thesis, integrated planning generally involves first determining those areas where competing areas are not encountered and therefore where land use management and

regulation is relatively easy. Areas where there are competing uses will require a consultative process amongst all users to:

1. Identify the potential for multiple use without jeopardizing the objective of each stakeholder.
2. Identify possible changes in individual stakeholder criteria which are acceptable to the stakeholder and might be applied to determine sensitivity of competing use selection.
3. Identify possible adjustments to normal management practice that will permit each stakeholder to participate in a multiple use setting.

Through the use of a GIS the process of exploring these possibilities and quickly assessing sensitivity to minor alterations in criteria can greatly enhance the efficiency of the integrated resource planning process.

5.4.2 Quantifying the Costs and Benefits

The index overlay modelling process provides information to the users' groups so that they may make trade-off decisions for their particular land use priorities. However, the trade-offs are often made between qualitative and quantitative objectives. The modelling process provides a systematic method to identify the issue and provide information to support the decision of the user group. For example, the cost of constructing a visibility

barrier around the logging clear cut areas to minimize the aesthetic impact on the area deemed suitable for back country tourism must be examined. Is the trade-off value worth the cost of construction? It must be noted that the modelling process does not automatically provide the answers: subjective value judgements must still be made by the users' groups.

5.4.3 Refining the Analysis Toward the Final Selection

Once the costs and benefits have been settled for a given area the process of generating alternative scenarios may be required. Inputs from the sensitivity analysis and costs of construction or alternative site selection may be added to the modelling process. Through an iterative process, with all of the users' groups participating, a series of judgements may be arrived at. Ideal solutions are rarely achieved. The final selection between land uses, however, may be narrowed down to a "best" site based on agreement by the groups involved.

5.5 Insights

Over the past decade various practical approaches have been taken to implement GIS as part of a natural resource management planning process. This thesis continued to explore the process of integrating data, by means of a GIS, for a natural resource data base, but added two new dimensions: 1. the utilization of GIS within the tourism planning process and 2. establishing a cooperative effort of analysis between groups competing for the same land resource.

Two of the three land use sectors examined in this thesis: mining and forestry, have been two of the "traditional" disciplines that have utilized GIS over that past two decades. GIS offers these analysts and managers a practical means to manage large and diverse spatial data bases and provides effective tools to understand the relationships among diverse phenomena (Aronoff, 1989).

With the expanding demand by tourists to experience "adventure" vacations, the tourism industry is a new field in the land resource sector. British Columbia in particular is experiencing a increasing demand on its wilderness areas as tourists come to experience "Super Natural British Columbia".

A GIS provides the means for geographic information to be used for a broad range of applications and by users with a wide range of skills. GIS are a powerful resource for analyzing the inter-related systems involved in these types of problems. They provide flexible methods for exploring relationships among geographic data and assisting experts from diverse fields in pooling their knowledge to solve complex problems. Indeed, our success in dealing with many global environmental issues will depend on this type of multi-disciplinary effort. The GIS offers a practical means to manage large and diverse spatial data bases and provides effective tools to understand the relationships among diverse phenomena. An increasing number of decision-makers and managers have recognized that GIS technology will be essential if they are to address the expanded mandates and complex decisions they now face and decisions they may face in the future.

We are only beginning to grapple with the many managerial, legal, and social issues that are accompanying the wide-spread use of geographic information systems (Aronoff, 1989). This thesis examines the managerial issues from the point of view of three specific groups who use land based data within the management context of their daily requirements. With the processing power of GIS this thesis also inquired into the potential competition these three land uses might encounter for the study area around Kootenay Lake.

Appendix A

Indexing Overlay Templates

```

: Indexing Overlay Input File
:-----
:new mapid & title : frontrec      Front-Country Summer Recreation
:-----
: no of Input Maps : 2
: Input Maps (Id Max Color)
veg 5 fcwildvw 12
:
: Format = Weight Map ID Title
:-----
50.000 veg : Vegetation * weight
:-----
:      - 0: 0
:Glacier - 1: -1 * score
:Alpine - 2: 0
:SubAlpin - 3: 2
:ESpr/SaF - 4: 8
:InDF/PoP - 5: 10
:-----
50.000 fcwildvw : Suitable Front-Country Wildlife Viewing
:-----
:      - 0: 0
:In 10 - 1: 10
:In 9 - 2: 9
:In 8 - 3: 8
:In 7 - 4: 7
:In 6 - 5: 6
:in 5 - 6: 5
:In 4 - 7: 4
:In 3 - 8: 3
:In 2 - 9: 2
:In 1 - 10: 1
:In 0 - 11: 0
:In -1 - 12: -1
:=====

```

Notice the value of 50.000 appears twice in the template. This is the weight that has been assigned to each map and since two maps were provided, SPANS assigns an equivalent weight (50) to each of the maps. The sum of the weights is 100%. Notice also the column of numbers down the right side of the template. Each of these groups of numbers corresponds to the scores each user assigned to the scale of values used in the analysis, in this particular case study, a scale of 1 through 10.

: Indexing Overlay Input File

:-----
:new mapid & title : fcwildvw Suitable Front-Country Wildlife Viewing

:-----
: no of Input Maps : 4

: Input Maps (Id Max Color)

ungulate 7 waterfwl 7 roadbuff 5 attractn 1

:

: Format = Weight Map ID Title

:-----

30.000 ungulate : CLI Land Capability for Ungulates

:-----

: - 0: 0

:class 1 - 1: 10

:class 2W - 2: 10

:cl 3+3W - 3: 10

:class 4 - 4: 10

:class 5 - 5: 5

:class 6 - 6: 2

:class 7 - 7: 1

:-----

30.000 waterfwl : CLI Land Capability for Waterfowl

:-----

: - 0: 0

:class 1 - 1: 10

:class 2S - 2: 10

:all Cl 3 - 3: 10

:class 4 - 4: 8

:class 5 - 5: 5

:class 6 - 6: 2

:class 7 - 7: 1

:-----

30.000 roadbuff : Road Buffers

:-----

: - 0: 0

:0 - 5 Km - 1: 10

:6 - 10km - 2: -1

:11- 15Km - 3: -1

:16- 25Km - 4: -1

:>25km - 5: -1

:-----

10.000 attractn : Rest Stop or Wildlife Viewing Site

:-----

: - 0: 0

:< .5 Km - 1: 10

:=====

: Indexing Overlay Input File

:new mapid & title : frontour Front Country Tourism Potential

: no of Input Maps : 2

: Input Maps (Id Max Color)

fcwildvw 12 frontrec 12

:

: Format = Weight Map ID Title

50.000 fcwildvw : Front-Country Wildlife Viewing

: - 0: 0

:In 10 - 1: 10

:In 9 - 2: 9

:In 8 - 3: 8

:In 7 - 4: 7

:In 6 - 5: 6

:In 5 - 6: 5

:In 4 - 7: 4

:In 3 - 8: 3

:In 2 - 9: 2

:In 1 - 10: 1

:In 0 - 11: 0

:In -1 - 12: -1

:

50.000 frontrec : Front-Country Summer Recreation

: - 0: 0

:In 10 - 1: 10

:In 9 - 2: 9

:In 8 - 3: 8

:In 7 - 4: 7

:In 6 - 5: 6

:In 5 - 6: 5

:In 4 - 7: 4

:In 3 - 8: 3

:In 2 - 9: 2

:In 1 - 10: 1

:In 0 - 11: 0

:In -1 - 12: -1

:

=====

: Indexing Overlay Input File

:new mapid & title : midrec Mid-Country Summer Recreation

: no of Input Maps : 4

: Input Maps (Id Max Color)

landstat 6 ungulate 7 veg 5 waterfwl 7

:

: Format = Weight Map ID Title

25.000 landstat : Land Status

: - 0: 0

:provincl - 1: 10

:private - 2: 0

:indian R - 3: 5

:parks - 4: 10

:protect - 5: 10

:recreat - 6: 0

25.000 ungulate : CLI Land Capability for Ungulates

: - 0: 0

:class 1 - 1: 10

:class 2W - 2: 10

:cl 3+3W - 3: 10

:class 4 - 4: 8

:class 5 - 5: 5

:class 6 - 6: 3

:class 7 - 7: 0

25.000 veg : Vegetation

:Glacier - 1: 3

:Alpine - 2: 4

:SubAlpin - 3: 5

:ESpr/SaF - 4: 6

:InDF/PoP - 5: 8

25.000 waterfwl : CLI Land Capability for Waterfowl

:class 1 - 1: 10

:class 2S - 2: 10

:class 3 - 3: 10

:class 4 - 4: 8

:class 5 - 5: 5

:class 6 - 6: 3

:class 7 - 7: 0

```

: Indexing Overlay Input File
:-----
:new mapid & title : midview      Mid-Country Wildlife Viewing
:-----
: no of Input Maps : 5
: Input Maps (Id Max Color)
cabins 1 hiketrl 1 roadbuff 5 ungulate 7 waterfowl 7
:
: Format = Weight Map ID Title
:-----
20.000 cat :
:-----
:      - 0: 0
: < .5 km - 1: 10
:-----
20.000 hiketrl :
:-----
:      - 0: 0
: < .5 km - 1: 10
:-----
20.000 roadbuff : Road Buffers
:-----
:      - 0: 0
: 0 - 5 km- 1: -1
: 6 - 10 km- 2: 5
: 11- 15 km- 3: 10
: 16- 26 km- 4: 5
: > 25 km - 5: -1
:-----
20.000 ungulate : CLI Land Capability for Ungulates
:-----
:      - 0: 0
: class 1 - 1: 10
: class 2W - 2: 10
: cl 3+3W - 3: 10
: class 4 - 4: 10
: class 5 - 5: 5
: class 6 - 6: 2
: class 7 - 7: 1
:-----
20.000 waterfowl : CLI Land Capability for Waterfowl
:-----
:      - 0: 0
: class 1 - 1: 10
: class 2S - 2: 10
: class 3 - 3: 10
: class 4 - 4: 8
: class 5 - 5: 5
: class 6 - 6: 2
: class 7 - 7: 1

```

```

: Indexing Overlay Input File
:-----
:new mapid & title : midtour      Mid-country Tourism Potential
:-----
: no of Input Maps : 2
: Input Maps (Id Max Color)
midrec 11  midview 12
:
: Format = Weight Map ID  Title
:-----
50.000 midrec : Mid-Country Summer Recreation
:-----
:      - 0: 0
:In 10 - 1: 10
:In  9 - 2:  9
:In  8 - 3:  8
:In  7 - 4:  7
:In  6 - 5:  6
:In  5 - 6:  5
:In  4 - 7:  4
:In  3 - 8:  3
:In  2 - 9:  2
:In  1 -10:  1
:In  0 -11:  0
:-----
50.000 midview : Mid-Country Wildlife Viewing
:-----
:      - 0: 0
:In 10 - 1: 10
:In  9 - 2:  9
:In  8 - 3:  8
:In  7 - 4:  7
:In  6 - 5:  6
:In  5 - 6:  5
:In  4 - 7:  4
:In  3 - 8:  3
:In  2 - 9:  2
:In  1 -10:  1
:In  0 -11:  0
:In -1 -12: -1
:=====

```

: Indexing Overlay Input File

:-----
:new mapid & title : backrec Back Country Summer Recreation:-----
: no of Input Maps : 4

: Input Maps (Id Max Color)

veg 5 waterfwl 7 ungulate 7 landstat 6

:-----
: Format = Weight Map ID Title:-----
25.000 veg : Vegetation:-----
: - 0: 0

:Glacier - 1: 8

:Alpine - 2: 10

:SubAlpin - 3: 7

:ESpr/SaF - 4: 5

:InDF/PoP - 5: 8

:-----
25.000 waterfwl : CLI Land Capability for Waterfowl:-----
: - 0: 0

:class 1 - 1: 10

:class 2S - 2: 10

:class 3 - 3: 10

:class 4 - 4: 8

:class 5 - 5: 5

:class 6 - 6: 3

:class 7 - 7: 0

:-----
25.000 ungulate : CLI Land Capability for Ungulates:-----
: - 0: 0

:class 1 - 1: 10

:class 2W - 2: 10

:cl 3+3W - 3: 10

:class 4 - 4: 8

:class 5 - 5: 5

:class 6 - 6: 3

:class 7 - 7: 0

:-----
25.000 landstat : Land Status:-----
: - 0: 0

:provincl - 1: 10

:private - 2: 0

:indian R - 3: 5

:parks - 4: 10

:protect - 5: 10

:recreat - 6: 0

```

=====
: Indexing Overlay Input File
:-----
:new mapid & title : wildview      Backcountry Wildlife Viewing Suitability
:-----
: no of Input Maps : 6
: Input Maps (Id Max Color)
ungulate 7  waterfwl 7  roadbuff 5  hiketrl 1  cabins 1  tours3 2
:
: Format = Weight Map ID  Title
:-----
20.000  ungulate : CLI Land Capability for Ungulates
:-----
:      - 0: 0
:class 1 - 1: 10
:class 2W - 2: 10
:cl 3+3W - 3: 10
:class 4 - 4: 10
:class 5 - 5: 5
:class 6 - 6: 2
:class 7 - 7: 1
:-----
20.000  waterfwl : CLI Land Capability for Waterfowl
:-----
:      - 0: 0
:class 1 - 1: 10
:class 2S - 2: 10
:class 3 - 3: 10
:class 4 - 4: 8
:class 5 - 5: 5
:class 6 - 6: 2
:class 7 - 7: 1
:-----
20.000  roadbuff : Road Buffers
:-----
:      - 0: 0
:0 - 5 Km - 1: -1
:6 - 10km - 2: 10
:11- 15Km - 3: 5
:16- 25Km - 4: 5
:>25 Km - 5: 5
:-----
10.000  hiketrl : Hiking Trails
:-----
:      - 0: 0
:< .5 km - 1: 10
:-----
10.000  cabins : Cabins

```

```

:-----
:      - 0: 0
: < .5 km - 1: 10

```

```

:-----
20.000 tours3 : Backcountry Hiking and Downhill Skiing

```

```

:      - 0: 0
: BCHike - 1: 10
: DSkiing - 2: 0
:=====

```

: Indexing Overlay Input File

:new mapid & title : backtour Back Country Tourism Potential

: no of Input Maps : 2

: Input Maps (Id Max Color)

backrec 11 wildview 12

:

: Format = Weight Map ID Title

50.000 backrec : Back Country Summer Recreation

: - 0: 0

:In 10 - 1: 10

:In 9 - 2: 9

:In 8 - 3: 8

:In 7 - 4: 7

:In 6 - 5: 6

:In 5 - 6: 5

:In 4 - 7: 4

:In 3 - 8: 3

:In 2 - 9: 2

:In 1 - 10: 1

:In 0 - 11: 0

50.000 wildview : Backcountry Wildlife Viewing Suitability

: - 0: 0

:In 10 - 1: 10

:In 9 - 2: 9

:In 8 - 3: 8

:In 7 - 4: 7

:In 6 - 5: 6

:In 5 - 6: 5

:In 4 - 7: 4

:In 3 - 8: 3

:In 2 - 9: 2

:In 1 - 10: 1

:In 0 - 11: 0

:In -1 - 12: -1

=====

: Indexing Overlay Input File

:-----
:new mapid & title : minconf Long-Term Opp. for Mineral Resource Exp.
:-----

: no of Input Maps : 12

: Input Maps (Id Max Color)

canmin 2 minlduse 10 copper 9 lead 9 zinc 9 roadbuff 5 landstat 6
agrc 8 heritage 1 ungulate 7 waterfwi 7 recreatn 7

:

: Format = Weight Map ID Title

:-----

15.00 canmin : CANMINDEX Buffers

:-----

: - 0: 0

:< .25 km - 1: 10

:< .50 Km - 2: 10

:-----

15.00 minlduse : Mineral Inventory - Land Use Map

:-----

: - 0: 0

:L.DepKnP - 1: 10

:M.DepKnP - 2: 9

:S.DepKnP - 3: 8

:L.DepP2A - 4: 7

:M.DepP2B - 5: 6

:S.DepP2C - 6: 5

:L.DepP3A - 7: 4

:M.DepP3B - 8: 3

:S.DepP3C - 9: 2

:SomeInd - 10: 5

:-----

10.00 copper : Copper - Regional Geochem. - Contour

:-----

: - 0: 0

:0 - 10 - 1: 1

:11 - 16 - 2: 2

:17 - 26 - 3: 3

:27 - 28 - 4: 5

:28 - 44 - 5: 6

:45 - 58 - 6: 7

:59 - 80 - 7: 8

:80 - 112 - 8: 9

:> 112 - 9: 10

:-----

10.00 lead : Lead - Regional Geochem. - Contour

:-----

: - 0: 0

:0 - 9 - 1: 1


```

:9 - 14 - 2: 2
:14 - 24 - 3: 3
:24 - 26 - 4: 5
:26 - 42 - 5: 6
:42 - 72 - 6: 7
:72 - 170 - 7: 8
:170 - 280 - 8: 9
:> 280 - 9: 10

```

10.00 zinc : Zinc - Regional Geochem. - Contour

```

: - 0: 0
:0 - 44 - 1: 1
:45 - 64 - 2: 2
:65 - 94 - 3: 3
:95 - 104 - 4: 5
:105- 150 - 5: 6
:151- 275 - 6: 7
:276- 515 - 7: 8
:515-1040 - 8: 9
:> 1040 - 9: 10

```

5.000 roadbuff : Road Buffers

```

: - 0: 0
:0 - 5 Km - 1: 10
:6 - 10km - 2: 10
:11- 15Km - 3: 6
:16- 25Km - 4: 4
:>25 km - 5: 2

```

15.000 landstat : Land Status

```

: - 0: 0
:provinci - 1: 10
:private - 2: 8
:indian R - 3: 5
:parks - 4: 1
:protect - 5: 0
:recreat - 6: 6

```

8.333 agrc : CLI Soil Capability for Agriculture

```

: - 0: 0
:class 1 - 1: 6
:class 2 - 2: 6
:class 3 - 3: 0
:class 4 - 4: 0

```

```

: class 5 - 5: 0
: class 6 - 6: 0
: class 7 - 7: 0
: organic - 8: 0

```

8.333 heritage : Heritage Buffer Areas

```

: - 0: 0
: < .25 Km - 1: -1

```

5.000 ungulate : CLI Land Capability for Ungulates

```

: - 0: 0
: class 1 - 1: 1
: class 2W - 2: 2
: class 3 - 3: 4
: class 4 - 4: 8
: class 5 - 5: 10
: class 6 - 6: 10
: class 7 - 7: 10

```

5.000 waterfowl : CLI Land Capability for Waterfowl

```

: - 0: 0
: class 1 - 1: 1
: class 2S - 2: 2
: class 3 - 3: 4
: class 4 - 4: 8
: class 5 - 5: 10
: class 6 - 6: 10
: class 7 - 7: 10

```

5.000 recreatn : CLI Land Capability for Recreation

```

: - 0: 0
: class 1 - 1: 2
: class 2 - 2: 4
: class 3 - 3: 8
: class 4 - 4: 8
: class 5 - 5: 10
: class 6 - 6: 10
: class 7 - 7: 10

```

```

:=====

```

: Indexing Overlay Input File

:new mapid & title : neffm Front Country Land Use Conflict NE

: no of Input Maps : 3

: Input Maps (Id Max Color)

fcover 9 frontour 12 minconf 12

:

: Format = Weight Map ID Title

33.333 fcover : Classified Satellite Image

: - 0: 0

:conshade - 1: 8

:conopen - 2: 10

:mixed - 3: 7

:deciduou - 4: 5

:decidope - 5: 3

:clrregrw - 6: -1

:barerck - 7: -1

:icesnow - 8: -1

:water - 9: -1

33.333 frontour : Front Country Tourism Potential

: - 0: 0

:In 10 - 1: 10

:In 9 - 2: 9

:In 8 - 3: 8

:In 7 - 4: 7

:In 6 - 5: 6

:In 5 - 6: 5

:In 4 - 7: 4

:In 3 - 8: 3

:In 2 - 9: 2

:In 1 - 10: 1

:In 0 - 11: 0

:In -1 - 12: -1

33.333 minconf : Long-Term Opp. for Mineral Resource Exp.

: - 0: 0

:In 10 - 1: 10

:In 9 - 2: 9

:In 8 - 3: 8

:In 7 - 4: 7

:In 6 - 5: 6

:In 5 - 6: 5

:In 4 - 7: 4
:In 3 - 8: 3
:In 2 - 9: 2
:In 1 - 10: 1
:In 0 - 11: 0
:In -1 - 12: -1

=====

: Indexing Overlay Input File

:new mapid & title : nemfm Mid Country Land Use Conflict NE

: no of Input Maps : 3

: Input Maps (Id Max Color)

fcover 5 midtour 12 minconf 12

:

: Format = Weight Map ID Title

33.333 fcover : Classified Satellite Image

: - 0: 0

:conshade - 1: 8

:conopen - 2: 10

:mixed - 3: 7

:deciduou - 4: 5

:decidope - 5: 3

:clrregrw - 6: -1

:barerck - 7: -1

:icesnow - 8: -1

:water - 9: -1

33.333 midtour : Mid-country Tourism Potential

: - 0: 0

:In 10 - 1: 10

:In 9 - 2: 9

:In 8 - 3: 8

:In 7 - 4: 7

:In 6 - 5: 6

:In 5 - 6: 5

:In 4 - 7: 4

:In 3 - 8: 3

:In 2 - 9: 2

:In 1 - 10: 1

:In 0 - 11: 0

:In -1 - 12: -1

33.333 minconf : Long-Term Opp. for Mineral Resource Exp.

: - 0: 0

:In 10 - 1: 10

:In 9 - 2: 9

:In 8 - 3: 8

:In 7 - 4: 7

:In 6 - 5: 6

:In 5 - 6: 5

:ln 4 - 7: 4
:ln 3 - 8: 3
:ln 2 - 9: 2
:ln 1 - 10: 1
:ln 0 - 11: 0
:ln -1 - 12: -1

=====

: Indexing Overlay Input File

:new mapid & title : nebfm Back Country Land Use Conflict NE

: no of Input Maps : 3

: Input Maps (Id Max Color)

backtour 12 fcover 9 minconf 12

:

: Format = Weight Map ID Title

33.333 backtour : Back Tourism Potential

: - 0: 0

:In 10 - 1: 10

:In 9 - 2: 9

:In 8 - 3: 8

:In 7 - 4: 7

:In 6 - 5: 6

:In 5 - 6: 5

:In 4 - 7: 4

:In 3 - 8: 3

:In 2 - 9: 2

:In 1 - 10: 1

:In 0 - 11: 0

:In -1 - 12: -1

33.333 fcover : Classified Satellite Image

: - 0: 0

:conshade - 1: 8

:conopen - 2: 10

:mixed - 3: 7

:deciduou - 4: 5

:decidope - 5: 3

:clrregrw - 6: -1

:barerck - 7: -1

:icesnow - 8: -1

:water - 9: 1

33.333 minconf : Long-Term Opp. for Mineral Resource Exp.

: - 0: 0

:In 10 - 1: 10

:In 9 - 2: 9

:In 8 - 3: 8

:In 7 - 4: 7

:In 6 - 5: 6

:In 5 - 6: 5

:ln 4 - 7: 4
:ln 3 - 8: 3
:ln 2 - 9: 2
:ln 1 - 10: 1
:ln 0 - 11: 0
:ln -1 - 12: -1

=====

: Indexing Overlay Input File

:new mapid & title : westffm Front Country Land Use Conflict

: no of Input Maps : 3

: Input Maps (Id Max Color)

forest 7 frontour 12 minconf 12

:

: Format = Weight Map ID Title

33.333 forest : CLI Soil Capability for Forestry

: - 0: 0

:Class 1 - 1: 10

:Class 2 - 2: 10

:Class 3 - 3: 10

:Class 4 - 4: 8

:Class 5 - 5: 3

:Class 6 - 6: 2

:Class 7 - 7: 1

33.333 frontour : Front Country Tourism Potential

: - 0: 0

:In 10 - 1: 10

:In 9 - 2: 9

:In 8 - 3: 8

:In 7 - 4: 7

:In 6 - 5: 6

:In 5 - 6: 5

:In 4 - 7: 4

:In 3 - 8: 3

:In 2 - 9: 2

:In 1 - 10: 1

:In 0 - 11: 0

:In -1 - 12: -1

33.333 minconf : Long-Term Opp. for Mineral Resource Exp.

: - 0: 0

:In 10 - 1: 10

:In 9 - 2: 9

:In 8 - 3: 8

:In 7 - 4: 7

:In 6 - 5: 6

:In 5 - 6: 5

:In 4 - 7: 4

:In 3 - 8: 3

:ln 2 - 9: 2
:ln 1 - 10: 1
:ln 0 - 11: 0
:ln -1 - 12: -1

=====

: Indexing Overlay Input File

:new mapid & title : westmfm Mid Country Land Use Conflict

: no of Input Maps : 3

: Input Maps (Id Max Color)

forest 7 midtour 12 minconf 12

:

: Format = Weight Map ID Title

33.333 forest : CLI Soil Capability for Forestry

:

- 0: 0

:Class 1 - 1: 10

:Class 2 - 2: 10

:Class 3 - 3: 10

:Class 4 - 4: 8

:Class 5 - 5: 3

:Class 6 - 6: 2

:Class 7 - 7: 1

33.333 midtour : Mid-country Tourism Potential

:

- 0: 0

:In 10 - 1: 10

:In 9 - 2: 9

:In 8 - 3: 8

:In 7 - 4: 7

:In 6 - 5: 6

:In 5 - 6: 5

:In 4 - 7: 4

:In 3 - 8: 3

:In 2 - 9: 2

:In 1 - 10: 1

:In 0 - 11: 0

:In -1 - 12: -1

33.333 minconf : Long-Term Opp. for Mineral Resource Exp.

:

- 0: 0

:In 10 - 1: 10

:In 9 - 2: 9

:In 8 - 3: 8

:In 7 - 4: 7

:In 6 - 5: 6

:In 5 - 6: 5

:In 4 - 7: 4

:In 3 - 8: 3

:ln 2 - 9: 2
:ln 1 - 10: 1
:ln 0 - 11: 0
:ln -1 - 12: -1

=====

: Indexing Overlay Input File

:new mapid & title : westbfm Back Country Land Use Conflict

: no of Input Maps : 3

: Input Maps (Id Max Color)

backtour 12 forest 7 minconf 12

: Format = Weight Map ID Title

33.333 backtour : Back Tourism Potential

:In 10 - 1: 10

:In 9 - 2: 9

:In 8 - 3: 8

:In 7 - 4: 7

:In 6 - 5: 6

:In 5 - 6: 5

:In 4 - 7: 4

:In 3 - 8: 3

:In 2 - 9: 2

:In 1 - 10: 1

:In 0 - 11: 0

:In -1 - 12: -1

33.333 forest : CLI Soil Capability for Forestry

:Class 1 - 1: 10

:Class 2 - 2: 10

:Class 3 - 3: 10

:Class 4 - 4: 8

:Class 5 - 5: 3

:Class 6 - 6: 2

:Class 7 - 7: 1

33.333 minconf : Long-Term Opp. for Mineral Resource Exp.

:In 10 - 1: 10

:In 9 - 2: 9

:In 8 - 3: 8

:In 7 - 4: 7

:In 6 - 5: 6

:In 5 - 6: 5

:In 4 - 7: 4

:In 3 - 8: 3

:In 2 - 9: 2

:In 1 - 10: 1

:In 0 - 11: 0

Appendix B
Base Map Layers

Source: Environment Canada

Canada Land Inventory - Agriculture

-116 50

Land Capability

- Class 1
- Class 2
- Class 3
- Class 4
- Class 5
- Class 6
- Class 7
- Organic
- Water

0 8 km

49

-118

Figure B-1

Figure B-2

Back Country Recreation Potential

Figure B-3

Source: BC EMPR

Copper - Regional Geochemistry

Figure B-4

Front Country Wildlife Viewing Potential

Figure B-5

Source: Kootenay Commercial Winter
Recreation Opportunities Study

Land Status

-116 50

- Land Status
- Provincial
 - Private
 - Indian Reserve
 - Parks
 - Protected Wilderness
 - Recreation Areas

49 -118
8 km

Figure B-7

Source: BC EMPR

Lead - Regional Geochemistry

Figure B-8

Mid-Country Recreation Potential

Figure B-9

Mid-Country Wildlife Viewing Potential

Source: Environment Canada

CLI Land Capability for Recreation

Figure B-11

Source: EMR Road File

Distance to Road Network

Figure B-12

Source: Environment Canada

Canada Land Inventory - Ungulates

Figure B-13

Source: Kootenay Commercial Winter
Recreation Opportunities Study

Figure B-14

Canada Land Inventory - Waterfowl

Figure B-15

- Capability
- Class 1
 - Class 2S
 - Class 3, 3S and 3M
 - Class 4
 - Class 5
 - Class 6
 - Class 7

Figure B-16

Back Country Wildlife Viewing Potential

Figure B-17

Source: BC EMPR

Zinc - Regional Geochemistry

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